Utilizing Unmanned Aerial Vehicle (UAV) for Unexploded Ordnance (UXO) Trials: A Survey Using MagDrone R4 Magnetometer.

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ABSTRACT

This paper presents the first survey utilizing Unmanned Aerial Vehicles (UAVs) equipped with a MagDrone R4 magnetometer to survey Unexploded Ordnance (UXO) trials. The study aimed to investigate the processing of UAV UXO trials for future research and evaluate the performance of the MagDrone R4. The test site was in Bearwood Park Training Ground, Wokingham, United Kingdom. Our team trialed four flights at different altitudes (4 m, 3 m, 2 m, and 1 m) to assess the effectiveness of the method. Results showed that the larger surrogate targets (100kg, 50kg, and 10kg) were detected at all altitudes, whereas the smaller targets (5 kg, 2.5 kg, and grenade clusters) were only detected at lower altitudes (1 m and 2 m). The quality of the collected data was clear with minimal noise present. However, Total Field Analytical Signal (TFAS) gridding could generate slightly false positive detections and affect the target picking. Overall, the UAVs equipped with magnetometers method is potential and effective to develop for detecting surrogate UXO targets, providing a cost-effective solution for magnetic exploration in inaccessible areas.

Keywords: UXO, UAV, target, magnetic exploration

1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), or drones, equipped with lightweight magnetometers offer a unique opportunity to conduct high-quality, large-scale magnetic surveys in previously inaccessible areas at significantly reduced costs and with greater flexibility in planning and operation. The increased reliability of survey-grade drones enables efficient investigation of large areas in a short time, providing a cost-effective solution for magnetic exploration. However, the main challenge in conducting high-resolution UXO magnetic exploration using drones is the magnetic interference from the drone itself. While most drone systems are non-magnetic, components such as batteries, motors, and wires can create strong magnetic fields that interfere with the survey. Despite this limitation, advancements in drone technology and survey-grade magnetometers continue to improve the effectiveness and efficiency of magnetic surveys using UAVs [2,3].

This paper presents the first survey utilizing Unmanned Aerial Vehicle (UAV) to survey Unexploded ordnance (UXO) trials and data collecting with the MagDrone R4 magnetometer with paper aims to investigate the processing of UAV UXO trials for future research and to evaluate the performance of the MagDrone R4 when used with UAVs. The survey area was in Bearwood Park Training Ground, Wokingham, United Kingdom. The surrogate items were in a known location that was free of any background magnetic anomalies. During the survey, four flights were conducted, with each flight repeated at different altitudes. Data is collected throughout the trial to assess the effectiveness of the methods used and to identify any potential limitations or areas for improvement.

Fig. 1 MagDrone R4 was surveying the surrogate targets.

2. MATERIALS AND METHODS

2.1 Materials

The project setup for the magnetic drone survey involved creating a Geosoft Oasis Montaj software and generating a processing template, followed by importing the data and conducting quality control checks on the channels. Preliminary processing steps included processing navigation and motion data, as well as processing altitude and total field measurements with corresponding quality control checks. Initial output generation involved calculating residuals and checking for noise and gaps, masking noise, and generating final XY values while highlighting gaps. The final output generation steps included recalculating final XY values, picking anomalies, and exporting track lines. Overall, these steps enabled the effective processing and analysis of the magnetic drone survey data for UXO detection purposes [1].

The surrogate targets or waypoints are placed on the identified locations from the clearance survey. The ferrous masses are 100 kg equaling 1000 lb bomb, 50 kg equaling 250 kg bomb, 10 kg equaling 6-inch shell, 5 kg equaling 4-inch shell, 2.5 kg equaling artillery shell and grenade cluster, as in the Fig. 2. A minimum of 10-m separation between the targets would be observed to avoid any interference from each other during the surveys.

Fig. 2 The selected surrogate targets

2.2 Methods

Initially, the survey ground, survey equipment, and UAV were prepared and checked under standard requirements. The marker points of surrogate items and survey boundary are positioned by RTK receivers. MagDrone system, cables, NA24 radar were fitted with the power supply and tested. The weather was in good condition with moderate cloud cover. The wind reading was recorded every 20 minutes and showed a low speed of up to 20 kts.

The survey flights were operated in two parts. The mission of the first flight was the clearance survey to detect the magnetic background anomalies in the trial area. The flight speed was between 5-10 m/s at the terrain altitude of 1.5 m. The course angle was fixed. The mission of the second flight was for the surrogate trials. The different altitudes of the flights were 4 m, 3 m, 2 m, and 1 m at a speed of 5 m/s. A wing line set at a 2.5-m offset to each target, along with a cross line that also passed directly over the target. The wing lines would be acquired in a reciprocal direction. The MagDrone R4 magnetometer is directly installed on the UAV to investigate the survey. Each UAV would be fitted with a NA24 Nano Radar maintaining an accurate height. The actual survey tracks of the missions are shown in Fig 3.

Fig. 3 The survey flights of site clearance (left) and surrogate trial. (right)

The collected survey data was processed using Geosoft Oasis Montaj software to generate total field residuals and analytic signals. These signals were analyzed to detect any anomalies that might indicate surrogate targets. The processing workflow is:

1) Project setup
2) Preliminary processing
    - Navigation
    - Motion
    - Altitude
    - Total field
3) Initial output generation
    - Residual
    - Noise and gap processing
    - Final position
    - Mark the gaps
4) Final output generation
    - Recalculate the final position
    - Anomaly picking
    - Trackline exporting

3. RESULTS AND DISCUSSION

In this study, four flight surveys were conducted at different altitudes to assess the effectiveness of using a UAV equipped with a MagDrone R4 magnetometer to detect surrogate UXO targets. Results indicated that the 100kg, 50kg, and 10kg targets were detected at all altitudes, although it was not feasible to detect the 10kg target against the background at 4m altitude. The 5kg and 2.5kg targets, and grenade clusters were only detected at 1m and 2m altitude. The 2.5kg target could only be reasonably detected against the background at 1m altitude.

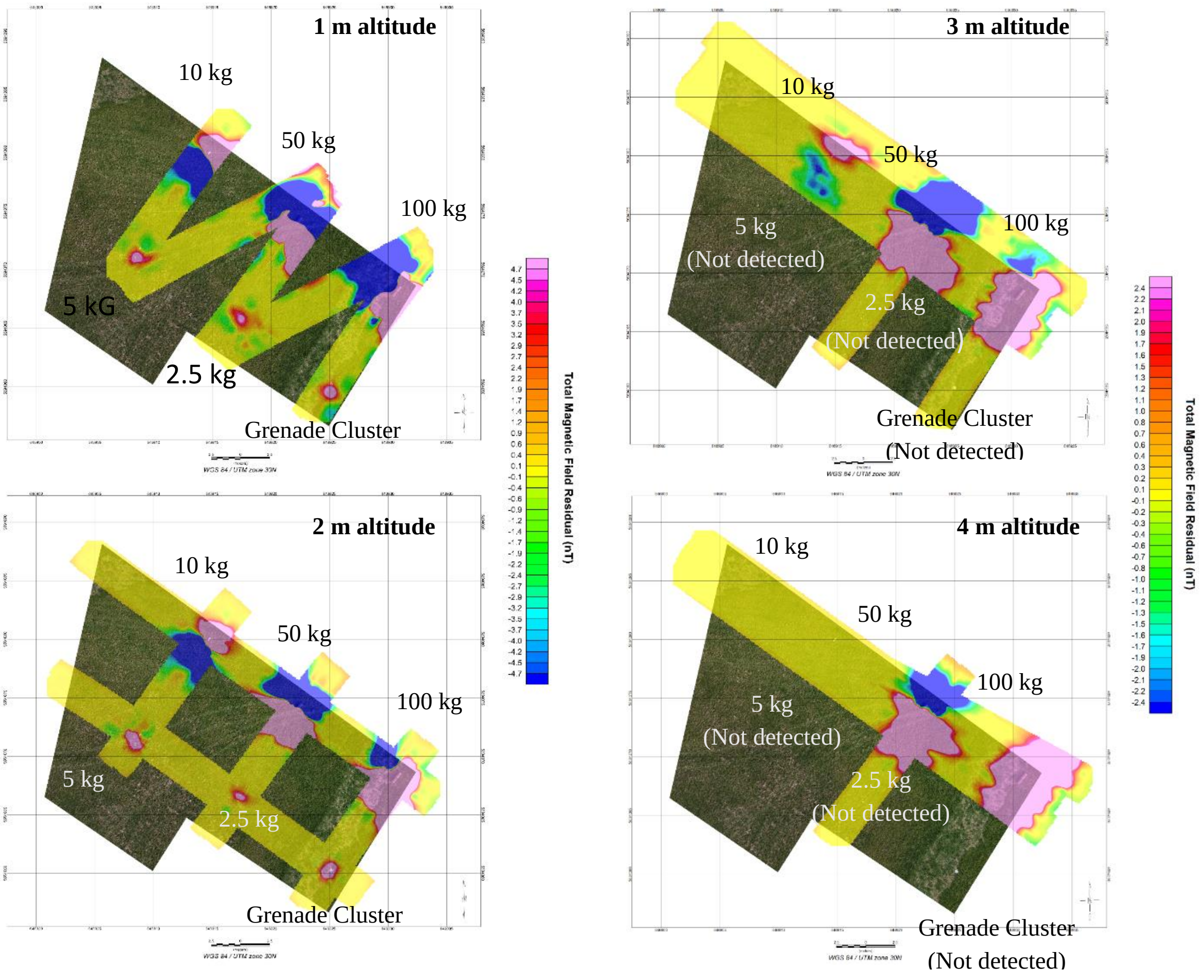

Fig. 4 Total field residual plots of 1m, 2m, 3m, and 4m altitude passes over all targets. At 1-2m altitudes, all targets were detected. At 3-4m altitudes, 5kg, 2.5kg, and grenade clusters cannot be detected.

Data quality of line 11 at 3 m altitude comparing the reading numbers and noise amplitudes has been plotted and considered. The histogram in Fig. 5 shows very little noise in the data. About 75 percent of the amplitude noise is less than 0.5 nT.

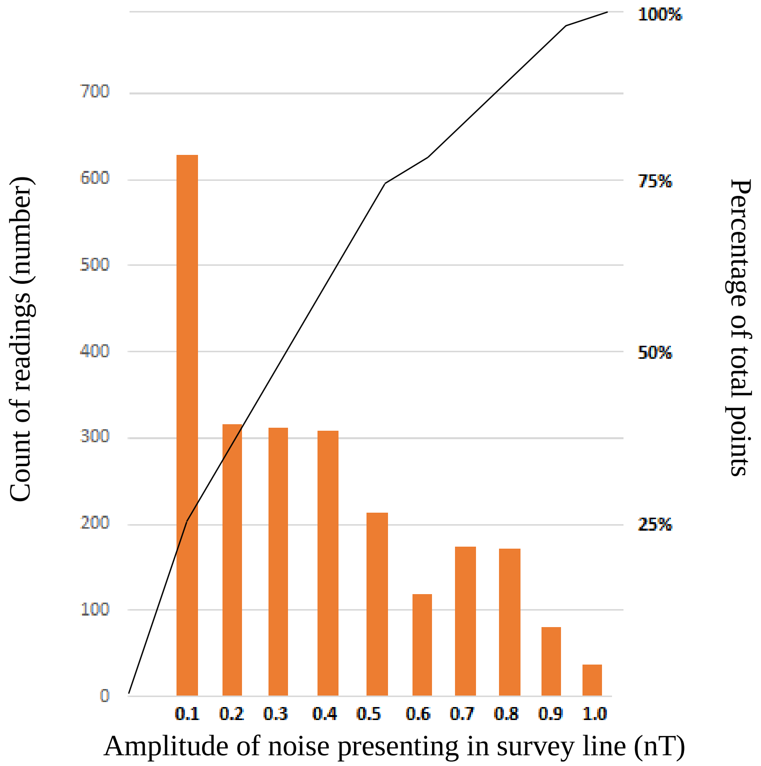

Fig. 5 Noise histogram of line 11 at 3m altitude.

The graphs depicting the comparison between the Total Field Residual and 3D range for all targets (Fig. 6) and the Total Field Analytical Signal and 3D range for all targets (Fig. 7) suggest that selecting targets based on the Total Field Analytical Signal (TFAS) can improve the detection capability, but it may also lead to false positive detections. Additionally, these graphs aid in determining a suitable altitude for detecting actual targets.

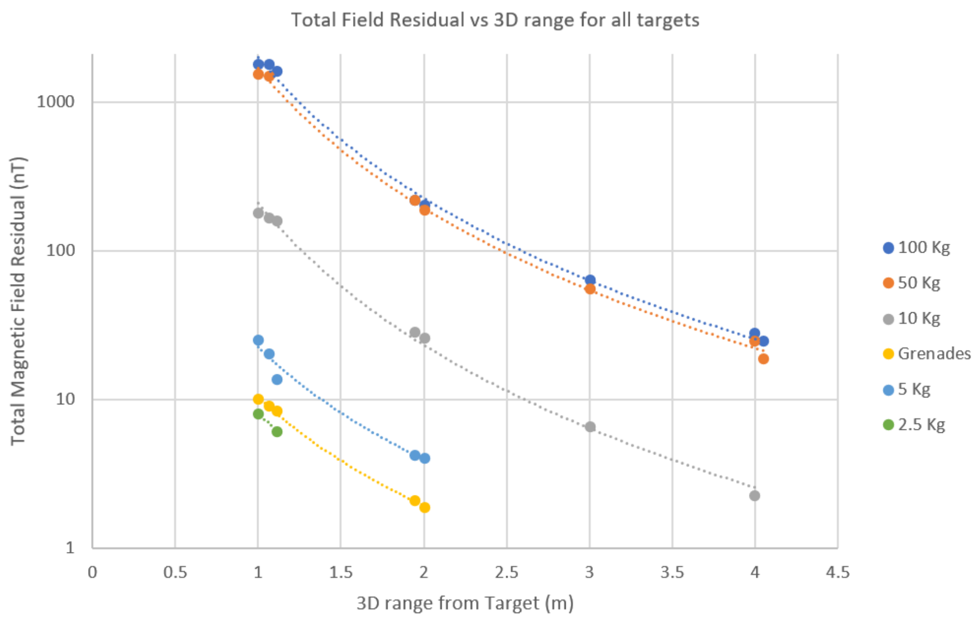

Fig. 6 Total Field Residual vs 3D range for all targets.

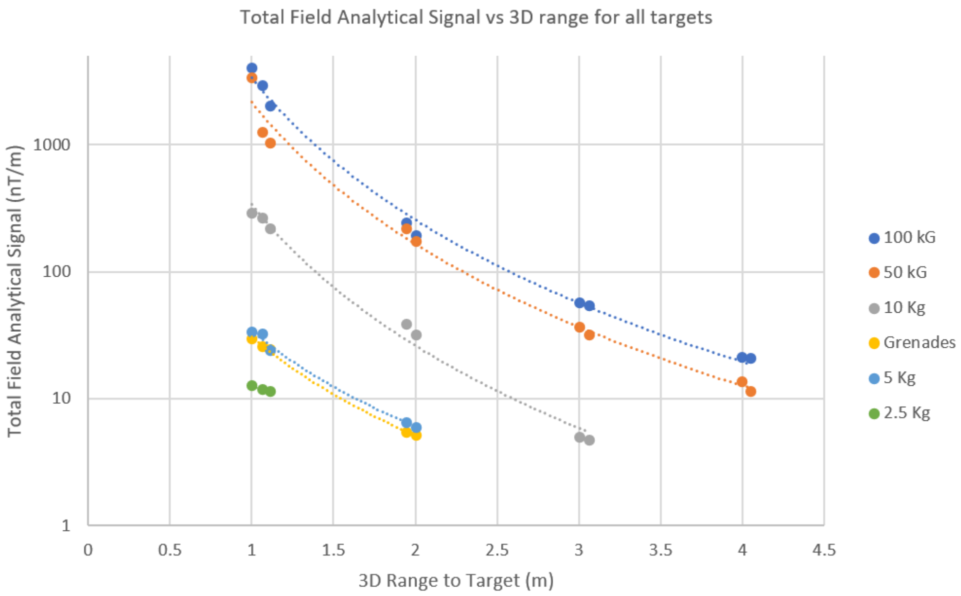

Fig. 7 Total Field Analytical Signal vs. 3D range for all targets

4. CONCLUSIONS

The study showed that using a UAV equipped with a MagDrone R4 magnetometer is an effective method for detecting surrogate UXO targets. The results indicated that the larger surrogate targets (100 kg, 50 kg, and 10 kg) were detected at all altitudes, while the smaller targets (5 kg, 2.5 kg, and grenade clusters) were only detected at lower altitudes (1 m and 2 m). The study also showed that the quality of the collected data was excellent, with minimal noise present. However, using the Total Field Analytical Signal (TFAS) to pick the targets could potentially generate false positive detections.

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