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IMPROVING SAFETY AND EFFICIENCY FOR FIXED-WING UAVS BY UTILIZING AN UNMANNED GROUND PLATFORM

The object of this research was the launch process of fixed-wing unmanned aerial vehicles. Military unmanned aerial vehicle systems are rapidly improving and becoming increasingly effective on the battlefield and in the enemy's rear. However, the complex and dynamic environment of modern warfare significantly impacts the preparation and launch of UAVs. Therefore, ensuring the maximum safety of these operations is one of the key factors influencing the overall effectiveness of these systems. At the same time, the launch operation requires personnel to be in an open area, making it a critical task to find solutions to protect UAV crews from enemy attacks. A possible solution is the remote control of the UAV launch. This article proposes using unmanned ground platforms for the remote launch of fixed-wing UAVs to reduce the probability of enemy strikes against crews and equipment. The research included modeling and comparing the launch of a fixed-wing UAV from a runway and with the help of an unmanned ground platform. The modeling results showed that launching from the platform reduces the takeoff distance by 39.1% (from 273.6 m to 166.7 m) and the operation time by more than half (from ~23 s to 9.2 s). This overall reduction will decrease the probability of the unmanned equipment being struck by the enemy. An additional advantage of this method is reduced fuel consumption. It also allows for the use of a propeller that is more efficient for flight, which is not possible with a traditional runway takeoff. Reducing the strength requirements for the drone's airframe allows for a decrease in its mass, which, in turn, increases the mass of the warhead or reconnaissance equipment.

Keywords: *unmanned ground platform, UAV, military personnel safety, remote launch, modeling.*

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1. Introduction

Active hostilities in Ukraine, caused by the military aggression of the Russian Federation, demonstrate the significant effectiveness of unmanned aerial vehicles (UAVs) of the copter type on the battlefield and aircraft type – when striking targets behind enemy lines. The number of UAVs involved is increasing every day on both sides. They have already become a decisive factor in the military confrontation. Active research and development work are gradually increasing the perfection of UAVs, and scaling up production is reducing their cost. As a result, the effectiveness and range of hitting targets with relatively cheap unmanned vehicles is increasing, and the impact zone on both sides of the line of combat contact is rapidly growing. At the same time, along with the effectiveness of the combat use of UAVs, their relatively low cost and rapid scalability have become one of the main factors of their advantage on the battlefield.

At the same time, the use of many types of weapons to conduct combat operations or counter UAVs themselves is becoming ineffective. In addition, UAVs have changed the very tactics of conducting combat operations on both sides.

At present, there is no generally accepted strategy for effective countermeasures against unmanned aerial vehicles. The emergence of an effective solution provides only a temporary effect until the development of an appropriate countermeasure. In a rapidly changing technological environment, the effectiveness of government decisions largely depends on the ability to promptly integrate scientifically sound developments [1]. Research in this area, in particular, the identification of air targets using hybrid clustering algorithms, is extremely important for increasing the effectiveness of countermeasures against UAVs [2]. An example is the surge in the use of electronic warfare [3] and countermeasures in the form of fiber-optic communication with UAVs. At the same time, control of the battlefield, logistical routes, and the destruction of bases and enterprises of the enemy's military-industrial complex allow to increase the effectiveness of our own units. Assistance in this is provided, in particular, by developing software and hardware solutions for detecting objects of complex shape in a video stream from UAVs [4].

A completely logical consequence of such a situation on the battlefield for both sides was the strategy of the primary destruction of the enemy operators and crews who launch and control the UAVs, and the places of their deployment. Based on this, one of the priorities is the development and implementation of any solutions that will reduce the likelihood of detection and impression of military personnel involved in the operation of UAV complexes. This problem is especially acute during take-off and landing operations of aircraft-type UAVs [5]. Compared with classic manned aircraft, UAVs have the advantages of small size, ease of operation, low production and maintenance costs, as well as low requirements for combat conditions [6, 7]. However, the range and duration of the flight of multicopters was limited by the energy storage capacity (about 200 W · h/kg of the battery versus 11,600 W · h/kg of liquid fuel). As a result, this limitation stimulates the development of aircraft-type UAV designs, which, in order to increase the range and duration of the flight, are equipped with internal combustion engines in addition to the supporting surfaces [8]. At the same time, unlike the battery, the amount of fuel during the flight gradually decreases. This facilitates the operation of the engine, and therefore reduces its consumption. Compared to copter-type drones, aircraft-type UAVs have a relatively high speed and load capacity [9]. However, similar to conventional aircraft, they still have to perform classic and most complex takeoff operations, and in the case of reconnaissance and reusable vehicles, landing. The need for more powerful aircraft, mainly in terms of payload and duration of operation, is also emphasized in [10]. At the same time, the complexity of their launch will increase in accordance with the mass (dimensions) of the UAV. However, as noted in [11], the takeoff characteristics of unmanned aerial vehicles are an important component that affects their combat effectiveness.

Currently, ground takeoff of medium and heavy UAVs is carried out in two main ways. The first is acceleration using its own chassis and engine along the runway. The second is launch from ground launchers, in particular catapults [12]. However, the aircraft chassis and its supporting structure are heavy, complex and expensive components, its mass usually varies, depending on the type of aircraft, within 6–15% of the mass of the empty aircraft [13]. As a result, the chassis system increases the mass of the aircraft, complicates its design and requires the implementation of advanced control algorithms during takeoff and landing. In addition, the chassis negatively affects the aerodynamic characteristics of the UAV – it increases the frontal resistance and requires an additional fuel supply, which increases the weight of the aircraft. In addition, the takeoff procedure itself requires significant power reserves, and the propellers, which have a fixed pitch, are selected from the point of view of maximum efficiency during takeoff [14]. However, this seriously degrades the UAV's flight performance.

At the same time, in a situation on the front line, the urgent task is to increase the duration of the flight and operation in places where runways may be unavailable.

To minimize these limitations, a number of methods have been developed. They help the aircraft to reach take-off speed faster. For example, this is catapult take-off (GLDs) [15] or vertical take-off and landing (VTOL) [16]. There is also rocket-assisted take-off (RATO) [17]. However, the current priority is the use of catapults (hydraulic, pneumatic, elastic cord, electromagnetic, kinetic) using a rocket booster [17].

For a successful take-off, the UAV must have sufficient lift at the moment of separation from the catapult, when its propeller enters stable flight mode. The speed should be at least 15% higher than the stall speed for a given UAV design [18].

Take-off assistance can dramatically reduce the runway spacing and increase the overall efficiency of the UAV by reducing engine power requirements [19]. In addition to the fact that catapults solve the problem of the lack of a runway, their use allows to save fuel during take-off, and therefore extend the mission time and flight range [20].

Also, dismantling most of the elements of the landing gear system (with the exception of structural elements necessary for reliable attachment of the UAV airframe to the catapult) allows to increase its load capacity [21].

However, at the beginning of the UAV's movement, when launched from the catapult, it undergoes a rapid and significant acceleration, similar in effect to a strong impact. This occurs because in a distance of just a few meters the UAV must accelerate from a state of rest to a speed exceeding the stall speed. This requires appropriate mechanical strength of the UAV airframe and resistance to overloads of its systems (even causing the warhead explosive device to be triggered). Increasing the fault tolerance of computer systems that control such devices can be achieved by using calculation systems in residual classes, which is also worth considering [22]. In most cases, this sharply increases the cost of UAV production.

From the analysis of existing methods of launching UAVs, it can be concluded that, despite their widespread use, there are still a number of technical problems that require further research and development for operational solutions. The crews of UAV complexes and the main equipment can be relatively reliably protected in shelters and camouflaged facilities, however, the operations of UAV takeoff and landing of some of them (reusable drones) require personnel to be in open terrain. Therefore, the current task is to find solutions to protect UAV crews from enemy damage. In addition to physical protection, it is critically important to ensure the survivability of computer systems that control the devices in combat conditions, where partial damage or failure of individual components is possible [23]. Given the importance of safety, the impact of diagnostic errors on the overall reliability and functioning of the system should also be taken into account [24]. Such a solution, of course, can be remote control of UAV preparation, launch and landing operations. However, based on the realities of technological development, the state of the defense-industrial complex and the economy of the state as a whole, in the near future such a modernization of the forces of unmanned systems of the Armed Forces of Ukraine looks unrealistic. That is why, in conditions of limited resources, the priority is to search for and substantiate more accessible and effective solutions that meet strategic needs.

The study was conducted taking into account the ideas of defense planning and the military doctrine of Ukraine, which gives it practical value and strategic significance.

Based on this, *the aim of research* is to develop technical and technological solutions to reduce the likelihood of aircraft-type UAV crews being hit by the enemy during their launch.

To achieve the aim, the following objectives were defined:

- substantiate the concept of using a ground-based unmanned platform as a technical solution for remote launch of aircraft-type UAVs, aimed at increasing crew safety;
- develop a mathematical model and conduct numerical simulation of the UAV takeoff process, comparing the traditional method (runway) and the proposed one (use of a ground platform);
- compare key performance indicators of both methods (acceleration distance, takeoff time) and assess their impact on the overall safety and efficiency of UAV use.

2. Materials and Methods

The object of this research is the process of launching an unmanned aircraft of the aircraft type and the development of technical solutions aimed at improving the safety of the crew. *The subject of the study* is the dynamic characteristics of this process. *The research methodology* is based on a combined approach, including theoretical modeling and numerical experiments. First of all, it was necessary to achieve the level of readiness of the model to function in laboratory conditions, which became the basis for further, more complex tests. This allowed for a comprehensive analysis without the need for expensive full-scale tests at the initial stage.

The main research methods were:

1. *Theoretical analysis and modeling.* At the initial stage, a mathematical model of the UAV system was developed – a ground platform. The model is built on the basis of the laws of classical mechanics and takes into account the main dynamic parameters. A system of differential equations was used to describe the motion of the system. It includes kinematic and dynamic equations of motion of the ground platform and the UAV, describing their interaction at the moment of acceleration, as well as equations of forces acting on the system. This allowed to formalize the problem and obtain a system of differential equations, which is the basis for further calculations.

2. *Numerical experiments.* To solve the system of equations describing the acceleration process of the UAV and the platform with the UAV, the MATLAB software environment was used. The results of numerical experiments were presented in the form of graphs, which

made it possible to visualize the dynamics of the process, determine the optimal operating modes of the platform and identify critical points. The use of numerical methods to solve the developed system of equations allowed to obtain quantitative indicators, such as the acceleration distance and take-off time, for two scenarios:

- classic take-off, which is carried out using its own engine and chassis on the runway;
- takeoff using a ground-based unmanned platform that functions as a mobile catapult. This method allows for remote launch of the device, minimizing personnel stay in the high-risk area.

The simulation was conducted for conditions typical of the spring-summer period, in the absence of precipitation and snow cover.

The RQ-7 Shadow UAV was selected as the object for simulation, the main characteristics of which are known [25]. This allowed the use of real parameters, such as the maximum take-off weight (mUAV) – 148 kg; the total wing surface area (S_w) – 1.97 m^2; and also to introduce the coefficients of lift of the UAV wing (C_{lift}) – 1.2 and aerodynamic drag ($C_{aer.drag}$) – 0.02, obtained for the Clark-Y wing profile of 12% at an angle of attack of 4°. The parameters used in the simulation correspond to the scaling plans of the project, which is currently at the stage of creating a light prototype.

Thus, the research methodology included the following stages:

1. Selection of the research object (UAV) and collection of its characteristics.
2. Construction of mathematical models for two takeoff scenarios.
3. Development of an algorithm for numerical solution of the equations of motion in the MATLAB environment.
4. Conducting numerical experiments and obtaining data.
5. Analysis and comparison of the obtained results, formulation of conclusions.

3. Results and Discussion

The complex and changing environment of the modern battlefield, including enemy electronic warfare equipment capable of intercepting control, blocking communication channels or distorting navigation data [26], significantly affects the course of UAV preparation and launch operations. Therefore, the ability to ensure maximum safety of these operations will be one of the main indicators that affect the overall effectiveness of the use of unmanned systems.

For take-off, copter-type drones only need a small area of open space among surrounding objects, and the final preparatory operations and the launch itself on unprotected terrain can be reduced to seconds. Therefore, crews operating copter-type devices with vertical take-off and landing are less likely to be attacked compared to the personnel of aircraft-type UAVs.

The situation is somewhat different with aircraft-type UAVs. Preparatory operations of the device in open terrain last much longer. In addition, based on the flight trajectory [27], a UAV requires a runway several hundred meters long (even in the case of a catapult launch). These forces, in order to prevent shelling, to remove the launch pads of aircraft-type UAVs at the maximum distance from the combat zone. However, the distance from the mission execution zone significantly reduces the effectiveness of their use, and a significant amount of fuel or battery charge is spent on the distance to the target. Given the enemy's real capabilities, a significant part of the territory of Ukraine is controlled by its reconnaissance UAVs. This territory can be hit from any distance. Threats range from fiber-optic drones to cruise and ballistic missiles. Therefore, the issue of protecting UAV crews is extremely relevant. This especially applies to aircraft-type drone operators. At the same time, most of the above disadvantages of launching aircraft-type UAVs can be eliminated when carrying out this operation from a mobile platform. To do this, the drone is rigidly mounted on it, the platform smoothly starts moving, and after gaining the required speed, it is separated by analogy with a catapult. In this case, the acceleration of the platform, and therefore the UAV, will be significantly less than the acceleration that will be given to the drone by the catapult. In addition, if there is a runway of sufficient length, it can be adjusted.

Therefore, when launching from a mobile platform, the strength of the UAV fuselage elements should be oriented only to the loads that occur during its flight. This will allow reducing the mass of the fuselage in favor of the payload and reducing the cost of its manufacture.

Given the excellent acceleration dynamics of the electric drive, the best basis for such a platform will be an electric vehicle. In this case, it is advisable to use truck vans as mobile stations for storing, repairing and preparing the UAV. For launching, it is possible to use sections of general roads and individual sections of unpaved roads.

However, at the moment there are several circumstances when launching a UAV, to perform a combat mission, from a vehicle-based platform, although it looks quite acceptable, is not desirable. The reasons are the possibility of the platform being hit by the enemy, the possible operation of the warhead, the danger of fuel leakage from the UAV and its ignition, and so on. In any case, the platform crew is exposed to danger.

However, in parallel with the development of UAVs, ground-based robotic complexes for military purposes are also actively developing [28]. Their appearance on the battlefield is a natural phenomenon. The availability of most components allows this direction to be scaled.

A ground-based robotic platform is most often equipped with an electric power plant. Also, depending on the purpose and power, they can be equipped with hybrid power plants and internal combustion engines. They begin to perform a significant part of the tasks in order to preserve the lives and physical health of military personnel.

Based on the tasks set in the work, it is proposed to use ground-based unmanned systems with an electric drive as a mobile platform for launching aircraft-type UAVs. The scheme of launching a UAV from a ground-based unmanned platform is presented in Fig. 1.

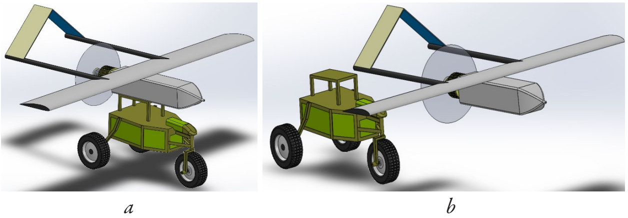

Fig. 1. Scheme of launching a UAV from a ground unmanned platform:
a – UAV–platform connection at the moment of acceleration;
b – UAV separation from the platform

As an example, for comparing the dynamics of take-off from the runway and using an unmanned platform, the RQ-7 Shadow UAV was chosen. Its main characteristics are given in [25].

To determine the lift coefficient of the UAV wing (C_{lift}) and the aerodynamic drag coefficient ($C_{aer.drag}$), a Clark-Y profile of 12% and an angle of attack $\alpha = 4$ were used. Then $C_{lift} = 1.2$, and $C_{aer.drag} = 0.02$. The total wing surface area (S_w) of this UAV is 1.97 m^2, the maximum take-off weight (m_{UAV}) is 148 kg [25]. The air density was taken as $\rho = 1.225$ kg/m^3.

When accelerating a UAV on a runway, the movement will be uniformly accelerated only in the initial segment, and the speed will constantly change. The process of accelerating a UAV on a runway consists of three stages:

1) *the beginning of acceleration*. For a propeller gasoline engine at medium speeds, the thrust will be approximately constant. Air resistance is minimal, acceleration is approximately constant;

2) *increasing speed*. The aerodynamic resistance of the UAV increases according to the quadratic dependence of the speed of movement

$$F_{aer.drag} = \frac{1}{2}\rho \cdot C_{aer.drag} \cdot S_w \cdot v^2, \tag{1}$$

where ρ – air density, kg/m^3; $C_{aer.drag}$ – the coefficient of aerodynamic drag; S_w is the wing area, m^2; v – the UAV speed, m/s.

The wing lift increases, unloading the landing gear wheels. Air resistance increases, due to this acceleration decreases. Engine thrust remains stable;

3) *before the landing gear separates from the runway*. The lift will be equal to the mass of the aircraft, the load on the wheels gradually disappears, the air resistance will be significant. The speed stabilizes within the calculated lift (separation speed) $v_{lift.(sep.)}$, after which the aircraft separates from the runway.

The lift of the aircraft is calculated by the formula

$$F_{lift}=\frac{1}{2}\rho\cdot C_{lift}\cdot S_w\cdot v^2, \tag{2}$$

where C_{lift} – the lift coefficient.

Hence, the speed of the aircraft is equal to

$$v=\sqrt{\frac{2F_{lift}}{\rho\cdot C_{lift}\cdot S_w}}. \tag{3}$$

Using formulas (1) and (2), it is possible to determine the take-off speed $v_{lift.(sep.)}$ for the RQ-7A Shadow UAV, and the maximum aerodynamic resistance at the same time.

Fig. 2 shows the effect of the UAV speed on the lift force and aerodynamic resistance. According to Fig. 2, the take-off (take-off) speed of the RQ-7A Shadow UAV from the runway is 31.7 m/s (the intersection of the $F_{lift}(v)$ line with the line corresponding to its weight N_{UAV} = 1450 N).

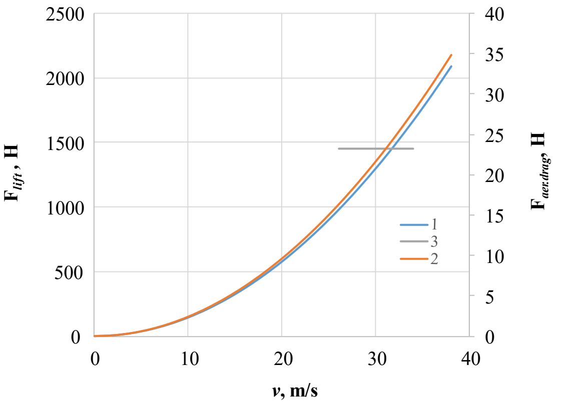

Fig. 2. Dependence of lift force and aerodynamic drag of the UAV on its speed: 1 – $F_{aer.drag}$; 2 – F_{lift}; 3 – N_{UAV} = 1450 H

The acceleration of the aircraft on the chassis from $v_0 = 0$ to $v = v_{lift.(sep.)}$ occurs using the engine thrust $F_{eng.thr.UAV}$. The aerodynamic drag force F_{lift} (2) and the rolling resistance force $F_{rol.res}$ act against the engine thrust force

$$F_{rol.res}=\mu_r\left(N_{UAV}-F_{lift}\right), \tag{4}$$

where μ_r – the friction coefficient; $F_{rol.res}$ – the rolling resistance, N; N_{UAV} – aircraft weight, N, N_{UAV} = 1450 N.

The rolling resistance force will change with the change in speed. As the speed increases, the lift of the aircraft wing increases, so the initial weight of the aircraft N_{UAV} will change, thereby reducing the force of the pressure of the wheels on the surface. The aerodynamic drag force will also change, according to equation (2).

The engine installed on the RQ-7A Shadow UAV (Wankel UEL AR-741) provides static thrust $F_{eng.thr.UAV}$ = 400 H. When gaining speed, the lift force of the UAV increases according to formula (1).

The resultant force acting on the UAV is determined by the formula

$$m_{UAV}\frac{dv}{dt}=F_{eng.thr.UAV}-F_{aer.drag}(v)-F_{rol.res}(v), \tag{5}$$

where $F_{eng.thr.UAV}$ – aircraft thrust force, N; dv/dt – UAV acceleration, m/s^2.

After substituting (1) and (2) into formula (4)

$$m_{UAV}\frac{dv}{dt}=F_{eng.thr.UAV}-\frac{1}{2}\rho\cdot C_{aer.drag}\cdot S_w\cdot v^2-$$
$$-\mu_r\left(N_{UAV}-\frac{1}{2}\rho\cdot C_{lift}\cdot S_w\cdot v^2\right). \tag{6}$$

To determine the distance at which the UAV will reach the speed required for separation from the support (runway), its speed (v) is expressed in terms of the change in distance with time:

$$v=\frac{dx}{dt}, \tag{7}$$

$$\frac{dv}{dx}=\frac{1}{v}\cdot\frac{dv}{dt}. \tag{8}$$

Hence, the dependence of the speed on the acceleration distance of the UAV is described by the differential equation

$$m_{UAV}\cdot v\frac{dv}{dx}=F_{eng.thr.UAV}-\frac{1}{2}\rho\cdot C_{aer.drag}\cdot S_w\cdot v^2-$$
$$-\mu_r\left(N_{UAV}-\frac{1}{2}\rho\cdot C_{lift}\cdot S_w\cdot v^2\right). \tag{9}$$

The dependence of $v(x)$ was determined in the Matlab program. The obtained graph of the dependence of the acceleration interval of the UAV on its speed is shown in Fig. 3. Given that the separation speed was 31.7 m/s, such a speed was achieved on a segment of 273.6 m.

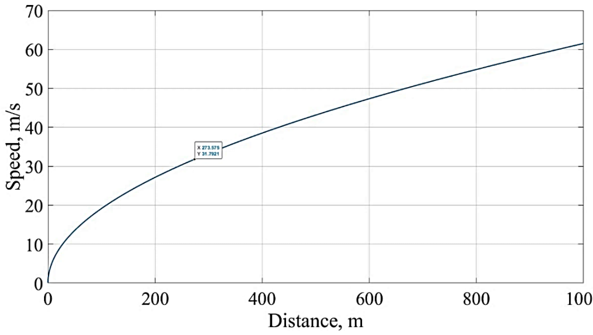

Fig. 3. UAV acceleration to takeoff speed when taking off on the chassis from the runway

The option of launching a UAV from a ground unmanned platform is as follows. The UAV is fixed on the platform, the movement of this link along the runway is provided simultaneously by the platform's electric drive and the UAV engine thrust, after reaching takeoff speed, the drone separates from the platform and begins independent flight.

During acceleration and until the moment of separation, the mass of the unmanned platform-UAV link changes. Mass before takeoff

$$m_{syst}=m_{UGV}+m_{UAV}, \tag{10}$$

where m_{UGV}, m_{UAV} – the mass of the unmanned platform and UAV, respectively, kg.

And the mass after takeoff is

$$m_{syst}=m_{UGV}. \tag{11}$$

Until the moment the UAV is separated from the platform, the following forces act on the system: platform engine thrust ($F_{eng.thr.UGV}$), UAV engine thrust ($F_{eng.thr.UAV}$), rolling resistance ($F_{rol.res.syst}$), air resistance ($F_{aer.drag}$). The combined effect of these forces

$$m_{syst}\frac{dv}{dt}=F_{eng.thr.UGV}+F_{eng.thr.UAV}-F_{rol.res.syst}-F_{aer.drag}. \tag{12}$$

The rolling resistance force depends on the mass of the system and is determined by the formula

$$F_{rol.res.syst}=\mu_r\left(N_{UAV}+N_{UGV}-\frac{1}{2}\rho\cdot C_{lift}\cdot S_w\cdot v^2\right)=$$
$$=\mu_r\left(m_{UAV}\cdot \mathrm{g}+m_{UGV}\cdot \mathrm{g}-\frac{1}{2}\rho\cdot C_{lift}\cdot S_w\cdot v^2\right). \tag{13}$$

The air resistance force depends on the frontal area of the UAV and is calculated by the formula

$$F_{aer.drag}=\frac{1}{2}\rho\cdot C_{aer.drag}\cdot S_{front.UAV}\cdot v^2, \tag{14}$$

where $S_{front.UAV}$ – the frontal area of the UAV, m^2.

The unmanned platform – UAV system exists as long as the condition

$$F_{lift}<m_{UAV}. \tag{15}$$

The UAV takes off from the platform under the condition

$$F_{lift}\geq m_{UAV}. \tag{16}$$

In this case, the forces act on the platform: its engine thrust and rolling resistance. The resultant of these forces

$$m_{UGV}\frac{dv}{dt}=F_{eng.thr.UGV}-F_{rol.res}, \tag{17}$$

where $F_{rol.res}$ – the rolling resistance force of the platform, N

$$F_{rol.res}=\mu_r\cdot m_{UGV}\cdot \mathrm{g}. \tag{18}$$

Then the equations describing the process of acceleration and launch of the UAV from the unmanned platform form a system and have the form

$$\frac{dv}{dt}=\begin{cases}\dfrac{F_{eng.thr.UGV}+F_{eng.thr.UAV}-F_{rol.res.syst}-F_{aer.drag}}{m_{UGV}+m_{UAV}}, F_{lift}<m_{UAV},\\[2ex] \dfrac{F_{eng.thr.UGV}-F_{rol.res}}{m_{UGV}}, F_{lift}\geq m_{UAV}.\end{cases} \tag{19}$$

The system of equations (19) was solved numerically using the MATLAB program. The resulting graphical dependence is shown in Fig. 4.

The following parameters were used for calculations. The mass of the platform was 120 kg, and the mass of the UAV was 148 kg. The total power of the unmanned platform engines reached 9 kW. Its maximum thrust was 945 N. The thrust of the UAV engine was 400 N. The rolling resistance coefficient of the platform was 0.015. Air density was 1.225 kg/m^3. The UAV wing area was 1.97 m^2, and its frontal area was 0.6 m^2.

Thus, the unmanned platform with the aircraft will reach a separation speed of 31.7 m/s (114.1 km/h) at an interval of 166.7 m in 9.2 s. Then the UAV will detach from the platform and begin its flight.

Thus, the use of an unmanned platform will ensure the remote execution of the UAV launch operation. In addition, launching using an unmanned platform will significantly reduce the interval of speed gain until the moment of UAV separation and the duration of the operation.

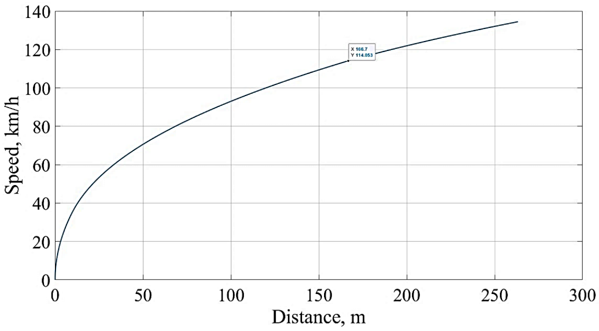

Fig. 4. Acceleration of the unmanned platform – UAV system to the take-off speed of the UAV

The practical significance of the results obtained lies in substantiating and proving the feasibility of using ground-based unmanned platforms to launch aircraft-type UAVs. The proposed method allows significantly increasing the safety of military personnel, minimizing their stay in open terrain during the critically important and dangerous takeoff phase. Reducing the required acceleration length and operation time, confirmed by modeling, makes it possible to use smaller and better camouflaged launch pads, which reduces the likelihood of their detection and destruction by the enemy. This directly affects the preservation of lives, equipment and increasing the overall combat effectiveness of units operating unmanned systems.

The limitations of the proposed study are:

1. The simplified dynamics model does not take into account all possible factors. These include real-world weather conditions, such as wind gusts, and surface irregularities. The model also does not take into account the full dynamics of the interaction between the platform and the UAV. In addition, it does not take into account changes in friction and drag coefficients depending on the type of coating.
2. Idealized characteristics, since all parameters of the UAV (RQ-7 Shadow) and the unmanned platform are assumed to be idealized (constant engine thrust, fixed drag coefficients) to simplify calculations. In real conditions, these indicators may change.
3. Lack of experimental verification, since the results were obtained exclusively by numerical modeling in the MATLAB environment, without physical verification and full-scale tests, which limits the accuracy and practical reliability of the conclusions obtained.

The direction of development of the conducted research is:

1. Creation of a full-fledged dynamic model that will take into account nonlinear engine characteristics, changes in fuel mass during operation, dynamic resistance from road irregularities, as well as real variations in weather conditions.
2. Development of automatic control algorithms, as well as design and optimization of algorithms for automatic synchronous control of UAV engines and a ground platform, which will ensure optimal and safe acceleration.
3. Creation of a prototype of a ground unmanned platform and conducting its full-scale tests to confirm the results of numerical modeling.
4. Assessment of effectiveness and safety in real conditions, which will include a comprehensive analysis of the protection of the ground platform and UAV from enemy weapons in order to confirm the practical safety of the proposed approach.

4. Conclusions

1. The concept of using a ground-based unmanned platform with an electric drive as an effective technical solution for remote launch of UAVs is substantiated. This approach allows transferring the entire preparation and launch process to a safe, protected shelter, minimizing the crew's stay in the open area and significantly increasing their safety. An additional advantage of this method is the possibility

of reducing the requirements for the strength of the UAV airframe, since it is not subject to high overloads typical of launching from a catapult. This, in turn, allows to increase the payload, for example, a warhead or reconnaissance equipment, which increases the overall efficiency of the device.

2. A mathematical model has been developed for numerical modeling of the dynamics of UAV acceleration. The modeling covered two scenarios: takeoff from its own chassis on the runway and launch using a ground-based unmanned platform. This allowed to obtain quantitative indicators that confirm the advantages of the proposed approach.

3. The simulation results compared the key performance indicators of both methods. It was found that the use of a ground platform significantly reduces the required acceleration distance – from 273.6 m to 166.7 m, which is a reduction of 39.1%. The duration of the take-off operation itself was also significantly reduced – from approximately 23 s to 9.2 s, i. e. more than twice. These results indicate that the proposed launch method significantly reduces the time during which the UAV and its operators are at risk of detection and damage by the enemy, thereby increasing the combat effectiveness of the units.

Conflict of interest

The authors declare that they have no conflict of interest in this research, financial, personal, authorial or other, which could affect the research and its results presented in this document.

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Data availability

The manuscript has no related data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

References

1. Onyshchenko, S., Skryl, V., Hlushko, A., Maslii, O. (2023). Inclusive Development Index. *Proceedings of the 4th International Conference on Building Innovations.* Cham: Springer, 779–790. https://doi.org/10.1007/978-3-031-17385-1_66
2. Laktionov, O., Yanko, A., Pedchenko, N. (2024). Identification of air targets using a hybrid clustering algorithm. *Eastern-European Journal of Enterprise Technologies, 5 (4 (131)),* 89–95. https://doi.org/10.15587/1729-4061.2024.314289
3. Yanko, A., Pedchenko, N., Kruk, O. (2024). Enhancing the protection of automated ground robotic platforms in the conditions of radio electronic warfare. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 6,* 136–142. https://doi.org/10.33271/nvngu/2024-6/136
4. Laktionov, O., Yanko, A., Hlushko, A. (2024). Development of a hardware-software solution for detection of complex-shaped objects in video stream. *Technology Audit and Production Reserves, 6 (2 (80)),* 35–40. https://doi.org/10.15587/2706-5448.2024.319799
5. Barabash, O., Kyrianov, A. (2023). Development of control laws of unmanned aerial vehicles for performing group flight at the straight-line horizontal flight stage. *Advanced Information Systems, 7 (4),* 13–20. https://doi.org/10.20998/2522-9052.2023.4.02
6. Xiaoning, Z. (2020). Analysis of military application of UAV swarm technology. *2020 3rd International Conference on Unmanned Systems (ICUS),* 1200–1204. https://doi.org/10.1109/icus50048.2020.9274974
7. Jackman, A. (2019). Consumer drone evolutions: trends, spaces, temporalities, threats. *Defense & Security Analysis, 35 (4),* 362–383. https://doi.org/10.1080/14751798.2019.1675934
8. Edward, M. (2009). Exploring Transportation Applications of Small Unmanned Aircraft. *Ite Journal, 79,* 32–36. Available at: https://www.researchgate.net/publication/298279257_Exploring_Transportation_Applications_of_Small_Unmanned_Aircraft
9. Yue, S. (2013). Small Unmanned Aircraft: Theory and Practice R. W. Beard and T. W. McLain Princeton University Press. 6 Oxford Street, Woodstock, OX20 1TW, UK. 2012. 300pp. Illustrated. £69.95. ISBN 978-0-691-14921-9. *The Aeronautical Journal, 117 (1194),* 861–861. https://doi.org/10.1017/s0001924000008496
10. Cabarbaye, A., Leal, R. L., Fabiani, P., Estrada, M. B. (2016). VTOL aircraft concept, suitable for unmanned applications, with equivalent performance compared to conventional aeroplane. *2016 International Conference on Unmanned Aircraft Systems (ICUAS),* 219–226. https://doi.org/10.1109/icuas.2016.7502649
11. Liu, D., Liu, G., Hong, G. (2016). Analysis of Onboard Takeoff and Landing Characteristics for Unmanned Aerial Vehicles. *AIAA Modeling and Simulation Technologies Conference.* https://doi.org/10.2514/6.2016-3376
12. Novaković, Z., Medar, N. (2013). Analysis of a UAV Bungee Cord Launching Device. *Scientific Technical Review, 63 (3),* 41–47. Available at: http://www.vti.mod.gov.rs/ntp/rad2013/3-13/6/6.pdf
13. Lütjens, K., Lau, A., Pfeiffer, T., Loth, S., Gollnick, V., Klimek, H. et al. (2012). Airport2030-Lösungen für den effizienten Lufttransport der Zukunft. *Deutscher Luft- und Raumfahrtkongress,* 1–10. Available at: https://www.dglr.de/publikationen/2012/281494.pdf
14. Austin, R. (2010). *Unmanned aircraft systems: UAVS design, development and deployment.* John Wiley & Sons Ltd. https://doi.org/10.1002/9780470664797
15. Zhen, Z., Jiang, J., Wang, X., Li, K. (2017). Modeling, control design, and influence analysis of catapult-assisted take-off process for carrier-based aircrafts. *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, 232 (13),* 2527–2540. https://doi.org/10.1177/0954410017715278
16. Wang, Z., Gong, Z., Zhang, C., He, J., Mao, S. (2021). Flight Test of L1 Adaptive Control on 120-kg-Class Electric Vertical Take-Off and Landing Vehicles. *IEEE Access, 9,* 163906–163928. https://doi.org/10.1109/access.2021.3132963
17. Fahlstrom, P. G., Gleason, T. J. (2012). *Introduction to UAV Systems, Fourth Edition.* https://doi.org/10.1002/9781118396780
18. Novaković, Z., Medar, N. (2014). Design of UAV Elastic Cord Catapult. OTEH 2014. *6th International Scientific Conference on Defensive Technologies,* 141–150. Available at: https://www.scribd.com/document/326791980/Zbornik-radova-sa-OTEH-2014
19. Bertola, L., Cox, T., Wheeler, P., Garvey, S., Morvan, H. (2015). Electromagnetic launch systems for civil aircraft assisted take-off. *Archives of Electrical Engineering, 64 (4),* 535–546. https://doi.org/10.1515/aee-2015-0039
20. Kloesel, K., Sayles, E., Wright, M., Marriott, D., Kuznetsov, S., Holland, L., Pickrel, J. (2009). First Stage of a Highly Reliable Reusable Launch System. *AIAA SPACE 2009 Conference & Exposition.* https://doi.org/10.2514/6.2009-6805
21. Yi, Z., Heping, W. (2006). A study of structure weight estimating for high altitude long endurence (hale) unmanned aerial vehicle (UAV). *ICAS-Secretariat-25th Congr. Int. Counc. Aeronaut. Sci.* Available at: https://www.icas.org/icas_archive/ICAS2006/PAPERS/019.PDF
22. Yanko, A., Krasnobayev, V., Martynenko, A. (2023). Influence of the number system in residual classes on the fault tolerance of the computer system. *Radioelectronic and Computer Systems, 3,* 159–172. https://doi.org/10.32620/reks.2023.3.13
23. Ruban, I., Volk, M., Filimonchuk, T., Ivanisenko, I., Risukhin, M., Romanenkov, Y. (2018). The Method for Ensuring the Survivability of Distributed Computing in Heterogeneous Computer Systems. *2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T),* 233–237. https://doi.org/10.1109/infocommst.2018.8632099
24. Ponochovniy, Y., Bulba, E., Yanko, A., Hozbenko, E. (2018). Influence of diagnostics errors on safety: Indicators and requirements. *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT),* 53–57. https://doi.org/10.1109/dessert.2018.8409098
25. Alsaidi, B., Joe, W. Y., Akbar, M. (2019). Computational Analysis of 3D Lattice Structures for Skin in Real-Scale Camber Morphing Aircraft. *Aerospace, 6 (7),* 79. https://doi.org/10.3390/aerospace6070079

26. Onyshchenko, S., Zhyvylo, Y., Hlushko, A., Bilko, S. (2024). Cyber risk management technology to strengthen the information security of the national economy. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 5,* 136–142. https://doi.org/10.33271/nvngu/2024-5/136

27. Semenov, S., Jian, Y., Jiang, H., Chernykh, O., Binkovska, A. (2025). Mathematical model of intelligent UAV flight path planning. *Advanced Information Systems, 9 (1),* 49–61. https://doi.org/10.20998/2522-9052.2025.1.06

28. Hrubel, M., Kraynyk, L., Mikhalieva, M., Zalypka, V., Manziak, M., Khoma, V. et al. (2024). Improving a methodology for estimating the cross-country ability of all-wheel-drive vehicles. *Eastern-European Journal of Enterprise Technologies, 2 (1 (128)),* 64–72. https://doi.org/10.15587/1729-4061.2024.302833

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