# Smart Underwater UXO Detection using AUV-based Magnetics

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## Introduction

Fig. 1: World War 2 torpedo head in German coastal waters (© J. Ulrich).

Unexploded ordnance (UXO) originating mainly from two world wars are distributed in the seas and oceans worldwide. According to estimations, around 1.6 million tons of conventional and 5,000 tons of chemical munition are expected to remain in German waters alone. Due to corrosion, the munition's explosive compounds dissolve into the seawater over the years. Besides the threat to the marine ecosystems, this legacy represents a direct threat to offshore construction work (dredging, pipeline and cable laying, windfarm constructions), maritime traffic, the fishing industry, and beach visitors.

SMART AUV-BASED MAGNETICS

## AUV-based Magnetometry

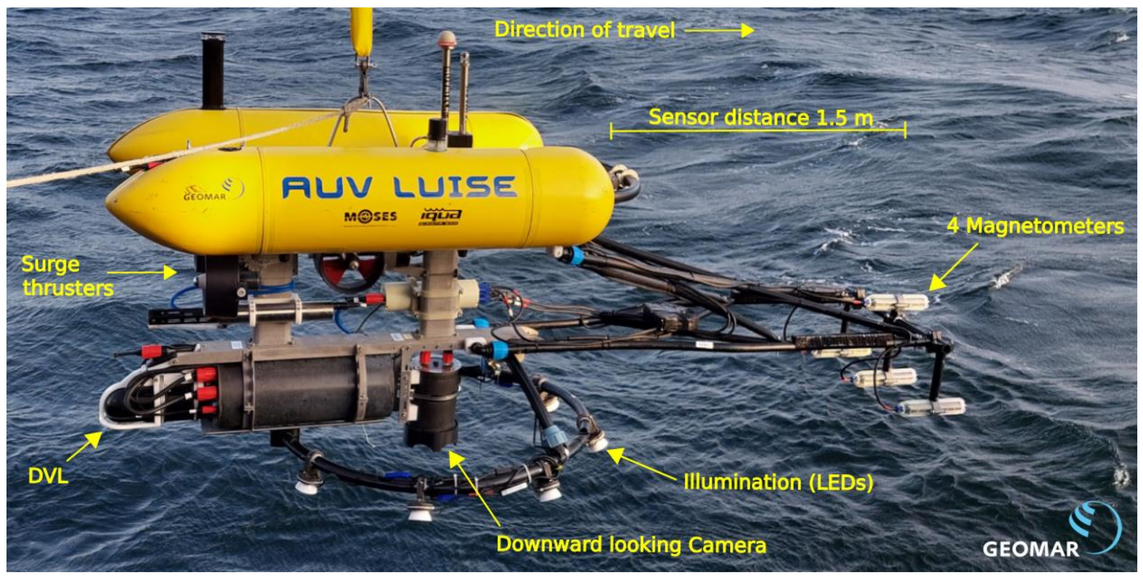


Fig. 2: GEOMAR's Girona 500 AUV "Luise" with 4 fluxgate magnetometers and a camera system.

Autonomous underwater vehicles (AUVs) can assist with the automatic detection, confirmation, and classification of offshore UXO. Our magnetic sensors are rigidly attached to the nose of a Girona 500 AUV at a distance of 1.5 m reducing the AUV-inherent magnetic noise to a satisfying degree. For ground-truthing purposes and to create seafloor photo mosaics, the AUV is equipped with a camera system including illumination.

## 2D Results

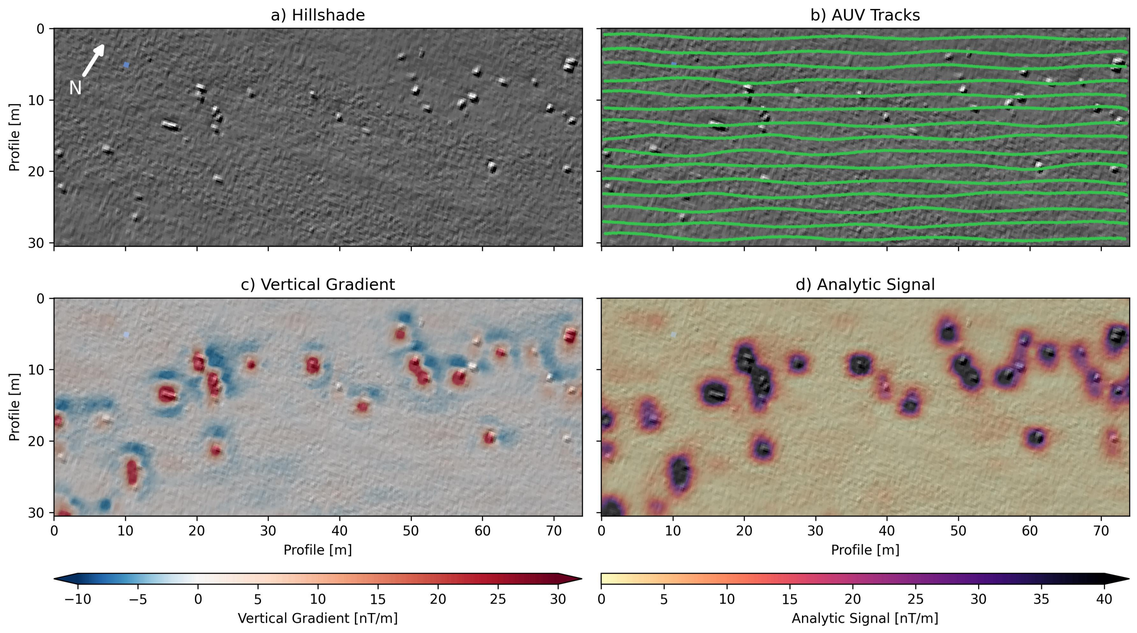


Fig. 5: Bathymetry (hillshade), AUV tracks and magnetic 2D maps of dumped munition.

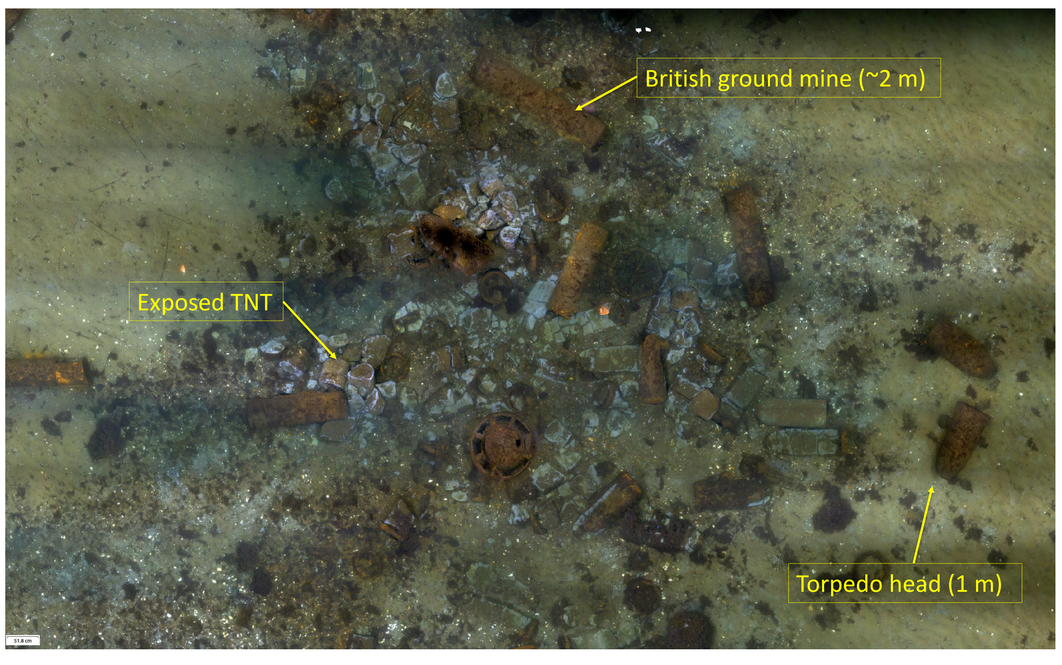


Fig. 6: Photo mosaic of a munitions hotspot at a dumping site near Kiel, Germany.

## Validation

To validate the system's capabilities and limitations, a supervised field test using surrogate objects was conducted during the 2023 UXO trials at the NATO STO CMRE (Science and Technology Organisation - Centre for Maritime Research and Experimentation)* in La Spezia, Italy. The testbed was sponsored by the US SERDP/ESTCP. In the *Calibration Area* of the testbed, 12 different types of UXO and non-UXO objects have been placed at known locations, see Fig. 4.

All objects were reliably detected except the ones made from non-magnetizable materials mostly (e.g. cement, aluminum). Fig. 3 exemplary shows the 1D raw and filtered total magnetic intensity (TMI) values of AUV measurements across a 155 mm projectile.

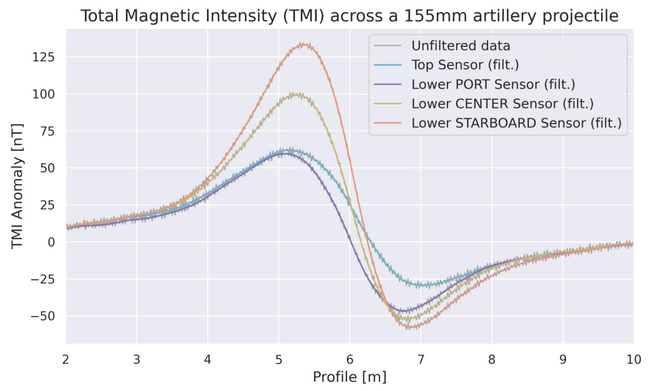


Fig. 3: TMI anomaly fields above a 155 mm artillery projectile in the Calibration Area of the La Spezia UXO test site.

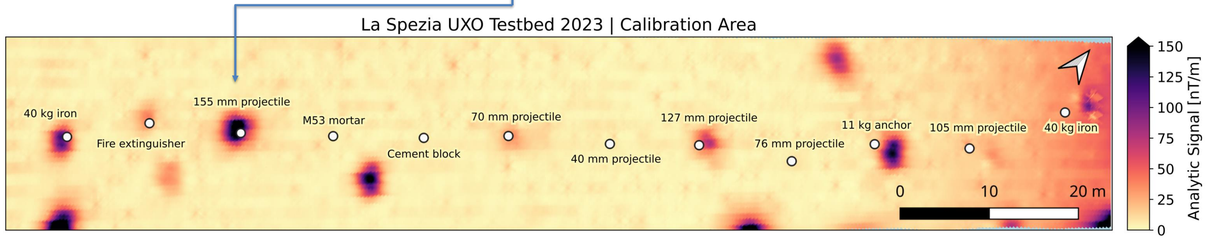


Fig. 4: 2D analytic magnetic signal of the AUV measurements inside the Calibration Area at the CMRE UXO test site (AUV altitude 1.1 m, line spacing 1 m, AUV velocity 0.4 m/s ).

## Smart AUV Mission Design

After a coarse AUV magnetic reconnaissance survey, potential UXO targets are investigated in greater detail by the AUV. To decrease total AUV mission time to a minimum, it is beneficial to cluster adjacent targets that are aligned with the water current direction since it affects the AUV navigation precision and magnetic data quality. The calculation of the clusters is based on the distances between the targets in combination with the water current direction. For the resulting clusters, a traveling salesman problem is solved to obtain the shortest way along all cluster centers. Finally, the optimal start and end point of each cluster is calculated by comparing the AUV path length of all possible combinations.

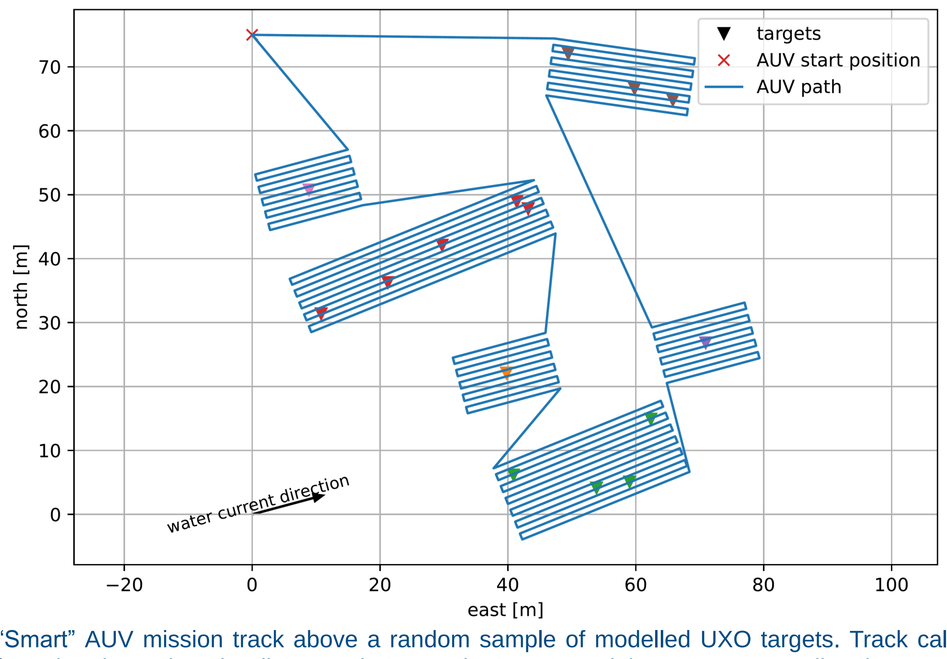


Fig. 7: "Smart" AUV mission track above a random sample of modelled UXO targets. Track calculation and target clustering depend on the distances between the targets and the water current direction.

QR code links to a publication containing technical descriptions of the system.

For more information please visit:
www.geomar.de/deepsea-monitoring

Event: 2023 SERDP/ESTCP/OE-I Symposium
Crystal Gateway Marriott in Arlington, Virginia
from Nov 28 to Dec 1, 2023.
Poster Number: 180
Presentation Date: 11/28/2023

* For further information regarding the CMRE test site see:
Poster Number: 1
Title: "CMRE UXO test site implementation, demonstration and maintenance"
Presentation Date: 11/29/2023

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