

Leveraging Magnetic Drone Technology for Shallow Water UXO Detection



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+ Many other Deeper



Why Drones?

- Shallow water, intertidal areas and beach environments require magnetic UXO coverage
- These areas are difficult and time consuming to access with traditional methods
- Drone offers a safer, more efficient and consistent dataset.

Goal of the survey

- Determine if horizontal and vertical configurations can be used successfully
- Determine limitations and required calibrations for the system:
 - Detection altitude (source-sensor separation) for each configuration
 - Drone stability over water
 - Calibration and speed requirements
 - Positional accuracy

Deep Sparrow

Sensys R3 with SPH SkyHub

Triaxial fluxgate sensors

(Measure 3 vector components of the magnetic field)

200Hz

Horizontal Configuration



1.0m

Vertical Configuration



1.0m

Munitions

Marine UXO minimum threat items

250lbs MC (+/-50kg) (British)

SC 50kg (+/- 25kg) (German)

3inch rocket (60lb) (British)

3.7inch Grenade (British)



Smaller items

25pdr (British)

12cm mortar (+/- 13kg) (German)

4.5-inch Grenade (British)

10.5 cm LFH Grenade (German)

Very small items

2inch mortar Grenade (British)

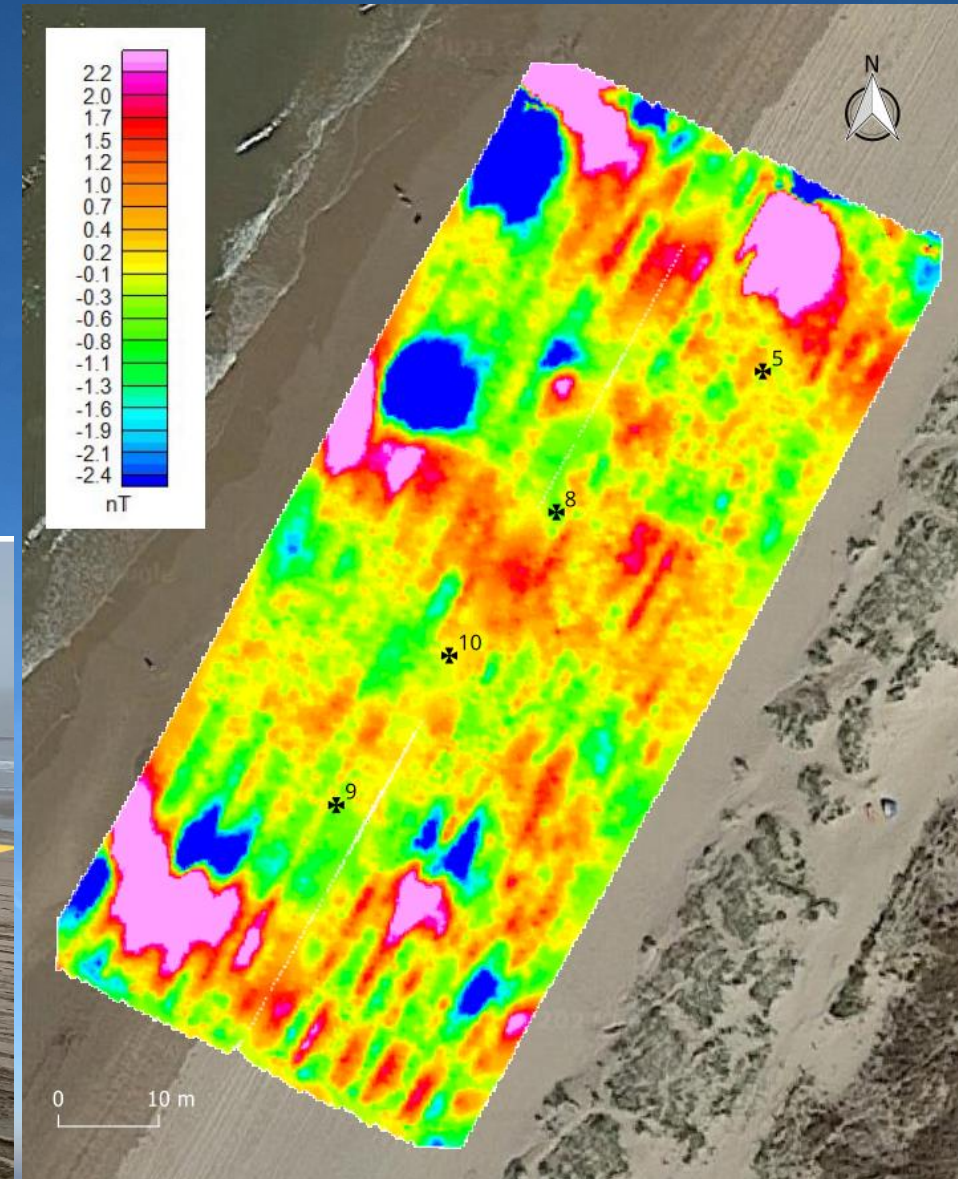
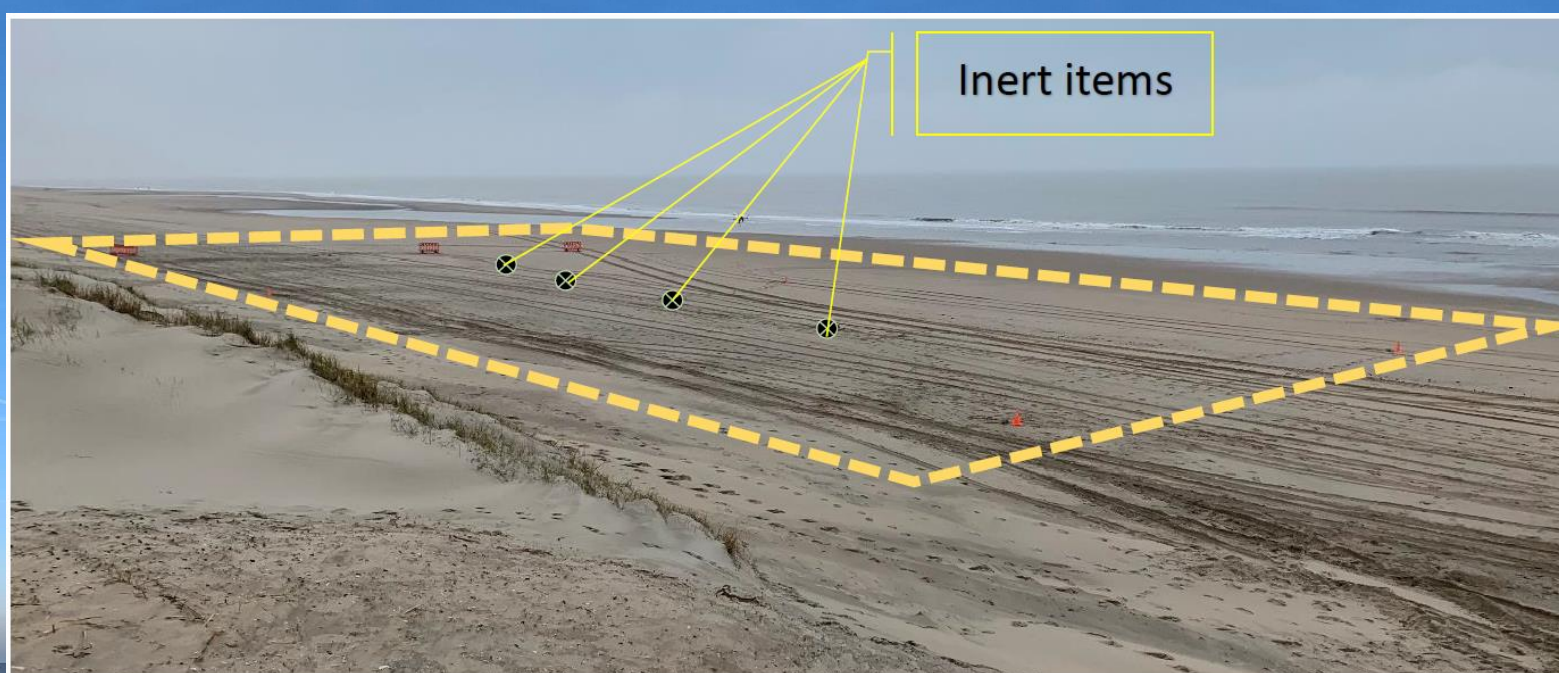
8cm mortar Grenade (German)

2 cm caliber projectile (German)

40mm Grenade (British)

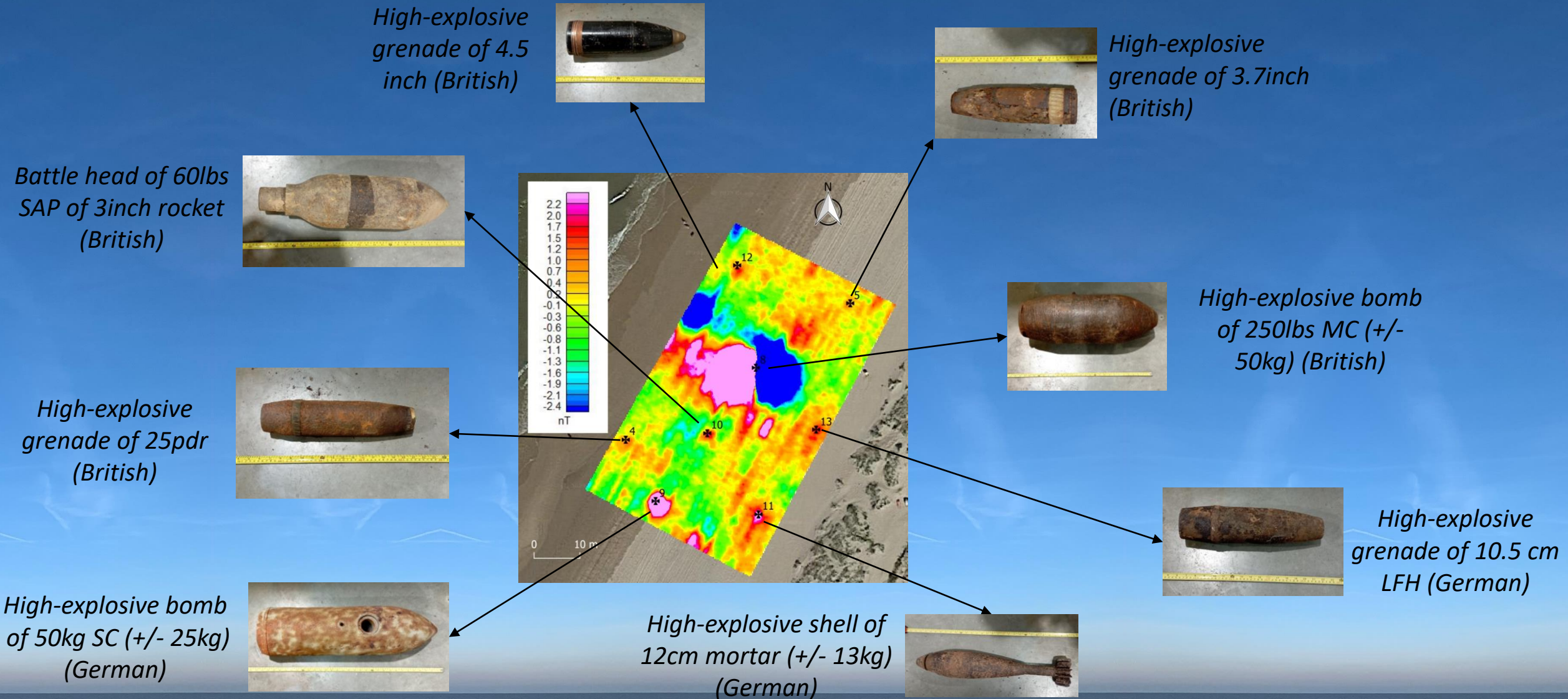
Clearance survey

- Quiet magnetic areas identified for munition placement
- Interested in the lowest response:
 - UXO laid long-axis East-West



Munition Response

Horizontal Configuration, 3m altitude



Munition Response

Vertical Configuration, 3m altitude

*High-explosive
grenade of 4.5
inch (British)*



*High-explosive
grenade of 3.7inch
(British)*



*Battle head of 60lbs
SAP of 3inch rocket
(British)*



*High-explosive
grenade of 25pdr
(British)*



*High-explosive bomb
of 250lbs MC (+/-
50kg) (British)*



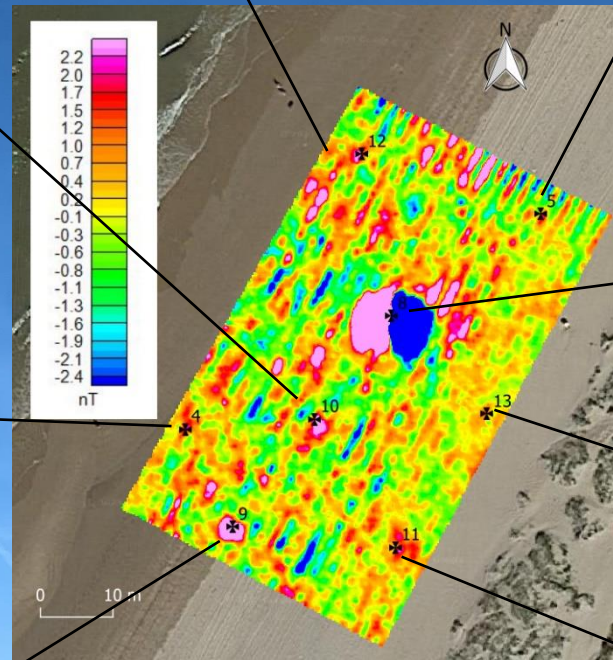
*High-explosive
grenade of 10.5 cm
LFH (German)*



*High-explosive shell of
12cm mortar (+/- 13kg)
(German)*

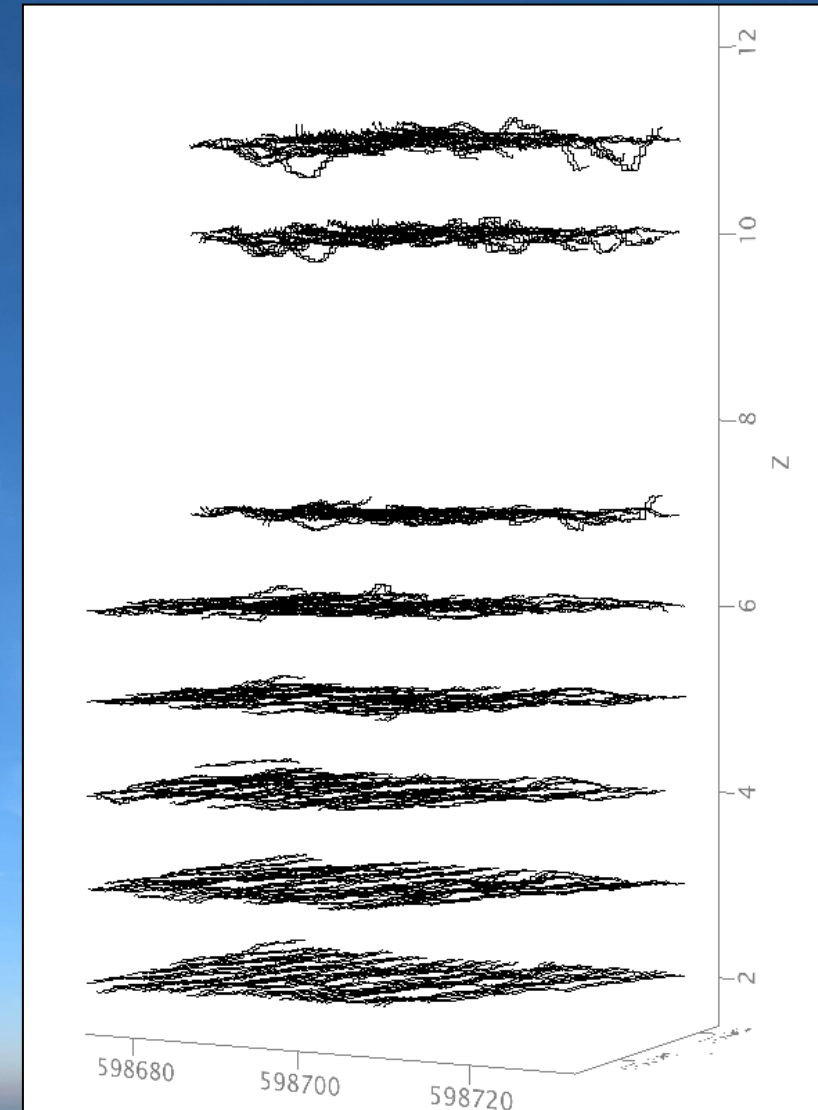


*High-explosive bomb
of 50kg SC (+/- 25kg)
(German)*



Survey altitudes and detection ranges

Item description	Max. detection range	
	Horizontal Gradient	Vertical Gradient
High-explosive bomb of 250lbs MC (+/-50kg)	11m	7m
High-explosive bomb of 50kg SC (+/-25kg) (German)	5m	4.5m
Battle head of 60lbs SAP of 3inch rocket (British)	3m	3m
High-explosive grenade of 3.7inch (British)	3m	2m



Small items

0.25m Altitude

*Grenade of
2inch mortar
(British)*



*2 cm calibre
German
aircraft gun
ammunition*



*Grenade of
40mm
(British)*

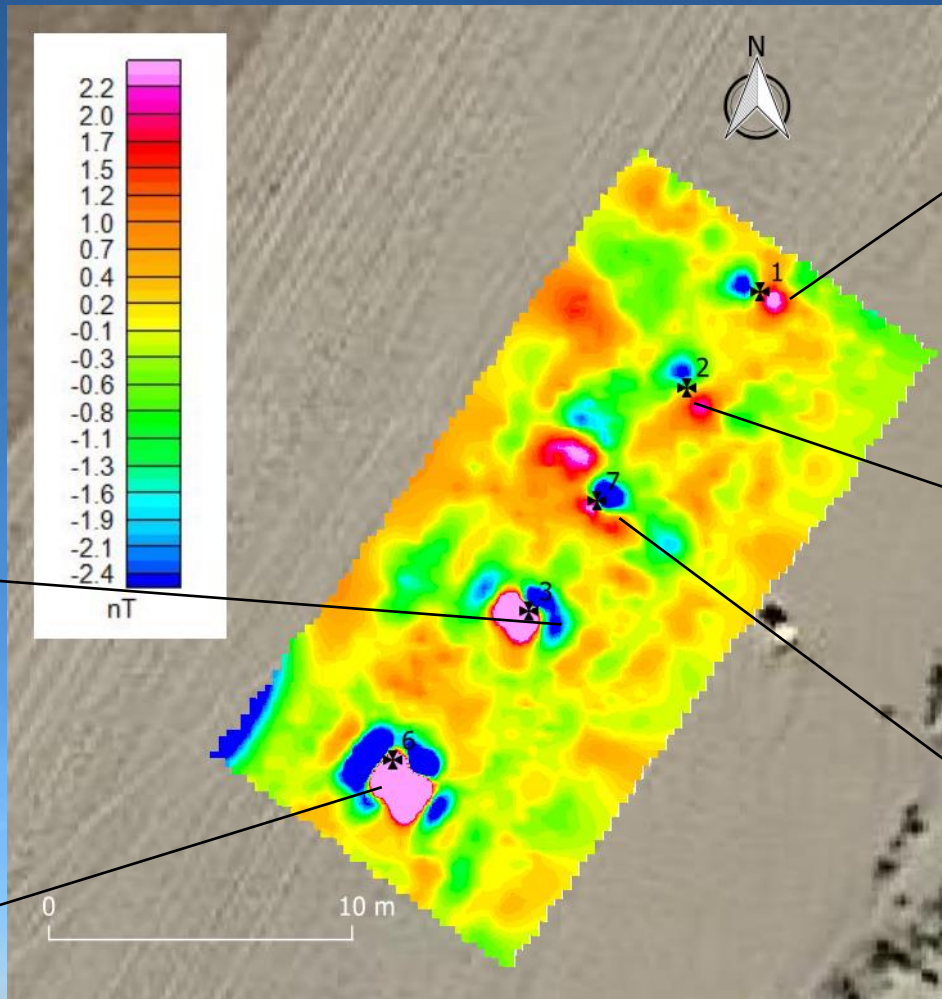


*Hand grenade No. 36
Mills (British)*



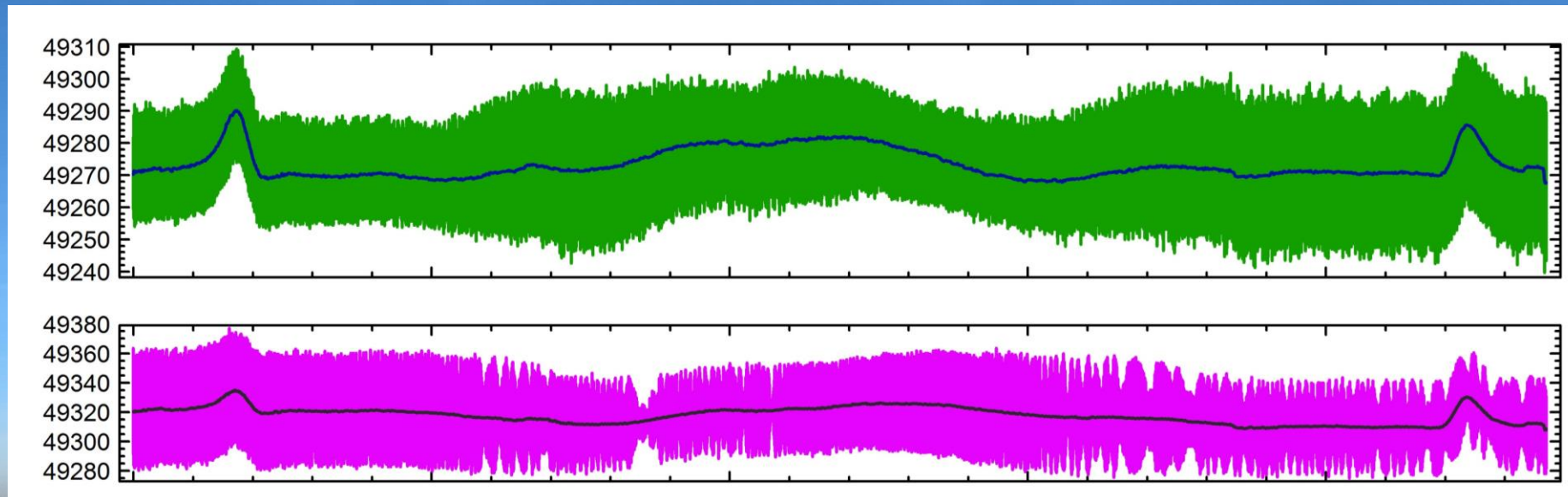
Test Altitudes
0.25m
0.50m
0.75m
1.00m
1.25m
1.50m

*Grenade of
8cm mortar
(German)*



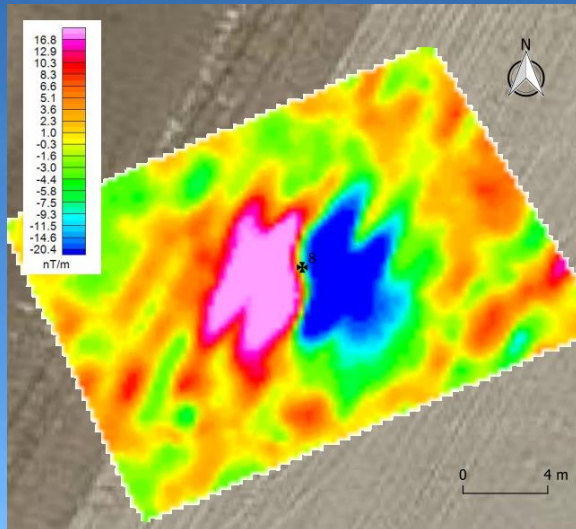
Initial data processing

- 3 vector components need to be combined into Total magnetic intensity
- Periodic noise in data up to 100nT
- Low pass filter required to extract usable signal

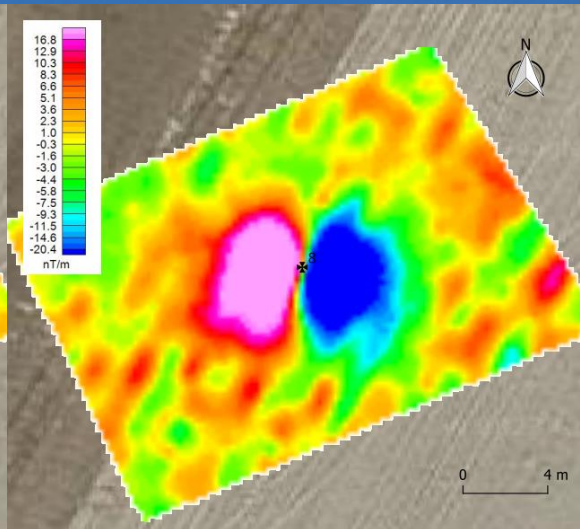


Lag test & Correction

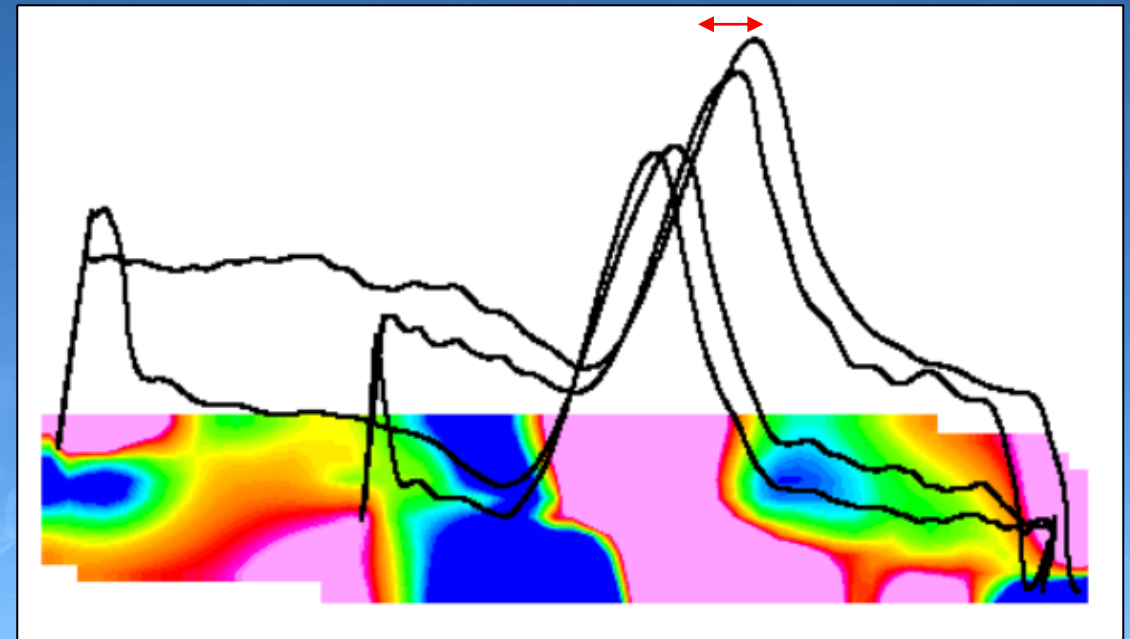
No Lag Correction

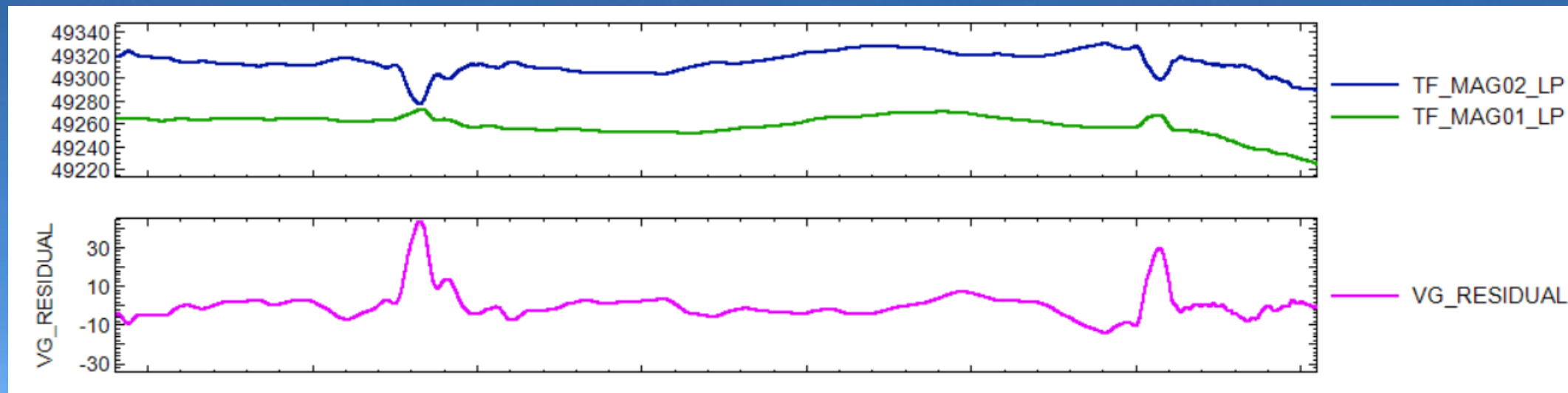


Lag Correction

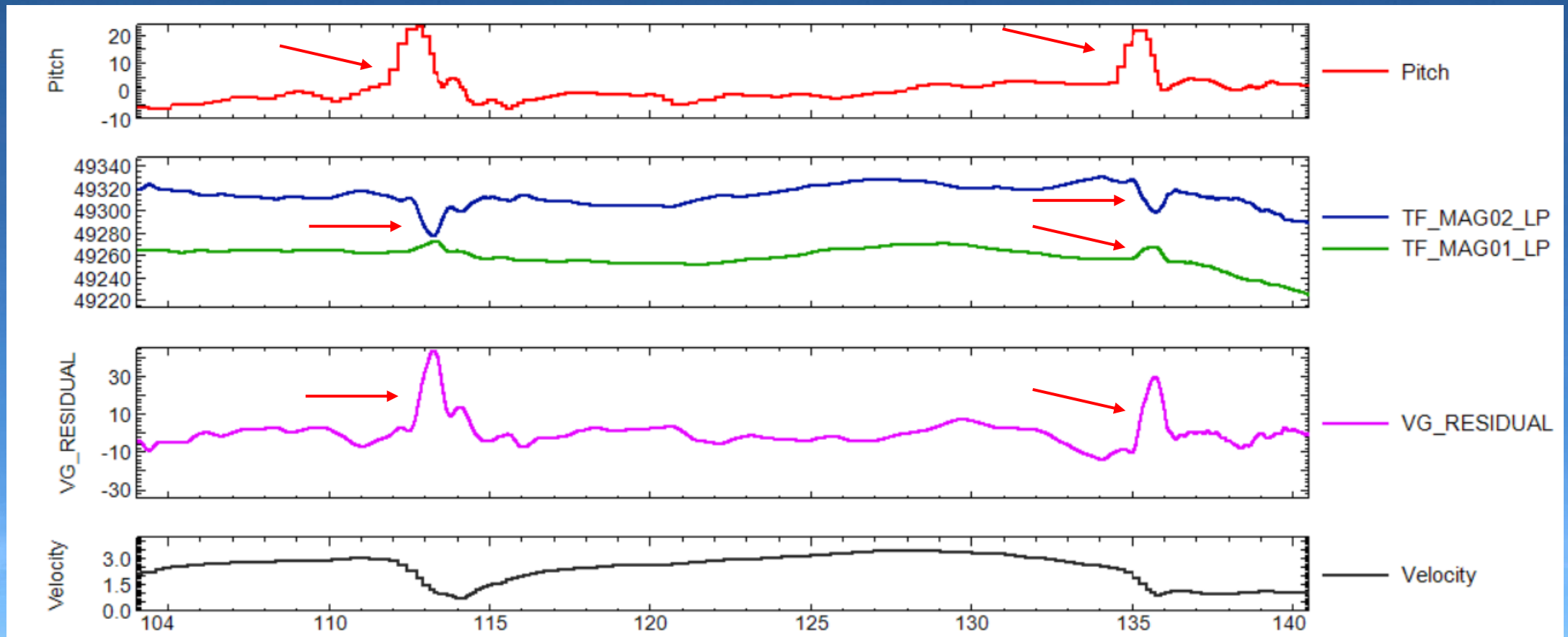


Lag test Profiles





Pitch & Speed



Positional Accuracy

ID	X [m RD]	Y [m RD]	ΔX [m]	ΔY [m]	Distance [m]
Control Point	90815.98	475859.43	-	-	-
Check February 9 th	90815.99	475859.48	-0.01	-0.05	0.05
Check February 10 th	90816.05	475859.48	-0.07	-0.05	0.09
Check February 21 st	90816.04	475859.47	-0.06	-0.04	0.07
Check February 22 nd	90816.03	475859.46	-0.05	-0.03	0.06

Flights over water

Date	Wind speed	Wind direction	Significant wave height
08-02-2023	2 Bft	SW	0.4 m
09-02-2023	3 Bft	S	0.8 m
10-02-2023	3 Bft	W	1.0 m
21-02-2023	4 Bft	W	0.9 m
22-02-2023	3 Bft	SE	0.6 m

Clearance		Over water	
Range (nT)	Std Dev (nT)	Range (nT)	Std Dev (nT)
48.9	9.8	40.4	9

Speed test

Speed [m/s]	Ground Sample Rate [m]	Standard deviation [m/s]
2	0.01	0.6 (± 0.4)
3	0.015	0.4 (± 0.2)
4	0.02	0.6 (± 0.2)
G882 at 4 knots (~2 m/s)	0.20	

Conclusion & Lessons Learned

- Both horizontal and vertical configurations were successful
- Larger marine munitions were detectable to several meters, allowing for beach and shallow water surveys
- The drone was stable while flying over water, and no additional noise was present
- Pitch and speed will affect the data, and lar
- Heading correction wasn't necessary as the background removal fixed that
- A lag line is required during each flight, which is then used as a correction during the processing
- The speed of the drone was limited by safety & stability rather than aliasing issues (Vertical needed to fly slower)