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PERFORMANCE OF FIRE TASKS WITH A QUADROCOPTER-TYPE UNMANNED AIRCRAFT

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This manual was written on the basis of the Rules of Shooting and Fire Control, technical documentation of unmanned aerial vehicles and the experience of their use in local wars and armed conflicts.

For the first time in world history, quadcopters are being used so intensively in war. Without them, combat operations are virtually unthinkable: artillery fire adjustment, reconnaissance, and even air strikes. The essence of a household copter is simple - you launch it, raise it above you to a height of 200-500 meters and see what is happening around you without putting yourself at risk. It is not necessary to occupy heights for observation. If the copter is powerful and can hover in the air for longer than 30 minutes, fly 1-3 kilometers to the side and conduct reconnaissance/adjustment. It is almost impossible to shoot down such a quadcopter without special systems - at an altitude of 500 meters it will not be heard. Nimble, small, compact - it will even fit into your pocket. 90% of all copters currently used during CBO are from the Chinese company DJI.

The manual outlines the concepts for the development of copter-type UAVs, an overview of the main UAVs, their design, preparation for flight, features of organizing aerial reconnaissance and artillery fire control when performing fire missions, as well as methods for their detection and destruction.

LIST OF ABBREVIATIONS

battery **–** UAV battery **–** unmanned aerial vehicle DV **–** remote fuse DT **–** remote tube OP **–** RV firing position **–** radar fuze ROgZ **–** reconnaissance and fire mission ROV **–** special attention area of the Central Development Center **–** center of discontinuity group

INTRODUCTION

The real rise of small unmanned aerial vehicles (UAVs) began in the late 2000s, when it was spurred by the rapid development of consumer electronics, and primarily cell phones. It was for them that many components necessary for building an effective and miniature reconnaissance vehicle were developed and began to be mass produced: electronics that allow for sufficiently high-quality photography and video recording, radio communication modules, global positioning receivers, as well as capacious, lightweight and compact batteries.

The most widespread among them are traditional aviation designs—multi-rotor helicopters (multicopters), which are well known today to all fans of radio-controlled models.

Micro (mini) UAVs are now usually classified as devices with a maximum take-off weight of less than 5 (25) kg. Even in such dimensions, it is now quite possible to create an effective tactical reconnaissance unit capable of providing the unit armed with it with significant superiority on the battlefield.

Simple, cheap and reliable devices of this design are light and stable in flight and, unlike classic "aircraft" aerodynamic designs, have much better controllability and maneuverability at low speeds. Design features make it possible to modularize and easily change target loads in the field. In addition, this design is easily scalable in size and load capacity.

The most pressing task of micro (mini) UAVs for tomorrow is to deepen their integration into automated control systems at the tactical level.

1. MODERN DEVELOPMENT OF MICRO (MINI)-UAV

1.1 Basic concepts

An unmanned mobile vehicle is an artificial mobile object of reusable or semi-reusable use that does not have a crew (human pilot) on board and is capable of independently purposefully moving in space to perform various functions in an autonomous mode (using its own control program) or through remote control (carried out by a human operator or a dispatch center).

It is the term "unmanned vehicle" that seems to be the most accurate Russian-language equivalent of the term "unmanned vehicle" (UV).

An unmanned mobile vehicle does not function completely independently, but as part of a complex that may include other unmanned mobile vehicles, a control center, control centers, relay nodes, charging stations, transportation, launching, landing, etc. All together this is usually called UVS - Unmanned Vehicle System - an unmanned mobile system.

Unmanned mobile vehicles can be remote-controlled or autonomous. There are common names for them - ROV - Remotely Operated Vehicle and AUV - Autonomous Unmanned Vehicle. As a rule, autonomy is not one hundred percent: usually the operator has the ability to correct the behavior of the device or transfer it to manual remote control.

There is the following division of unmanned systems according to the degree of autonomy of mobile vehicles: "man-in-the-loop"

systems" (with controlled objects, when the remote operator is a necessary link in the control system), "man-on-the-loop systems" (with controlled objects, when all ordinary tasks are solved without the participation of the operator, and his intervention is required only in critical cases), "fully autonomous systems" (fully autonomous systems, when the operator only initiates the system to perform the task).

1.2 UAV development concept

The purpose of small tactical UAVs follows from its name - work in the interests of the lower tactical level of units (battalion, company, platoon), which is determined by the small radius of action of such devices. In any case, even a micro-UAV will be a collective weapon, requiring specially trained operators and competent technical maintenance personnel.

In terms of the range of tasks to be solved, micro (mini) UAVs can be assigned not only reconnaissance and fire correction tasks, as the most obvious ones. Such aircraft can already be used at this technical level of development as flying repeaters, which is especially important for use in rough terrain, where even satellite communications have “shadow zones.” This is especially important for low-power individual transmitters used in a company-platoon unit. Micro (mini) UAVs can also be used as a target marker. In this case, the device can land in the target area or directly on it (for example, on a tank) and, taking advantage of its low visibility, work for quite a long time as a radio beacon or laser reflector. If there are dipole reflectors and radio transponders, UAVs can play the role of false targets. It is possible to deliver UAVs of various weapons (CS type tear gases, incendiary charges, grenades, small caliber mines...).

Such UAVs have another important advantage - the ability to take off again in the event of a crash to the ground or an intermediate landing. Considering the complex electronic content and the low weight of micro (mini) UAVs, there is a fairly high probability of loss of control due to a malfunction of the electrical

nicknames or, for example, a sharp gust of wind. An electric aircraft, especially with a helicopter design, may well take to the air again after restoration of performance. Micro (mini) UAV can also be used to perform its tasks from an intermediate landing site, not only from the ground, but also from the roof of a building or vehicle.

Navigation can be carried out both using traditional means (gyros, receivers of GPS global positioning systems, beacon systems), and using, for example, “sense organs” close to the echolocation of bats. Receiving a reflected electronic or ultrasonic signal (sonar operation) can allow a micro-scout to avoid collisions with surrounding objects and operate effectively in buildings, cities, forests and mountains. Already now, micro (mini) UAVs are capable of solving a number of tasks in a combat situation.

Distribution of UAV developments by categories of leading countries - developers (Fig. 1) and manufacturers (Fig. 2) according to Rosoboronexport.

Fig.1 Distribution of UAV developments by category

Fig.2. Leading countries producing UAVs.

According to research results published in the American weekly Aviation Week & Space Technology, the volume of the global market for the development and production of unmanned aerial vehicles in 2014-2023. will amount to 3 billion. About 6 billion will be spent on the production of UAVs, 7 billion on R&D in the field of unmanned vehicles, and 3 billion on UAV service maintenance. Forecast of the commercial UAV market (Fig. 3) by the end of 2022 from the international analytical agency Interact Analysis.

Fig.3. Commercial UAV market forecast.

The international market for unmanned vehicles will be on the rise in the coming years. In this regard, the forecasts are interesting

analytical firm Forecast International: global sales of UAVs will grow to \$2.3 billion in 2023. The United States will retain leadership, accounting for 65% of the market (Northrop Grumman 41% and General Atomics 22%). The remaining 37% will come from other countries, including Israel, France, Great Britain, Italy, etc.

As for the volume of UAV purchases, the first place in the next decade is also still occupied by the United States - 34.9% (\$13.66 billion). The Asian region will account for 36.6% (\$14.33 billion), European countries - 14.6% (\$5.77 billion), and the rest of the world - 13.9% (\$5.45 billion).

Among various types of UAVs, tactical TUAVs will lead in sales volumes – 40.7% (\$15.94 billion). Long-endurance MALE vehicles will account for 34.6% (\$13.56 billion), high-altitude long-endurance HALEs and attack UCAVs will account for 21.4% (\$8.39 billion). The market size of portable UAVs will be 1.7% (\$0.64 billion).

The specifics of flight performance characteristics determine a number of additional, extremely important advantages of building and operating commercial UAVs:

the use of a classic aerodynamic design that ensures stability and ease of control;

the use of “pushing” motors, which have a higher efficiency compared to a pulling motor;

equipping with electric motors, which are advantageously easy to operate;

the possibility of using non-traditional types of energy (solar batteries, cryogenic fuel, etc.), allowing the use of UAVs without limiting their flight time;

a significant reduction in the overall level of costs associated with the transfer and temporary deployment of fairly compact UAV units to combat areas, repair and maintenance of UAVs and supporting equipment in the field;

low radar signature (the ESR of the UAV is in the range of 0.01-0.001 m^2), visual visibility less than 100 m (with

ideal weather conditions), audibility 15-50 m, small IR signature at reconnaissance altitudes from 100 to 1000 m;

small geometric dimensions, which determine low values of the probability of being hit by anti-aircraft artillery shells, and also lead to the failure of radio fuses of missile defense systems when they approach the target area;

low flight speeds (10-30 m/s). Most modern air defense systems have restrictions on firing at air targets with a minimum speed of up to 100 m/s. In addition, when small UAVs are irradiated by radars, they may fall into the strobes of the radar protection from passive interference and local objects, which makes them indistinguishable against the background of the terrain or in a cloud of passive interference;

providing information consumers with streaming video practice technically in real time;

low cost of developing and operating UAVs, tens or even hundreds of times less than the cost of modern manned aircraft that perform many similar combat missions. At the same time, expensive flight personnel, airplanes, helicopters, etc. are preserved.

1.3 Overview of commercial drones

According to [26], the top best UAVs by flight range (Table 1).

Table1 Top best UAVs by flight range

Xact Sense Titan
Xact Sense Titan
Xact Sense Titan

Name Microdrones

md4-3000

AEE F100

Technology International AgBOT

AEE F100

The Allied Drones HL48 «Chaos»

AEE F100

The Allied Drones HL48 «Chaos»

AEE F100

The Allied Drones HL48 «Chaos»

AEE F100

Xact Sense Titan

Range, km 50 27 20 16 10 Flight time, min 45 26 45 60 70 Speed, m/s 20 17 13.4 27 27.7 Weight, kg 10.4 4.7 6.8 8.1 6

DJI, Syma, Hubsan, MJX, JXD, Parrot, Walkera, Holy Stone, Autel are the most famous manufacturing companies. According to analytical

According to Interact Analysis agency, DJI Innovations’ dominance in the market is obvious. In recent years, it controlled more than 50% of the market, which is 2 times more than the next 5 players combined. DJI is one of the best manufacturing companies (has been developing drones for 10 years) represented on the Russian market: the Mavic and Phantom line of drones. In addition to DJI, the comparative review includes a foldable drone from the famous GoPro brand – Karma. (Table 2).

Table 2 Comparative review of copters

Name **DJI Inspire 2 DJI Phantom 4 DJI Mavic Pro GoPro Karma**
Appearance
Quadcopter foldable not foldable foldable foldable
Weight, g 1388 1380 743 1000 Maximum horizontal
tal speed, m/s 20 20 18 15 Maximum permissible speed
wind speed, m/s 20 10 10 10 Flight time, min 30 30 27 20
Times may vary depending on driving style, weather conditions and altitude.

Operating temperature, °C

from 0 to 40 (if there is a self-heating system, it will maintain the optimal battery temperature even at - 20 Mach flight range,

km 7 7 15 3 Max working
height, m 4500 6000 5000 4500 Hovering accuracy, m
vert +/-0.5 +/-0.5 +/- 0.3 +/- 0.1 hor +/-1.5 +/-0.3, +/- 0.1 +/- 1 Angular control accuracy, deg ± 0,01 ± 0,02 ± 0,02 ± 0,01 Battery charging time, min On average 60, the number of simultaneously charged batteries and charging time depends on the power
charger (50 W, 100 W...) Control range with
remote control, km 7 4 7 3 Range
sonar, m from 0.7 to 15 from 0.7 to 15 15-30 no
Camera included, 4K included, 4K included, 4K
not removable
not included, usually they install 4K Gimbal removable not removable not removable removable Propellers removable removable folding removable Manual gimbal yes no no yes
Means of transportation case case bag case

Battery operating time 4-5 flights 4-5 flights 5-6 flights 4 hours Remote control charging time, hours On average up to 4 2.5
operating room
system iOS, Android
Remote controller + tablet or
smartphone
+tablet or smart
background +smartphone with built-in 5" monitor Image broadcast 7 km 5 km 7 km 1 km Wi-Fi
DJI Go Go Pro Passenger program
Camera yes yes yes yes Gimbal All have three-axis stabilized gimbals that can be controlled from a remote control
and rotate the camera down 90° while in flight. Lens Horizontal 60°,
vertical 54°
Horizontal 94°, vertical 54°
Horizontal 78°, vertical 54°
Horizontal 122°, vertical 94° Camera yes yes yes no (optional) Batteries, mAh 5835 5350 3830 5100 Battery charging time, min On average 60, the number of simultaneously charged batteries and charging time depends on the power
charger (50 W, 100 W...) GPS sensors, GLONASS GPS, GLONASS GPS, GLONASS GPS Detection sensors
obstacles, pcs. 2 ahead 2 ahead 2 ahead,
2 from below No Information storage Micro SDTM max. volume: 64 GB, speed: Class 10 or UHS-1
all specifications are subject to change

There are two classes of copters. The first class is for civil and domestic purposes. This class includes those that can be purchased at retail outlets: DJI Phantom; DJI Mavic and even DJI Matrice, as well as similar ones from other brands. The second class is specialized, which are developed and supplied in the interests of special government services and departments: R.A.L. X6T, ZALA AERO, and others like them.

Now, the most accessible and in demand class of copters among the troops are precisely those drones that have a civilian purpose. But there are also nuances here. These drones have very different technical characteristics and may not be suitable for solving all tasks. These copters can be divided into day and night, and which in turn can be divided into three more groups: short-range, medium-range and long-range reconnaissance. Copters that can perform tasks in night conditions include: DJI Matrice 300 or DJI Matrice 30T with a set of additional equipment, namely a specialized camera and thermal imager. The cost of such a kit is about 4 - 5 million rubles, depending on the characteristics of the additional equipment. This copter can solve a whole range of reconnaissance and

Control panel and online broadcast (optional)

target designation at long and medium distances - from 5 kilometers and above. Mavic 2 Enterprise Advanced and Mavic 2 Enterprise Dual. These models differ in the size of the thermal imager matrix. The Mavic 2 Enterprise Advanced has a thermal imager matrix of 640×512 @30 Hz and a digital zoom of 16x, which already allows it to observe at medium distances - up to 2 km, and the Mavic 2 Enterprise Dual has a 640×480 image without scaling the image, that is, at short distances of no more than one kilometer. In daytime conditions, both copters, due to their good optical matrix and 4K video resolution, can monitor the enemy at a distance of 2-3 kilometers. Accordingly, the price of the first is more than a million rubles, and the simpler version of Enterprise Dual costs about half a million rubles. Now, as for copters, which are suitable for operation exclusively during daylight hours. Let's start with short-range reconnaissance. At their core, these are tasks to see what is behind the nearest house, forest plantation, hill, everything that is within 1-1.5 kilometers. Typical representatives of this class are DJI Mini SE and DJI Mini 2. These fairly small copters can solve immediate surveillance tasks and are capable of transmitting video information at a distance of up to 2-3 kilometers. This is their maximum operating distance at which they are effective. The continuous flight time on one battery is on average about 20 minutes, and is capable of solving tactical reconnaissance tasks in the interests of a platoon or company. The cost of such products is within 100 thousand rubles. The following members of the DJI family that can be used for medium-range reconnaissance are such as the Mavic 2 Pro, DJI Mavic Air 2S or Mavic 2 Zoom. They already have a fairly good battery and a more advanced camera, due to which they can stay in the air for up to 30 minutes and conduct reconnaissance from a distance of up to 5 kilometers. By and large, they can solve tactical reconnaissance or target designation tasks in the interests of the battalion. Similar products cost from 200 to 350 thousand rubles, depending on the configuration. I would also like to say something about the DJI Mavic 3. Despite the fact that this is a more modern version of the copter and it has more outstanding characteristics compared to its younger models, such as a flight time of up to 40 minutes and a high-definition video camera, nevertheless, it is more capable of solving tactical reconnaissance tasks.

it is in the interests of the battalion, that is, up to 5 kilometers. The cost of such a product, depending on the configuration, is from 400 to 950 thousand rubles. Basic performance characteristics of the Mavic family of copters (Appendix 6). TOP 10 copters of 2022 (Appendix 7).

1.4 Classification and design of UAVs

The International Association for Unmanned Vehicle Systems AUVSI (Association for Unmanned Vehicle Systems International) proposed a universal classification of UAVs (Table 3). The above classification applies to both existing and future UAVs.

Table 3

Classification of unmanned aerial vehicles

Category BpLA Take-off mass, kg

Flight range, km

Flight altitude, m

Flight time, h Nano <0.025 <1,100 1 to 0.5 Micro Micro (μ) <5 <10,250 to 1 Mini Mini 5-25 <10,500 to 2 front Easy for edge control defense Close Range (CR) 25-150 10-30 3000 2-4 Lightweight with short range flight Short Range (SR) 50-250 30-70 3000 4-6 Medium Range (MR) 150-500 70-200 5000 6-10 Medium with long flight duration

Endurance Medium Range

(MRE) 500-1500 >500 8000 10-18

Low-altitude UAVs for penetrating into the depths of enemy defenses

Penetration Low Altitude (LADP) Deep

250-2500 >250 50-9000 1

Low-altitude UAVs with long flight duration

Low Endurance Altitude (LALE) Long
15-25 >500 3000 over 24

Medium-altitude UAVs with long flight endurance
Medium Altitude Long Endurance (MALE)

1000- 1500 >500 5000-

8000 24-48

The most widely used UAVs are helicopter-type ones. The lifting force of devices of this type is created by the rotating blades of the main rotor (rotors). Wings are either absent altogether or play an auxiliary role.

The obvious advantages of helicopter-type UAVs are the ability to hover at a point and high maneuverability. Schemes for constructing helicopter-type UAVs (Table 4).

Table 4

Schemes for constructing helicopter-type UAVs

Single-rotor with tail tail rotor

With crossed rotors

Jet helicopters

Hybrid rotorcraft:

gyroplanes

Double-screw transverse

Multi-rotor helicopters (multicopters)
Twin-screw coaxial

Twin-screw longitudinal

Helicopters with wing

craft

The most common and affordable multicopter design is devices with two or more rotors. Reactive moments are balanced by rotating the rotors in pairs in different directions or by tilting the thrust vector of each rotor in the desired direction (Fig. 4).

TriCopter +Copter XCopter

Rice. 4. Schemes for constructing multicopters

Accordingly, with two symmetrical rotors - bicopters, three-rotor - tricopter, four-rotor - quadrocopter, six-rotor - hexacopter, eight-rotor - octocopter.

Quadcopter is the most common design for multicopters. The presence of four rigidly fixed rotors makes it possible to organize a simple motion control scheme. There are two such movement patterns: the “+" and diagram "X". In the first case, one of the rotors is front, the opposite one is rear, and two rotors are side. In the “X” scheme, two rotors are simultaneously front, the other two are rear, and displacements in the lateral direction are also realized simultaneously by a pair of corresponding rotors. Algorithm for controlling the rotation of screws for the circuit "+" some

HexaCopter H6Copter OctoCopter

simpler and clearer than for the “X” scheme, however, the latter is still used more often due to design advantages: with this scheme it is easier to place the fuselage, which can have an elongated shape, the on-board video camera has a freer view. Typical composition of quadcopter equipment (Fig. 5). For devices with a different number of rotors it is similar.

Rice. 5. Typical composition of quadcopter equipment

The quadcopter is equipped with an onboard GPS receiver, a set of navigation sensors (accelerometer, gyroscope, barometer, ultrasonic rangefinder), a camera with a three-axis gimbal that provides good stabilization, and light status indicators. Commands received by the receiver are sent to the flight controller in the form of a pulse-width signal. Here, taking into account current navigation information (received in the flight controller itself from built-in microsystem gyroscopes and accelerometers), as well as taking into account signals from the GPS module, they are converted into pulse-width engine control signals, which are fed to engine speed controllers (ESC - Engine Speed Control).

The quadcopter is controlled using a remote control. The task of the flight controller is to translate the command

signals from the control panel that set the engine speed. It also has inertial measurement sensors that allow you to monitor the current position of the platform and make automatic adjustments. The flight controller consists of two blocks: a power stabilizer with an LED, and the control electronics itself.

Quadcopters use special brushless motors with self-tightening propellers or a new mechanism for attaching propellers (Push-and-Release). With this locking mechanism, the propellers can withstand sudden changes in engine speed, allowing the copter to be maneuverable and responsive to the pilot's commands.

To control these motors, it is necessary to generate three-phase voltage and relatively large currents, which is what speed controllers do. Each engine requires its own speed controller. To control the speed controllers, the same signal is used as for the servos, that is, pulses with a frequency of 50 Hz and a duration varying from 0.8 to 2.1 ms. The longer the control pulse, the higher the engine speed. All four speed controllers are connected to the flight controller.

Quadcopter motors, depending on their size, can consume significant currents - the total current can reach 100 A when climbing. The weight of the battery should be as small as possible and have high current output. And the best characteristics from this point of view are lithium polymer batteries (Li-PO) (Fig. 6.)

Fig.6. Appearance of Li-PO battery

The characteristics of Li-PO batteries include: capacity, maximum discharge current, voltage.

Capacity (Ah) - this is the current that the battery can produce within an hour until it is completely discharged. For example, if the battery capacity is 3 A/h, then it can supply a current of 3 A for one hour. At a current of 1 A it will last for 3 hours, and at a current of 30 A it will be discharged in 6 minutes.

Maximum discharge current (A) indicates how much the maximum discharge current exceeds the capacity. For example, the value “30-40 C” for a battery with a capacity of 3 A/h means that it can briefly produce a current of 90-120 A. Naturally, when choosing a battery, you must be guided by a lower value.

Voltage (V) One cell of a Li-Po battery is about 3.7 V. Accordingly, the more cells, the greater the battery voltage.

In addition to the listed advantages, Li-Po batteries have low self-discharge, no memory effect, a wide range of operating temperatures and a small voltage drop during discharge. The disadvantages include not the highest charge density, a small number of operating cycles and a fire hazard. In addition, to charge Li-Po batteries consisting of several cells, it is necessary to use special chargers operating from a 12-15 V network (Fig. 7), ensuring uniform charging of the cells.

Rice. 7. Appearance of the charger

The peculiarity of this charger is that it can balance battery cells - the battery is connected

It is connected to it not only with a power connector, but also with an additional balancing connector, to which all cells are connected separately. This makes it possible to charge all cells evenly, which gives an equal distribution of the load on the battery banks during operation. The charger can measure internal resistance and carry out a capacitance measurement cycle. In the latter case, it completely discharges and charges the battery and provides information about the actual capacity it has.

It is necessary to charge not only the quadcopter battery, but also the control panel, information display device (phone, tablet, laptop...), therefore, during autonomous operation, an electric generator is required (Fig. 8)

Fig.8. Electric generator

If there is more than one battery, then a charging hub (splitter) is required to simultaneously charge several batteries (Fig. 9).

Fig.9. Charging hub (splitter)

To connect the battery, special connectors are used (additionally spring-loaded to provide a large area

contact) and wires (Fig. 10) in silicone insulation, which can withstand high temperatures.

Fig. 10 Appearance of connectors and wires

The remote control charges within 4 hours, and its charge is enough for 4-5 flights with fully charged batteries. It is prohibited to charge the control panel and the battery at the same time.

To protect propellers, special enclosing guards are often provided (Fig. 11).

Rice. 11 Quadcopter with propeller protection

To increase the lifting force and increase the survivability of the device, pulling and pushing propellers with corresponding engines are often combined on one beam (Fig. 21). Hexacopters and octocopters, which have 6 and 8 rotors respectively, have a greater payload capacity compared to quadcopters.

21

Rice. 12 Quadcopter with combined propellers

They are also capable of maintaining stable flight if one rotor fails. Such devices also have a much lower level of vibration, which is especially important for video shooting.

2. Composition and capabilities of the UAV complex

2.1 Composition of the UAV complex

Typical crew composition of a UAV complex (Fig. 13): crew chief, operator, driver (if there is a means of transportation). There may be one person in the composition, but this does not provide the opportunity for timely maintenance and preparation of the next UAV for flight.

Fig. 13 UAV operator in position

A typical composition of a UAV complex with a quadcopter may include (Fig. 14):

two or more copters with a set of interchangeable target loads of various types in shipping containers;

equipment for displaying, processing, transmitting and recording information (control console, control panel, video camera filters);

means of communication and switching; battery charging facilities, additional batteries; means for supporting UAV launches and operation (spare parts).

Fig. 14 Typical composition of a UAV complex with a quadcopter

Control consoles are the most important element (Fig. 15). Many consoles have touch screens and joysticks similar to game consoles; They are often designed as one-piece devices that combine a screen and controls (sometimes with sun protection).

Fig.15 Types of control consoles

2.2 Software capabilities

The following can be used: a signal amplification station with a circular or linearly polarized antenna (Fig. 15), a digital video signal transmission module (Fig. 16) and glasses for first-person flights (Fig. 17)

Rice. 15 Signal amplification station on a tripod together with an additional information display device

Rice. 16 OcuSync video transmission module

Fig. 17 Glasses for first-person flights

Reducing the operating burden on operators is a key design principle that most manufacturers strive to implement.

The software is designed to work with portable computers (tablets, laptops, smartphones, etc.) and specialized controllers.

These include: DJI GO 4, Litchi, Autopilot and others, running on the Android and iOS platforms. They provide setup of the quadcopter, calibration of its navigation devices, telemetry output, and camera control. According to reviews and surveys of pilots, preference is often given to **Litchi** (cost 25$ for IOS and 30$ for Android) – one of the best programs in Russian, provides onboard coordinates in real time (WGS 84). It has a conditional grid on the screen that allows you to quickly determine the distance depending on the height. There is a diagonal crosshair that serves as target designation when lowering the camera straight down. Implemented automatic flight to points without communication with the operator. Those who want great opportunities choose **Autopilot** ($30 cost for IOS only). If you are interested in a free application, then this is **DJI GO**. In any case, you will need a program like “Geodesist” to convert coordinates from the international WGS 84 to the Russian SK42 Gauss-Kruger.

Program interface (Fig. 18-20).

Rice. 18. DJI GO program interface

Rice. 19. Autopilot program interface

Rice. 20. Litchi program interface

UAV intelligent flight modes. **1. Draw.** In order to set the course of the UAV, you need to draw points on the screen, and it will follow the specified route at a given altitude. This allows the operator to fully concentrate on video or photography after specifying the route. This type of flight has two subtypes:

Standard – the flight is carried out at specified points at a given speed. In this case, the camera of the device is turned towards the flight.

Free – the flight is carried out along a predetermined course, but the camera of the device is freely accessible and under the full control of the pilot.

2. ActiveTrack – The UAV will follow the selected moving target – recognizes the image and tracks the object. Three object capture modes:

Trace – The UAV will automatically fly around all obstacles and follow either “behind” the object or “in front” of it.

Profile – the flight is carried out in close proximity to the subject from different angles, which makes it possible to obtain more complete information.

Spotlight – in this case, the camera focuses only on the object, and the flight is carried out in any position.

3. Follow Me – allows the UAV to follow an operator who is in motion (in a car).

4. TapFly – the mode allows the UAV to fly autonomously to a given point on the display. Click on any point within the display radius, and then click on the “Go” button. The UAV will go to a given point directly, flying around possible obstacles in automatic mode. But at the same time, it remains possible to intervene in the flight process. The mode has three options:

TapFly Forward – the flight is carried out in direct and autonomous mode, and the camera is fixed in the direction of flight.

TapFly Backward – the flight is carried out in a forward direction and in autonomous mode, but at the same time the camera of the device is fixed in the opposite direction from the direction of flight.

TapFly Free – the flight is carried out in a straight line, but subsequent control of the device is blocked, but becomes

available ability to rotate the camera in any direction. In this flight mode, the UAV will not automatically fly around obstacles. **5. Return to Home или Failsafe** – The UAV will automatically record its route so that in case of loss of communication with the pilot, it will return to the starting point, flying around obstacles in automatic mode, based on the previously recorded route. Returning to the take-off site, the device will perform a soft landing.

6. **Gesture Mode** – selfie mode. To turn it on, you need to raise your hands up and the device will switch to selfie mode, placing the subject in the center of the frame.

The DroneDeploy program (available for free on the Play Market): you draw a reconnaissance area on a map background, set the shooting parameters (height, overlap, direction), select the shooting start point, and click “Start”.

The variety of possible movements of the quadcopter in space (Fig. 21).

Rice. 21. Variety of possible movements of the copter

The designation terms come from aviation. **Throttle** – “throttle”, “thrust” or “gas” in everyday life. In gliders, the “throttle” determines the forward speed, that is, the force vector is applied along the X axis. In quadcopters, it controls the rise of the platform, that is, along the “Z” axis.

Rudder - "rudder". On gliders, this is the part of the tail that allows the plane to turn. In quadcopters, this word also refers to controlling the nose of the platform.

Elevator - “elevator”. In gliders it is located in the tail and allows you to raise or lower the nose and, thereby, descend or gain altitude. In quadcopters, it allows you to move forward or backward.

Aileron - “ailerons”. Part of the glider wing structure that paradise allows you to control the roll. Due to the roll, the quadcopter can move sideways to the left or right.

In addition to converting operator commands into engine commands, the flight controller stabilizes the platform's flight. Stabilization is necessary for the following reasons:
non-identity of propeller groups and speed controllers; uneven load distribution on engines due to a shift in the center of gravity; "blown away" by the wind. To compensate for these effects, the flight controller contains an inertial measurement system, which includes an accelerometer, gyroscope, magnetometer and barometer. More expensive models additionally use GPS receivers. Even when the operator tries to hold the copter in place, the flight controller continues to actively change the thrust of the engines, compensating for all possible accelerations and rotations.

3. ORGANIZATION OF INTELLIGENCE USING UAVS

3.1. Air reconnaissance missions

UAVs are capable of solving artillery maintenance tasks: reconnaissance and determination of target coordinates; maintenance of artillery shooting (target sighting, fire adjustment during shooting to kill, determining the meeting point when hitting moving ground targets, determining the results of shooting to kill).

Determining the results of lethal shooting consists of collecting information about the target after firing on it. This produces:

determining whether the target is in its previous position; assessment of the target's condition after fire exposure; determination of quantitative and qualitative indicators of fire impact on the target (amount of damage caused);

revealing the nature of the target's actions or changing it; clarification (if necessary) of the target coordinates and its other characteristics for repeated engagement.

The time for performing basic operations by the crew of a quadrocopter UAV is given in Appendix 1.

Main tasks of aerial reconnaissance: reconnaissance of artillery and mortar batteries (platoons), tanks and infantry in areas of concentration and on the march, defensive structures, launchers and other important objects;

additional exploration of objects; confirmation of objects (targets) and clarification of their coordinates, sizes and engineering equipment;

monitoring the actions of the enemy and friendly troops; control of artillery firing results;

artillery fire correction; reconnaissance of the location of friendly troops in order to control the camouflage of units in the areas where they are located;

patrolling the area in areas where units are deployed for the purpose of organizing security and escorting convoys.

During the battle, UAVs may be involved to establish: preparation, beginning and direction of actions of the main enemy group;

artillery movements and locations of their positions; the degree of passability of the terrain, as well as the presence of barriers and obstacles on the routes of movement;

the presence of road surfaces and reservoirs; the presence of defensive lines and their occupation by the enemy; deployment of reserves from the depths, their composition and deployment lines.

Intelligence data about a target (object) obtained using a UAV includes:

detection time; number and nature of the target; coordinates and dimensions of the target; the nature of the target's activity, the degree of protection of manpower and equipment.

In addition, for a moving target (column): speed and direction of movement, length of the column and the number of its elements and coordinates of the meeting point. Unmasking signs of targets are given in Appendix 2.

3.2. Organization of the use of UAVs

The organization of interaction with the crew (operator) of the UAV is carried out in advance and consists of coordinating their actions in time, place and tasks. The direct organizer of interaction is the commander of the artillery unit.

Along with general issues, it establishes: the tasks and areas of responsibility of aerial reconnaissance; areas of special attention; the procedure for conducting aerial reconnaissance and providing information

mation (intelligence);

procedure for planning the use of UAVs; measures to ensure the survivability of UAVs, including from high temperatures and dust formation.

UAV crew commander (operator) reports: location; communication capabilities, availability of additional monitors, including remote range capabilities; number of UAVs, target load capabilities; availability of flight life (number of batteries) and state of charge, flight time on one battery;

capabilities to ensure artillery fire (range of action (range), flight altitude, shooting order, determination and issuance of target coordinates and explosions (volleys)).

When setting tasks For reconnaissance, the UAV crew commander (operator) is instructed to:

brief information about the enemy, the front line, the location of the nearest anti-aircraft weapons, possible areas for the location of artillery, reserves and defensive lines;

areas of reconnaissance and special attention; reconnaissance and artillery firing maintenance tasks; numbering of goals; landmarks (presence of benchmarks) in the target area, their coordinates; the procedure and methods for transmitting intelligence data; communication data (radio signal table, frequencies, call signs, passwords, card encoding).

UAV crew commander (operator) carries out route planning, assignment of flight modes taking into account the terrain, location of reconnaissance zones, information about enemy air defense systems. Defines a UAV flight mission in order to maximize the use of their capabilities to detect certain objects (perform a task), which reflects:

launch readiness time; reconnaissance area (reconnaissance zone, search sector);

flight altitude; type of flight path; magnification factor; observation range;

flight path turn radii; payload; launch and landing site.

3.3. Determination of flight mission parameters and preparation

UAV to perform the task The type of UAV flight path (Fig. 22-28) depends on the specific task [5].

Rice. 22 Search for a target in a given executive zone

Rice. 23 Loitering in the executive zone

Rice. 24 Flying around a given boundary

Rice. 28 Finding a target on a given route

Recommendations for preparing UAVs to perform a mission. The crew is preparing the UAV for launch: removing the UAV from the transport container, monitoring the deployment of aerodynamic surfaces (checking the fastening of the propellers), checking

Rice. 25 Exit to a given point and fly around it

Rice. 27 Search for a target in a given sector
Rice. 26 Flight over several points

battery, exchange of command and telemetry information via radio control channel.

Features of preparation for flight: the take-off (landing) area must be flat, without fine sand, away from bushes and trees. If possible, launch and catch the UAV from your hand (to land on your hand, hold the left stick down for 3 seconds). as turning points, use characteristic landmarks that are clearly recognizable in flight (river bends, road intersections, single buildings, bridges);

when laying a route, there must be an overlap of fields of visibility (Fig. 29)

Fig.29 Longitudinal overlap of UAV fields of view.

If possible, the route should not pass near power lines (regular up to 50-100 m, high-voltage up to 300-500 m) and other objects with a high level of electromagnetic radiation (cell phone towers 200-300 m, radar stations, transmitting and receiving antennas...);

do not approach protected facilities (8 km from nuclear power plants, 5 km from the airport and state border, 2 km from military facilities);

the estimated flight time should not exceed 2/3 of its maximum duration (battery charge remaining 30%);

provide for a reduction in battery capacity in cold weather;

provide protection for the battery from high temperatures (use reflective materials);

Use a conductive cleaner to clean the exposed battery contacts and inside the UAV body (every 10 flights). Check the batteries after 25 flights, and then monitor their condition every 10 flights. Swelling indicates that the battery life is running out. To increase the service life of Li-Po batteries, they must be stored with a charge of no more than 40%;

To obtain smooth video, in the settings, reduce the yaw rate of the copter as much as possible and reduce the sensitivity of the gimbal for smoother lowering and raising of the camera;

set the cameras to NTSC mode, set the light balance to Sunny if it’s sunny outside, if it’s cloudy - Cloud, disable autofocus;

to facilitate the use of batteries, number them so as not to get confused in charging and use;

turn off the luminous diodes on the body, and if it is impossible, seal (paint over) due to their visual manifestation in flight;

In order to prevent the UAV from reflecting in the sun (the possibility of its visual detection by the enemy), apply matte paint to it.

Flight control features: control smoothly, without jerking; use mixed control with a partner (one will be the flight operator, and the second will be the shooting service) to facilitate work during the fire mission (Fig. 30);

Fig.30 Using two remote controls when working with a partner

the depth of the working area must be within the limits of stable reception of the video signal and telemetric information (without “dead zones” (Fig. 31) that create various obstacles (mountains, forests, buildings, etc.). Fly in the line of sight. This does not mean that you need to see the UAV in the air, it means that there should be no obstacles between you and the UAV that can block the signal. And the further we fly, the higher the UAV should be.

Rice. 31 Dead zone caused by obstacles

for rational use of the battery, the first half of the flight should be against the wind;

approach the target from the direction of the sun or at a slight angle, since the dynamic range of the camera may not be enough; shoot towards the sun;

at sunset or dawn, turn off the front visors (when flying towards the sun, they may perceive it as an obstacle and refuse to fly further);

do not fly in difficult weather conditions (storm, storm, hurricane, rain, snowfall, fog) with wind speeds exceeding 10 m/s, the lower edge of the clouds is not lower than 150 m.

Wind level is usually measured on the Beaufort scale (Table 5)

38

Beaufort scale level

Beaufort scale

0 less than 1.5 No 1 1.5-5 Light wind, zero influence 2 5-11 Suitable for comfortable controlled flight 3 11-19 Affects devices with a mass of up to 250 g 4 19-29 Moderately strong wind, is the maximum for flights of some civil-purpose copters 5 29-39 Strong wind, flight is not possible for civil-use copters, flight is only for specialized copters 6 39-50 Upper limit, flight is not possible

Pre-flight preparation ***1) Charging.*** Check that all batteries are fully charged: UAV, control panel, phone (tablet).

2) Screws. Tighten the screws tighter, you don't even need a special wrench for this, just hold the motor with one hand and with the other turn the screw towards the drawn closed lock on the screw until it stops (replace the screws after 200 hours or 3 months). ***3) Propellers***. Must be balanced and not have severe damage.

4) Battery compartment. Check the latching reliability. ***5) Compass.*** Do not grab it with your hands, do not bring it closer to sources of increased magnetic field. It should absolutely not be placed next to computer speakers (which very often happens when the copter is connected to a computer). Calibrate your compass before every flight, even if you fly to the same location every day.

Compass calibration: place the copter on a flat and open surface with its back facing you (to see the warning lights);

turn on the remote control, launch the control program; turn on the copter and let it find satellites;

39

press the compass calibration button and follow the program instructions;

put the copter on the ground and turn it off; turn on the copter and let it find satellites. **DO NOT MOVE OR TOUCH the copter while it is searching for satellites and recording the "Home" point!** Take off only after he writes down the "Home" point - the program will show the recorded point with a special marker. Make sure that the "Home" point on the map corresponds to your real location. Calibration complete!

IMPORTANT: *Make sure that when calibrating, there are no sources of magnetic fields or cell phones near the compass.*

6) Cell towers and power lines. Visually check the presence of power lines and cell towers near you.

7) Camera lock. Detach the plastic clip of the camera before turning on the power. If you forget to remove it, you will overheat the gimbal with subsequent failure.

8) Software. Launch the program. Check the displayed battery charge level. Check for satellites (at least 12). If there are fewer of them, change the location.

9) Distance to copter. Check the distance from you to the aircraft displayed on the mobile application screen. If it differs significantly (you are at a distance of a meter, but it shows, for example, 10 m), turn off the copter, and after turning it on, recalibrate and let it find the satellites again and register the “Home” point.

10) Starting engines. Start the engines. The copter must operate quietly and stand steadily. There should be no vibrations or suspicious noises. If you hear something suspicious, turn off the engines by tilting the left stick all the way down towards you for 3 seconds. DO NOT take off in this case!

The UAV launches at the specified time. The initial stage of the UAV flight with altitude climb is carried out according to a standard program. After takeoff, do not make sudden movements with the copter. Assess its stability and controllability, then let it hang in the air for 10-20 seconds with minimal load, and then smoothly start moving, assessing the battery readings.

Flight control is carried out manually or automatically in accordance with the flight mission. The operator controls the telemetric data displayed on the screen (speed, flight altitude, etc.). It can issue one-time commands to change the flight mode and operation of on-board equipment. Registration of video information received from the UAV and associated navigation and telemetry information is carried out on a storage device (micro SD/SDHC/SDXC, HDD, etc.).

Video information is displayed on the operator’s screen, which recognizes and determines the coordinates of objects.

Depending on the type and equipment of the UAV, this operating procedure may have a number of features. Brief instructions for using the copter (Appendix 5).

3.4. Statement of the task (target designation) to the operator

Setting the task (target designation) to the operator can be carried out in the following ways: indication on the monitor; from the control point (local object); in rectangular coordinates. Setting a task by indicating it on the monitor is the simplest and most reliable way. For example: “Target mortar is in position. Detect." However, this method is possible with joint actions of the operator and the battery commander.

The formulation of the task from a control point (local object) is used without recalculation when the commander and operator are together or have information exchange with each other in the form of a television image in real time. In this case, the commander determines and transmits to the operator the distance of the target from the control point (local object) in meters (further or closer by so many meters). For example: “Control 2-storey building (oil rig). Left 300. Closer 100. Self-propelled gun. Detect."

The operator, having measured the required distances by eye from the control point (local object), finds the target taking into account its signs. When formulating the problem in rectangular coordinates, the command

41

The director determines the rectangular coordinates of the target (square) and transmits them to the operator, indicating the number, name of the target, its characteristic features and the reconnaissance task. For example: “Target 10. Group of militants. X=57680, Y=34850 (square 5734). Observe (detect).” Using the received coordinates, the operator searches for the target based on its characteristic features.

To detect targets, the operator carefully studies the terrain in the enemy’s location, conducting surveillance along the lines and areas in a given ROI, identifies changes associated with the activities of the intended target (the appearance of people, various objects, smoke, dust, changes in the color and type of vegetation, thermal radiation, etc.), making a note about this on the operator’s reconnaissance form. The operator watches especially carefully those areas of the terrain where signs of an object (target) are detected. Such continuous observation makes it possible to reconnaissance even a well-camouflaged target by indirect signs.

3.5. Tactical techniques for conducting reconnaissance with UAVs

In order to fully utilize the capabilities of the UAV and minimize losses from the effects of enemy air defense systems and small arms, the operator can use a number of tactical techniques [7]:

single pass reconnaissance; multi-pass exploration; carding; exploration in two stages or more. The choice of tactical technique is carried out taking into account: the presence of landmarks on the ground; target load capabilities and control system; characteristics of reconnaissance objects, relative positions of their main elements;

the nature of the underlying surface in the exploration area; expected enemy opposition; flight performance characteristics of the UAV. Single-pass reconnaissance is used: when reconnaissance of objects with previously known coordinates; during exploration of small-sized objects;

42

when exploring extended objects. When reconnaissance of objects with known coordinates, an approach is usually made from the most advantageous (from the point of view of using reconnaissance equipment) direction. In this case, the UAV flies either directly above the reconnaissance object, or away from it at a distance that ensures that the object falls into the field of view.

If it is necessary to clarify the characteristics of an object or when reconnaissance of a newly discovered object, reconnaissance with several passes is used.

If it is necessary to explore areas of a large area, i.e., it is necessary to perform a large number of passes, combing is performed. The flight is carried out along parallel or intersecting sections of the route at the same altitude.

In the case of reconnaissance of area areas by a pair of UAVs, the essence of tactical techniques does not change. In this case, the characteristic features are: determination of a rational UAV battle formation; technical features in organizing the control and reception of intelligence information from two UAVs.

In order to reduce the time of continuous presence of a UAV in an area, reconnaissance is used in two or more stages: the UAV makes several passes over reconnaissance targets and leaves (at the same time, it can perform reconnaissance missions in another area or carry out tactical techniques to overcome enemy air defenses), then it returns (returns) to this area. In this case, it is advisable to approach the reconnaissance area from different directions and heights with constant maneuvering of the UAV.

The results of reconnaissance in the form of prepared formalized reconnaissance reports are sent to the commander of the artillery unit. All reconnaissance results, primary reconnaissance materials and related information are recorded in a storage device.

Features of conducting aerial reconnaissance in various terrain conditions and at night are given in Appendix 3.

Upon return, the UAV lands at the planned site. Serviceable UAVs can be used many times after post-flight maintenance. Minor damage is eliminated by replacing it with spare parts.

The completion of the mission is reported to the control center of the artillery unit, and at the same time the readiness of the UAV complex to perform the next mission is reported.

The movement of a UAV complex to a new area or a change of position is carried out in a planned manner or by the next task (order).

4. FIRE CONTROL WHEN USING A UAV

4.1. Features of fire control organization

The organization of fire control is influenced by the placement of UAV control points, the control and engagement subsystem of the artillery unit.

1. During the organization of work at the control point and battery substations: additionally determine the type of UAV used, location area, placement of information display equipment, distribution of communication equipment across the control panel;

specify (select) UAV launch and landing sites; clarify the responsibilities of the UAV operator; clarify the order of target designation.

2. When organizing communication: determine the capabilities of the UAV by the amount and type of information provided, the availability of communications;

determine the procedure for using communication means, the possibility of operating an additional means of displaying information at a distance;

clarify the procedure for exchanging information (Fig. 3.2); clarify the presence of dead spaces in communication and telemetry transmission;

clarify (clarify) the identification features (data) of "friend or foe" and the procedure for action in the event of loss of communication with the UAV.

Placement of automated workstations when integrated with UAVs (Fig. 32).

Control subsystem Subsystem

intelligence UAV operator **together with KB** at the forefront (does not require additional means of communication)

Rice. 32 Placement of automated PU workstations when integrated with UAVs (option)

Some additional information display and controls are used for visual display purposes only

UAV operator **together with the GSS** on the OP (does not require additional means of communication)

UAV operator **together with NS** on PUOD (does not require additional means of communication)

UAV operator **completes tasks independently**

If additional means of displaying information are available and possible

Options Subsystem

defeats

KNP KB

intelligence information, without the possibility of interference in the control of the UAV.

3. When organizing interaction: determine the required intelligence data about objects determined by the operator;

determine the methods and order of sighting, provide the required data on the target (gun systems, caliber, coordinates, flight time to the target area, trajectory altitude);

determine the number of UAVs simultaneously conducting reconnaissance and their target loads;

establish control signals, distribution of remote information display devices and the procedure for their use;

draw up a flight plan; They bring up the capabilities of enemy air defense and small arms to detect and destroy UAVs, experience of use in the current situation.

4. When monitoring the readiness of the control system, check:

knowledge of the duties of officials during the performance of reconnaissance and fire missions;

knowledge of the procedure for performing a reconnaissance and fire mission, the procedure for zeroing and firing maintenance;

knowledge of the procedure for action in the event of target loss (failure of the target load or the UAV itself), failure of the launcher, lack of communication and display of information.

In order to increase the combat readiness of UAVs, duty may be introduced. It involves maintaining specially allocated forces and assets in readiness to solve unexpected problems.

4.2. Fire control when performing reconnaissance and fire missions

Fire control is carried out according to general rules [6], taking into account a number of features that must be taken into account.

Upon understanding reconnaissance and fire missions: select a target in accordance with the assigned tasks in the reconnaissance and engagement zone;

determine the reliability and actual state of the goal; determine its danger and importance at a given time, position in the enemy’s battle formation, time of detection, nature of activity and maneuverability;

determine the remaining time the UAV remains in the air (battery charge).

When assessing fulfillment conditions ROgZ: determine the position of the OP and the time of opening fire; determine the total time to complete the task, taking into account the ambient temperature;

clarify the capabilities of the UAV for servicing zeroing and shooting to kill, the procedure for obtaining information;

determine the nature of the ground, the presence of unprotected personnel, the position of their troops, the possibility of using ammunition with proximity fuses and firing on ricochets.

Making a decision To carry out a reconnaissance and fire mission, as a rule, on his own initiative, the battery commander determines:

target to hit; shooting task and type of fire; order of task execution; the number of weapons used; a method for determining settings for shooting to kill; method of firing at a target; type of projectile, type of fuse, type of firing and charge; shooting to kill order; servicing UAV; shell consumption; safety requirements for friendly troops and UAVs during firing service.

When setting reconnaissance and fire missions are guided by [6]. In addition indicate:

when determining the shooting method, the procedure for obtaining and communicating information;

procedure for calculating proofs; OP number, maneuver order and time of readiness to open fire.

Installations for shooting to kill determine the way

Bami [6]:

full (reduced) training; use of targeted amendments; zeroing in on the target. Sighting is carried out at targets whose coordinates are determined by the same device. If the target coordinates are determined by other means, then they are clarified using this UAV. To calculate the corrections, only the target coordinates determined using the UAV are used.

During zeroing (shooting to kill), the operator reports:

coordinates of the explosion (the center of the group of explosions in the salvo); deviation of the center of the group of discontinuities from the target; category of ruptures (air, ground); action of the target during shooting. **Shooting using UAVs is carried out:** by observing signs of ruptures; consistent controls across the world;

according to a schedule or scale; on a grid with visual assessment of gaps; based on measured deviations (if appropriate software is available).

The starting point, as a rule, is chosen near the control point of the artillery unit (in this case, the coordinates of the observation point coincide with the coordinates of the control point). If necessary, any point within the range of the UAV over which it hovers, providing good conditions for observing the target (explosions), is taken as an observation point. In some cases, primarily when servicing the firing of a mortar battery, it is envisaged to service the firing directly from the OP area; in this case, the coordinates of the observation point usually coincide with the coordinates of the main mortar. If there are smoke mines at the beginning of the shooting, instead of a salvo, it is allowed to assign one shot with a smoke mine.

If the person performing the fire task and the UAV operator are not at the same point (OP), when setting the task for reconnaissance and firing service, he is indicated the nature of the target, its coordinates or the expected area (square) of location. Having scouted

target, the operator reports its coordinates, dimensions along the front and depth, determined perpendicular and parallel to the firing plane, the number of individual targets in its composition, the conditions for the location of targets (open or in trenches), readiness for firing service, available to him, in these conditions, the method of zeroing and the time interval between salvoes (shots), **IMPORTANT – coordinates of the observation point.**

When the battery is ready, the operator is informed of the number of explosions in the salvo or shots that need to be observed, and the flight time of the mine. Fire is opened after the operator reports readiness to detect explosions and informs him about the volleys (shots) fired. The UAV operator determines and reports center deviations groups of explosions in a salvo (explosion) from the target.

1.Sighting based on observation of signs of ruptures Sighting for NZR is carried out according to the general rules until a 100 m fork or a covering group is obtained. If the starting point is not located near the control point (OP), then the UAV operator reports the name of the observation point, which is taken as the OP point, for example: “Observation point - bridge in square 2315.”

When the observation point is removed from the OP, not exceeding 1/10 of the firing range in any direction, the range and direction adjustments are taken equal to the deviations taken with opposite signs.

2.Sighting by sequential controls according to cardinal directions (PCSS) The PKSS is fired until the target is covered or until the deviation of the center of the salvo (explosion) from the target is no more than 100 m.

The operator reports deviations to the sides of the horizon (N-S, W-E) or $X\Delta$, $U\Delta$ along the axes of rectangular coordinates in meters. The essence of zeroing is to determine the deviations of the explosions from the target along the coordinate axes *X* And *U* (CA = ΔX and CV = ΔU) and in the subsequent calculation of range (CR') and direction (β) corrections based on these deviations (Fig. 33). If the operator reports discontinuity deviations towards the sides of the horizon: positive axis direction *X* is the direction to the NORTH, and the negative

noe to the SOUTH. Positive axis direction *U* corresponds to the direction to the EAST, and negative to the WEST.

Rice. 33. Determination of corrections for CR range and direction *b*

Shooting is carried out by successively bringing the explosions closer to the target until the explosion is covered or the deviation from the target is no more than 100 m along the coordinate axes. Corrections are determined using a computer, MK, PUO, PRK or using a grid. The grid for determining proofs is built on a sheet of checkered paper. When constructing a grid (Fig. 34), two mutually perpendicular lines are drawn corresponding to the coordinate axes *X* (NORTH – SOUTH) and *AND* (WEST – EAST).

The intersection of these lines is taken as the center of the target. By directional angle of the target (firing direction) $_{Ts}$a Draw a target line on the grid. To do this, the AK-3(4) is placed with the center on the center of the reticle and rotated until the division aligns, corresponding to the directional firing angle with the reticle line at the top, after which a dot is placed opposite the zero division of the circle. Having removed the AK, draw a target line through the center of the reticle and the marked point and, perpendicular to it, a line of lateral deviations. On a grid scale (50 m in one cell), scales with a division value of 50 m are applied to the target line and the line of lateral deviations. Based on the deviations received from the operator ΔX = +350 (north 350), ΔY = +250 (east 250) applied to

mesh center group gaps *R*. From point *R* lower the perpendiculars to the target line and the line of lateral deviations and determine the range corrections (ΔD= +360) and direction (Δd = –240).

Fig.34. Grid for defining corrections

Corrections define:

$\Delta P = \Delta^{\Delta} X^{D}{}_{outside}$

$= ^{+} 18 ^{360} = + 20$ out; (1)

$\Delta\partial = ^{\Delta} {}^{d}0,001\ D$

$_{T}{}^{h} = ^{-} 12$

$^{240} = - 0\text{-}20.$ (2)

3.Sighting according to schedule Since the UAV has a significant excess over the target, shooting according to the schedule is possible (Fig. 35).

At the calculated installations, one shot is fired and according to deviations (30 to the right, below 8) a P1 gap is applied. The second shot is fired at the sight setting, increased (decreased) by 200–400 m with the expectation of capturing the target within the range range. Draw a second break on the graph (to the right 10, above 6) P2 and connect points P1 and P2 with a line showing the direction of fire.

52

Dividing the segment P1P2 into 4-8 parts, a range scale is obtained with a division value of 50 m. The third shot is fired with the goniometer changed to 20-40 divisions, with the expectation of capturing the target in the goniometer fork.

Fig.35. Shooting schedule

By drawing a third gap (to the left 35, above 4) P3 and connecting points P, P3 with a line, a line of lateral deviations for the OP is obtained. By dividing the segment P2P3 into 4-8 parts, we obtain a scale of lateral deviations with a division value of 0-05. To determine the corrections from the last break, draw through the point *Ts* parallel to segment PP2 is the target line and parallel to segment P1P3 is the line of lateral deviations for the OP (range less than 140 m, to the right 0-23).

Having made adjustments to the sight and protractor, they proceed to shooting to kill according to the general rules.

Firing according to a simplified schedule With this method, two points P1 and P2 are placed in advance on a sheet of checkered paper at a distance of 8 cells from each other (the cost of dividing one cell is 50 m) (Fig. 36).

At the operator's command, two shots (volley) are fired on a calculated inclinometer with the shortest possible time interval between them: the first shot (volley) on a sight reduced by 4

divisions compared to what was calculated; the second is on the sight, enlarged by 4 divisions.

Fig.36. Determination of proofs using a simplified schedule

The operator, assessing by eye the relative position of the target and two explosions (CRG) on the ground, plots the target on a graph in cells and transmits to the shooter the position of the target relative to the nearest explosion (volley). For example, for the case shown in the figure, the operator must transmit "Target from the second salvo. Back 2, right 3.5". In this case, if in the second salvo the sight is 212, it is not difficult to determine the correction of the sight (it is, in principle, known less than 2) and the protractor:

$\partial\Delta =$ 001,0 Δ ^{d}

D_T

$h =$ 5,350

$m \cdot$ 001,0

.

6000 m

$= +$ 29029 $= + -$ (3)

Command to start shooting to kill: "Battery. Sight 210, to the right 0-29. The fan is concentrated...Fire!

4. Zeroing with a scale Zeroing with a scale is used in the absence of a sufficient number of contour points or sharply distinguishing points on the ground.

local objects, which presents sufficient difficulties in sighting in cardinal directions and orientation (finding the target line on the ground).

The essence of zeroing with a scale is that two groups of explosions at different sight settings in the target area indicate the shooting plane and a scale is created to determine the deviations of the explosions from the target in range and direction in meters.

When zeroing the battery with a scale for the first salvo, the calculated installation of the sight in the center of the target for the first platoon is reduced by 100-200 m (the first group of explosions), and for the second platoon it is increased by 100-200 m (the second group of explosions).

When zeroing with a scale, the operator determines and transmits deviations of the group of discontinuities closest to the target, indicating its number (Fig. 37), for example: "To the right 50, second flight 160." Measurements are made by eye, comparing the magnitude of the deviation of the nearest

CGR from the target in range with the 200-400 m distance indicated by the extreme gaps.

Fig.37. Sighting a target with a scale

Having received the operator's report on the position of the closest target

groups of explosions, calculate a single sight setting for assigning a battery salvo:

$$P_{outside} = P_{is\,bl} - \Delta \Delta X^{D}, \quad (4)$$

Where, P_{bl} – installation of the sight corresponding to the nearest to the target (group of discontinuities); $D\Delta$ – deviation of the group of gaps closest to the target in range in meters, with a “+” sign if overshoots relative to the target were obtained, “-” – undershoots

The direction correction is calculated using the formula:

$$\Delta\partial = - 0,001 \Delta dD_{T h}, \quad (5)$$

Where, $d\Delta$ **–** lateral deviation of the center of gravity from the target.

A battery salvo is assigned to one sight setting. The operator determines and reports deviations of the center of the salvo from the target in range and direction. After introducing the corrections, they proceed to shooting to kill.

When receiving overshoots and undershoots or hits in a salvo, the operator reports that the target has been covered.

5.Sighting using information display tool *a) Shooting according to a schedule with finding the range and direction scales.* For zeroing, a discontinuity pattern is built on the information display device by gluing a transparent film to the screen. The operator marks the position of 1, 2, 3 bursts (volleys) with a marker (Fig. 38).

Fig.38. Constructing a discontinuity pattern on the monitor

Knowing the distance between the explosions at a range of 200 m and in the direction of 20 divisions, it determines the deviation of the last explosion from the target and transmits: «Don". I see the gap. To the right 8. Undershoot 75. I am “Owl” or proofs: “Don”. Battery. The fan is concentrated. Range is greater than 75. To the left is 0-08. 2 mines. Fluent. Fire".

b) Shooting on the grid with visual assessment of gaps. Due to the UAV's elevation above the target, all overflight gaps will appear above the target when observed from it, and all underflight gaps will appear below the target (Fig. 39). Consequently, the operator can observe not only lateral deviations of the explosion from the target, but also deviations along the range; in this case, range deviations will be measured not in meters, but as the excess of the gaps above the target - in protractor divisions.

Fig.39. UAV surveillance scheme

From the CAR triangle, the deviation of the gap from the target in range:

$$\Delta D = D_{n}^{BLA} \frac{\sin b}{\sin(b-a)}, \quad (6)$$

Where, D_{n}^{BLA} – surveillance range from UAVs; a – angle between the observation line and the horizon; b – exceeding the gap relative to the target.

Since the angle b compared to anglea is very small, then without much error we can consider sin(a b-) equal sin a .

Meaning that sin a = ^{N} D_{nBpLA}

$_{BpLA}$ and what can be considered sin β = $_{1000}$ ^{b} ,

Where ^{b} expressed in protractor divisions, the formula for determining the deviation of discontinuities will take the form:

$_{BpLA}$ $_{G}$

$_{BpLA}$ $_{BpLA}$$^{\Delta}$ D

b= 1000 D_n

$_{BpLA}$ N

$_{BpLA}$

$_2$β≈ 1000 D $_{G}$ $_{BpLA}$ N

$_2$b= 001,0 N

D

$_2$, (7)

58

Where, $_{BpLA}$ N – UAV flight altitude;

$_{BpLA}$ $_{G}D$ – horizontal range to the target.

Firing is carried out with volleys of the battery (platoon) with a concentrated fan, and under favorable conditions with single shots of the main gun. To ensure reliable detection of explosions, the main weapon of the battery is assigned a high-explosive fuse setting. If there are smoke shells, it is allowed to fire with single shots of the main gun. Firing is carried out until the target is covered or until the deviation of the center of the salvo (explosion) from the target is no more than 100 m.

If the target leaves the location or performs a counter-fire maneuver, it is possible to zero in on the previous area of its location (using certain adjustments) with transferring fire (transition to shooting to kill) at the target in the new area [9].

4.4. Hitting stationary observed targets

Observable targets include those that are observed during the entire shooting process. Since the UAV provides observation of the state of the target during the entire shooting to kill, shooting to kill is carried out according to the rules for hitting observed targets [6].

Manpower and unarmored targets located openly or in trenches (trenches) without overlap, in addition, are hit by shooting on ricochets or shells with explosive power, and openly located manpower with shells with diesel fuel.

A battery (platoon) fires to kill in series of rapid fire of 2-4 rounds per gun, and a division fires in series of rapid fire of 2 rounds per gun (gun-mount) or by fire raids.

Individual armored targets (tanks, infantry fighting vehicles, armored personnel carriers), anti-tank systems, anti-tank guns, etc., fire weapons in wood-earth structures and prefabricated structures are destroyed by a battery (platoon, gun), using shells with an explosive or impact fuse when it is installed, depending on the nature of the target. Shooting is carried out on one sight setting with a concentrated fan until the fire mission is completed.

Group targets with a depth of less than 100 m are hit by fire from batteries (platoons), and less often from divisions, in series of rapid fire before the fire mission is completed.

The battery (platoon) fires on one sight setting and on one or two goniometer settings with a fan along the width of the target front. The division fires with batteries at one aiming point or with target areas distributed between batteries.

Group targets with a depth of 100 m or more are hit by division (battery) fire with one or more fire raids before the fire mission is completed.

The division fires with batteries side by side, batteries with a scale, or with the distribution of target areas between batteries, and the battery, as if firing independently, to hit an unobserved target.

Covered manpower and fire weapons located in defensive positions, as a rule, are suppressed by one or several fire raids.

At least two batteries are involved in shooting to kill manpower and fire weapons located in a platoon defensive position.

During shooting to kill between series of rapid fire or fire raids, and, if necessary, during fire raids, the condition of the target is assessed, corrections are determined and introduced.

When performing a fire mission by a battery (platoon, gun) independently or as part of a division with the distribution of target areas between batteries, the fire is adjusted by the battery commander based on the battery salvo (a series of rapid fire).

Fire adjustment is carried out based on the results of assessing the deviation of the center of gravity in the salvo from the target center. When adjusting fire, adjustments to the range, direction, fan, height of explosions and jump (scale) of the sight are determined and introduced.

If it is impossible to determine the deviation of the CGR in a salvo in terms of range using a UAV or by eye, it is determined by the NZR and accepted as equal along the observation line:

at a target depth of less than 100 m - 50 m, if all overshoots or undershoots were obtained when determining installations by shooting the target or checking installations with shots of the main guns (100 m, when determining installations by other methods without checking the shot -

mi main guns), and 25 m, if a covering group with a predominance of overshoots or undershoots is obtained;

at a target depth of 100 m or more - the target depth if all overshoots relative to the far boundary of the target (undershoots relative to the near target boundary) are obtained after zeroing the target or when determining settings by other methods with checking the settings with shots from the main guns (1.5 target depths, if the settings were determined by other methods without checking them with shots from the main guns), 2/3 of the target depth if a predominance of overshoots (undershoots) is obtained relative to the far (near) target boundary and 1/2 of the target depth, if an approximate equality of overshoots and undershoots relative to the far (near) target boundary is obtained.

Range and direction corrections are determined using instruments (PRK, PUO, MK, computers, smartphones with special programs based on Android or Windows mobile), and when corrected for a displacement of less than 5-00 - by calculation.

When firing projectiles with LW, adjustments to range, direction, fan and scale value are determined according to general rules. Correction of the range is accompanied by a change in the installation of the fuse.

The excess of air bursts of projectiles with LW over the target is corrected by changing the level setting in the same way as when zeroing in on the target [6].

When firing projectiles with diesel fuel, excess air gaps are corrected by changing the tube setting by one division, if the average height of air gaps differs from the most favorable height by more than half. The installation of the tube is increased if the gaps are above the best height, and decreased if below. The best height is determined using shooting tables.

Shooting to kill self-propelled artillery (mortar, MLRS) batteries (platoons) is carried out with the goal of their disorganization, suppression or destruction.

Suppression consists of inflicting casualties on it (damage rate 30%) and creating conditions by fire under which it is temporarily deprived of combat capability.

The task of destruction is to inflict such losses on it (the degree of destruction is 60%) in which it completely loses its combat capabilities.

ability, i.e. ability to carry out assigned combat missions. Disorganization consists of creating conditions under which control is disrupted, the maneuver is limited (prohibited), or the battery stops performing the fire mission and leaves the occupied OP, its maneuver is limited or control is disrupted.

Due to the fact that self-propelled artillery (mortar, MLRS) batteries (platoon) are capable of leaving the outpost in a short time (1.5-2.5 minutes) after the start of shelling, the task of destroying such targets can only be set if the battery (platoon) remains at the outpost throughout the entire fire raid.

Enemy MLRS batteries (platoons) carry out fire missions from temporary, usually unprepared positions in engineering terms, and the task completion time is 30-60 seconds, after which they move. Therefore, if they are discovered while they are performing tasks, it is difficult to cause damage. Consequently, it is necessary to hit them in positions (in areas) even if they are not firing, and if there are sufficient means (ammunition) and on the march.

The firing method is prescribed in accordance with [6], as when hitting stationary observed targets.

The total time of fire impact and the number of fire attacks will depend on achieving the required degree of target destruction (suppression for a certain time, prevention of deployment, prevention of firing from the ground, delivery and unloading of ammunition).

The duration of each fire raid depends on the rate of fire of the guns and the possible time spent at the outpost before performing the counter-fire maneuver.

Firing order: rapid fire with maximum rate of fire.

Option to perform a reconnaissance and fire mission with a quadcopter-type UAV (Appendix 4).

5. METHODS OF DETECTING AND DESTROYING UAVs

Like any aerodynamic aircraft equipped with a propulsion system and equipped with a set of electronic equipment, a UAV during its combat use has a number of unmasking features: electromagnetic and thermal radiation, noise from a running engine, airframe, rotating propeller, etc.

The greatest vulnerability of UAVs is due to the presence of electromagnetic radiation. Electromagnetic unmasking features include:

on-board transponder signals; radar signals reflected from the body and components of the UAV;

signals from television repeaters, broadcast stations, cellular base stations reflected from UAVs;

commands and "reports" of the control channel between the ground control point and the UAV, as well as between the UAV and the navigation system relay satellite;

side-view radar signals; intelligence sharing channels; signals from the automatic landing system at the airfield, etc. *Detection and identification.* Before deciding how best and cheapest to destroy a UAV, it must first be detected and identified. Like any material object, a UAV carries unmasking characteristics. The degree of visibility is determined by the size of its signatures in the radio frequency, infrared and visible spectra, as well as the acoustic signature. Commercial UAVs have small signatures: they are made of composite materials and plastic with

With a special color and a special combination of layers, their small gasoline and especially electric engines emit little heat and operate almost silently.

The tactics of using UAVs are varied and include not only flying at extremely low altitudes, in folds of terrain, the use of active and passive jamming, reducing radio signature (radio frequency signature - effective scattering surface (ESR)), the level of infrared radiation and acoustic noise, but also the highest maneuverability up to stopping ("freezing") the UAV in folds of terrain with a subsequent change in the flight path. UAV flight trajectories can take place at extremely low altitudes - 0.5-2 m, in a wide range of speeds - 0-100 km/h, in gorges and ravines, in the shadow of local hills and beyond the horizon, and therefore their detection by military air defense radars is impossible in these conditions.

To effectively counter enemy UAVs, radar creators have to solve several problems at once. First:

improving the characteristics of the station, making it possible to detect objects with a lower RCS. Second: correct target identification.

So, for detecting UAVs in anti-aircraft missile systems (SAM); Anti-aircraft missile and gun systems (ZRPK), anti-aircraft artillery systems (ZAK), as a rule, use standard radars, optical and passive direction finders. The assessment shows that for existing domestic air defense systems this detection probability is 0.5-0.8 for UAVs with an ESR of at least 2 m^2.

True, progress in radar makes it possible to solve such problems. With the detection of UAVs with an EOD of no more than 0.1 m2, these radars no longer encounter difficulties, but in return they receive a more complex problem - identifying the target and separating it from the signatures of flying birds, interference and other reflected signals that locators usually filter out.

The solution to such problems is seen in locators with variable resolution in the detection cycle. Such radars are capable of reliably detecting and identifying flying objects with a small radar signature moving along nonlinear, almost random trajectories. At the same time, a proven bird identification algorithm was used in the new generation locators, and the military should be grateful to the ornithologists

logs, whose “bird mathematics” is now used for military purposes. The radar “analyzes the signatures and kinematics of the UAV in order to classify and identify it and sends a signal to an optoelectronic (infrared) camera for more accurate identification.

At the 2015 Paris Air Show, Controp Precision Technologies showed off its Tornad thermal imager. It is capable of detecting the slightest changes in space associated with the flights of small UAVs. It incorporates an automatic audible and visual warning system to notify the operator of any intrusion into the no-fly zone. In order to neutralize the threat, this system can be integrated into an electronic countermeasures or weapons system.

ECS created the AUDS system, which during testing demonstrated the ability to detect, track and neutralize targets in just 15 seconds. In order to expand the surveillance area, these systems can be combined into a network, be it several full-fledged AUDS systems or a network of radars connected to one block of the “survey and search system-jammer”.

The Hawkeye system has a Doppler radar operating in the Ku band with a maximum range of 8 km, can determine the effective area of reflection measuring up to 0.01 m2.

The DRONESHIELD detector is capable of detecting small and light copters, has a minimum of triggering on “non-core” targets (birds, kites, balloons, fireworks, “Chinese lanterns”), is insensitive to interference and non-solid obstacles (trees, poles, wires, antennas), is able to filter out background and city noise, isolating only the characteristic sound of engines and propellers. A system based on the principle of acoustic detection has a number of advantages over laser, light, radar, optical, infrared and radio frequency detection systems. The acoustic detector software contains a database of sound characteristics of all UAVs. This allows the system not to react to birds and aircraft, identifying only potentially dangerous objects. Detection range is up to 1000 m in distance to the target and 500 m in target height.

Counteraction. Destroy. The simplest and most logical way to get rid of a UAV is to destroy it. To carry out an attack, any available weapon can be used, the use of which is most appropriate in the current conditions: contact impact - small arms, air defense systems, anti-aircraft missile systems and non-contact, based on new physical principles.

1. Air defense systems, **small arms.** To destroy UAVs, they can use both missile and cannon weapons. However, from the point of view of military-economic feasibility and rational consumption of air defense missile systems, the use of guided missiles to destroy UAVs in the tactical zone is clearly not profitable. Therefore, the main means of defeating them at present are air defense missile systems.

Direct destruction of air defense missile systems by UAVs will be carried out by high-explosive, fragmentation, armor-piercing, cumulative and incendiary projectiles of cannon weapons.

The small overall dimensions of UAVs do not allow them to be effectively hit by anti-aircraft artillery systems and small arms. Small ESR makes it difficult to hit them with guided missiles with radar seekers. The use of guided missiles with infrared seekers against UAVs is also ineffective due to the fact that the IR radiation of low-power UAV engines is almost equal to background values.

It is very difficult to expect direct hits when firing a conventional shell from a cannon - the likelihood of such an event is low. But if a conventional cannon fires a shot with a special warhead, then everything will become simpler. Special equipment consists of striking elements in the form of tungsten balls. Each weighs about 1 g, and their total number is about 400-500 pieces. When a shell detonates near a UAV, it forms a covering cloud, and the vehicle is successfully hit by shot, like game when hunting with a shotgun.

The emergence of ammunition with smart fuses and a given impact makes it possible to add capabilities to combat UAVs. Programmable fuses technology ensures “standard” explosions throughout the entire effective destruction zone,

typical dimensions of which, for example, are 200–4000 m in width and 0–3000 m in height.

An example is the 35-mm KETF (Kinetic Energy Time Fuse) anti-aircraft projectile with a fuse using AHEAD (Advanced Hit Efficiency and Destruction) technology; 40-mm PMD 330 projectile with the number of striking elements 407, weighing 1.24 g each; PTFP (Programmable Time Fuse Pre-Fragmented) projectile - more than a hundred cylindrical tungsten projectiles, stabilized by rotation, to improve the structure of the fragment cloud for more effective target destruction. Typical ones consist of 24 shots.

As is known, a UAV is a complex combination of elements, assemblies, parts and systems assembled into a single object, which to varying degrees affect its survivability as a whole. Thus, if one of them fails, the UAV is destroyed, i.e., shot down or unable to carry out a combat mission, while other minor elements fail or are damaged, it will remain capable of continuing the flight mission.

The probability of defeat, calculated in relation to the capabilities of the air defense missile systems in service, shows that most of them are capable of hitting UAVs with an ESR of more than 2 m^2 with a probability of 0.3-0.7. However, this does not apply to UAVs with low RCS. The problem is determined by the fact that air defense systems adopted for service in the USSR were designed and created to solve the problem of repelling group and concentrated attacks by enemy air attack weapons and were intended to search for and destroy targets that differ in their characteristics from tactical UAVs.

Moreover, it will be extremely difficult for an air defense radar to detect a target when a UAV is flying at low altitude above buildings within populated areas due to numerous reflections of the probing radio signal from objects that have a much larger ESR than the UAV.

2. Microwave emitter. According to some reports, work is underway abroad to create microwave emitters capable of “burning” the electronics of an aircraft. Modern UAVs are characterized by the widespread use of composite materials in the airframe design, the use of which

This leads to a significant reduction in radar signature. At the same time, this technical solution makes it possible for electromagnetic radiation to pass through the UAV body and affect its electronic equipment. Numerous conductors included in the UAV equipment can be considered as parasitic antennas that receive or radiate electromagnetic fields.

When a UAV is detected, the radiating antenna is oriented in its direction and electromagnetic radiation is generated, as a result of which induced currents appear on its parasitic antennas, which will cause failures in the operation of the electronic equipment of the on-board control system of the UAV (from intermittent failures (failures) to irreversible catastrophic failures), which will result in the crash of the vehicle.

Another innovation is the precision-directed impact on a target with powerful microwave radiation, which burns any radio-electronic equipment and disables computers and software.

3. Laser. Where missile or gun air defense may be inappropriate, too expensive or ineffective against UAVs, directed energy weapons may provide another option.

In Western countries, laser guns with a power of 5-10 kW are at various stages of testing with the prospect of increasing it to 50-100 kW. The guns have one or more laser barrels. The laser system control system focuses the laser beam on the most vulnerable part of the UAV - its tail and rear.

When there were no high-power lasers yet, work was carried out with low-power lasers, the beam of which, hitting an air target (UAV), simply heated it to a “very good” thermal signature, and the UAV became a good target for Stinger-type MANPADS with a thermal seeker.

Neutralize. Electronic warfare. The main methods of hacking UAVs are: hacking an encrypted channel or substituting authorization data and thereby gaining access to control;

exploitation of software vulnerabilities, including buffer overflows;

using interfaces and data channels of the original software to “pull” third-party code.

To successfully suppress the operation of a UAV, it is necessary to establish the frequencies at which it is controlled, and then “clog” them with interference - to organize curtains on the UAV flight paths. Once a UAV is exposed to radio interference, it will typically initiate its own security protocol. Most often, this involves three possible scenarios for the development of events: the UAV hovering over the current position (before falling after the batteries are discharged), landing on the ground, or returning the device to the starting point. In this case, in any case, the UAV’s mission will be interrupted. Electronic warfare equipment suppresses not only the control channel, but also signals from the navigation system.

The British company SRC announced the development of a system to combat UAVs Anti-UAV Defense System (AUDS). Radar is used to detect UAVs, a search and search system for tracking and directional radio frequency as a neutralizing component. AUDS has demonstrated the ability to detect, track and neutralize targets in 15 seconds at a range of up to 2.5 km.

But the most insidious are not forceful techniques, but intelligent electronic spoofing attacks (spoof - deception) on the navigation system: coded introduction of an error in determining the coordinates of the UAV location, creation of a false constellation, etc. During the attack, simulated navigation signals are sent to the UAV receivers, giving it false navigation data, which is therefore perceived by it as true. Due to this “substitution”, the navigator incorrectly determines its location.

Capture. To combat UAVs, special capture systems are being developed for both ground and air use. The essence of their use is that a special net is either stretched (for example, between buildings and trees) or placed in a box and fired in the direction of the UAV in order to catch it. Malou Tech presented a hexacopter equipped with a special frame with replaceable cartridges charged with CO^2 and a net that is fired when approaching the UAV.

IMPORTANT!!! DJI DRONE DETECTION PLATFORM – AEROSCOPE

In the SVO zone, the Ukrainian side is actively using the DJI drone detection tool – DJI Aeroscope. The system was designed to protect critical infrastructure from surveillance and threats from third parties. No one imagined that in war conditions this could play against the rules and did not provide a “switch off button” that would not harm both sides.

How AeroScope works: all DJI drones released since 2017 broadcast information that can be detected by a special receiver at a distance of up to 50 kilometers (in ideal conditions without wind): location; flight altitude above the ground; movement speed; drone direction; device serial number; the location of the pilot who controls it. The detection range depends, first of all, on the openness of the terrain at the installation site, the level of interference in the monitoring area, the degree of signal amplification (omnidirectional antenna = 0 dB, G8 = 8 dB), the direction of the antenna, the type of data transmission protocol (OCUSYNC, LB, WiFi) used by the UAV.

Unfortunately, there are no saving firmware from Aeroscope, although there is a lot of talk about them. DJI, as a drone manufacturer, has indeed created a drone detection tool. The only reasonable reaction of the operator, if shortly after turning on the remote control they started shooting at him, is to turn off the remote control and hide.

DJI sells two types of receivers for drone detection: a compact version (Fig. 40), and a stationary version that provides long-range detection capabilities (Fig. 41). All data that can be detected through AeroScope can be easily downloaded by the user to a private cloud or server. Technical

Ski, tracking through a portable device does not even require the Internet.

On average, the price of a “DJI Aeroscope Portable Unit” ranges from 10 thousand dollars, and the price of a mid-range G8 system ranges from 25 and 150 thousand dollars.

Fig.41. Stationary option

Why can't AeroScope be disabled? The drone user cannot disable himself from AeroScope detection because this is in the drone's software code.

Rice. 40. Compact version

hawker The signal is transmitted locally at standard frequencies of 2.4 GHz and 5.8 GHz.

It is possible to release new firmware for drones taking into account the disabling of detection. Because for some earlier models, that's how the system was added. But, again, there is no possibility that detection will be disabled on the territory of Ukraine or Russia.

In theory, DJI could set inactive geofences over certain areas. Or revoke AeroScope detection certificates. But this also has its own nuances: users will be able to bypass the problem of “inactive zones” if they do not install the latest software. And we don't know if DJI has the ability to revoke detection certificates and then disable them. If systems operate without an Internet connection, this is almost impossible.

How to protect yourself when launching a DJI drone 1. During launch, turn off GPS, switch your phone to “Airplane Mode”;

2. Choose a safe place for yourself (it should be located at a distance from the drone launch site);

3. Turn on the drone exactly at the place chosen for launch, and not along the road or in a place of refuge;

4. After turning on, return to a safe place and control the drone there;

5. After finishing the flight, turn off the drone at the same place where you launched it: first the remote control is turned off, and then the drone itself. It’s better if you have someone to help you to disconnect from a distance.

Methods of camouflage from UAVs: 1. Daytime camouflage: hide in the shade of buildings or trees. Use dense forest, dugouts and blocked crevices as natural cover, or use camouflage nets.

2. Night camouflage: hide inside buildings and structures or under the cover of trees and foliage. Do not turn on flashlights or car headlights again.

3. Thermal masking: survival blankets (so-called space blankets) made of Mylar do not transmit infrared radiation. At night, wear a safety blanket like a poncho to help you hide from detection by the infrared camera. In hot weather, when the air temperature is 36°-40°C, the infrared camera cannot distinguish a person. In hot weather, you should also hide in the thermal shade of heated objects (stones, walls of buildings, etc.). In cold weather, a thick cotton pea coat or an old Soviet overcoat significantly reduces the thermal radiation of the body.

4. Wait for bad weather. Many drones cannot operate in high winds, smoke or thunderstorms. But at the moment there are several models of all-weather attack UAVs.

5. No wireless connection. The use of radios, mobile phones or GPS devices may give away your location.

6. False targets. Use mannequins or life-size stuffed animals to deceive aerial reconnaissance. Use reflective elements or mirrors, carpets made from turf, dirt (clay) on the roof of buildings and cars

CONCLUSION

This training manual outlines the issues of preparing and performing fire missions with quadcopter-type UAVs with artillery formations.

The material in the first chapter allows you to gain knowledge about the concept of development of micro (mini) UAVs, their classification and the tactical and technical characteristics of UAVs used to perform fire missions by artillery units.

The second chapter describes in detail the composition and capabilities of complexes with quadcopter-type UAVs.

The third chapter discusses the organization of aerial reconnaissance with UAVs. The fourth chapter reveals the features of fire control during performing reconnaissance and fire missions with artillery from UAVs, methods of sighting are given.

The fifth chapter provides methods for detecting and destroying UAVs, and features of the work of operators in combat conditions.

The methods of sighting with short-range UAVs outlined in the manual contribute to the formation of in-depth knowledge of shooting and fire control, and their skillful use when performing fire missions in combat.

APPLICATIONS

Appendix 1

AVERAGE TIME OF MAIN OPERATIONS FOR PERFORMING TASKS OF A QUADROCOPTER UAV

1. Deployment of the UAV to a position and preparation for work - up to 10 minutes.

4. Preparation of a flight program – up to 2 minutes. 5. Preparing the UAV for launch – up to 5 minutes. 6. Monitoring readiness to complete the assigned task - up to 0.5 minutes.

7. Changing the flight mission program – up to 1 minute. 8. Maintenance of artillery firing - up to 30 minutes. (depending on battery capacity).

9. Rolling up from a combat position to a traveling position and leaving the position - up to 5 minutes.

Appendix 2

DEMASKING SIGNS OF OBJECTS (TARGETS)

General unmasking signs of objects (targets) during reconnaissance include:
characteristic location of objects; signs of activity (movement, dust, smoke, fire, etc.); traces of activity (freshly discarded soil, behind muzzle cones, etc.);

color of objects (if it differs from the color of the surrounding area);

reflections from glass and unpainted metal parts. *Unmasking signs of launch positions from which missiles and missiles are launched are:*

rockets installed on launchers open or under covers;

availability of car radios with antennas at the position; the appearance after the launch of a large cloud of smoke and dust over the position; glowing missile tracks on the active part of the trajectory; rocket contrail on trajectory; flash and glow when starting at night. *Artillery batteries at firing positions that are not firing are detected by the following unmasking signs:*

a) location of the firing position. Depending on the nature of the terrain, the mission being performed, the type and caliber of guns, and the firing range, the artillery is echeloned to a depth of 1 to 10 km from the front line.

The dimensions of the OP battery, taking into account the location of vehicles and direct security, are up to 300-800 m along the front and up to 800 m in depth.

In wooded and swampy areas, OPs are located on the edges of the forest facing the front line, on clearings, near roads and on elevated areas overgrown with bushes. In rugged terrain, OPs are located in groves, hollows, ravines, behind reverse slopes of heights.

In populated areas, OPs are selected in squares, parks, squares, stadiums, near buildings, in the shade of buildings and trees.

b) the order of placement of guns (gun trenches). On the OP of medium-caliber batteries, guns are located at intervals of 30-50 m. The placement of guns can be in a line and figured (circle, wave, ledge to the right, ledge to the left).

For self-propelled guns, gun trenches in the shape of trapezoids and corners can be created. For towed guns, gun trenches with a circular or limited sector of fire are equipped. The diameter of the trench, taking into account the parapet, is 18-22 m. At the OP, large-caliber batteries of guns are located in a battery line or platoon-by-platoon with intervals between platoons of 200-300 m.

c) presence of signs of activity. *Firing batteries can be detected by the following unmasking signs:*

by the shine of the shots; through dust and smoke above the OP during firing. One of the main signs of OP activity when conducting reconnaissance by visual observation is the presence of rear cones formed in front of the gun on the ground (snow) from shots (in the summer in the form of a light cone, in the winter in the form of a dark cone).

If an OP is detected, but without signs of activity, then it is also necessary to determine its coordinates in order to target it with other artillery reconnaissance means and establish periodic surveillance.

At night and at dusk, batteries unmask themselves by the glare of shots (in the form of a short tongue of pale pink or reddish flame) and the reflection of shots against the background of clouds and forest edges. Flares are clearly visible in the morning and evening, even in the presence of fog.

During the day, in sunlight, the glare of shots is very rarely observed. In some cases, when shots are fired, smoke rings are formed, rising upward in the direction of the shot. If the enemy battery fires rapidly, then the individual hazes of shots do not have time to dissipate and, layering one on top of the other, form a cloud of smoke.

Smoke from shots in dry weather lasts for 1-2 seconds. In humid air or after rain it is more noticeable, lasts longer and

takes the correct oval shape. If the battery firing is located in the forest, then sometimes it is not possible to observe the brilliance of the shot; in this case, the location of the battery should be judged by the smoke. Remembering the characteristic outlines of the tree tops between which smoke appeared, you should link the firing position to the nearest landmarks.

False batteries that simulate firing differ from firing batteries in the following ways:

simulated flashes have a longer lasting effect than gun flashes;

the smoke of false flares is thicker, swirling, and does not have the shape of a stream;

there are no shell explosions in the location of friendly troops. OP mortar platoons are located in battalion defense areas, in the areas of companies of the second echelon of the battalion. The mortar base occupies up to 100-150 m along the front. Mortar trenches can be connected by communication passages.

Mortar bases are usually selected in the forest, in ravines and hollows, in quarries, in the ruins of buildings, in large craters from shell and bomb explosions, in pits, near steep river banks, on reverse slopes of heights, in bushes and other places that facilitate camouflage and make detection difficult.

Mortar positions include trenches for mortars, communication passages between trenches, shelters for crews and vehicles. The trenches are located at different distances from each other. Such a pattern of placement of trenches, like on a firing line, artillery battery position, no. Sometimes positions can be located in trenches.

Mortar trenches look like round dots of a dark gray tone. Near these points, cracks and communication passages in the form of dark stripes are sometimes observed.

In wooded and swampy areas, trenches for mortars are built on the surface of the ground, the walls of the trenches are made of wooden frames or wickerwork, covered with earth. The height of the walls reaches one meter or more.

When reconnaissance of mortar units, it is necessary to keep in mind that the firing range of mortars does not exceed 3-6 km, meaning

Read, having determined the area of mortar fire, you should conduct reconnaissance of the mortar position within the specified range.

Unmasking signs of firing mortars: During the day, in the absence of wind, a characteristic stream of smoke is observed in the direction of shooting up to a height of 10-15 m. Sometimes, along with the stream, a smoke ring is formed, rising to a height of 15-20 m. In the presence of wind, the smoke is observed worse and for shorter periods of time;

at night, a slight glow or reflection may be observed against the background of local objects located behind the OP (edge of a forest, front slope of a height, etc.);

at night, and in cloudy weather and during the day, oval-shaped red flashes are observed when firing.

Rocket launchers unmask yourself in appearance and shooting. During the day, in the absence of wind, dark clouds of smoke are observed at the end of the active part of the trajectory and a large cloud of smoke and dust above the firing position, which dissipates only after 20-30 s.

In the presence of wind, dark clouds of smoke at the end of the active part of the trajectory quickly dissipate and become unnoticeable; the cloud of smoke and dust above the OP also dissipates and lengthens in the direction of the wind. During the day in cloudy weather and at night, growing glow and fiery trails are visible on the active section of the trajectory 1-1.5 km long, along which the direction to the firing battery can be established.

The enemy can use the following methods of camouflage from aerial reconnaissance:

location of positions on a motley background of the terrain, in small continuous bushes, where special clearing is not required for firing;

placement of tools in buildings or artificial structures, which are given the appearance of civil-type buildings;

maintaining traffic discipline to avoid the formation of paths, roads, as well as camouflage of paths, roads and “backdoor” cones;

the use of special service masks to cover trenches, turfing the surface of dugouts;