Some views on the detection and determination of unmanned aerial vehicle of the shahed-136 (geran-2) type

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Abstract
Purpose: The Russian Federation resorted to terrorist acts, namely strikes with cruise missiles, unmanned aerial vehicles, etc. on critical infrastructure due to significant losses in weapons and military equipment, personnel. Thus, the Russian army is trying to influence the military-political leadership of Ukraine and the population to recognize the annexed territories as Russian by destroying the economy of Ukraine. Therefore, in order to protect critical infrastructure, there is an urgent need to find economically feasible ways to combat unmanned aerial vehicles and develop recommendations for detecting and defeating them with the least expenditure of resources. Design/Method/Approach (only for empirical papers): To achieve the goal of the study, the analysis of the use of unmanned aerial vehicles by Russian troops, which were purchased in Iran Shahed-136 (Geran-2), was carried out. The means used for their destruction were also analyzed. Findings: Unmanned aerial vehicles of Shahed-136 (Geran-2) type are usually used in groups. The frequency of their use indicates that they are controlled by the GLONASS navigation system, i.e. at the time when Russian satellites are over the territory of Ukraine. Among this group, one unmanned aerial vehicle is the master, which is controlled through the GLONASS system, and the rest are slaves and receive a signal from it. Theoretical implications (fipple cable): It consists in the fact that for the first time the use of unmanned aerial vehicles of Shahed-136 (Geran-2) type by the Russian army was analyzed and the ways of their defeat were considered. Practical implications (fipple cable): The generalized and systematized data on the use of unmanned aerial vehicles of the Shahed-136 (Geran-2) type by the Russian army and the analysis of the ways of their defeat by the Armed Forces of Ukraine, make it possible to analyze this information and determine the most economically feasible ways to defeat them. Also, the availability of generalized data provides an opportunity to develop practical recommendations for the development of complexes for the destruction of unmanned aerial vehicles of the Shahed-136 (Geranium-2) type, which would defeat both single and launched in groups. Originality/Value: The value of the research lies in the proposed method of using the proposed complex of detection and defeat of the target, which works in both automatic and controlled modes. So that this complex can detect, track and defeat both single unmanned aerial vehicles and those launched by a group. Research limitations/Future research: The limitation of the study is the use of sources that are in the public domain. Further research requires the development of a model of the target detection and defeat complex, evaluation of its effectiveness and feasibility study.

Key words: aggression, analysis, unmanned aerial vehicles, complex, detection, defeat.

Introduction

The aggressor's army has suffered significant losses both in personnel and in weapons and military equipment (WME) since the aggression of the Russian Federation against Ukraine [1]. During the eight months of full-scale aggression, the Russian army lost about 68,900 personnel, 2,628 tanks, 5,351 armored combat vehicles, 1,686 artillery systems, 379 multiple launch rocket systems, 192 air defense systems, 271 aircraft, 248 helicopters, 1,379 operational-tactical UAVs, 350 cruise missiles, 4,076 vehicles and tank-vehicles, 149 samples of special equipment [2-3]. In order to influence the economy of Ukraine, in early October 2022, Russian troops began to use purchased Iranian kamikaze drones Shahed-136 (Gheran-2) mainly to attack buildings and infrastructure facilities of the state, since these UAVs are ineffective for attacking military positions [4-5].

Analysis of the use of unmanned aerial vehicle (UAVs) of the Shahed-136 (Geran-2) type by Russian forces indicates that these UAVs can fly 1,500 km and carry up to 40 kilograms of explosives [6]. The periodicity of their use indicates that they are controlled by the GLONAS navigation system, and since the Russian Federation doesn't have a group of satellites that could fully cover the territory of Ukraine, they are used accordingly when Russian satellites are over the territory of Ukraine. Also, the analysis of UAV wreckage of the Shahed-136 (Geran-2) type indicates that if they are launched in groups (5-6 UAVs), among which one UAV is the leader and flies using the GLONAS system, and the rest receive a signal from it. Accordingly, after hitting the leading UAV, the rest may lose control.

The use of this type of UAV by Russian troops is aimed at terrorizing the civilian population, destroying civilian infrastructure and exhausting the resource of air defense equipment.

Material and methods

A number of works by both domestic and foreign scientists are devoted to the study of the detection and destruction of UAVs, in particular, in work [7], an analysis of tests of anti-aircraft missile systems (SAMS) on the destruction of UAVs, an analysis of the low efficiency of UAV destruction by air defense systems, and an economic assessment of the feasibility of destroying UAVs by SAM are provided. The work [8] is devoted to the classification of UAVs and the analysis of 35-40 mm gun complexes and microwave guns designed to destroy UAVs. In work [9], a general approach for combating UAVs is defined. For example, in work [10] an analysis of the experience of combat use of UAV groups to defeat air defense systems was carried out, which made it possible to identify the main shortcomings of air defense systems (ADF) and to determine the level of survivability of air defense systems in the conditions of mass use of UAVs, and in work [11] the results of fire and radio electronic defeating UAVs, the main features of UAVs are determined, and the effectiveness of UAVs defeat by means of detection and defeat is determined. In paper [12], the ways of defeating UAVs are mentioned, namely, electronic warfare devices, laser systems for defeating the control system and kinetic means for their mechanical damage. In the source of literature [13], a remote-controlled 12.7-mm machine gun is proposed, which has several gun barrels and television and thermal imaging cameras for detecting UAVs, i.e. this unit is a prototype of anti-aircraft guns ZU-23-2 and the similar ones. In work [14], an anti-drone laser system for ship-based placement and placement of this system on various moving platforms was considered, and in study [15], acoustic, visual, thermal imaging radio frequencies for UAV detection were considered. In the work [16] the ZRN-01 Stokrotka multiple launch rocket system is considered, which is designed to detect and destroy ground objects as well as air objects, primarily UAVs, and in the work [17] radar systems for detecting, tracking and destroying UAVs are considered, and in the paper [18] some types of UAVs and their main technical characteristics are considered. In the literature [19-21], anti-aircraft systems of modular layout, which include several elements for various purposes and are capable of monitoring the air situation in the near zone and destroying targets of various types, are presented.

Therefore, the purpose of the article is to find economically feasible ways to combat UAVs and to develop recommendations for detecting and destroying UAVs with the least expenditure of resources.

Results and discussion

The use of Iranian UAVs by the Russian army causes significant damage to the economy of Ukraine, as these kamikaze drones attack Ukrainian cities and critical infrastructure facilities if the Ukrainian Armed Forces fail to hit them in time. To effectively combat UAVs, they need to be detected, identified and, if necessary, destroyed in a timely manner. Since UAVs can be launched anywhere along the entire front line, this requires effective means to defeat them [22-23]. Also, information about possible launches of UAVs of the Shahed-136 (Geran-2) type from the 30-kilometer Chornobyl zone of the Republic of Belarus appears in the information space [24], which further complicates the possibility of their detection and destruction. It should also be noted that the use of UAV data will not change the course of the war in favor of the aggressor, as it is observed by the use of high-precision ammunition of the Armed Forces of Ukraine to destroy bases and warehouses with ammunition of the aggressor's army [25].

Analysis of combat actions to defeat the armed aggression of the Russian Federation indicates that air defense units shot down 15 UAVs "Shahed-136" out of 20 launched by the aggressor's army on one of the days of confrontation with the armed aggression [26]. Thus, it can be confidently asserted that the units of the Armed Forces of Ukraine, armed with Soviet-made air defense systems, can defeat up to 80% of these UAVs. Also, these UAVs were repeatedly hit by firearms as the maximum flight altitude is up to 5 km and the maximum speed is up to 180 km/h. In addition, due to the fact that the UAV is equipped with a petrol piston engine, it emits a loud sound, thus it is quite easy to detect [27].

After almost a month of the use of Shahed-136 (Geran-2) UAVs by the Russian Federation, a lot of information has appeared in the media about the ways of defeating this type of UAV. That is, these drones are shot down by all available weapons, namely machine guns, portable anti-aircraft missile systems or anti-aircraft artillery systems, airplanes, anti-aircraft gun ZU-23-2, electronic warfare systems, etc. [28-29].

Some information sources indicate that the price of one UAV Shahed-136 (Geran-2) for Russia is around 20,000 euros, while the price of missile systems for their destruction will exceed the price of UAVs several times, namely the price of a portable SAM of the "Arrow" or "Stinger" type can amount to 60-70,000 dollars, and medium-range SAM starting from 250,000 dollars [30]. This does not take into account the damage that may be caused to the state if this UAV hits critical infrastructure facilities. Thus, the price of the building in which the transformer substation, pumping station, etc. is located, can reach from $ 8 million and of course the price of transformer substations, pumping units located in these buildings can reach from $ 350,000. Therefore, by comparing the price of damage to the infrastructure and the price of air defense missile systems, we can definitely assert that the price of the missile is much lower than the price of the infrastructure that will be destroyed.

But it is also necessary to understand that at the next stage, Russia will use the cheapest UAVs in large amounts to terrorize the population centers of Ukraine. That is, groups of UAVs (loitering munitions) will be used, which will fill the niche between cruise missiles [31]. Therefore, to detect and defeat them, it is necessary to find the most appropriate ways to create the means of destroying this type of UAV. These means should be cheap to produce, easy to use and effective in defeating UAVs.

One of the ways to solve this problem can be creating a complex of targets detection and destruction, based on the use of engineered fragmentation munitions Fig. 1 [32-34].

This complex of detection and destruction of targets, depending on the need, can be used in a guided or unguided version, installed on the ground or on any vehicle.

Using an uncontrolled version of the sound sensor, it detects an air target and puts the complex in readiness to defeat, when the air target enters the range of the infrared sensor, the complex captures the target and accompanies it, during the tracking of the target, the laser meter determines the distance to the target and the area of destruction, in turn, the video camera captures the video image of the target. All information received from the target detection means is sent to the executive device in which the navigation system determines the coordinates of the target, after which the information is recorded by the executive device.

During the tracking of the target, the signal from the control device is sent to the executive units that provide a change in the angle of inclination of the launch container, and its rotation by 3600 relatives to its longitudinal axis. When the signal is received, the rotating platform is automatically fixed, after which the cassette with engineering ammunition is launched.

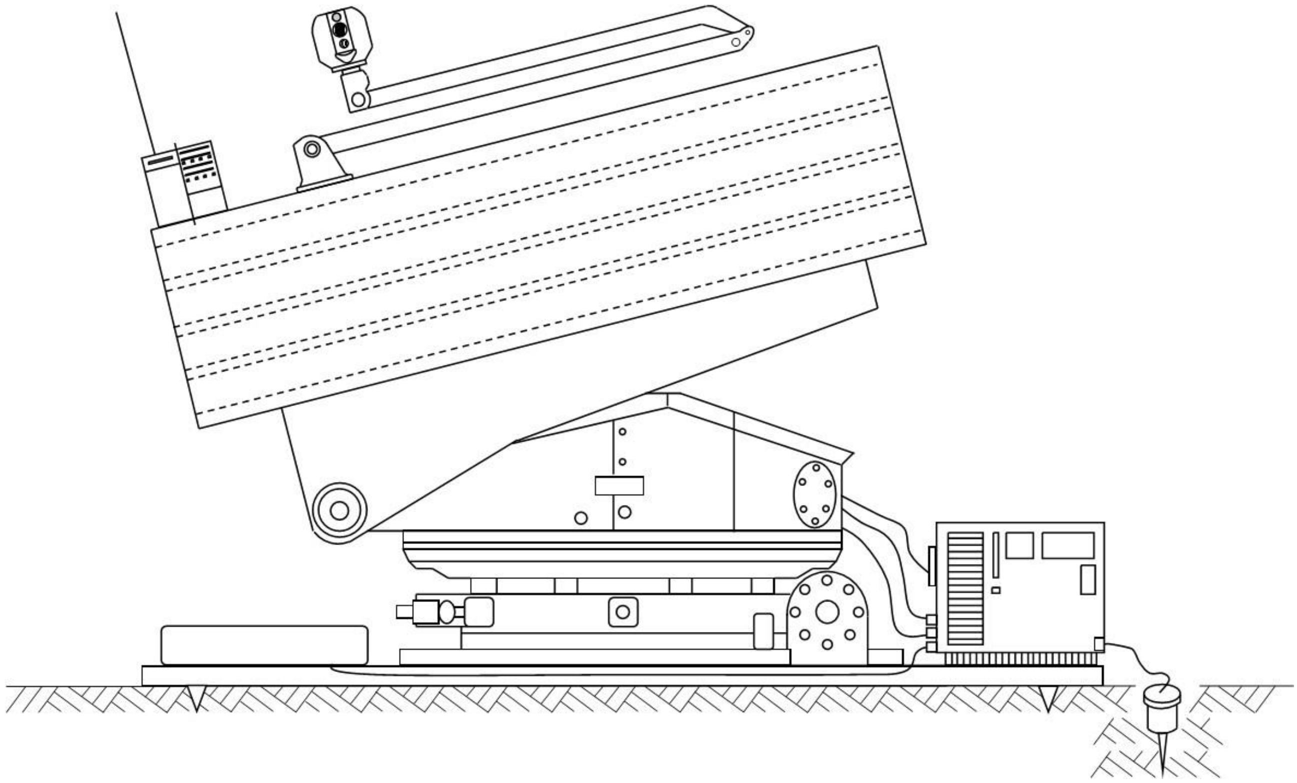

Figure 1 – Target detection and defeat complex

In its turn, the launch of a cassette with engineered ammunition occurs due to the fact that a current pulse enters the electric capsule sleeve, which leads to the ignition of the pyrotechnic composition, which ignites the explosive charge. The expanding gases of the explosive charge move along the duct and ignite the detonator and pyrotechnic moderator. In its turn, the expanding gases push the cassette with engineered ammunition out of the glass. After the ejection, the detonator activates the separating charge of the upper and lower blocks, which leads to their separation in the air Fig. 2. At the same time, the pyrotechnic retarder burns out, which initiates the charge of the explosive and leads to the instant ejection of fragments of longitudinal or round shape. Since there are four engineering munitions in one cassette, each of which contains 2700 fragments in advance, a cloud of 100x100 m is formed, as the radius of flight of fragments of each of the engineering munitions is about 50 m, with a total number of 10800 fragments, which covers and hits the air target.

To prevent the defeat of its technical devices, the complex of detection and defeat of the target can also be used in a controlled version. In this case, the signal from the detection means is transmitted to the appropriate navigation system and through the communication unit and remote control is transmitted to the operator. Accordingly, the operator can manually give a command to hit the target.

When the enemy tries to seize the complex, a self-destruct sensor is triggered, which sends a signal to the explosive charge.

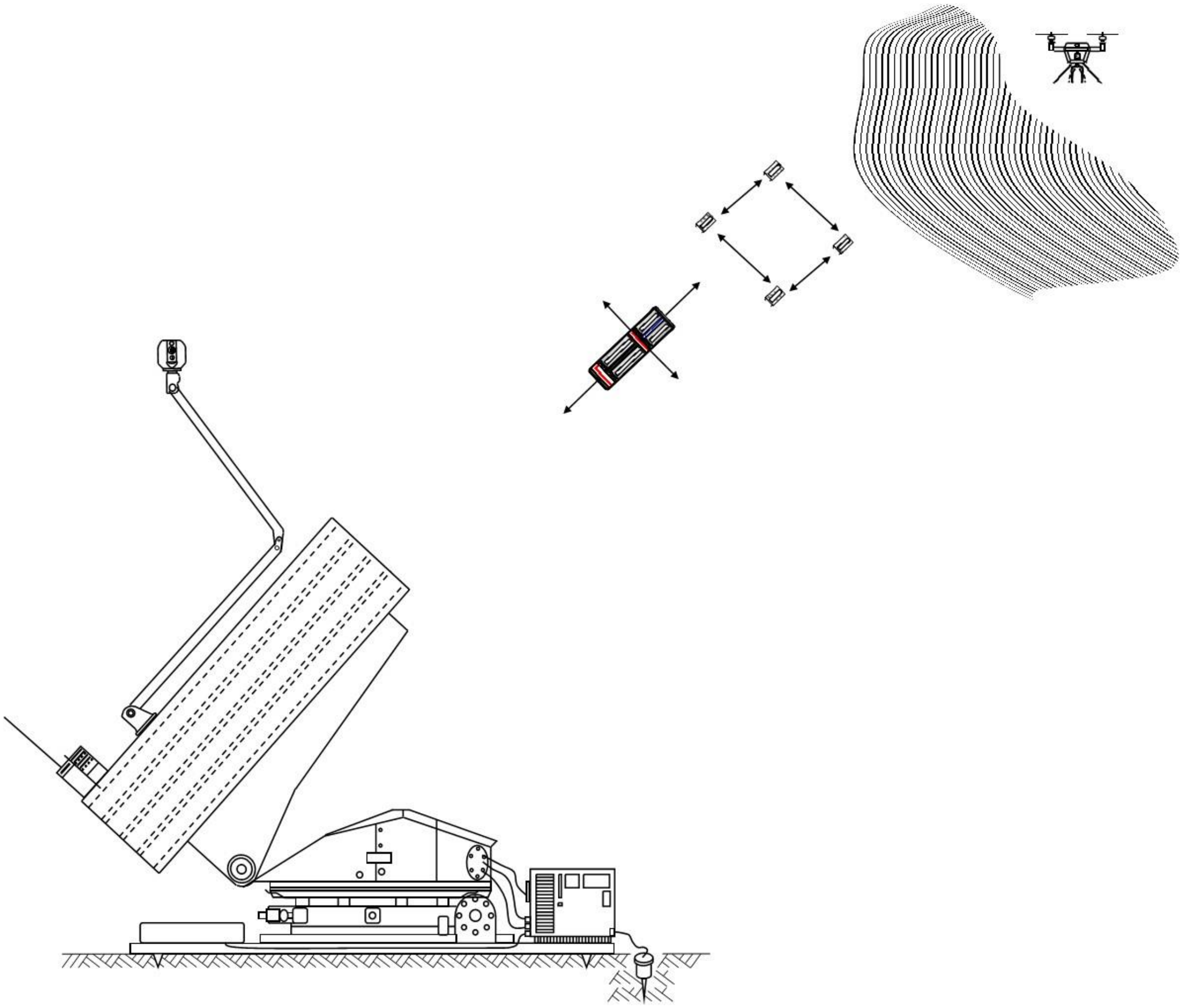

Figure 2 – Scheme of work of the target detection and destruction complex

Since this complex can operate in controlled and uncontrolled modes of operation, monitoring of the affected area, detection of air moving objects, bringing the means of destruction in the readiness for destruction, an algorithm for its operation was developed, which is shown in Fig. 3 [35-36]. During operation in uncontrolled mode – the coordinates of the detected moving object are determined, the distances to the detected moving object and its destruction zone are determined, the detected moving object is tracked, the threat degree of the detected moving object is assessed, and the command “Destruction” or “Stand down” is given accordingly. After the command “Destruction” – activation of ammunition and destroying the moving object. After the “Stand-down” command – re-monitoring of the target area with subsequent performance of the above operations. During operation in the controlled mode, after detecting an air and ground moving object separately, the moving object is additionally recorded on video, transmitted to the operator, who assesses the degree of threat of the moving object and makes a decision to give the command “Destruction” or “Stand down”, which are accompanied by actions similar to those in the uncontrolled mode. Further, the captured information is sent to the server of the information system to accumulate a database on the detection and destruction of moving objects.

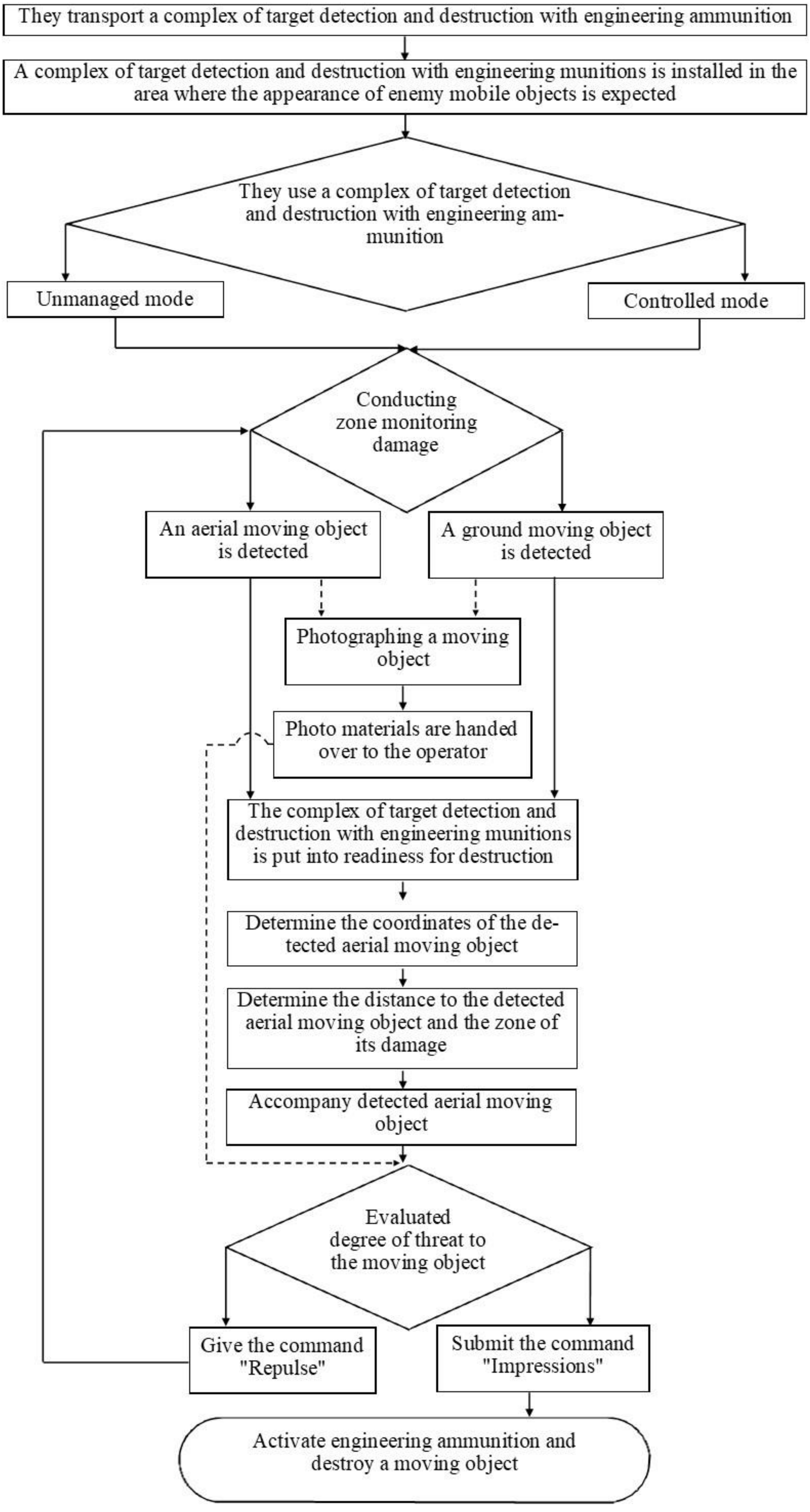

Figure 3 – The algorithm of application of the complex of detection and destruction of the target

Conclusions

Thus, the use of this complex will make it possible to detect, fix and remotely defeat various types of UAVs in real time, and the possibility of using the complex in autonomous mode will make it possible to cover areas that are not covered by constant control.

It is clear that the Russian Federation in the future will more actively use groups of cheap UAVs to destroy critical infrastructure of Ukraine. Therefore, there is a need to introduce this complex into production. Since the price of engineering ammunition compared to the means of destruction used to defeat these UAVs is 7-8 times lower, this complex would be economically feasible.

In the future, it is necessary to develop a model of defeating UAVs with this complex.

References

[1]. Dachkovsky, V., Kondratiuk, I., Diadechko, A., Sampir, O., & Pavlov, D. (2022). Cross-temporal analysis of the Russian Federation weapons and military equipment losses during the wars on the territory of other states over the last 30 years. *Journal of Scientific Papers "Social Development and Security*, *12*(3), 14-29. https://doi.org/10.33445/sds.2022.12.3.3

[2]. Since the beginning of the full-scale war against Ukraine, Russia has already lost 190 air defense systems, 271 aircraft and 248 helicopters of the enemy have been shot down - the General Staff of the Armed Forces of Ukraine. Available from : https://www.mil.gov.ua/news/2022/10/25/vid-pochatku-povnomasshtabnoi-vijni-proti-ukraini-rosiya-vtratila-uzhe-190-zasobiv-ppo-zbito-271-litak-ta-248-gelikopteriv-voroga-generalnij-shtab-zsu/

[3]. The losses of the Russian occupiers amount to more than 5,350 armored combat vehicles, almost 4,100 units of enemy vehicles and tank trucks were destroyed – the General Staff of the Armed Forces. Available from : https://www.mil.gov.ua/news/2022/10/26/vtrati-rosijskih-okupantiv-stanovlyat-ponad-5350-bojovih-bronovanih-mashin-znishheno-majzhe-4100-odinicz-avtomobilnoi-tehniki-ta-avtoczistern-voroga-%E2%80%93-generalnij-shtab-zsu/

[4]. Russia has ordered more than 2,400 kamikaze drones from Iran — Zelenskyi. Available from : https://suspilne.media/293006-rosia-zamovila-v-irani-ponad-2400-droniv-kamikadze-zelenskij/

[5]. The Armed Forces of Ukraine explained why the Russian Federation uses “Shahids” for attacks on infrastructure. Available from : https://suspilne.media/294234-u-zsu-poasnili-comu-rf-vikoristovue-sahidi-dla-udariv-po-infrastrukturi/

[6]. How do Shahids work? Available from : https://hromadske.ua/ru/posts/rossijskie-shahidy-pochemu-protivovozdushnaya-oborona-ne-vsegda-sbivaet-iranskie-drony-kamikadze

[7[. Makarenko S.I., Timoshenko A.V. (2020) Analysis of means and methods of countering unmanned aerial vehicles. Part 2. Fire defeat and physical interception. *Control, communication and security systems*. № 1. C. 147-197. https://doi.org/10.24411/2410-9916-2020-10106 .

[8]. Korolev, R.V., Koroliuk, N.O., Petrov, O.V., Syulev, K.V., Analysis of modern means of destroying unmanned aerial vehicles. Available from : https://www.ukrmilitary.com/2017/10/zasoby-proty-bpla.html

[9]. The fight against UAVs: the search for a magical solution. Available from : https://www.nato.int/docu/review/ru/articles/2020/12/16/bor-ba-s-bpla-poisk-volshebnogo-resheniya/index.html

[10]. Afonin, I. E., Makarenko, S. I., Petrov, S. V., Privalov, A. A. (2020). Analysis of the experience of combat use of groups of unmanned aerial vehicles to destroy anti-aircraft missile systems of

the air defense system in military conflicts in Syria, in Libya and in Nagorno-Karabakh. *Control, communication and security systems. № 4. С. 163-191.* https://doi.org/10.24411/2410-9916-2020-10406. Available from : https://webcache.googleusercontent.com/search?q=cache:-L8DSRKAFtAJ:https://sccs.intelgr.com/archive/2020-04/06-Afonin.pdf&cd=5&hl=ru&ct=clnk&gl=ua

[11]. Makarenko S.I., Timoshenko A.V., Vasilchenko A.S. (2020) Analysis of means and methods of countering unmanned aerial vehicles. Part 1. Unmanned aerial vehicle as an object of detection and destruction. *Control, communication and security systems. №1. С. 109-145* https://doi.org/10.24411/2410-9916-2020-10105. Available from : https://webcache.googleusercontent.com/search?q=cache:MWdXk3vpVhYJ:https://doi.org/10.24411/2410-9916-2020-10105&cd=7&hl=ru&ct=clnk&gl=ua

[12]. How to catch “Shaheeds”: top technologies for destroying Iranian drones. These things will be able to intercept the Iranian Shahed and Russian Geraniums. Available from : https://dev.ua/ru/news/shahid-1665663459

[13]. A multi-barreled machine-gun anti-drone installation was created in Poland. Available from : https://rg.ru/2022/02/15/mnogostvolnaia-pulemetnaia-antidronovaia-ustanovka-sozdana-v-polshe.html

[14]. The new anti-drone “multi-barreled” laser system for ship placement from “Rheinmetall Defence Electronics”. Available from : https://topwar.ru/83006-novaya-antidronovaya-mnogostvolnaya-lazernaya-sistema-dlya-korabelnogo-razmescheniya-ot-rheinmetall-defence-electronics.html

[15]. Drone detection systems and anti-drone systems. Available from : https://www.bezpeka-shop.com/blog/obzor/sistemy-obnaruzheniya-dronov-i-protivodronnye-sistemy/

[16]. Ukroboronprom showed the ZRN-01 Stokrotka multiple launch rocket system designed to destroy drones. Available from : https://itc.ua/news/ukroboronprom-pokazal-sistemu-zalpovogo-ognya-zrn-01-stokrotka-prednaznachennuyu-dlya-unichtozheniya-dronov/

[17]. How modern anti-drone systems work. Available from : https://kalashnikov.media/article/technology/kak-rabotayut-sovremennye-sistemy-dlya-borby-s-bespilotnikami

[18]. RAM II UAV – “revenge drone” for the Russian shelling of Ukraine on October 10. What is known about him? Can this drone compete with Iranian ones Shahed-136? Available from : https://zaborona.com/pro-bajraktary-vy-vzhe-chuly-os-shho-treba-znaty-pro-inshi-drony-yaki-vykorystovuye-ukrayina-ta-shho-yim-protystavlyaye-rosiya/

[19]. Anti-aircraft missile and gun complex Oerlikon Skyranger. Available from : https://topwar.ru/151448-zenitnyj-raketno-pushechnyj-kompleks-oerlikon-skyranger-shvejcarija-germanija.html

[20]. Korkut. Available from : http://factmil.com/stuff/armija/zenitnye_ustanovki/korkut/47-1-0-54

[21]. “IM-SHORAD”, new anti-aircraft complex for the US army. Available from : https://anna-news.info/im-shorad-novyj-zenitnyj-kompleks-dlya-armii-ssha/

[22]. Iranian “strike” of the Russian Federation: what drones did the enemy buy for the war with Ukraine. Available from : https://mind.ua/openmind/20247496-iranski-udar-ni-rf-yaki-bezpilotniki-zakupiv-vorog-dlya-vijni-z-ukrayinoyu

[23]. Not only air defense: the best means for combating kamikaze drones in Ukraine were named. Available from : https://focus.ua/uk/digital/532864-ne-tolko-pvo-nazvany-luchshie-sredstva-dlya-borby-s-dronami-kamikadze-v-ukraine

[24]. "Belarusian Gayun" named the likely location of the launch of the Russian kamikaze drones. Available from : https://mil.in.ua/uk/news/belaruski-gayun-proviv-rozsliduvannya-zapuskiv-rosijskyh-droniv-kamikadze/

[25]. Russia's use of kamikaze drones in Ukraine will not change the course of the war – General Herting. Available from : https://ukrainian.voanews.com/a/drony-ne-zminyat-hid-viyny-general/6795247.html

[26]. Air defense units shot down 15 Iranian drones, aviation struck 6 Russian positions, – General Staff. Available from : https://lb.ua/society/2022/10/20/533284_pidrozdili_ppo_zbili_15_iranskih.html

[27]. They fly low and slowly, but are very noisy: we are discussing the threat level of Iranian kamikaze drones with experts. Available from : https://uatv.ua/uk/litayut-nyzko-ta-povilno-ale-duzhe-galaslyvo-riven-zagrozy-iranskyh-droniv-kamikadze-obgovoryuyemo-z-ekspertamy/

[28]. Information material on countering the use of "kamikaze drones" of the "Shahid-136" type on the territory of Ukraine. Available from : https://vysocka-gromada.gov.ua/news/1666353271/

[29]. How to deal with Iranian kamikaze drones, which Russia uses to attack Ukraine. Available from : https://www.bbc.com/ukrainian/news-63287529

[30]. Iranian drones: shooting down Shahed is more expensive than buying – The Guardian. URL: https://suspilne.media/298926-iranski-droni-zbiti-sahed-dorozce-aniz-kupiti-the-guardian/

[31]. China practices launching a "swarm" of suicide drones filled with explosives. Available from : https://habr.com/ru/post/527580/

[32]. Pat. 98552 Ukraine, IPC (2009) F42 B 23/00, 39/26. The complex of detection and destruction of targets / Dachkovskyi V.O.; – applicant and owner of the patent V.O. Dachkovsky. – No. u201413542; statement 16.12.2014; published 27.04.2015; Bul. No. 8.

[33]. Dachkovskyi, V.O. (2016). The complex of detection and destruction of targets. *Popular science, scientific journal "Inventor and rationalizer" Ukrainian Academy of Sciences.* – No. 6, pp. 4-7.

[34]. Dachkovskyi, V.O., Gimber, S.M. (2018). Ways of development of damage systems for ground and air moving objects. Problems of coordination of military-technical and defense-industrial policy in Ukraine. *Prospects for the development of weapons and military equipment VI International scientific and practical conference*. October 9-12, 2018 theses add. Kyiv, 2018. P. 264.

[35]. Pat. 115362 Ukraine, IPC (2017) G06G 7/80. The method of target detection and destruction with engineering ammunition / Dachkovskyi V.O., Kotsyruba V.I.; – applicant and holder of the patent National University of Defense of Ukraine named after Ivan Chernyakhovsky – No. u201611560; statement 11/15/2016; published 10.04.2017; Bul. No. 7.

[36]. Dachkovskyi. V.O., Matsko. O.Y., Gimber S.M. (2017). Method of detection and destruction of air and ground moving objects. Problems of coordination of military-technical and defense-industrial policy in Ukraine. *Prospects for the development of weapons and military equipment V International scientific and practical conference.* October 11-12, 2017 theses add. Kyiv, 2017. P. 347.