Recent developments in marine geophysical methods for UXO detection

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• Overview – UXO survey in marine environment
• Case Study 1 – Optimisation of magnetometer survey
• Case Study 2 – Gradiometer Survey
• Case Study 3 – LMB mine detection
• Recent Developments
• Summary
Management of UXO risk in the marine environment

- **UXO threat assessment**: Identifying the potential for UXO to be present on the shoreline or seabed from a range of potential threat sources.

- **UXO risk assessment**: Assessing risk using the widely accepted concepts of ‘likelihood’ of an event occurring and ‘consequences’ of that event occurring and considering the sources of a risk, the receptor to that risk and the pathways through which a risk can become manifest.

- **UXO risk management**: Assessing the risk management approaches of avoiding or mitigating the risk to tolerable levels and then sharing, transferring or tolerating the residual risk.

- **UXO risk mitigation**: Investigating identified UXO and rendering it safe, in situations where it is not practicable to avoid the risk.

*Geophysical Survey: Identify anomalies that might be associated with UXO*

*CIRIA PGS Report 05, Assessment and management of unexploded ordnance (UXO) risk in the marine environment, December 2014*
Elements to consider when designing a marine UXO survey:

- Type of UXO that you might encountered (size, material etc)
- Local marine environment (water depth, currents, distance from the shore etc)
- UXO risk strategy
- Schedule / Budget

Survey design options:

- Platform:
  - Towed Equipment
  - ROV/AUV
- Sensors:
  - Sonar / MBES
  - Magnetic
  - Seismic
  - Electromagnetic/Pulse Induction
Conventional UXO survey

- Conventional Method: Independently towed magnetometers and sidescan sonar and MBES

Magnetometer:
- Caesium vapour
- Sample rate ≥ 10 Hz
- Altimeter and depth sensor
- Sensitivity up to 0.02nT/m
- Cable length – 3x vessel length

Sidescan Sonar:
- Dual Channel
- High Frequency ≥ 600 kHz
- Data resolution ≥ 0.3m
- 200% coverage

MBES:
- High Frequency ≥ 400 kHz
- Ping Rate ≥ 30 Hz
- Data density of 0.5m

USBL Positioning
- Positioning Accuracy +/- 2m
Conventional UXO survey

Pros:

• Towed system
• Relatively cheap day rate
• Reliability of the sensors

Cons:

• Infill Requirement
• Positioning accuracy / Vertical Control
• How to discriminate UXO targets from local geology / background noise
• Limitation on the size of the object that can be detected and its depth of burial

Case Study 1 – Optimisation of UXO survey by using 2 EIVA scanfish ROTV

Data Example – Magnetic Data – Analytical signal Residual Grid
Case Study 1 - Optimisation of conventional UXO survey

Fugro Survey BV recently worked on a OWF project deploying the EIVA scanfish simultaneously.

4 Magnetometers were independently towed from each scanfish reducing the requirement for infill to almost 0%

Distance between the 2 arrays = 3.5m

Dual EIVA Scanfish deployment on the Fugro Pioneer (Fugro Survey BV)
50 x 50 m survey areas
- Very few infills needed in comparison to surveys without EIVA wings
- Flying altitude control very good – no reruns for altitude
- High resolution magnetic data
- Tried and tested work flows
**Conventional UXO survey**

**Pros:**

- Towed system
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**Case Study 2 – Gradiometer Survey**

**Case Study 3 – LMB detection**
In 2014, Fugro EMU was contracted to do a UXO survey in the NW coast of England. Array of independently-towed magnetometers was initially used to survey around turbine locations.
Case Study 2 – Gradiometer Survey

- Vertical gradiometers utilised to remove noise from vertical structures – Monopiles, Platforms etc.
Case Study 2 – Gradiometer Survey

4 independently towed magnetometers

Vertical gradiometer array
LMB Luftmine type Bravo (Germany)

During WWII the German Navy fabricated mines from aluminium and other non-ferrous materials. Originally designed as a magnetically triggered sea mine, two of the (German) designations were Luftmine A (LMA) and Luftmine B (LMB), which were 305 kg and 515 kg HE masses and were 2 m and 2.9 m long, respectively.

The detonator of the LMB mine was made of ferrous materials with a mass of approximately 25 kg

LMB mines are present in along the French and German coasts and some on the UK waters.

In January 2015, Fugro EMU conducted sea trials on a confirmed German LMB mine to test the ability of magnetometers (caesium vapor) to detect it.
Case Study 3 - Detection of German LMB mine

Mag 1 and Mag 2 setup on a frame. Magnetometers were 1m apart.

- Small distance between sensors required
- Sensors need to be near the seabed - controlled altitude required

- How to reduce number of contacts detected?
Summary of the Case Studies

What have we learned from each case study:

• **Case Study 1** – Optimisation of magnetic survey by using a ROTV

• **Case Study 2** – Noise can be removed by using the gradiometer configuration (as opposed to single axis magnetometer)

• **Case Study 3** – To detect object with a low ferrous content, the following is required:
  - Small sensors spacing
  - Controlled Altitude
  - Reduction of ambient noise

  Gradiometer alone might not be enough to mitigate potential high number false-positives in contact list
Fugro EMU GeoWing has been designed to detect objects with small ferrous content (such as the LMB mine) and buried items.

The system is easy to deploy and recover and can survey at a speed up to 6kn.

Can operate with 5x G882 mags with a 1.25m spacing between sensor.

Data are processed as total field gradient.
Multibeam Seismic system for buried object detection

sub bottom profiler (0.4 to 8kHz) for shallow water combining super wide band Chirp technology with Synthetic Aperture Sonar and seismic inversion processing.

11 beams with a angle of 10° can be collected simultaneously

<table>
<thead>
<tr>
<th>Vertical resolution</th>
<th>Transversal resolution</th>
<th>Max. longitudinal resolution</th>
<th>Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 cm (full frequency range)</td>
<td>0.26 x target depth (central beam)</td>
<td>50 cm (after SAS processing)</td>
<td>15 m (sand, full frequency range)</td>
</tr>
</tbody>
</table>

3D SeaChirp (Soascy)

Data example show the LMB on 2 different profiles.
Fugro SubSea Services have primarily used a couple of methods for hunting for UXOs.

EM - Teledyne TSS440
Magnetometer - Innovatum SmartSearch

- Ease of use
- Standard equipment on FSSLTD vessel

- Hard to interpret small target close or large target far away
- Narrow Swath limited to 3m approximately
- Limited penetration of approximately 1.5-2m depending on soil conditions
<table>
<thead>
<tr>
<th>Platform</th>
<th>Buried LMB Detection</th>
<th>DoB</th>
<th>Line Spacing</th>
<th>Costs Implication</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetometer (independently towed)</td>
<td>Vessel</td>
<td>Dependant on ferrous content</td>
<td>Large line spacing (e.g..15m)</td>
<td>Green</td>
<td>Green</td>
</tr>
<tr>
<td>GeoWing (gradiometer frame)</td>
<td>Vessel</td>
<td>Dependant on ferrous content</td>
<td>Reduced line spacing (e.g. 5m)</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td>SSS / MBES</td>
<td>Vessel</td>
<td>Only object on the seabed</td>
<td>Will vary with depth (e.g. 6x WD)</td>
<td>Green</td>
<td>Green</td>
</tr>
<tr>
<td>Multibeam Chirp</td>
<td>Vessel</td>
<td>Down to 5m</td>
<td>Depending on the swath of the system (e.g. 15m)</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td>EM / PI</td>
<td>ROV</td>
<td>Dependant on metallic content</td>
<td>Depending on the swath of the system (e.g. 4m)</td>
<td>Red</td>
<td>Red</td>
</tr>
</tbody>
</table>

For LMB detection, a multi sensor approach (GeoWing + chirp) would mitigate the number of false-positive and provide an affordable solution for UXO survey on a large scale.
Thank You