# V2Mag Depth-Range Demonstration Report

2020
Scotland - Girvan

# Amendment record

| Version | Release date | Change description | Responsible |
|---|---|---|---|
| V0.0 | 21 October 2019 | General document creation and structure setup | M.E.K. |
| V1.0 | 26 October 2019 | First official version following full review | A.D.A. & L.N.D. & M.E.K. |
| V3.0 | 13 Aug 2020 | Depth range demonstration | A.D.A., M.E.K. |

# List of abbreviations

| | |
|---|---|
| UAV | Unmanned Aerial Vehicle |
| UMag | UMag Solutions ApS |
| UXO | Unexploded Ordnance |
| sUXO | Synthetic Unexploded Ordnance |
| GNSS | Global Navigation Satellite System |

# Contents

# 1. Summary


- A Depth-range demonstration test was conducted on a beach near Girvan, Scotland (UK) to prove the sensitivity of the UAV-based V2Mag magnetic gradiometer system of UMag
- A synthetic ferrous UXO with 50kg ferrous content was tested as target
- The target was overflown in both NNW- and ENE-directions and with three different ranges between the lower sensor of the V2Mag and the target: 4.0m, 7.0m and 10.5m. All altitudes were flown both with the target in place and without the target
- A peak-to-peak system noise level less than 0.02nT was obtained throughout the test
- The 50kg ferrous target is clearly detectable at all survey levels.
- A best fit curve to the total gradient amplitude shows that the potential detection range of the V2Mag system for the 50kg ferrous target is at least 15m.


# 2. Introduction

This report documents a Depth-range demonstration test of the UAV-based V2Mag magnetic gradiometer system developed by UMag.

The test was commissioned and carried out by UMag on the beach near Girvan, Scotland (UK) (Figure 2.1) on the 15th of June 2020. The primary scope was to document the performance of the V2Mag system at different altitudes above a ferrous target resembling Unexploded Ordnance (UXO). For the EVT, a 50kg ferrous pipe was employed as the Synthetic UXO (sUXO) target.

## 2.1. The V2Mag gradiometer system

All magnetic data were collected using UMags' patented V2Mag system, which collects consistently spaced, nearly noise-free, dual magnetic field measurements along with a measured vertical gradient using two highly sensitive scalar field sensors. The two sensors are individually positioned using a high-precision GNSS and IMU system integrated within the V2Mag setup. Key measurement uncertainties of the V2Mag positioning and magnetic reading systems are listed in Table 2.1.

| | | |
|---|---|---|
| GNSS Position | Total horizontal data uncertainty (standard deviation) | $< 0.08$ m |
| GNSS Position | Total vertical data uncertainty (standard deviation) | $< 0.10$ m |
| Magnetic | Total magnetic gradient data uncertainty (magnetic noise level) | $\pm\,0.01$ nT/m |

Table 2.1: *Key measurement uncertainties.*


Figure 2.1: *Location of the test survey.*

# 3. Planning

## 3.1. Ferrous item

A roughly 75cm long pipe-shaped ferrous object of 50kg was used as target for the test Figure 3.1.

Figure 3.1: *50kg ferrous target used for the test. The rod on top is about 33cm long. Target dimensions: 75cm long with a diameter of 32cm.*

## 3.2. Location and flight window

UMag carried out the test on a beach near Girvan, Scotland (Figure 3.2) on June 15th 2020, where a reasonable weather and tidal window was identified (low wind; no rain).

Figure 3.2: *Beach area near Girvan utilized for the test. The ferrous item is faintly visible near the waterline in the centre of the image.*

### 3.3. HSE and precautions taken

Apart from UMag's' general HSSE procedures for UAV operations, additional precautions were deemed necessary. The beach near Girvan is popular publicly accessible area, frequented by members of the public, and thus requires additional precautions to ensure public safety. For the test, UMag specified a safe flight zone using high-visibility warning signs and cones, and designated a team member to interface with the public and other interested third parties on site (mainly informing about flight operations and sating curiosities).

# 4. Data acquisition

## 4.1. Survey outline

The 50kg ferrous item was placed near the edge of the water on the Girvan beach and roughly at the center of a planned survey of twelve NNW- and twelve ENE-oriented crossing survey lines (Figure 4.1). The target was oriented flat and with an azimuth of 45° (Figure 4.2).

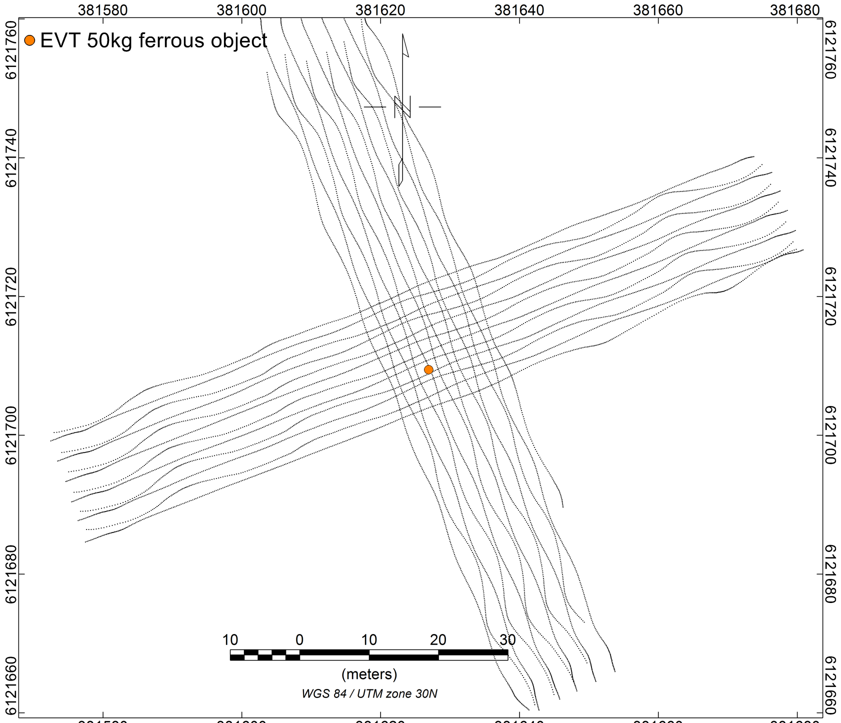


Figure 4.1: *Test survey lines with location of the 50kg ferrous object (orange marker).*

## 4.2. Survey altitudes

The test was carried out at three individual altitude levels, as measured from the top of the target item to the bottom-sensor of the V2Mag:

- Level 1 = 4.0m
- Level 2 = 7.0m
- Level 3 = 10.5m

## 4.3. Target positioning

In addition to the UAV-based magnetic survey, UMag carried out independent GNSS positioning of the item using a high-precision Ground Survey GNSS system (NORTH Surveying SmaRTK base-rover pair). The measurements were taken 45cm above the center of the item.


Figure 4.2: *Target orientation. Instrument on top of the target is a high-precision GNSS North positioning unit.*

Mean results of the independent target positioning are listed below (UTMzone 30U/WGS84 Ellipsoid Height):

- EVT item orientation by compass: 45 deg
- Center of item (measured by a 2min average of a fixed signal by CORS corrected GNSS):
  - North: 6121709.455m (StdDev: 0.0081m)
  - East: 381626.909m (StdDev: 0.0050m)
  - Elevation:55.404m (StdDev: 0.0191m)

GNSS CORS station ID: FOYL00GBR

# 5. Results

## 5.1. Noise

A peak-to-peak noise level less than 0.02 nT was generally obtained for both the upper and lower sensor readings of the V2Mag system during the test (Figure 5.1). This noise level is on par with the noise level of the V2Mag system as obtained during UMags' UAV magnetic surveys in general.

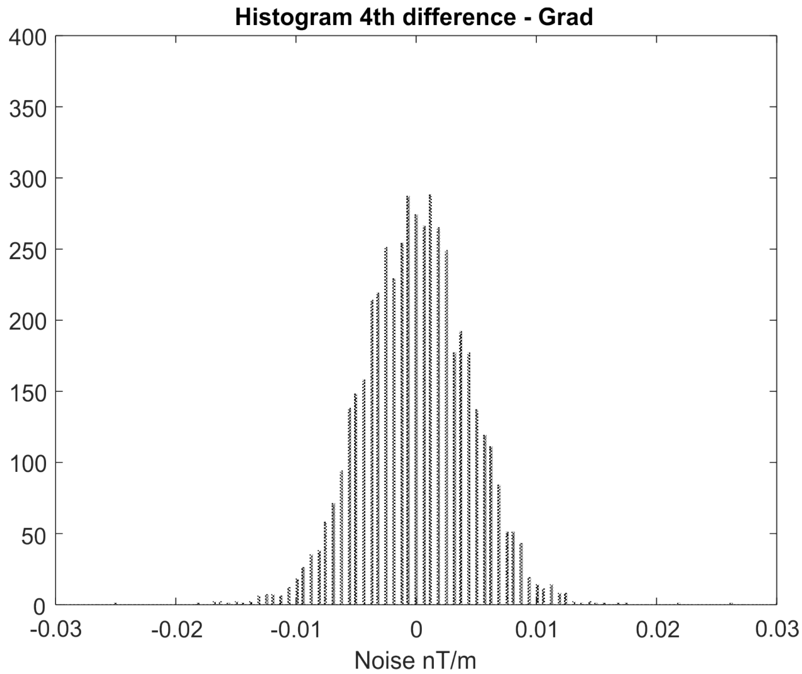


Figure 5.1: *Test survey noise as calculated from the fourth difference. This example is from Level 1 data (4m above target) in a NNW-direction. As shown, the noise level of the measured vertical gradient is less than 0.02 nT.*

## 5.2. Magnetic anomaly plots

All test survey data were processed using UMags' in-house processing software UMAG-PROC. All data are displayed using Geosoft Oasis Montaj.

The main outcomes of the test from all three levels are highlighted in Figure 5.2 and Figure 5.3.

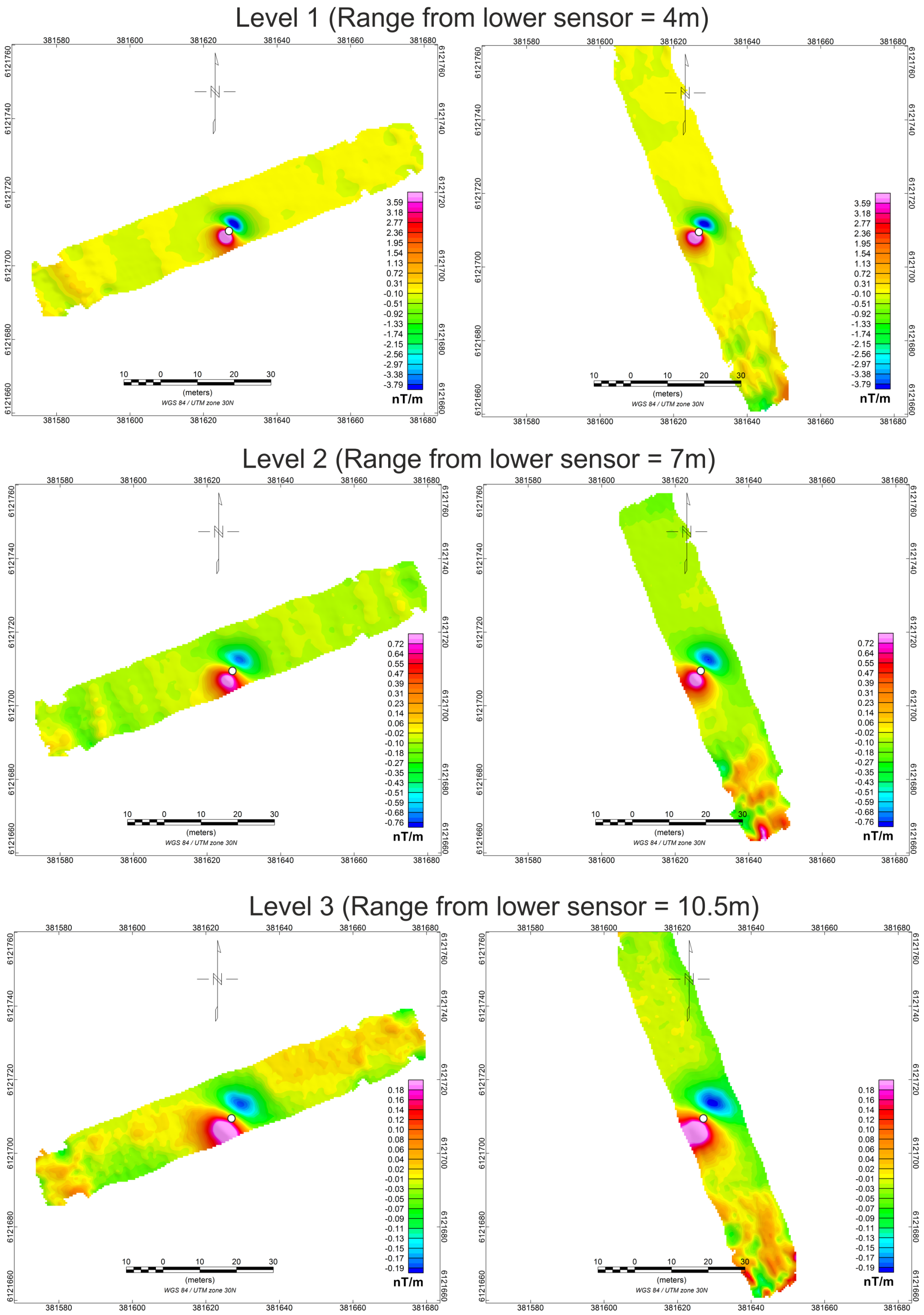


Figure 5.2: *Main results of the three test survey altitudes. For each altitude, gridded results are shown of the vertical gradient. The plots on the left and right are the ENE-oriented and NNW-oriented surveys, respectively. As shown, the 50kg ferrous target (shown as filled white circle - not to scale) is easily detected even with a 10.5m range between the lower sensor of the V2Mag and the top of the target. Position of the target in the figure is based on independent GNSS measurements (subsection 4.3).*

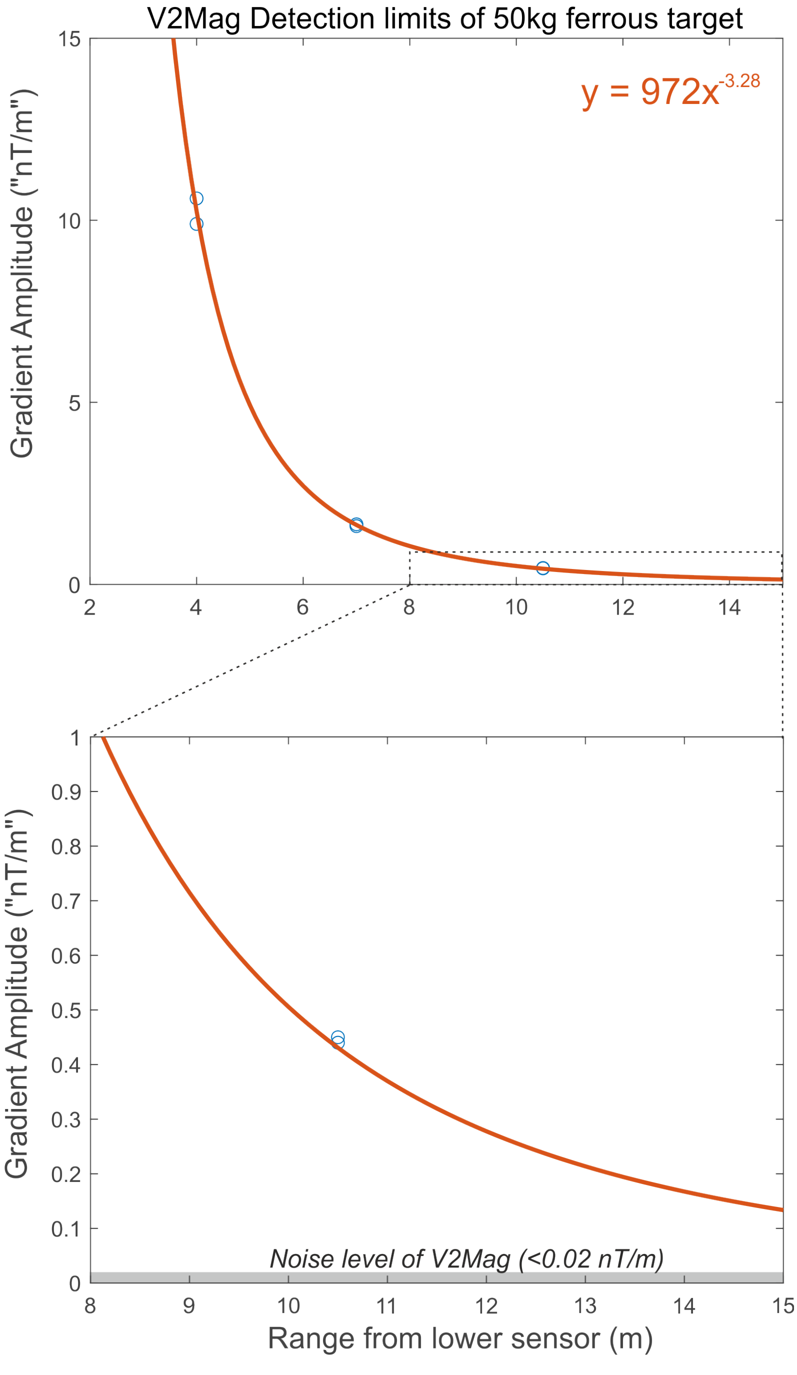


Figure 5.3: *Detection range of the V2Mag system. Based on the results in Figure 5.2, we calculated the gradient amplitude for each sensor distance and the best fit curve to the data. As shown, the detection limit of the V2Mag system for a 50kg ferrous target is >15m above the target, given the peak-to-peak noise-level of 0.02nT/m of the V2Mag system.*