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Preliminary results of UAV magnetic surveys for unexploded ordnance detection in Ukraine: effectiveness and challenges

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Over the past decade, the development of unmanned aerial technologies has allowed them to be considered a tool for conducting remote Earth sensing research. The use of such systems is primarily associated with solving geological and archaeological tasks. However, the armed aggression by the Russian Federation contaminated Ukrainian territory at an unprecedented scale, including unexploded ordnance (UXO). It is necessary to check unmanned aerial vehicles (UAVs) can be used to address this issue. An efficient solution can significantly expedite the process of surveying areas for the presence of UXO, minimizing risks to lives and health.

The research was conducted at test sites using full-scale models as targets, as well as disarmed mines and other ordnance. Additionally, a magnetic survey was carried out in areas directly affected by combat operations. Overall, within the scope of this work, approximately 30 hectares of territory were surveyed under various shooting modes and conditions. As expected, a high detection rate is characteristic of target objects with a high ferrous metal content. Unfortunately, the widespread use of plastic ordnance with low iron content and the high density of craters blasts create non-target magnetic anomalies, affecting the overall detection. However, with proper planning and shooting modes, the task of detection is partially addressed. Our preliminary results allow us to draw initial conclusions about the effectiveness of the complex and identify issues that require resolution.

Key words: magnetic survey, UAV, unexploded ordnance, magnetic field anomalies.

Introduction. Since the beginning of the armed aggression by the Russian Federation against Ukraine in 2014, Ukraine has suffered a significant number of casualties among its civilian population due to explosive devices. According to data from global monitoring groups, Ukraine ranks among the top five countries in the world in terms of territory contaminated with unexploded ordnance (UXO). With the onset of full-scale invasion, these numbers have significantly increased. As of March 2022, approximately one-seventh of Ukraine's territory was contaminated with UXO, and by the beginning of 2023, some reports indicate that this figure has increased to nearly one-third (Fig. 1).

Detection and clearance of contaminated areas have become critical issues. Many engineering units of the Armed Forces of Ukraine and the State Emergency Service of Ukraine are continuously surveyingthe lands for UXO. However, the work is primarily performed manually, posing a significant risk to the lives and health of the personnel. Further-

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Fig. 1. Map of Ukraine. Orange — territories potentially contaminated by UXO (https://mine.dsns.gov.ua/).

more, there is a noticeable disparity between the advancement of demining technology and the proliferation of mine warfare, leading to a dangerous trend. Mine warfare advances noticeably faster than the demining technology.

The limited set of available tools effectively limits detection to manual. Ukraine faces challenges in removing UXO using modern and safe means. This problem can be solved by improving existing technologies and developing new remote systems based on the state-of-the-art equipment and methods. Among the most promising methods today are magnetometric, electromagnetic, multi- and hyperspectral, and radar systems; most have proved relatively successful at the task. However, the most promising solution would be a comprehensive approach that would significantly enhance the overall efficiency.

Over the past decade, remote sensinghas greatly benefited from the use of unmanned technologies, including magnetic surveying [Lev, Arie, 2011; Tezkan et al., 2011; Stoll, Moritz, 2013; Wood et al., 2016; Parshin et al., 2018; Tuck et al., 2019; Walter et al., 2020; Cunningham et al., 2021; Døssing et al., 2021]. The method was successfully applied to archaeological and geological research, and its effectiveness is readily apparent in UXO detection. It provides dense coverage with high-quality data, and modern software processing tools yield comprehensive information on the geographic and spatial distribution of UXO [Butler, 2003; Nelson, McDonald, 2006; Ibraheem et al., 2021; Kolster et al., 2021a,b; Kolster et al., 2022]. Furthermore, reduces the risks faced by operator sand equipment at the site, leading to an overall improvement in safety. This paper presents preliminary results of using a UAV-based complex for a magnetic survey to detect UXO in Ukraine.

At this stage, we have done pilot testing and processed the data from a range on full-scale models of various types of ordnance and on territories where combat had taken place. Our preliminary findings show the method to be potentially effective but needing further research and development.

Materials and methods. ***Basic Principles***. The underlying principle is that the objects of interest sharply differ from the surrounding environment by their conductivity, dielectric permittivity, and magnetic susceptibility. In most cases, especially in Ukraine, the ability to detect and locate UXO is not strongly dependent on the physical properties of the surrounding environment, although there may be exceptions to consider.

The surveying involves the detection of magnetic anomalies created by iron-containing objects. The anomalies are found from the variations in the parameters of the horizontal and vertical derivatives of the magnetic field, which delineate the boundaries of magnetization contrasts. The observed magnetic field, saturated with anomalies potentially associated with UXO, is then filtered and processed to emphasize specific aspects of the resulting anomalies. The goal is to outline their sources and project them onto the surface or subsurface layers. This information is crucial for identifying potentially contaminated UXO zones.

Geological, technogenic, and anthropogenic background. When conducting magnetic surveys to detect mines and unexploded ordnance, it is crucial to consider all external factors that may affect the final result. Generally speaking, these factors can be geological or anthropogenic.

The ***geological*** include the following.

– Variability of magnetic parameters in the environment (soil, rock formations). It can have a significant effect on the survey data. Typically, high magnetic susceptibility is seen in volcanic, magmatic rocks and certain types of soils with a significant content of ferromagnetic minerals. Therefore, a useful signal will be hardest to obtain for objects located in areas with deposits of magnetite, hematite, siderite, silicate magnetic ores and iron-rich quartzites. Given the geography of contaminated areas in Ukraine, special attention should be paid to the southern regions of Donetsk and Zaporizhzhia oblasts, where the Bilozirsky and Priazovsky iron ore basins are located. As for the regions of Luhansk oblast and the southern territories of Ukraine (Mykolaiv and Kherson oblasts and the Crimea), the distribution of iron-bearing deposits that could have a significant impact on magnetic signatures is generally limited, except for the Kerch iron ore basin.

– Geomagnetic variations, which are any deviations of the Earth's magnetic field elements from the base level. They can significantly impact the results of magnetic surveys. These deviations can be periodic or non-periodic, ranging from nT to thousands of nT or more and lasting from seconds to several days.

The most influential on survey data are non-periodic variations, i.e., the magnetic storms. Their intensity can reach hundreds or even thousands of nT, and their duration can vary from several hours to two to three days, with rapid changes in field strength occurring within minutes. Therefore, to obtain a representative standardized dataset, it is important to use a magnetometer base station that can account for variations of the geomagnetic field during data processing.

– Landscape conditions. These are very important when setting up magnetic surveying operations, especially for the aeromagnetic surveying (in our case, using UAVs). To obtain high-quality information, it is crucial to adhere to technical UAV operating requirements, including maintaining a consistent flight altitude, assessing vegetation parameters (height, density), and applying appropriate technical solutions.

Technogenic and anthropogenic factors have a significant impact on the quality and reliability of the data. The key consideration is the presence, within the research area, of objects that create «false anomalies». Primarily, these include power lines, electromagnetic transmitters of various types in relative proximity, concealed infrastructure (communications), hidden remnants of domestic and industrial objects (iron-containing waste, remnants of agricultural and military machinery, etc.), as well as scattered or hidden remnants of exploded munitions (fragments).

Taking the above-mentioned factors into account is crucial as these considerations significantly influence the reliability of the data and so the chances of identifying targets.

Equipment. For an effective and working platform, we used the following hardware solutions.

Mag Drone R3. A two-sensor magnetometer produced by German SENSYS company and designed for UAV application. The magnetometer was tested in the lab and in the field. It produces repeatable results for the

Table 1. Technical specifications of Sensys Mag Drone R3 magnetometer

Operating Temperature	–20°C to +50°C
Weight/with Li-Ion battery	750 g/884 g
Overall power consumption	500 mA
Sensor tube dimensions (*W*×*D*×*H*)	1,070 × 22 mm
Specified measurement range	±75,000 nT (higher ranges available on request)
Number of sensor axis	3
Distance between sensor centre points	1.000 mm
Sampling rate	200 Hz (higher rates available on request)
Internal memory	2 GB
Survey pre-processing software	Mag Drone Data Tool

same survey area with low background noise. It showed satisfactory stability of operations in various weather conditions. Selected technical specifications are given in (Table 1).

Mines Eye Proprietary extender (patent application No. a202302941). Self-transforming extender made of low-magnetic materials (mainly aluminum) that allows to achieve controlled vertical distance to UAV and high flight stability. The extender was designed to reduce background magnetic noise from the UAV and keep minimal safe distance from the surveyed surface. The operation of the system is fairly simple. The magnetometer is installed within a special holder which ispart of the installation and the extender is then attached to the UAV. The UAV operator sends the vehicle off and the installation self-extends vertically. Once the UAV achieves the required altitude, the set-up is ready. Additionally, the extender is equipped with an automatic folding-unfolding system, a sensor for collecting data on the magnetometer's altitude, and a data collection system (time, geographic coordinates, and altitude) (Fig. 2).

Drone DJI Agras T16. This is a smaller specimen of the agricultural UAV series Agras (T20, T30, and T40 are also common). The UAV was designed for seamless operations on large open fields. It has maximum payload of ~15 kg and can easily carry a magnetometer along with supplementary hardware. It is equipped with 4 battery sets and a fast charger that, assuming stable power supply, charges a single battery in 20 min. At the same time, one battery is sufficient for a flight of 10—15 min which allows to cover 1600 m^2 (0.16 ha) with this magnetometer setting. Limitations of this UAV for our purposes: spray tank and working pumps are required for mission flying, software limitations imposed by DJI after the start of active conflict(?), inconvenient mission planning process. Below are selected technical specifications of the UAV (Table 2).

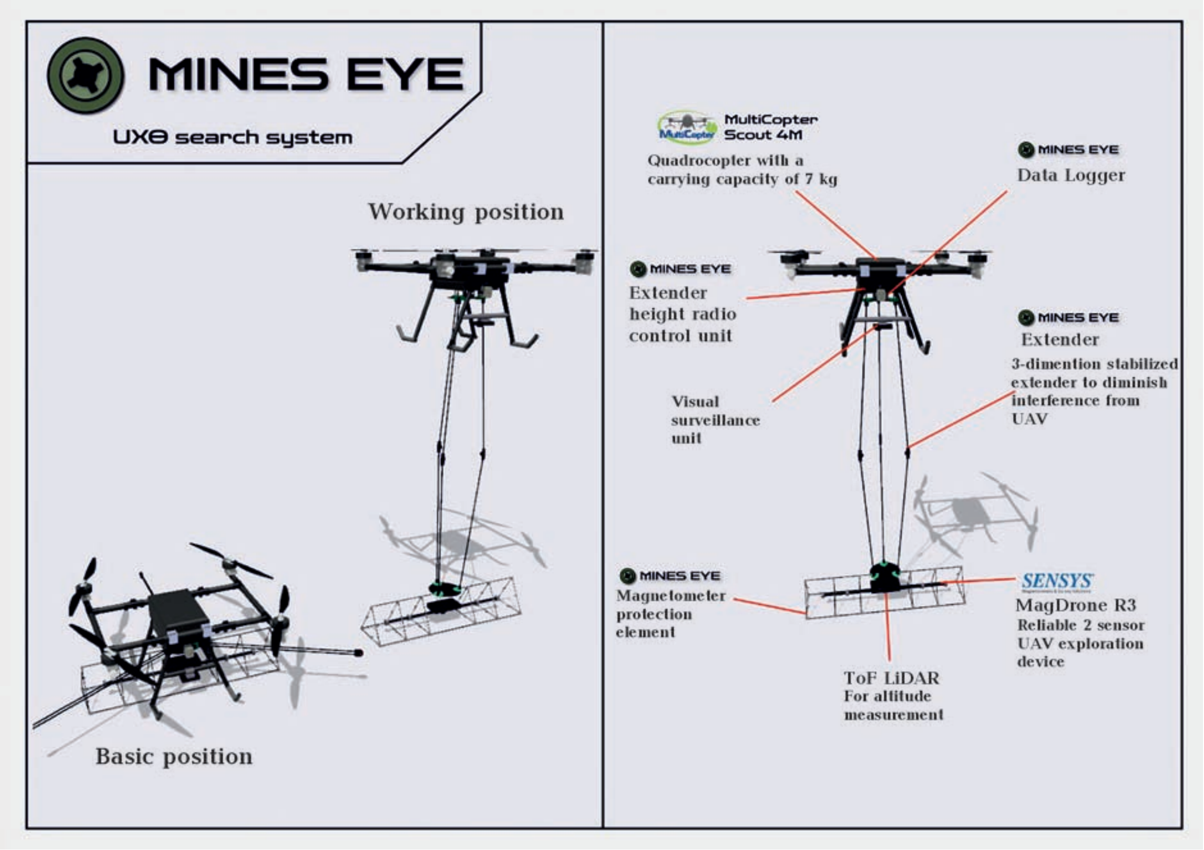


Fig. 2. Design, principle of operation and technical components of the integrated system of magnetometer equipment for UAVs.

Table 2. Technical specifications of DJI Agras T16 UAV

Max Diagonal Wheelbase	1883 mm
Operating Payload	Rated: 15 kg, Full: 16 kg
Operating Frequency	2.4000—2.4835 GHz, 5.725—5.850 GHz
Total Weight (Excluding battery)	18.5 kg
Standard Takeoff Weight	39.5 kg
Max Takeoff Weight	40.5 kg (At sea level)
Hovering Accuracy (With strong GNSS signal)	D-RTK enabled: Horizontal: ±10 cm, Vertical: ±10 cm
D-RTK disabled:	Horizontal: ±0.6 m, Vertical: ±0.3 m (Radar module enabled: ±0.1 m)
RTK/GNSS Operating Frequency RTK	GPS L1/L2, GLONASS F1/F2, BeiDou B1/B2, Galileo E1/E5
GNSS	GPS L1, GLONASS F1, Galileo E1
Battery DJI-approved battery pack	AB2-17500mAh-51.8V
Max Power Consumption	5600 W
Hovering Power Consumption	4600 W (Takeoff weight of 39.5 kg)
Hovering Time	18 min (Takeoff weight of 24.5 kg with a 17500 mAh battery), 10 min (Takeoff weight of 39.5 kg with a 17500 mAh battery)
Max Operating Speed	7 m/s
Max Flying Speed	10 m/s (With strong GNSS signal)
Max Wind Resistance	8 m/s
Recommended Operating Temperature	0—40°C (32—104°F)

Software Oasis Montaj (Seequent). For processing the data, we utilized the professional software package Oasis Montaj (License No. 27816). In addition to basic functionalities, this package includes a modeling module (Potent Q) and modules for processing and analyzing magnetic data related to the identification and partial classification of unexploded ordnance — «UXO marine» and «UXO land». We were able to process the data, analyze them, and present them as graphs and maps of magnetic anomalies with geospatial referencing.

Results. ***Impact of magnetic signals from UAV.*** The use of equipment for magnetic survey based on UAVs has some specifics to consider when planning and executing magnetic survey tasks. Firstly, there are deviations in the magnetic field caused by the operation of the UAV engines, which can affect the quality of the signal and lead to false magnetic anomalies. To address this, a decision was made to test the existing setup in two modifications: the first involved placing the magnetometer directly on the UAV chassis, and the second involved installing the magnetometer two meters below the UAV chassis using a specially designed extender. A testing ground was set up with non-military iron-containing objects (Fig. 3, *a*), and test measurements were conducted with subsequent comparison of the obtained results.

When the magnetometer was placed under the UAV chassis, there was a magnetic background with average values of 33 nT (Fig. 4, *a*). In contrast, for the extender of 2 m, the average values were 2.45 nT (Fig. 4, *b*), which is more than ten times less. Therefore, an extender allows for more accurate detection of magnetic anomalies related to target search objects (see Fig. 3, *a*, *b*).

Furthermore, the use of an extender increases the flight altitude of the drone, minimizing the negative impact of updrafts cre-

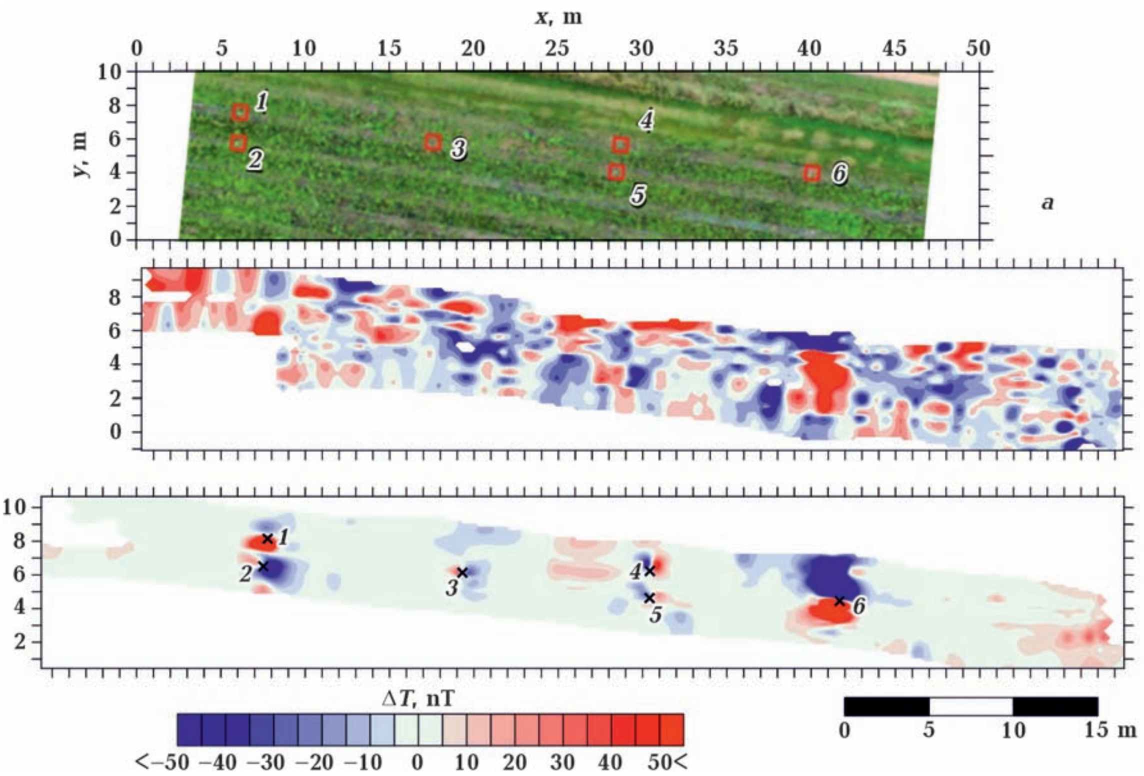


Fig. 3. Location of test search objects (*a*), comparative maps of magnetic anomaly intensity Δ*T* for different positions of the magnetometer relative to the UAV: *b* — directly under the UAV chassis; *c* — 2 m below the UAV chassis.

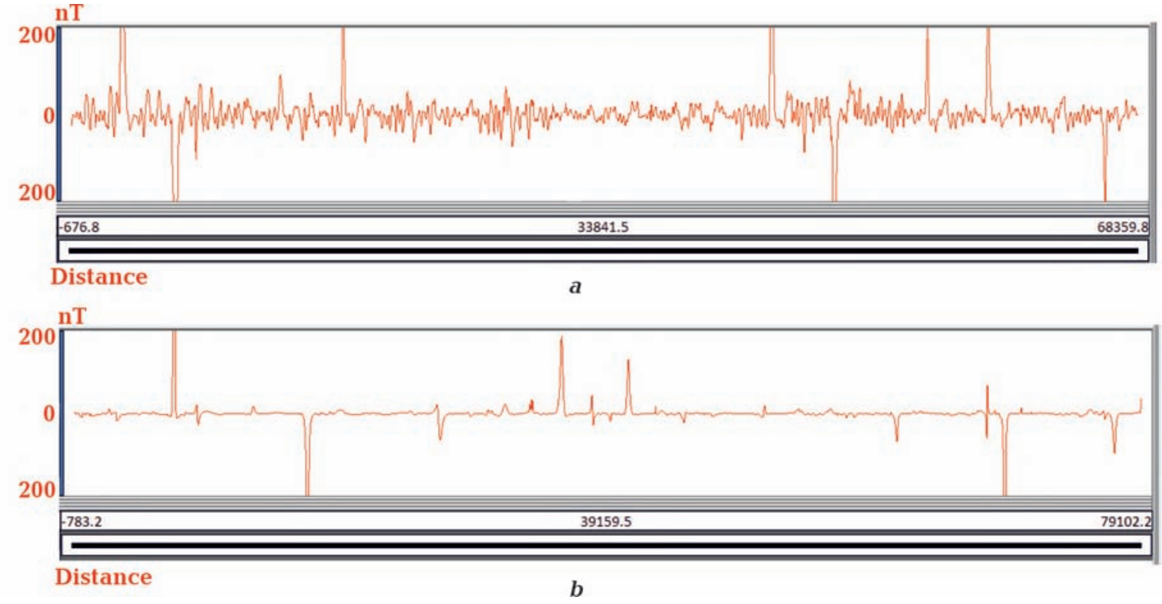


Fig. 4. Comparison of magnetic parameters recording for different modifications of the magnetometer placement relative to the UAV: *a* — directly under the UAV chassis, *b* — 2 m below the UAV chassis.

ated by the propellers. These updrafts can impact flight stability. It is worth noting that the extender structure is robust and resistant to obstacles, which is crucial when operating in complex landscape conditions, reducing the likelihood of accidents or equipment damage.

Research objects and survey planning. To conduct controlled experiments (with known target objects and their locations), our team was given access to an experimental training ground in the Kyiv region. This site represents a typical agricultural landscape. Additionally, the State Emergency Service of Ukraine provided us with various full-scale models of different types of munitions commonly encountered on a battlefield (Table 3).

An area of 8—40 m was designated on the test range, where the inert munition models were placed in two configurations. Our team followed predefined flight paths set 2 m apart. Magnetic sensors were positioned 1 meter apart from each other, resulting in scan lines spaced 1 meter apart (Fig. 5). The flight altitude varied from 0.3 to 0.7 m depending on the terrain and vegetation height.

This approach allowed us to accurately scan the area for magnetic anomalies associated with the target inert munition models.

Controlled field tests. The controlled tests involved detecting targets knowing what they were and where they were located. Essentially, this meant a direct magnetic survey task. The aim was to determine the effectiveness and limitations of using magnetic surveying to detect iron-containing objects of military origin under various conditions. Key criteria for planning the experiment included the parameters of the target (volume, iron content) and the conditions of its burial (at or beneath the ground surface).

Table 3. Names and parameters of test search objects

Number	Name	Type	Pictures	Size, mm	Weight, kg	Material
1	TM-62	anti-tank blast mine		Ø 320 *H*: 128	7.5	many variants+ iron elements
2	PFM-1	anti-personnel high-explosive mine		11.9×6.4×2	0,08	Plastic+ iron elements
3	MON-50	anti-personnel high-explosive mine		226×155×35	2	Plastic+ iron elements
4	F-1	hand grenade		Ø 55 *L*: 117	0.6	iron

Number	Name	Type	Pictures	Size, mm	Weight, kg	Material
5	VOG-25	grenade		Ø 40 *L*: 103	0.225	iron
6	RGN	hand grenade		Ø 61 *L*: 113	0.530	iron
7	PMN-2	anti-personnel high-explosive mine		Ø 120 *H*: 54	0.4	Plastic+ metal elements
8	OZM-72	anti-personnel fragmentation anti-personnel mine		Ø 108 *L*: 172	5	iron

Fig. 5. An example of flight planning for magnetic surveying with a UAV. The red lines show the UAV flight profiles, and the green lines show the profiles along which the data are collected.

Test № 1. On the prepared test range (cleared of iron objects), three TM-62M mines, one TM-62P mine, one MON-50 mine, and one PMN-2 mine, were buried. The objects were placed at depths ranging from 15 to 50 cm, with the MON-50 and PMN-2 mines on the surface. Based on four flights with two different object configurations, 100 % of the TM-62 and MON-50 mines were detected, while the PMN-2 mine was not detected (Fig. 6).

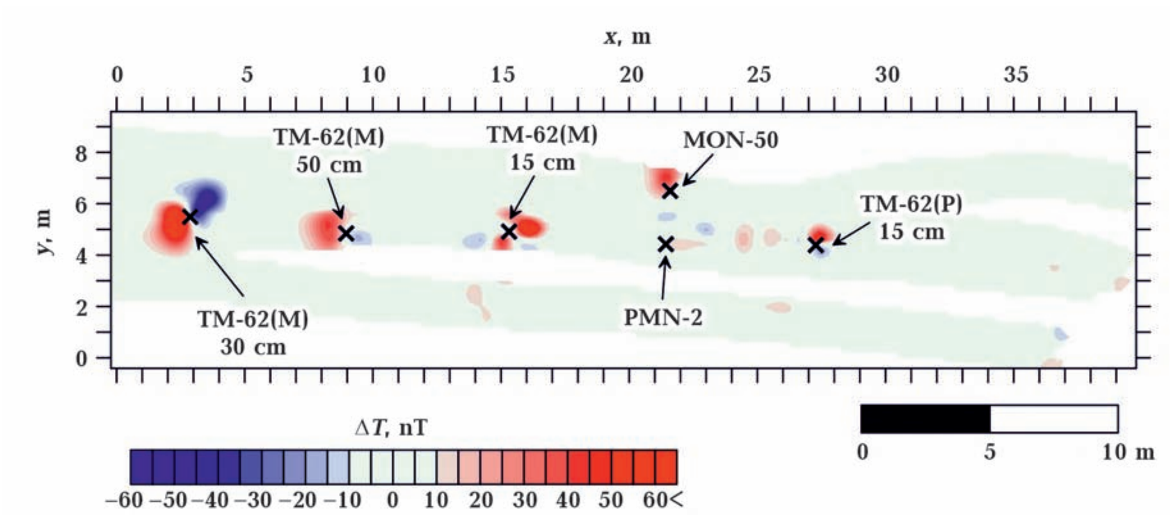


Fig. 6. Map of the intensity of magnetic anomalies Δ*T* over the controlled survey area. The indices show the names of the search objects (according to Table 3) and their depths.

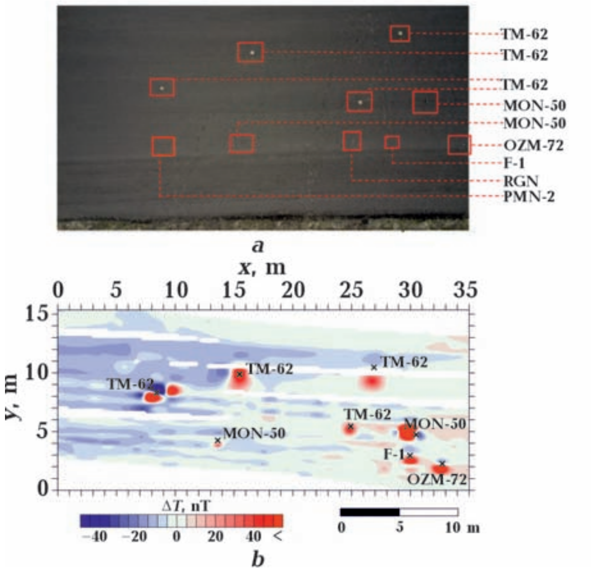


Fig. 7. Aerial photo of the study area with the target search objects marked on it (*a*) and a map of magnetic anomaly intensity Δ*T* over the controlled survey area (*b*). Indices show the names of the search objects (according to Table 3).

Test № 2. For the next experiment, ten different mines and grenades, including PMN-2 mines, were placed on the ground surface. During the first flight, all objects were detected, while during the second flight, 80 % were detected (Fig. 7). The difference in results was attributed to variations in flight altitudes. Objects with low ferro-metallic content (PFM-1, PMN-2) were detected at extremely low altitudes (up to 0.2 m), and reproducing the results was challenging even so.

Field tests (real conditions). The next stage of the research was conducted in areas that were actually mined and had experienced combat operations.

Test № 1 (Kharkiv region). Testing was done in an open area classified as a mixed minefield based on non-technical survey findings (Fig. 8, *a*). The goal was to practice measurements in the field without access to direct sources of electricity and under increased risk. An additional task was to improve the quality of measurements for further determination of the minefield's size and classification of the found objects. Since this was the first flight of this system in real conditions, it was essential to understand the actual operational speed of this equipment and the potential problems we could encounter during flights. An important feature of this location is its proximity to Russian army's defensive positions at the time of occupation.

The testing consisted of five magnetometer measurements, and during the flights, up to 10 landings were made to replace the drone's battery. The flights were conducted in a back-and-forth method without making any turns. During the flights, the magnetometer operator adjusted the flight altitude to ensure a minimum safe magnetometer-to-ground distance.

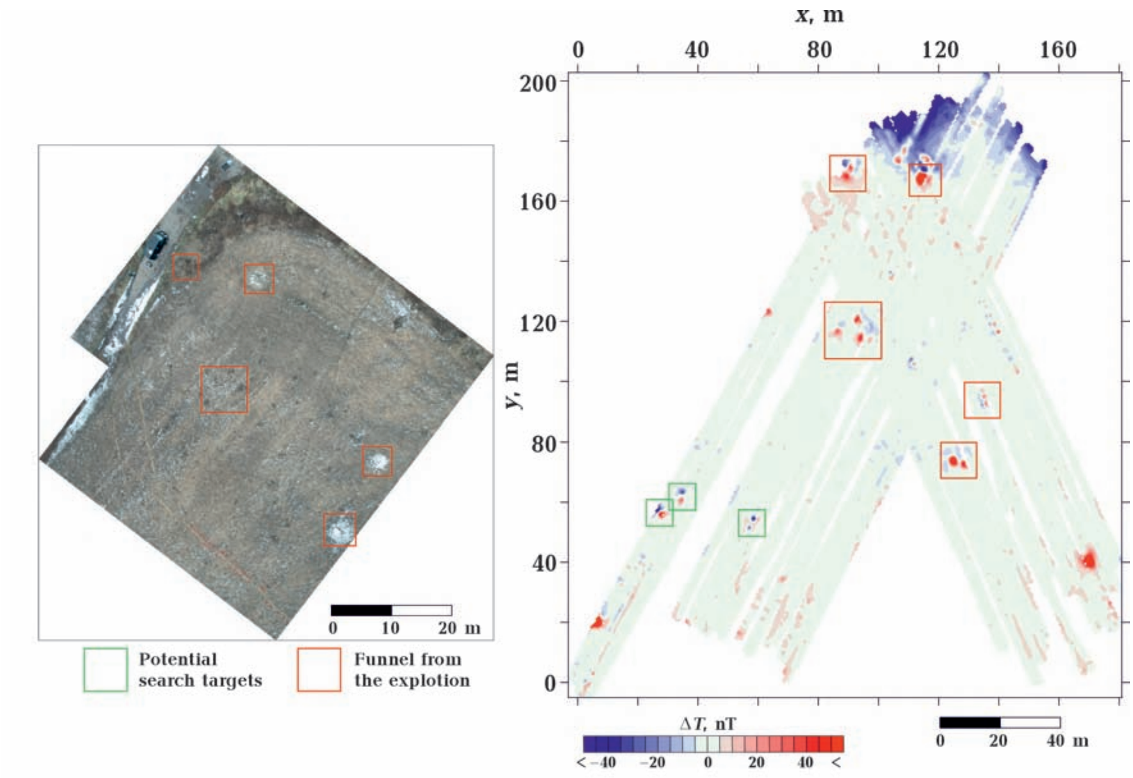
In total, an area of 17,435 m^3 was scanned. High-variation magnetic signatures were measured during the testing, with the largest anomalies having signals exceeding 100 nT (Fig. 8, *b*).

Most of the anomalies were observed with absolute signal power exceeding 15—30 nT (see Fig. 8, *b*). According to the specifications obtained during the non-technical survey, the scanning was carried out on a mixed minefield, which contained a significant number of anti-tank TM-62 and anti-personnel mines that could not be identified through drone photography. The nature of the field (including its proximity to defensive positions) suggests that, in addition to mines, a significant number of craters from explosions and remnants of exploded ordnance with a high iron content were found.

It is difficult to assess the effectiveness of the magnetometer for detecting anti-tank mines in plastic casings. However, given several technical limitations such as the absence of precise elevation data, low data density, and the lack of Real-Time Kinematic (RTK) location correction, the data have limited practical utility for demining units.

On the other hand, such data can be valuable for detecting hidden objects with a high iron content that could pose a significant danger to demining personnel, such as OZM-72 mines or unexploded ordnance. It was recommended to take a closer look at the magnetic field map in the area where signs of systematic placement of objects with a significant iron content were found.

Test № 2 (Kyiv region). This area in the Kyiv region was one of the most heavily contaminated during active hostilities in March 2022. It was subjected to heavy artillery strikes and combat encounters. After the de-occupation, during agricultural work on the research site, three agricultural vehicles were damaged driving over mines. Recent explosive ordnance disposal surveys in this area resulted in the loss of an automatic demining complex belonging to an anti-mine activities organization. Prior to this, the tall vegetation



a *b*

Fig. 8. Aerial photo of the northern part of the test site (*a*) and map of magnetic anomalies intensity Δ*T* (*b*) over a territory affected by the hostilities (Kharkiv region).

made it difficult to do magnetic survey at an effective altitude.

The results of the survey are similar to those obtained in Kharkiv region. A significant number of intense anomalies caused by explosion craters were detected (Fig. 9), but the quality of the data did not allow for an objective classification of potentially hazardous objects.

Problems and Solutions. The testing revealed issues that require resolution for the purpose of assessing system effectiveness and obtaining reliable data. These problems can be categorized into instrumental and those associated with the initial conditions of the survey.

Instrumental Problems. ***Platform Stability.*** Issues related to the stability of the platform's operation, particularly concerning the stable spatial positioning of equipment for magnetic surveying during flight, can result in false anomalies. This problem arises when reconfiguring the UAV for a new measurement profile (Fig. 10). Two possible solutions are available: the first involves waiting for a certain period until the suspension stabilizes with the installed equipment, while the second entails stabilizing the equipment through suspension system upgrades involving hinges and gyro stabilizers.

Accurate Geographical Coordinates. Another critical issue is the precise determination of geographical coordinates for each measurement point. The integrated GPS equipment in the magnetometer introduces a measurement error of up to 2 m. Modernizing the equipment with precise RTK systems would increase the accuracy of geographical data to within a few centimeters.

Challenges Related to Initial Survey Conditions. Vegetation Obstruction: dense vegetation complicates data collection. Addressing this problem may involve taking measures to clear the area, such as using desiccants or applying herbicides to eliminate vegetation entirely. This approach not only facilitates unobstructed mission execution but also provides visual access to target objects, significantly simplifying ordnance disposal.

Non-Target Objects. A major limitation in obtaining high-quality magnetic data is the presence of non-target objects in the survey area. These objects may include non-military items like parts of agricultural machinery and military-origin debris, as well as magnetic anomalies created by blast craters (Fig. 11).

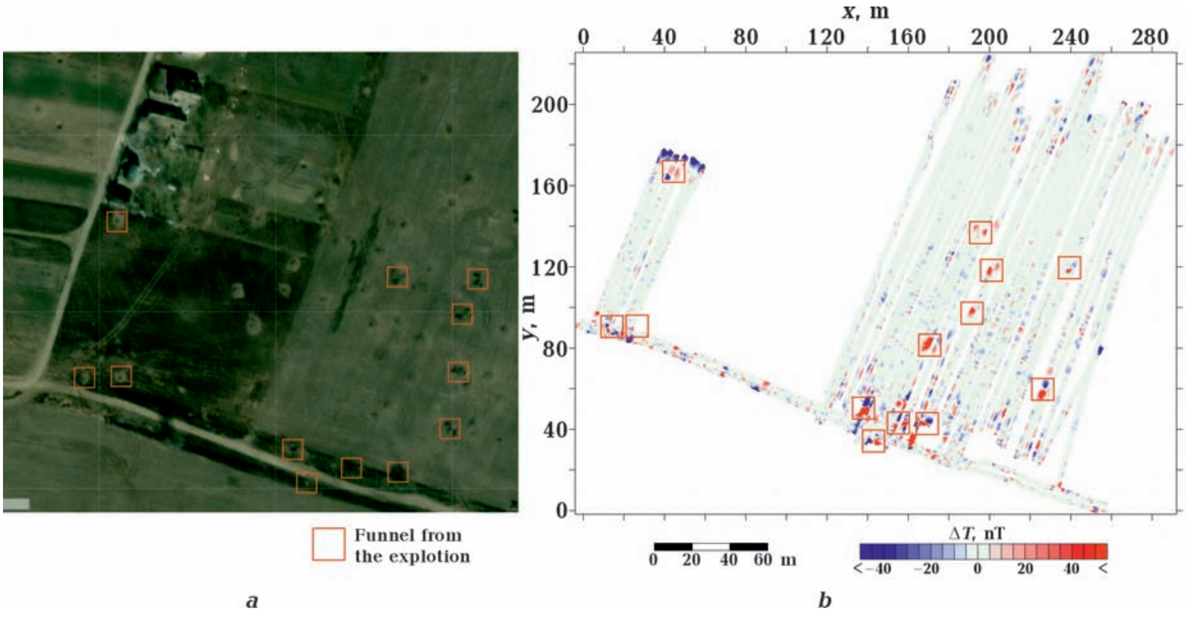


Fig. 9. Aerial photo of the test site affected by the hostilities (Kyiv region) (*a*) and map of magnetic anomalies intensity ΔT over the territory (*b*).

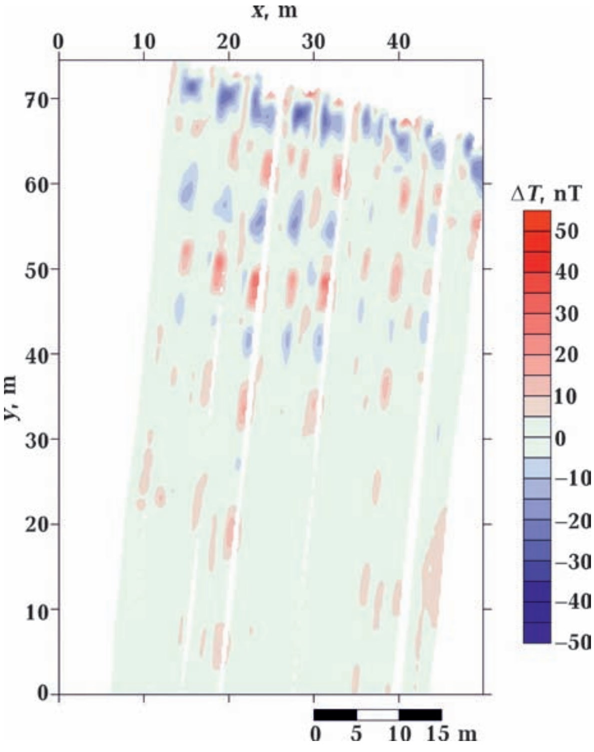


Fig. 10. Map of false magnetic field anomalies ΔT caused by the shaking of a UAV-based magnetic survey system during flight.

One solution is to increase the altitude of magnetic surveying. Objects with low magnetic signatures would not be detected by the magnetometer at higher altitudes, emphasizing the stronger anomalies. This hypothesis can be tested through a series of measurements on known nearby objects at various flight altitudes and through vertical gradient magnetic surveying with two or more vertically positioned sensors.

Data post-processing. Equally important is the post-processing of acquired data. Additional mathematical filtering algorithms significantly improve the final outcome (Fig. 12). Selecting and applying various combinations of filters allow for a more precise classification of different targets, differentiating them based on key shape and magnetic anomaly intensity parameters.

Addressing these issues will help to use the complex efficiently for precise location of hazardous explosive objects, providing crucial information to the explosive ordnance disposal specialists.

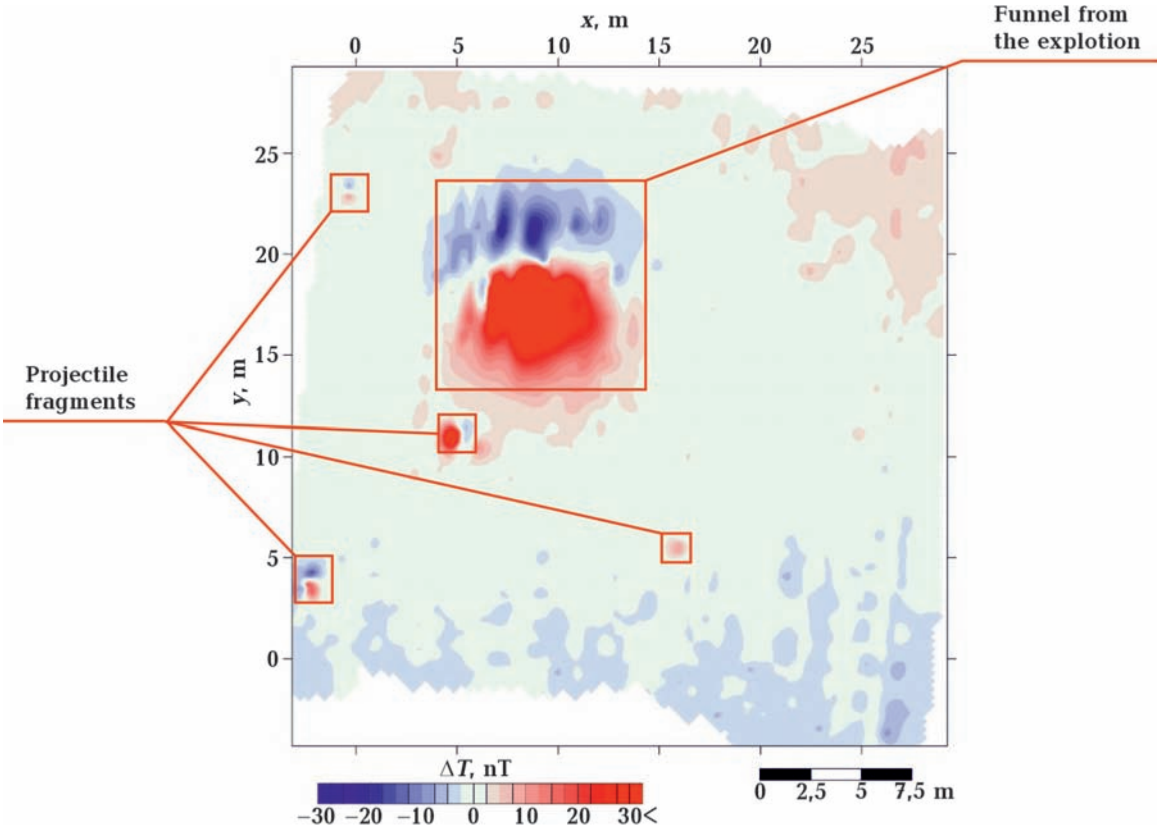


Fig. 11. Map of the intensity of magnetic anomalies ΔT in the area of artillery shell impact.

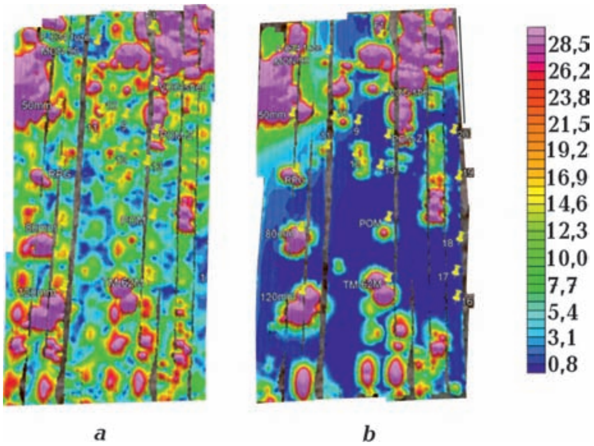


Fig. 12. Comparative maps of magnetic field anomalies: *a* — raw data, *b* — post-processing using sets of magnetic noise filtering algorithms.

Conclusions. As of today, the obtained results demonstrate a high efficiency of magnetic surveying in detecting and localizing UXO with a significant content of ferrometals. In a controlled setting, the detection of certain types of ordnance (TM-62M, MON-50, etc.) reached 100 %. For other types, the detection effectiveness depends on various physical parameters of the objects, their placing, and the overall conditions during aeromagnetic surveying. When doing research within the areas where combat had taken place, several issues negatively affecting data quality were identified. Primarily, these problems are associated with technological and anthropogenic contamination.

Further research will be focused on achieving reliable results under real blind measurement conditions. The main emphasis will be on platform stability and optimizing the system for collecting geospatial and magnetic data under significant magnetic contamination associated with ferromagnetic debris and exploded ordnance.

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Попередні результати магнітного знімання БПЛА для виявлення нерозірваних боєприпасів в Україні: ефективність і проблеми

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За останнє десятиліття розвиток безпілотних літальних технологій дав можливість розглядати їх як інструмент для проведення досліджень з дистанційного зондування Землі. Зрозуміло, що використання таких комплексів передусім пов'язане з вирішенням геологічних і археологічних завдань. Втім безпрецедентні масштаби забруднення території України через збройну агресію рф боєприпасами, що не вибухнули (НВБ), створюють необхідність оцінювання можливості використання безпілотних літальних апаратів (БПЛА) в комплексі з магнітометричним обладнанням з метою подолання цієї проблеми. Ефективне вирішення цього завдання може значно пришвидшити процес обстеження територій на наявність НВБ, мінімізуючи ризики для життя і здоров'я спеціалістів з розмінування.

Дослідження проведено на тестових полігонах з використанням цілей повномасштабних макетів, а також знешкоджених мін й інших боєприпасів. Додатково виконано магнітознімальні роботи на територіях, які безпосередньо перебували в зоні бойових дій. Загалом в рамках роботи було обстежено близько 30 га територій за різних режимів та умов знімання. Як і очікувалося, виявлено високий рівень цільових об'єктів з великим вмістом ферометалів. На жаль, широке застосування пластикових боєприпасів з незначним вмістом заліза, а також висока щільність вирв від розривів боєприпасів, що створюють нецільові аномалії магнітного поля, зменшують відсоток загального виявлення, але в разі певного планування і режимів знімання завдання виявлення частково вирішується. На цьому етапі отримано початкові результати тестувань, що дало змогу зробити перші висновки щодо ефективності комплексу, а також виокремити низку проблем, які потребують вирішення.

Ключові слова: магнітне знімання , БПЛА, нерозірвані боєприпаси, аномалії магнітного поля.