European Maritime and Fisheries Fund

PROPOSAL (PART B)

BASTA

Boost **A**pplied munition detection through **S**mart data inTegration and **A**I workflows

Blue Economy call

EMFF-BlueEconomy-2018[1]

[1] Call ID in 2018 EMFF Work Programme: EMFF-2018-1.2.1.7

CONTENTS

1. CONTEXT & NEEDS ANALYSIS

The problem of munition in the sea

After World War I and II, large quantities of chemical and conventional munitions were dumped in the seas and oceans worldwide (Figure 1). In 2010, the OSPAR's Quality Status Report listed 148 dumpsites in the North-East Atlantic Ocean and North Sea alone (Figure 2). On average, the reported encounters of munitions (not restricted to dumpsites) in these areas amount to approximately 900 each year. As such, these dumped munitions constitute a serious safety risk for users of our coasts and seas, ranging from commercial interests (e.g. dredging, pipeline and cable laying, windfarm construction) to safety issues in harbors and shipping routes to concerns of the tourisms economy and the public. In addition, there are growing environmental concerns, especially for sites which also contain chemical munitions.

Munition detection and removal operations are conducted in various judicial areas, some of which are only weakly regulated. While national law regulates labor, that is performed in the territorial waters, in a fashion similar to labor on land, the adjacent EEZ is subject to less regulation, as determined in the United Nations Convention of the Law of the Sea (United Nations 1994). In the case of Germany, labor law is valid in the exclusive economic zone (EEZ) (Bundesministerium der Justiz und für Verbraucherschutz 1996), explosives law however, is not (Bundesministerium der Justiz und für Verbraucherschutz 2002). This weak regulatory regime becomes especially noteworthy, when, as in Germany, the majority of offshore wind parks are erected in the EEZ (Federal Ministry for Economic Affairs and Energy (BMWi), 2015). Accordingly, there is limited leverage for enforcing high quality data acquisition. Coupled with the absence of an industry wide standard for data acquisition and handling, this has resulted in high diversity and heterogeneity in both workflows and data quality.

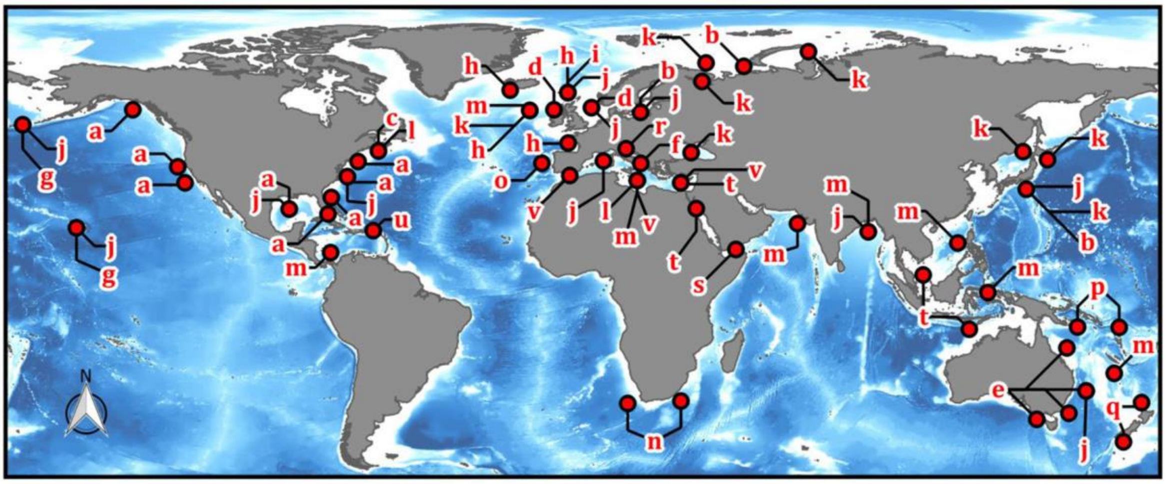

Figure 1: Global distribution of documented marine sites with munitions present. Letters refer to literature references as given in Beck et al. (2018). Note, that OSPAR report by Nixon (2009) (letter h) contains 148 individual munition dump sites (Image from Beck et al., 2018)

Munitions treatment is covered in a number of normative or other guiding documents. The most extensive document is the Quality Guideline for Offshore UXO treatment (Frey[2] & Holländer 2019), which is an output of the research project OffVali (Leipzig University). Another relevant document is an account on assessing and managing munitions risk, published by British construction industry and research association CIRIA. It focuses on the assessment of probabilities and consequences of munitions encounter and proposes management options (Cooper & Cooke 2015). A technical work aid (*Arbeitshilfen Kampfmittelräumung*) available in German, details the procedure of munitions treatment onshore. Notwithstanding its limited transferability to the offshore domain, it has been utilized during offshore munitions campaigns in the past (*Arbeitskreis Arbeitshilfen Kampfmittelräumung* (AK AH KMR) 2014). Other aspects, relevant to offshore munitions clearance, such as hydrographic measurements and piloting of remotely operated underwater vehicles (ROV) have been addressed in other documents published by certification organizations and international governmental organizations (e.g. International Hydrographic Organization 2005; International Marine Contractors Association 2016). However, there is a lack of a best-practice workflow and of detailed quality requirement definitions for the acquisition and handling of data during munition detection. The development of these most fundamental tools for the use of sensors with the purpose of detecting munitions becomes essential, as the inevitable future application of multi-sensor approaches exponentially increases complexity. In the past decade, European research projects such as DAIMON (Decision Aid for Marine Munitions), UDEMM (Environmental monitoring for the extraction/delaboration of munitions on the seabed), CHEMSEA (Chemical Munitions Search and Assessment), MERCW (Modelling of Environmental Risks related to sea-dumped Chemical Weapons), etc. have put the topic of offshore munitions dumpsites on the political agenda, especially for the Baltic Sea area.

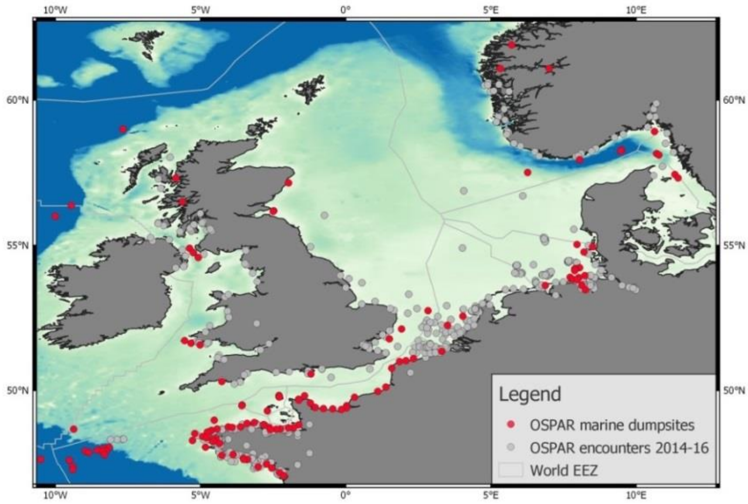

Figure 2: OSPAR area with reported marine munition dump sites and munition encounters between 2014 and 2016 (OSPAR webpage).

More recently, 'Munitions in the Sea' was launched as a joint action in the context of the Joint Programming Initiative 'Healthy and Productive Seas and Oceans' (JPI Oceans), highlighting the need to assess risks, define priorities and develop intervention options with regard to munitions in the

[2] Torsten Frey will be employed at GEOMAR for the *BASTA* project.

marine environment. One of the major knowledge and technological gaps identified concerns the efficient identification (accurate, quick, cheap) of buried and exposed munition within an ever growing set of available data. The research carried out so far has shown that for surface investigation (i.e. exposed objects; Figure 3) several good sensing technologies exist but the different data are seldom fully integrated into a consistent framework reaching from data acquisition via data processing and analyses until the final evaluation.

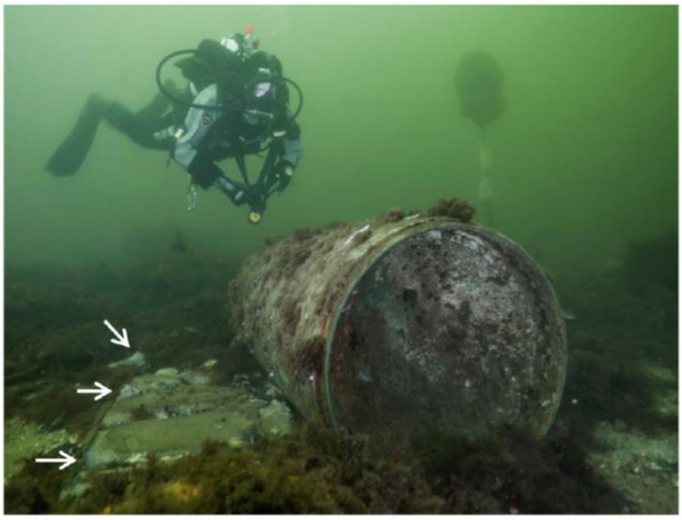

Figure 3: German mine (most likely a BM 1000 parachute mine, Wichert, 2018) on the seafloor in the Baltic Sea, weighing approximately 500 kg, with scientific diver for scale. The small grey objects in the sand near the ground mine (arrows) are likely intact, exposed pieces of explosives remaining after low-order detonation of other mines in the area (Photo: J. Ulrich). Image and figure capture from Beck et al., 2018.

For subsurface investigation (i.e. buried objects) available technologies are not sufficient with regard to spatial (x,y,z) resolution. For both types of munition, the interpretation of the data with respect to recognition of the objects is still not automated and accurate for large areas that need to be surveyed. Analytical methods/algorithms therefore need to be improved using Artificial Intelligence fed by different layers of information. The goal of the proposal is to develop a model that predicts the (buried and surface) munition. Such a model is a crucial step towards any sound risk analysis.

Brief State of the Art in munition reconnaissance

Conventional (large-scale) munition reconnaissance/mapping is time consuming and therefore a costly operation. There is no stringent industry wide standard for data acquisition and data handling, and this has resulted in high diversity and heterogeneity in process chains. A habitual approach includes independent ship-towed vertical magnetic gradiometer, multibeam echosounder system (MBES) and side scan sonar surveys. MBES and side scan surveys are broadly used for many different applications and are not really munition specific, thus they are not described in detail here. Both techniques and their respective data, however, will be part of the data sets compiled, used and generated during the project. More specific for munition detection is the use of magnetometers that can specify, to a certain extent and accuracy, if an object is made of metal (potential munition body) or not. Until recently the magnetic equipment involved a small array (2 vertical gradiometers) which has the advantage that it is a relatively cheap (day rate) and robust system, but a large number of lines are needed and gaps between lines need to be filled in. In more recent years, wider arrays (4-6 or more vertical gradiometers) are used. The advantage is that this allows less lines to be sailed (almost no gaps) and the detection of smaller or less ferruginous objects (depending on the sensor spacing). The disadvantage is that these are expensive systems and often less robust, and although the depth information is to some extent improved there is still a high degree of uncertainty. This inaccurate depth information makes recovery more time consuming, and deeper objects (> 1-2 m) may still go undetected. In some cases, AUV-towed magnetometers are used but this does not allow precise work (and is still time consuming due to the large number of lines needed) and the burial depth information is largely insufficient.

Notwithstanding the latest technical improvements, applying the above mentioned technologies remains very costly and the main problem still remains: how to discriminate between munition and other objects (natural or anthropogenic), and how to decrease the number of so-called 'false-positives'. For **exposed munition** high-quality multibeam and side scan (and sometimes optical) data complement the magnetic/gradiometric data set. For **buried munition** the multibeam, side scan and optical data are of no use. Object identification in this case usually depends on magnetic data, increasingly complemented by ship-based conventional acoustic sub-bottom profiling (SBP). If the object is large enough, SBP systems are able to provide more accurate depth information (though small mines will often be missed), but only in a 2D vertical plane directly below the towed system and buried objects outside of this plane will go undetected. Moreover, these data do not allow reliable information regarding the size or orientation of the objects which is important for clearance operations.

To a large extent the above listed survey methods are used as **separate data sets** and **analysed individually** on a survey to survey/contract to contract base. Sub-contracted survey companies certainly acquire substantial sets of data through time, but data exchange between different sub-contractors or even using data from previous clients for a new, integrative analysis is often not possible/paid for, or is legally not wanted. To this day, final 'classification' of an object still depends for a large part on subjective interpretation (i.e. human expert) which highly affects the repeatability and does not allow for a standardised and thus measurable uncertainty of the prediction. Furthermore, the constant technological advancements of acoustic, optical or magnetic sensors create an ever **faster growing amount of data** which humans cannot interpret and oversee in a truly integrated way. To clearly illustrate in detail the current workflow of state-of-the-art workflow for a UXO detection/removal campaign we list below the different steps (the typical approach of G-tec,):

1) Desk study of historical data regarding deployment and dumping of explosives and munitions
2) Geophysical UXO detection:
- Ship based multibeam survey for accurate seabed mapping
- Side scan sonar survey for seabed characterization and detection and identification of objects lying on the seafloor
- 2D SBP for detection of buried objects
- Magnetometry campaign, using ship towed magnetometers deployed in (multi-) vertical gradiometer setup for detection of metal objects on and below the seafloor

3) Data processing:
- All types of geophysical data are processed individually but resulting maps are jointly visualized and compared in order to evaluate the presence and risks of objects in the project area.
- The results of the geophysical campaigns are being assessed by qualified EOD experts who will advise on the targets to be identified and removed.

4) UXO identification campaign

- Identified targets are approached using ship-based ROV's, equipped with visualization methods to identify the visible objects.
- Sediment removal: in case the objects are buried under sediments, the sediment is being removed using various tools to bring the target on top
- Identification: EOD divers manually identify object as being non UXO or (possible) UXO and recommend possible removal strategies

5) Removal campaign:

- Non-UXO targets are being removed using grab or other methods
- UXO targets are being dismantled under the lead of EOD experts or by military instances (depending on national legislation)

Needs Analyses and *BASTA*s solutions

Based on many years of studying munition in the sea, their safety risks and potential environmental threats, and through close cooperation with the industry and governmental bodies, we can distinguish and define a number of **needs to improve accuracy and cost efficiency** of munition reconnaissance (see table below). One important task to advance accuracy and cost effectiveness will be to deal with **Big Data** and use computational means to learn from existing data. The trend of an ever faster growing amount of data during munition mapping will continue and is already part of the general Big Data problematic. Single data sets alone are already 'big' and analysing several different layers is very time consuming (magnetic, multibeam, SBP, sidescan, multibeam backscatter and various properties of these datasets). Because of this, data are often analysed separately and the final 'classification' of an object often still depends on subjective (i.e. human) interpretation which highly affects repeatability. The following table summarises the needs regarding the above mentioned issues and how the partners of *BASTA* aim to tackling them.

Weaknesses/insufficiencies	Needs	Solutions
A) Time consuming magnetic surveys , no automation applied so far	Additional means for highly detailed magnetic surveys, need for speeding up the detection process; improving both cost effectiveness and safety of these campaigns at sea	Integration of magnetic gradiometer on hover AUV; implementation of adaptive mapping self-learning routines on AUV
B) Inaccurate depth information of buried munition	Better depth information through new approach in 3D SBP surveying, need for speeding up the detection process; Improving both cost effectiveness and safety of these campaigns at sea	Apply and advance ultra-high resolution 3D SBP data acquisition and data processing
C) Difficulties in integrating multi-sensor data for joined data presentation and analyses	Means for munition-specific multi-sensor Data digest, visualisation and analyses; need for a data base that holds 'all' available WWI/II data, combined with publicly available seabed data	Setup demonstrator of multi-sensor data base based on www.amucad.org

D) Subjective analyses without quality factors/uncertainty levels	Objective and repeatable means needed to evaluate data	Integrate quality criteria into the entire workflow starting from sensor selection to final evaluation and recommendation.
E) Missing application of computational analyses in existing workflows	Investigation of applicability of AI methods for munition detection in multi-parameter data sets	A set of AI methods/machine learning will be tested and workflows established to be used offline and in real-time during surveys and AUV-operations
F) No standardised requirements and workflow for munition reconnaissance	Promote and work towards an accepted document of requirement by indicating a potential approach	Establishing a public and standardised workflow using data base capacities and objective means for data interpretation -> C), D) and E).

2. OBJECTIVES, APPROACH & IMPACT

2.1 Objectives

The *BASTA* proposal aims at advancing the conventional approach for (large-scale and local) munition reconnaissance. Typical approaches (see section 2 for more details) are time consuming and therefore a costly operation and to a large extent they are not objective with uncertainties hardly measured and given, partly due to the lack of a stringent industry standard for data acquisition/handling resulting in high heterogeneity in process chains and data workflows (pre-processing, final evaluation of results). To advance the above sketched common approach we have three overarching objectives which will **Boost the Applied munition detection through Smart data inTegration and AI workflows (*BASTA*)**.

Objective 1: Advancing data acquisition through ultra-high-resolution 3D-SBP and intelligent AUV-based magnetic mapping as part of an adaptive and iterative survey approach (WP2 & 3 & 4)

In order to provide accurate information about the depth and shape of munition buried below the seabed, ultra-high-resolution 3D acoustic sub-bottom imaging will be applied. To make data acquisition more cost efficient, intelligent AUV-based magnetic mapping will be developed based on self-learning AUV's and near real time monitoring of data quality. This will be complemented with state-of-the-art multibeam, sonar camera and optical surveys. Use of different sensors in the same area simultaneously is a key factor. The new techniques and approach will be tested at well-chosen test sites in the North Sea and Baltic Sea covering different sedimentary conditions, water depth, burial depth, etc.; sites have been chosen in such way that a large set of ground-truth information is already available. Field work will also involve at least one 'real case' site where no information is available but where munition is suspected, this will provide verification of the applied approach. The overall outcome is to provide an adaptive and iterative survey approach, combining ship-based and AUV-based data acquisition in the most efficient way. We aim at tackling larger unknown areas (several km^2) as well as local sites of single or clusters of suspicious objects (few $100m^2$) to verify in detail the occurrence and type of suspicious objects. In this respect, the AUV-based magnetic surveys will use on-board running AI-algorithms (Objective 2 -> WP4) that will support the decision, where detailed, predefined survey patterns will be performed or not. We are convinced that AUV technology will become an essential tool for many marine applications; as one sub-objective will be to investigate advantages and disadvantages of ship- and AUV-based surveying and to find the ideal balance of using both technologies in the most efficient way. We will do this by considering the entire process chain from sensor selection, over data acquisition, processing, analyses, and interpretation to the final data synthesis and recommendations for governments, industry and other stakeholders. Achievement for ultra-high-resolution 3D imaging will be measured by the final resolution of the data volume (at least 25 cm laterally and 2 cm vertically; target value is 10-15cm laterally and 1 cm vertically).

Objective 2: Foster sustainable use of survey data with WW I/II archived data within a multi-sensor database for advanced data processing of underwater Big Data; use artificial intelligence for detecting/identifying munition with uncertainty levels (WP3 & 4)

Until today underwater munition detection is largely based on manual processing and visual interpretation of underwater datasets (side scan sonar, magnetic etc.) as outlined above. Due to the limited information given by these systems the efficiency in identifying munition related objects is extremely low. About 95% of objects detected during specialized offshore surveys are not related to munition but must be treated in the same expensive course of action until visually identified. Based on this, our second objective focuses on the development of an integrative approach applying multisensory data analysis, integrative computational and visual data analyses/interpretation including objective quality assessment. The multi-sensor database of https://www.amucad.org/ will be adapted for extraction and calculation of the most relevant parameters from raw datasets for quality management and smart data analysis purposes (e.g. position information, measurement accuracy). In addition, a visualization concept will be developed and implemented for visualizing uncertainty based on quality metrics and simplified indicators for situation assessment regarding detection of munition objects of all kind (based on Objective 3 results).

The two newly acquired data sets of Objective 1, ultra-high-resolution 3D-SBP and AUV-based magnetic surveys, will be incorporated into the standard set of data and jointly analysed by computational means of artificial intelligence (AI). Using such database integrated data set (pre-processing for similar cell sizes, cross-validation of data, etc.) with existing AI algorithms (e.g. Convolutional Neural Networks, Random Forests, Support Vector Machine, etc.) and respectively trained models allows for an objective, repeatable and thus quality controllable assessment. AI is better suited to objectively find correlations in 'Big Data' than experts can do and increasing complexity (additional data layers) can make predictions better. Thus tested and validated AI methods and streamlined workflows will be part of the final Data Base setup.

Objective 3: Discuss and formulate the new tools, methods and workflows with all stakeholders to formalize advanced recommendations for industry and governments (-> WP5)

Industry and research driven technology development has gradually been increasing the complexity of the process of munition detection. Technologies were developed and introduced with the aim of gathering a greater amount of meaningful information that should ultimately enable better data interpretation. Unfortunately, the understanding of the data and the circumstances und which they have been obtained has not kept pace with the speed of technology development. Accordingly, a gap has arisen between performing munition detection and the intricacy of evaluating the resulting data.

The advancement of data acquisition technologies (Objective 1) and the introduction of innovative data processing and integration methods (Objective 2) add new levels of complexity to the entire process of munition detection. In order to avoid increasing the disparity between technology application and results comprehension, Objective 3 is dedicated to the formalization of the data acquisition and handling process in general and of the developments made in objectives 1 and 2 in particular. This formalization will go beyond the technological focus of the project and include other available state-of-the-art technologies.

In order to achieve this, a workflow and quality requirements will be defined. Minimum quality requirements for data obtained with each of the sensors will be defined. A quality metric will be developed, that utilizes weighting and normalization of quality drivers to assign a single mid-point quality measure to the dataset. When merged with data of other sensors (as is mandatory in multi-sensor approaches) the resulting integrated dataset will receive an end-point quality measure, thereby making datasets, technologies and even surveyors comparable. At the same time, a detailed process workflow will be defined, that determines best-practice in data acquisition and handling by qualified personnel resources. The workflow will also prove the cost efficiency of the newly developed methods and enable the comparison of other sensors for their application in different scenarios. Achievement will be measured by the degree of stakeholder involvement. Stakeholder will be involved during workshops that are scheduled in connection with the annual meetings and via annotation of results. As it can be expected that stakeholder participation depends on the generation of representative results, the number of workshop participants and the number of annotations (as well as the ration accepted to rejected annotations) can be utilized to measure achievement.

2.2 Relevance

Relevance for the Blue Labs call: The proposal addresses the **Blue Labs action**, in particular the ***specific theme of unexploded ordnances at sea***. It directly aims at ***the development of innovative solutions and tools (algorithm, artificial intelligence systems, methods and standards) to identify and recognize different types of munitions/unexploded ordnances.*** Within the *BASTA* project new tools and techniques (efficient ultra-high resolution 3D-sub-bottom imaging, intelligent AUV-based magnetic mapping) will be developed and applied which will significantly advance data acquisition. New and existing data will be integrated sustainably into a multi-sensor database for advanced data processing, using artificial intelligence systems to detect and identify munition, on the seabed as well as buried, with uncertainty levels. The new methods/techniques and multi-sensor database, translated into a ‘best-practice’ workflow and associated quality requirements, will provide the industry with the tangible tools and solutions to increase the success and cost-efficiency of munition detection and removal in different marine settings including the Baltic Sea and North Sea.

The research will combine new PhD’s employed in the project and young scientists working already at the partner institutions, who will be supported by experienced researchers. Optimal exchange of (technical) expertise and equipment is foreseen between the research institutions and industrial partners in the project. They will team up to develop innovative technologies and products such as the integration of AI in the analytical workflow, making better use of autonomous vehicles, develop algorithms for determination of quantitative quality metrics of large scale underwater measurements and visualization of calculation and measurement uncertainties. Local stakeholders will be involved maximally to formalize advanced recommendations for industry and governments. The project is highly interdisciplinary, bringing together a wide range of disciplines and competences (among others acoustics, magnetics, automated/intelligent underwater vehicles, artificial intelligence, quality metrics) and combining research institutes and private companies into a common project idea development. The project is significantly stakeholder driven, with stakeholder input and interaction guaranteed by the two private partners (EGEOS, G-tec) and close consultation with relevant research institutes (Alfred Wegener Institute, Thünen Institute for Fisheries Ecology, Institute for Toxicology at CAU), businesses (e.g. SeaTera, Eggers Kampfmittelbergung GmbH) and local authorities (BSH, Wehrtechnische Dienststelle-71 Eckernförde, Marine Headquarters Rostock, Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung - Schleswig-Holstein Germany).

Relevance for the Blue Economy: On **European and global level** the proposal address ocean economy in general. Ocean economy is predicted to double in size by 2030, as compared to 2010, thereby reaching an annual gross value added of USD 3 trillion and providing more than 40 million full time equivalents to the global labor market (OECD 2016). The ocean economy's potential to outperform the expected growth of the overall global economy is reflected in the **Blue Growth Strategy** laid out by the European Commission (2017). In this strategy the economic potential for the extended economic use of the oceans was recognized and focus was placed on five blue growth sectors. Three of these sectors (ocean energy, seabed resources and aquaculture) require the capacity to safely access large areas of the sea floor. For sea floor utilization of this magnitude, sea-dumped munitions constitute a hazard and an obstacle (Bundesministerium für Wirtschaft und Energie w.Y.). In order to utilize the economic potential of the ocean energy, seabed resources and aquaculture sectors, an increase in munition detection and removal action in affected areas will become necessary.

The proposal anticipates valorisation potential for economic and technological developments. The presence of dumped munition may block new initiatives in strategic areas (e.g. related to coastal protection measures, shipping, renewable energy, etc.). The current proposal will deliver new information and important boundary conditions, which are indispensable to develop new management approaches for the munition sites, including the removal of munition.

Relevance to EU policies and legislation: The proposal lies within the scope of different **European environmental conventions and legislations**, some of the most evident instruments are:

- The **European Marine Strategy Framework Directive** (2008/56/EC) which intends to achieve the Good Environmental Status (GES) of the European marine waters by 2020, as well as the protection of the resources on which economic and social activities depend. The GES is described in article 9 of this directive based on 11 descriptors. Descriptor 8 is specifically relevant for the topic of offshore munitions dumpsites as it addresses 'Contaminants and pollution effects'. For each of these descriptors, the European Commission provides further scientific advice in terms of the criteria and methodological standards.
- The **OSPAR** and **HELCOM** Convention for the Protection of the Marine Environment of respectively the North-East Atlantic and Baltic Sea. A recommendation (2010/20) was issued on a framework for reporting encounters with conventional and chemical munitions in the OSPAR Maritime Area.

The implementation of this environmental legislation requires scientifically-underpinned criteria. Today these standards often do not exist. This project will be a major step forward to establish the criteria. Munition dumpsites are often located in nearshore waters, close to densely populated areas and in some cases even large harbours. This poses direct risks **public health and safety** on different levels:

- Risk of contamination of seafood due to marine organisms taking up chemical substances;

- Risk of contamination of (swimming) water due to leakage of chemical to the water column;
- Risk of explosion

With regard to public health major legal instruments include the **European Water Framework Directive** (WFD), the **Marine Strategy Framework Directive** (MSFD) and the **Bathing Water Directive**. Calamities related to dumped munitions however may have societal implications which are much wider than the coastal region and its inhabitants. For instance, the contamination of seafood would also influence the public perception regarding local seafood, which may affect the entire fisheries and fish processing sector. A contamination of the bathing water could potentially plummet coastal tourism which is often an important economic driver for the local economy of coastal regions.
Moreover, sea-dumped munitions also pose a major safety threat to critical infrastructure works such as the installation of offshore renewables (windfarms etc.), the installation of power cables and pipelines, fishing vessels (munition getting caught in fishing nets), and dredging (for aggregates and infrastructural reasons). The offshore industries involved are an important economic driver for the national and European economy. The results of the project will have a measurable impact on the safety of these offshore operations.

Relevance for Open Data/Science: Over recent years, the vision of **Open Science** has emerged as a new paradigm of transparent, data-driven science capable of accelerating competitiveness and innovation. The projects aim is to support this new paradigm by providing algorithms, visualization concepts and cost-efficient workflows for large scale data analysis. In particular, the approach of automated analysis of measurement quality and the development of quantitative metrics of large-scale underwater measurements will be made available. Therefore, during the project the possibility of providing services in the context of the **E**uropean **O**pen **S**cience **C**loud (EOSC) will be evaluated.

2.3 Concept & approach

Concept

The concept for a successful realization of the project follows the above defined objectives; it is designed out of several parts, which are interlinked and build on each other. Two technological development parts will be undertaken which are **a)** the integration of magnetic sensors into a hover AUV and the implementation of smart routines for autonomous mapping and **b)** the development of efficent 3D processing and visualization of ultra-high-resolution SBP information. Both of these developments are closely linked to the third part of our concept which is **c)** field work (sea trails and surveys) in areas of know buried and unburied munition. To combine this new information with standard data sets (multibeam, side scan and optical information) our fourth concept part **d)** deals with the establishment of a multi-sensor database is based on the already existing “Ammunition Cadastre Sea” AMUCAD run by our partner EGEOS (www.amucad.org). We aim at complementing AMUCAD with an architecture that not only allows to ingest large data sets of ‘unprocessed’ data but also to use **e)** artificial intelligence methods (AI) for a continuously-learning interpretation of data in an objective way where uncertainties can be quantified. Similar AI methods will be implemented for real-time learning on the AUV for smart and adaptive mapping (see above). The final part **f)** summarizes the newly developed workflows by critically including quality factors aiming at a standardization that can be used base for further international regulations. Considering stakeholder needs, wishes, views, constrains and concerns from the very beginning, **g)** a strong focus will be on stakeholder integration including companies, governmental bodies, policy makers, NGOs and where applicable the public. Within *BASTA* these seven parts are framed into four work packages (Figure 4).

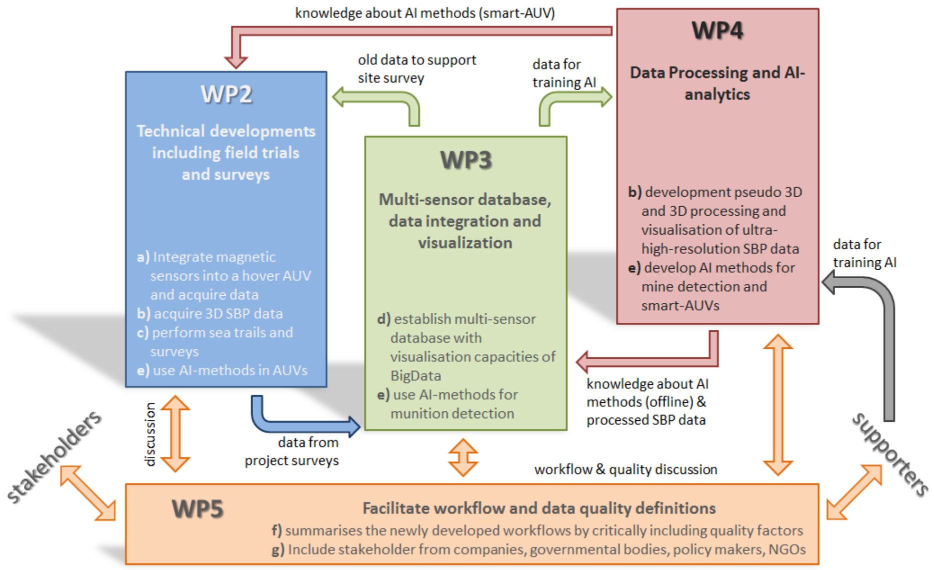

Figure 4: Concept of the *BASTA* project visualized by the interconnections between work packages. Stakeholders and supporters are essential parts who will contribute to the success of the project, being important partners for discussion and verification as well as supporters of data. They are integrated via WP5.

Approaches

1. AUV- Advancement (WP2 & WP4 Tasks 2.2, 2.3, 2.4, 4.3 & 4.4)

Autonomous underwater vehicles (AUVs) are platforms that perform predefined missions independently of any real-time intervention. They are not autonomous with respect to taking decisions e.g. to change the mission plan due to specific findings/sensor readings while the mission is executed. AUVs are very successfully used to map the seafloor in great detail, the close distance to the seafloor keeps the acoustic footprint small, and due to the proximity to the seafloor ping rates are high. Both of these facts together with the great stability of platform itself (no wind and wave motions) increases the resolution of the mapping operation. Such mapping surveys are typically done by torpedo shaped AUVs, streamlined to go long distances but in most cases not being able to go slow. AUVs are positively buoyant for safety reasons; fins keep the AUV at depth, but only when moving with a certain speed. Hover-AUVs as the GIRONA500 AUV from GEOMAR (Figure 5) are differently designed and can thus move in all directions freely in the water. They can be equipped with additional sensors ‘sticking’ out of their body, without losing manoeuvrability. Thus they are ideal tools for being equipped with sensors for very detailed magnetic measurements.

Equipped with DVL navigation the positioning accuracy over short distances and time (< 100m, < 1h) is very high. Thus it is possible to repeatedly go over one location from different directions and different altitude (-> 3D grid). For exactly targeting a metal object in the ground, determine the size and burial depth, this would be very valuable information. The AUV can achieve this if it records and analyses the magnetic signal of a gradiometer setup in real time and goes into a small-scale mapping mode around an object if certain value thresholds are reached or changes are higher than a certain rate.

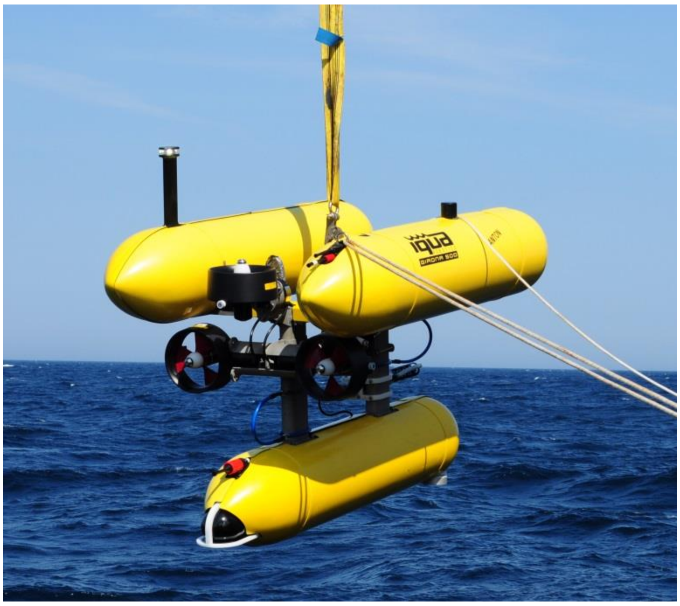

Figure 5: AUV GIRONA 500 of GEOMAR being hoisted into the North Sea at the Dogger Bank in 2018.

Predefined and continuously adapted filter routines can be used for such purpose. With this capability the AUV can follow a predefined path of potential objects (e.g. seen in bathymetric or magnetic maps), verify their existence, position and strength. With additional intelligence of pre-trained AI algorithms (e.g. CNN, see below) the AUV could autonomously learn which suspicious objects of a given set of data layers (map of spatial sensor data) are indeed metallic objects. The implementation of such functionality will be undertaken through the middleware ROS installed on the GIRONA AUVs of GEOMAR (Robot Operating System http://www.ros.org/) which can be modified and extended to the user's needs.

2. Sub-bottom profiling advancement (WP2 & WP4; Task 2.1, 2.4, 4.2)

To this day, efficient detection and imaging of buried munition remains a big challenge. Multibeam, side scan and optical data are of no use since they do not penetrate the seafloor. Magnetic data do not provide accurate depth information whereas deeper objects often go undetected. Conventional acoustic profiling provides a 2-dimensional cross-section of the sub-bottom. At its best this technique provides information about the depth (top) of the object, but not its size or orientation. Systems using a narrow acoustic beam (such as the parametric echosounder) provide the vertical and horizontal resolution (sub-decimeter resolution) needed for object detection, but any objects that lie outside the survey path remain undetected (Missiaen & Feller 2008). The only way to solve this is through 3D-sub-bottom imaging. This is a complex operation with regard to data acquisition and data processing (Missiaen, 2005; Gutowski et al., 2008). Recently, a novel approach was developed using a multitransducer parametric echosounder system (SES-2000 Quattro). The system consists of four individual transducers in a line array which allows 3D imaging with very high data density. The setup largely simplifies volume rendering processing, since time-consuming migration and beam forming processing are no longer required. Moreover, the simple acquisition makes this system particularly fit for rapid, cost-efficient site surveys (Missiaen et al. 2017).

An array of four individual transducers combined with close line spacing provides a high data density. Data (volume rendering) processing is largely simplified since time-consuming migration and beam forming processing are no longer required. The system can be deployed from small vessels and is highly flexible with different transducer configurations possible. Using a small transducer spacing (25 cm) provides ultra-high resolutions (bin size 20x20x1cm), but limits the maximum water depth to ~15 m (due to beam overlap) and requires skilled navigation. Smart visualization of the 3D volume is done using state-of-the-art software (e.g. Avizo, Voxler) including opacity & color map transfer functions, clipping planes, segmentation, animation, etc.

The SES-2000 Quattro system will be deployed in different configurations for optimal buried munition detection. The 3D approach will also be compared with a smart 2D approach using a single transducer which allows working in deeper water and offers the possibility to work from an autonomous vehicle or platform (which is not possible with the 3D system). Using a sufficiently close line spacing (e.g. 0.5m) this should allow a coherent, dense data coverage. The dense 2D data can be combined into a 3D volume and visualized the same as 3D data. The accuracy and applicability of both approaches (true 3D and 2D/pseudo-3D) will be tested in different settings. This should allow determining the most cost efficient system.

3. Field trials and surveys (-> WP2, Task 2.1)

The new techniques and data acquisition approach will be applied at three different test sites located in the North Sea and Baltic Sea. The sites will cover a range of settings (sedimentary conditions, water depth, amount, type and burial state of munition, etc.). Ship- and AUV-based surveying will be combined during the trials to find the ideal balance of using both technologies in the most efficient way.

In a first instance the field trials will be carried out in two different test sites with exposed munition (site A) and buried munition (site B) where ample of ground-truth data/information is available (UDEMM results, data owned by GEOMAR; public data and AMUCAD.org). This will allow testing the efficiency of the new techniques and applied approach. In addition to these well documented test sites, field trials will also be carried out in a ‘real case’ scenario (site C) where no/little information is available so far to the proponents, but where the occurrence of munition is documented. Site C will provide the final verification of the developed techniques and approaches in *BASTA*. We choose the below listed sites because of their accessibility through the proponents, the availability of data and different complexity.

<u>Test site A (exposed munition):</u> Possible sites include Lübeck Bay and Kolberger Heide in the Baltic Sea. Both sites are marked in nautical charts as munition dump grounds, they have been mapped with multibeam in very high resolution and ample of ground truth exists for specific objects and clusters of objects. Kolberger Heide is very sand and most munition objects are most likely still on the seafloor (Figure 6). Lübeck Bay is muddier and large areas have been covered by purpose in the 60es; this means partly buried munition will exist in this area.

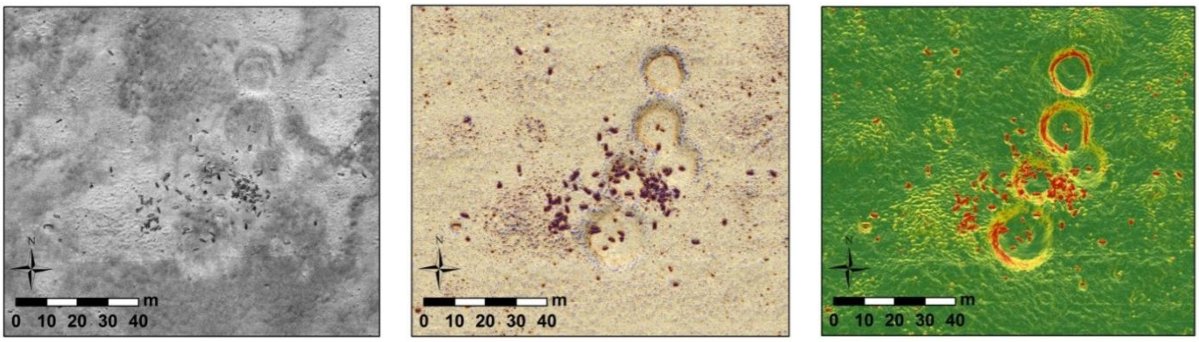

Figure 6: Data from the munition dump site in Kolberger Heide. Shown are explosion craters and a number of munition objects, these are mainly ground mines and torpedo heads. Left – backscatter data; middle – topographic positioning index; right – slope.

High-res multibeam and high-res camera will be deployed in both areas, towed from a ship and/or operated from AUV sailing slowly (0.1 – 0.5m/s) in 0.5 to 1.5m above the seafloor. Survey lines should allow for full bathymetric coverage adding to the existing dataset, ample of optical data will support the acquisition of ground truth data in form of photomosaics (Figure 7) which will be the base for finally identifying munition objects. High-res magnetic and ultra-high-resolution SBP data will be additionally obtained adding to the existing data base. Acquisition will be done by towing magnetic gradiometer arrays as well as using the AUV with the newly developed magnetic gradiometer set.

Figure 7: Top - Photomosaic of a 7m long German torpedo in Lübeck Bay, several of such torpedoes exist in that area, they can be rather easily identified in bathymetric data. Bottom – Several piles of munition boxes have been dumped in Lübeck Bay, the size of the image is about 24 x 10m, mean box size is about 60 x 60 cm. Images are from cruise POS530 (UDEMM), photos have been taken by one of GEOMARs GIRONA 500 AUVs. Image processing was done with Photoscan.

<u>Test site B (buried munition):</u> We expect that in Lübeck Bay buried munition exists. Final proof cannot be given, but archive data suggest that ca. 45,000 tons of munitions have been dumped in Lübeck Bay. During surveys in 2018 this amount of munition could not be detected in the designated dump sites and thus we believe that some of the munition must have been buried in the sediment. Because of this uncertainty, ultra-high-res 3D-sub-bottom data will be obtained in Lübeck Bay using the SES-2000 Quattro system with simultaneous multibeam data acquisition for high-res static-offset corrections.

A second, very prominent site would be Hooksielplate in the North Sea (near Wilhelmshaven; Fig. 8). At this location 650,000 to 1,300,000 tons of munition, inclusive heavy grenades haven been initially dumped. The sediment here is very muddy and almost all munitions will be buried even in greater depth. The proponents did work in this area before but it would be a good test side for detecting and quantifying buried munition. The very close proximity to shore will help. GEOMAR has good contacts the local Senckenberg Institute and support can be assumed. However, as logistics are more difficult here, this site is only an addition if all other studies go well and are less time consuming as currently anticipated. Lübeck Bay will be the main site.

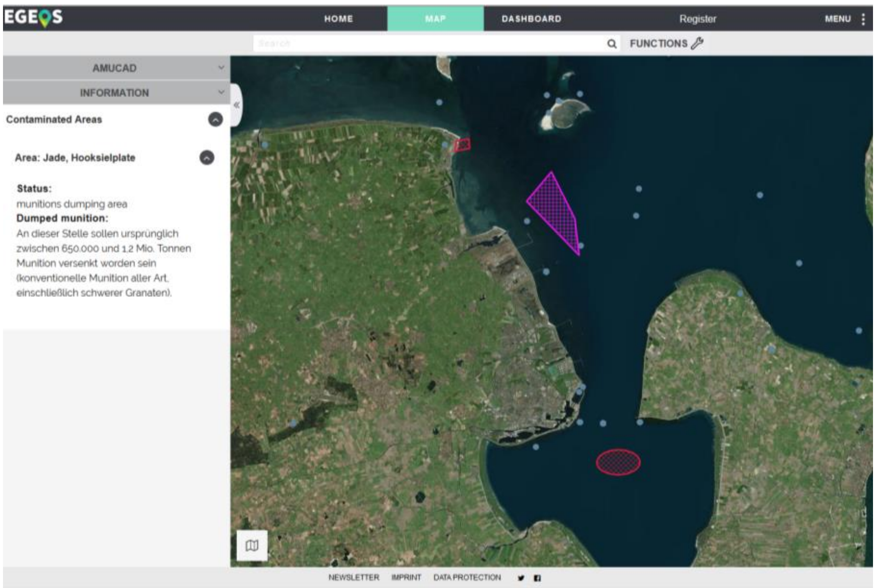

Figure 8: Screen shot of AMUCAD.org showing the Hooksielplate dump site near Wilhelmshaven (pink polygon).

<u>Test site C (unknown munition):</u> A possible site for a very complex occurrence of all kind of munition, which are now mainly buried but also washed on shore from time to time is Helgoland in the North Sea. Here all sorts of munition, including chemical munition (tabun ca. 13 tons) are reported from the two dump sites (a total of about 610 tons). The high energy regime around Helgoland certainly caused substantial munition burial and will also cause ongoing movement of individual munition bodies. All available techniques will be used offshore Helgoland; being successful in Helgoland would the final verification and quality proof of the project ideas.

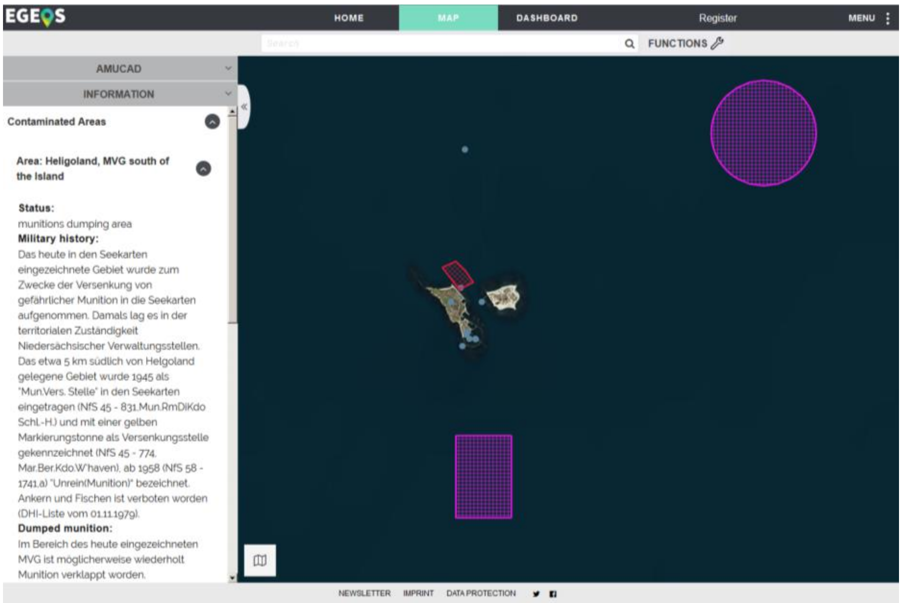

Figure 8: Screen shot of AMUCAD.org showing the two dump sites around Helgoland (pink polygon), as well as OSPAR reports of munition encounters (blue dots) and the munition contaminated area north of the island (red polygon).

4. Database & Visualization (-> WP3, Task 3.1, 3.2, 3.3, 3.4, connected to WP4)

The existing multi-sensor database of AMUCAD.org will act as the starting point for the development of several standalone modules. These modules will include artificial intelligence algorithms, quality metrics and visualization approaches for data imprecision. The concept of the existing multi-sensor database focusses on generalization of heterogeneous datasets resulting from underwater measurements. Generalization is a key element in the intended data processing chain of *BASTA* and in the whole context of maritime datasets. In the past, the complexity of underwater surveys resulted in a myriad of vendors, systems and formats which increases the intricacy of deep and detailed analysis. For generalization purposes all datasets will be transformed into three-dimensional point clouds where each point has multiple dimensions depending on the input datasets, the utilized survey technique and the measured parameters. In *BASTA* real-word datasets provided by stakeholders via OSIS will be analysed with regard to quality, precision and accuracy to receive an overview the entire spectrum, today's state-of-the-art in underwater measurements and nowadays applied techniques. The objective in this step is the identification of commonalities and differences which will affect the development of the artificial intelligence module and quality metrics. Results will be used for the determination of the first set of data quality parameters. These datasets in combination with the datasets acquired by multiple field trials will act as ground truthing and will enable the integration of new measurements techniques (e.g. photomosaics) and quality metrics for automated carrier platforms like AUVs. Algorithms for definition of quality metrics will be developed based on existing literature, the best-practice guide and use cases which will be included by definition of most common real-world scenarios of stakeholders and industry partners.

Another focus will be on providing an adequate visualization concept regarding data analysed with AI based technologies and quality metrics/uncertainties. Human centric visualization of calculation results and quality metrics/uncertainties is a key factor in the process of informed decision making where the quality of the underlying data plays an essential role. During the project a meaningful visualization of data values and corresponding uncertainties will be developed, and areas/regions/points of high interest will be explicitly visually emphasized. During the development process intensive discussions and incorporation of stakeholders will be carried out to provide solutions that could be commonly accepted and easily applied. Already existing concepts will be analysed regarding their strength and weaknesses and transformed including results of discussions and newly developed approaches.

5. Applying machine learning (-> WP2, 3 & 4, Tasks 2.3, 3.2, 4.4)

Machine learning can be a useful tool to automate the detection of munitions in multi-parameter data set as envisioned in *BASTA*. Due to the similarity between e.g. bathymetric, magnetic or side scan data and image data, convolutional neural networks (CNN) are potentially a very good option. They are successfully used for deep learning in various similar tasks like image classification and image segmentation. Applied to images, convolutional layers are able to extract and memorize features (e.g. shapes) of objects common in the images of the objects. For e.g. bathymetric data, this enables the algorithm to identify common shapes of objects because colours correspond to water depth. For other input data (side scan, 3D-SBP, magnetic) colours represent the respective variable as raster data of specific resolution (grid cell size). Exemplarily we tested the approach on multibeam-backscatter data from the Kolberger Heide (Figure 9).

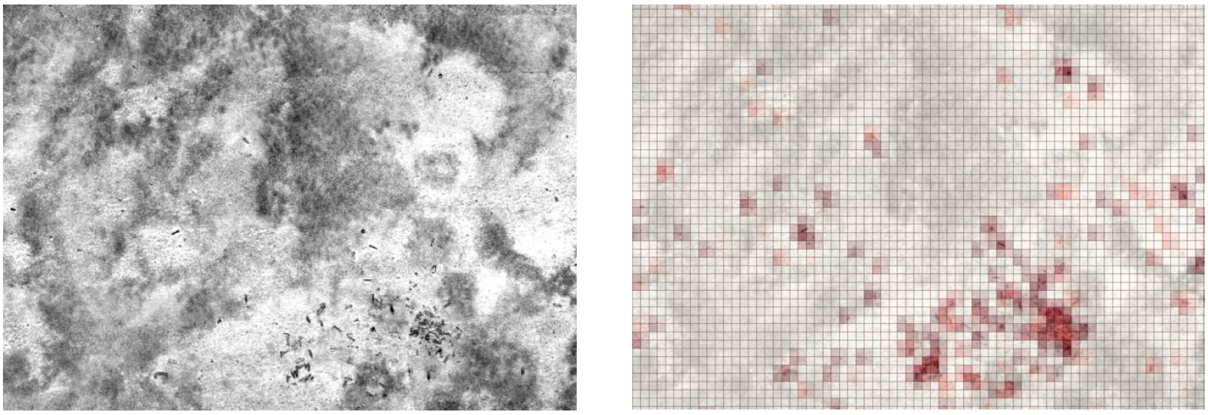

Figure 9: Left – Multibeam backscatter data layer from Kolberger Heide showing munition objects as slightly elongated dark features. Right – The input layer was split in 17 x 17 pixel tiles with each of them classified seperately. The red shade indicates the predicted probability to contain munitions. On the initial backscatter image clusters of munition are clearly visible and using the neural network larger datasets can be (pre-) labelled with nearly no human input.

We followed a supervised approach where 2300 locations were annotated as either munition or not (~50% munitions, ~50% normal seafloor). For a deep learning model, these are relatively few examples/training data. We therefore manipulated the images via mirroring and rotation to get eight times as many samples. Our neural network uses 17 x 17 pixel/neuron tiles around each location as input (25cm cell size of the backscatter map). This corresponds to a 4m x 4m area. Overall our simple network consists of five layers: two convolutional layers, a max pooling layer and two dense layers. The final output is the probability of the image tile to contain munition. In this model the neural networks first layer, a convolutional layer, applies convolutions to subsets of its input. For the first layer we used a 3 x 3 pixel subsets of the 17 x 17 pixel tile. The second convolutional layer uses the first layer outputs as inputs. The building blocks of the convolutional layers, behave similar to filters in classical image processing; they are able to detect simple shapes like edges which here correspond to backscatter intensity changes. The outputs of the convolutions are single numbers indicating how much the input resembles the desired shape. Because the convolutions are applied to multiple subsets of their input, the output of a convolutional layer is again a N x N tensor of neurons. Using multiple stacked convolutional layers, e.g. adding bathymetry, SBP or magnetic information it is possible to detect complex shapes in multi-dimensional input data. This is what makes these networks so powerful. In our case, in the max pooling layer the results of the second convolution layer are aggregated. The aggregated information is then processed by dense layers to generate the final output. In a dense layer all input values are used in all neurons. This is a major difference between dense layers and convolutional layers where subsets of the input neurons are used as inputs for the convolutions to compute the values of the output neurons.

The output of the network for a given image is the predicted probability of the tile to contain munitions. These probabilities can be used to classify the images. In our example, 90% of test data have been classified correctly, being munition or not. Upon visual inspection it seems like there are a couple of obviously misclassified tiles. Two reasons are plausible, first - the hand labelled data might not be accurate all the time and the locations might not be centred on the munition. Second - the number of observations is low, so not all possible inputs are among the training examples.

As mentioned above, 2300 data points are not many for a deep learning task. The model performance would benefit from a higher number of annotated locations. During *BASTA*, this will be achieved through a direct coupling of the AI methodology to the data provided from the data base. Areas of similar environmental conditions, expected munition and/or burial depth will be selected to train the network specifically. As more data can be used, as better the prediction. A large number of annotated data will be made available through our supporters (e.g. TenneT, BSH). From a modelling perspective, it might be worthwhile moving from the classification task to a segmentation task. This way the locations of individual objects would be clearly defined and it would be possible to count individual objects. Unfortunately, it is necessary to annotate the munitions in a different way to apply the algorithm.

6. Workflow integration and quality definition (WP5, Tasks 5.1, 5.2, 5.3)

Both the deployment of state-of-the-art sensors for munition detection in multi-sensor systems and the handling of data with new data science approaches (such as multisensory databases and machine learning) have to be streamlined for future application. Accordingly, a fully integrated best-practice workflow will be designed. In order to ensure that this workflow is performed with due diligence, quality requirements will be defined. The design of the best-practice workflow for existing survey methods will focus on comparing and assessing existing process descriptions for gaps, weak points and redundancies. For the advanced 3D sub-bottom profiling and AUV equipped with multiple sensors, new workflows have to be defined. The workflows for individual technologies will be aligned as far as possible to allow integration into a comprehensive best-practice guide. During workflow definition the individual process steps will be scrutinized. For each process step the definition of the process target, performance indicators, process variations and control measures will be defined.

Additional focus will be placed on the quality requirements of the data acquisition. For each of the applied technologies relevant quality drivers will be identified. This includes environmental drivers (currents, turbidity, etc.), sensor drivers (sensor noise, acoustic frequency, etc.) and operational drivers (height above ground, speed above ground, etc.). Furthermore, the way in which these quality drivers influence quality (criticality, failure rate, measuring uncertainty, etc.) will be analysed.

Next, minimum quality requirements for data obtained with each of the sensors will be specified. For data that meet these minimum requirements, a quality metric will be developed. Quality is the "degree to which a **set of inherent characteristics** […] of an **object** […] fulfils requirements" (DIN EN ISO 9000 2015). Since the best-practice workflow corresponds with the "object" and the quality drivers with the "set of inherent characteristics", the concept introduced above is considered to be suitable.

Both the workflow and the quality requirements will be validated in two ways. Practical validation will be performed during the field work. Expert validation will be done via stakeholder involvement. Engaging affected stakeholder is the key to the successful introduction of best-practice documentation, especially when it is connected with a quality value. This is true for two reasons. Firstly, stakeholders need their positions to be represented in normative initiatives and secondly, the knowhow of the entire munitions detection industry is highly appreciated as input. Accordingly, two stakeholder workshops will be organized. During these, results will be presented and discussed with surveyors, clients (e.g. wind farm and pipeline operators), UXO specialists and authorities.
The workflow and quality guideline, are a deliverable of WP5 and will be submitted to stakeholders for annotation. They will be documented in accordance with ISO recommendations (International Organization for Standardization 2016).

2.4 Impact

The impact the project will have directly results from the needs analyses presented in section 2 (Table 1). The target groups firstly include companies and governmental bodies who are involved in UXO detection and removal; they also include governmental bodies concerned with the good environmental state of Europe's seas as well as regulatory bodies. Furthermore, developments of *BASTA* will also have an impact on scientific workflows. The prominent incorporation of AI into data analyses workflows is currently receiving strong interests on all disciplines of marine science and other areas alike. Furthermore, advancing and applying the use of smart robotic systems in this project will have an impact to other ongoing and planned activities at the joining centres and the use of these scalable sensor-platforms in the scientific and commercial world in general. Focusing on the commercial unexploded ordnance cleaning sector impacts will occur on **short term** (1-2 years) by an immediate reduction of necessary field work and higher accuracy in the process of UXO identification and exclusion of non-UXO objects through the optimization of data analysis and information retrieval due to the application of advanced data analysing techniques. On **medium time** (2-3 years) the effect of *BASTA* will be a substantial automation of operations based on the use of autonomous underwater vehicles for data acquisition and target identification. Resulting in substantial savings of operational costs and highly increased security for humans. On **long term** (>3 years) standardized workflows and methods in form of a framework developed together with industry partners and stakeholders will lead to acceptance and adoption by administration and industry. *BASTA* will result in a financial and operational advantage for European marine industry in a growing global marine industry. European national authorities will benefit from the proposed database, centralizing all intelligence on marine unexploded ordnances. During the project, the transferability into other fields will be evaluated as well. One of the associated organizations (World Wildlife Fund) deals for example with the removal of marine litter in form of derelict fishing gears which can be probably identified with similar techniques. In addition, a transfer into other areas like e.g. identification of lost cargo, detection of wrecks etc. is conceivable.

2.5 Cost effectiveness

BASTA has been developed among two research centres (GEOMAR, VLIZ) active in field of investigating munition for environmental studies, a company active in establishing and running a database holding the "Ammunition Cadastre Sea" (EGEOS) and a second company being internationally active in UXO detection and clearance (G-tec). As such all partners have great experience with regard to the topic of the proposal. Through previous cooperation as part of national and international proposals, all partners know each other, in some cases for decades. Because of this existing close cooperation and experience in the filed we can highlight a number of points that will make this project very cost effective.

Sustainable and continuous use of knowledge and link to ongoing projects

Building on past experience a seamless continuation can be guaranteed. The following projects highlight different aspects that directly link to the work packages and tasks of this proposal.

DAIMON (2016 – 2019; Interreg) - EGEOS GmbH: The *Decision Aid for Marine Munitions* is an Interreg Baltic Sea Region project. It has the goal to provide information about risks resulting from identified and localized objects incorporating large amounts of spatial and non-spatial datasets based on latest scientific research. For each detected munition object, the software formulates a risk assessment, incorporating information about the localization and overall state of the munition, the surrounding environment and state of biological pollution/damage. In this context AMUCAD plays an important role as it provides extended functionalities including additional datasets, managing private data, versioning/history of found objects and many more. (https://www.daimonproject.com/)

UDEMM (2016 – 2019, BMBF) – GEOMAR, EGEOS GmbH: The project 'Environmental monitoring before, during and after the clearance of munition from the sea' studies munition dump sites in the Baltic among the Kolberger Heide (study Site A) and Lübeck Bay. In both areas extensive data sets of high resolution multibeam and optical data have been acquired, that clearly show different munition types on the seafloor. Studies regarding physical oceanography (measurements and modelling) chemical investigations in the water column and the sediment as well as toxicological studies on mussels give a conclusive picture of the environmental impact of a highly contaminated munition dump site. Data are owned by GEOMAR and can be used for planned work in the *BASTA* project. (https://udemm.geomar.de/)

North Sea Wrecks (2018 – 2022, Interreg) VLIZ, EGEOS GmbH: '*North Sea Wrecks'* is a recently started Interreg North Sea Region project aiming at developing and implement a common strategy for dealing with economical, ecological and safety challenges in the context of shipwrecks, lost cargo, disposed chemical waste and munition to enable a sustainable management of the ecosystem North Sea. Available knowledge and best-practices will be adapted to the requirements and prerequisites of the North Sea region. The prototype of NORTH SEA WRECKS will be integrated directly into AMUCAD and several newly developed approaches and technologies will be provided for a better understanding of the munition and wreck situation. (https://northsearegion.eu/nsw/)

ROBUST (2016 – 2020; H2020) GEOMAR: ROBUST is an EU project that aims at using smart AUV for resource exploration of the deep sea with regard to Manganese-nodule. It is a robotic project that I successfully integrating different sensors into a AUV platform and implement smart algorithms and routines for adaptive mapping and several levels. On-board processing of multibeam data and unsupervised classification are part of the project. GEOMAR is involved in the respective work packages dealing with the implementation of autonomy into the AUV, by reading sensor data and adjusting mission plans. (http://eu-robust.eu/)

COMPASS-DRIMP (2018 – 2021, BMWi) GEOMAR: COMPASS-DRIMP again is a project in the field of marine resources but deals with the software implementation of workflows including AI on small vehicles with restricted resources of computer power and energy. As part of COMPASS-DRIMP a computer module will be developed as 'Intelligence Unit' for GEOMAR GIRONA 500 AUVs. The gained knowledge will be transferred towards the application in *BASTA*.

DISARM (2020-2024, FWO-SBO) VLIZ, G-TEC: DISARM is a Strategic Research Project funded by Research Foundation Flanders (FWO) and aimed at multidisciplinary research of the WW1 munition dumpsite 'Paardenmarkt' off the Belgian coast. The project, coordinated by VLIZ, will start in Jan. 2020 and run for 4 years. Within this project G-Tec will carry out high-res gradiometric measurements combined with novel CPT/borehole techniques using built-in (electro)magnetic sensors to get accurate information on the burial depth of the munition. The gained expertise will be highly relevant to the *BASTA* project.

Complementary expertise

Based on the expertise of the proponents, the above detailed projects and the distribution of work as outlined in the work package descriptions in section 4. We are avoiding any duplication of work. This makes the project effective in respect to the workflow but also with respect to the costs.

Use of existing infrastructure and data

As all partners have substantial infrastructure at hand (see Annex 2 of Part B of the proposal). All can and will be utilized to the project without charge. Only direct consumables will be purchased through the project. Technical and support and maintenance is given as well from all partners. Infrastructure includes ships that have several 1000 EUR costs per day.

Use of free software packages

To a very large extent the project will build and use on free/open source software. The GIRONA AUVs run on the Robot Operating System software ROS (http://www.ros.org/) which can be modified and extended to the user's needs. Database software packages include PostgreSQL/PostGIS data bases and Tensorflow/CUDA for AI-applications, which again are free software packages, leaving the project with no additional costs for software licenses.

Easy field campaigns, close proximity of study sites to shore

The selected study sites are close to shore and can be reached during day cruises (Kolberger Heide), or cruises of a few days. Sites B and C can be reached from a near harbor with one hour or even less. Because of this no expensive logistics and mobilization costs are involved. However, some transport costs need to be covered bring equipment from the partners to the start and end harbor before and after the field work. Because of this proximity, small vessels from VLIZ and GEOMAR can be used, no additional cruise proposals need to be written and approved for RV Simon Stevin, RC Littorina and RB Polarfuchs.

Slim management structure and minimum meeting activities

BASTA with only four partners will have a very slim management structure; physical meetings will and can be kept to a minimum, reducing the costs. Meetings with stakeholders will be organized parallel to other activities and meetings of the respective groups, making rental costs for meeting-venues redundant.

2.6 European added value

The dumping of chemical weapons was banned under the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter in 1975 (International Maritime Organization 1975). This marks the acknowledgement of submerged munitions as an environmental problem. Regional conventions for the Baltic Sea (HELCOM), North Sea (OSPAR) and Mediterranean Sea (Barcelona Convention) soon followed suit in banning both the dumping of chemical and conventional (i.e. explosive) weapons. This displays the European dimension of the munitions threat. It does however exceed beyond Europe, as dumpsites exist off the coasts of the United States, Canada, Australia, Japan, Taiwan and further countries. Submerged munitions remain a long-term challenge, even in waters that have not been subjected to armed conflict in many decades. Consequentially, the main aspects of Integrated Coastal Zone Management – multi-sectoral economic growth, environmental protection and sustainable resource use – are negatively affected by the presence of munitions on a global scale.

A problem of such dimensions calls for solutions that do not only benefit a single country but the both the European and the international community. As the following paragraphs display, all of the *BASTA* objectives have been conceptualized to directly benefit all European coastal countries that are affected by munitions. The same is true on a global scale for all those countries that have declared territorial waters and an EEZ according to *The United Nations Convention on the Law of the Sea* (UNCLOS).

The advanced data acquisition technologies will be available for the detection of munitions in global waters (offshore, coastal and inland). The consequence is a technological advantage for European businesses in this highly competitive global market.

The improved handling and use of data promises to add European value in a multitude of ways. First, the database will be available online and therefore facilitate easy data exchange among actors from different European countries and simultaneously foster data availability. Data input will originate from all European Seas and numerous other waters worldwide. Database content will therefore represent the natural conditions, specific munitions types that need to be detected and the commonly applied survey technologies for all these conditions. Furthermore, data handling in a multi-sensor database, that is available online, is also far more sustainable than the current practice of isolated datasets. As munitions or suspected items are often not immediately cleared the long-term provision of data and potential to integrate with future surveys. In addition, numerous of these datasets can also be used for other purposes such as construction site investigation, environmental monitoring or cable tracking. In the long-term it will be possible to further develop a holistic all European munitions database. This will be further facilitated by standardized data quality flagging.

Workflow design and quality requirements definition hold numerous advantages both for European state actors as well as for European businesses. As best-practices serve as a step towards standardization, merging of data and vertical integration of business processes among companies will be facilitated. This will reduce costs for these companies as well as their employers (which may be authorities). The workflow and quality requirements will secure Europe's position as a pioneer in standard procedures for munition detection and the establishment of a quality initiative, which could subsequently be rolled out globally. Simultaneously, through involvement of stakeholders from all over Europe the quality requirements will lead to self-imposed regulation on what is currently widely considered an under-regulated market. All of this combined will again lead to a competitive advantage for European companies. All activities, that strengthen the maritime industry regarding UXO detection and removal, simultaneously have the potential to unburden military forces. At present they are heavily involved in the process in many European countries and have to allocate noticeable capacities which could be significantly reduced. The majority of project activities will take place at the offices of the project beneficiaries in Belgium and Germany. Field work will be conducted in German territorial waters. Nonetheless, results of all objectives will be applicable to European and global waters. Stakeholder involvement will be coupled to conferences in European countries (see section 5.3).

3. ACTIVITIES & WORK PACKAGES

3.1 Activities & Work Packages

Work Package 1	**Management & Coordination**
Duration: Month 1 - 36	Lead: **GEOMAR** Partners: VLIZ, EGEOS, G-tec

Objectives

The main objective of this WP is the internal management and coordination of project (administration, logistics for meetings & workshops; reporting towards the EU) as well as supporting outreach activities and stakeholder involvements as outlined in WP5. This includes establishing and managing the project governance boards, plan meetings and workshops, and support outreach activities. Outreach activities will include the project web page that informs about stakeholder events, lists project activities and informs about the progress of the project. Further, field campaign activities will be coordinated with help of the Management & Coordination Office (MCO) that will be established at GEOMAR. Joined proposals for larger field campaigns (ships proposals for German and Belgium research vessels) but also for smaller field trials will jointly organized with help of the MCO. The MCO will also oversee the entire quality of the project deliverables, each deliverable will be agreed on by all project members before it is finally accepted.

Tasks	**Name**	**Description**
Task 1.1	Management structure	Establish Management and Stakeholder Board
Task 1.2	Project meetings	Plan and execute Kick-off and annual meetings
Task 1.3	Web page	Establish and maintain webpage, design logo
Task 1.4	Stakeholder events	Organize and execute public stakeholder events and present the project during relevant conferences, information events and stakeholder meetings
Task 1.5	Joined field studies	Support initiation and planning of field work, proactively involve other stakeholders and members of other, relevant projects
Task 1.6	Project administration	Administer the project towards the EU; organise and deliver periodic progress reports as well as the interim and final report
Task 1.7	Project Quality Control	Performance and timeliness of project goals, discussion during 6monthly meetings of the MB to see and validate progress

Milestones	**Name**	**WP**	**Lead beneficiary**	**Means of verification**	**Due date**	**Description**
MS1	Governance	1	GEOMAR	List of board members published on webpage	1	Project Management Board and Stakeholder Board established
MS2	Kick-Off	1	GEOMAR	Minutes of Meeting	2	Kick-Off meeting; all project

	Meeting					participants meet including Stakeholder Board; details for data sharing and data aggregation will be discussed
MS3	1st Annual Meeting	1	GEOMAR	Minutes of meeting, publications of presentation	11	Annual meeting, involvement of stakeholders
MS4	2nd Annual Meeting	1	GEOMAR	Minutes of meeting, publications of presentation	23	Annual meeting, involvement of stakeholders
MS5	Final Event	1	GEOMAR	List of participants	35	A final event in order to present the results of the project

Deliverables	**Name**	**WP**	**Lead beneficiary**	**Type / Dissemination level**		**Due date**	**Description** *(including format and language)*
D1.1	Webpage	1	GEOMAR	DEC	Public	3	Webpage, English
D1.2	Meeting minutes of the Kick-Off Meeting	1	GEOMAR	R	Public	3	Different months, Digital report (pdf), English
D1.3	Periodic Progress Report	1	GEOMAR	R	Confidential	6	Report, Digital report (pdf), English
D1.4	Periodic Progress Report	1	GEOMAR	R	Confidential	12	Report, Digital report (pdf), English
D1.5	Meeting minutes of the 1st Annual Meeting	1	GEOMAR	R	Public	14	Different months, Digital report (pdf), English
D1.6	Periodic Progress Report	1	GEOMAR	R	Confidential	24	Different months, Digital report (pdf), English
D1.7	Meeting minutes of the 2nd Annual Meeting	1	GEOMAR	R	Public	26	Different months, Digital report (pdf), English
D1.8	Periodic Progress Report	1	GEOMAR	R	Confidential	30	Report, Digital report (pdf), English
D1.9	Meeting minutes of the Final Event	1	GEOMAR	R	Public	36	Report, Digital report (pdf), English

Division of work

Task	**Name**	**Participant**	**Role**	**With help of in-kind contribution/partner organisation**
1.1	Establish management structure	GEOMAR	COO	Stakeholders
1.2	Meetings	GEOMAR	COO	
1.3	Web page	GEOMAR (VLIZ, EGEOS)	COO (BEN, BEN)	GEOMAR IT and PR; TenneT and other stakeholders
1.4	Stakeholder events	GEOMAR)	COO	GEOMAR PR-Department
1.5	Joined field studies	GEOMAR (VLIZ, G-tec)	COO (BEN, BEN)	GEOMAR; Marine Facility Planning Tool; OSIS Data Base for preliminary filed data
1.6	Project Administration	GEOMAR	COO	GEOMAR administration
1.7	Project Quality Control	GEOMAR, (VLIZ, EGEOS, G-tec)	COO (BEN, BEN, BEN)	

Work Package 2	**Technical developments including field trials and surveys**
Duration: Month 1 – 36	Lead: **VLIZ** Partners: GEOMAR, G-tec

Objectives

The overall goal of WP2 is twofold: (1) to develop and advance new technologies for efficient detection and identification of buried/partly buried munition, and (2) to obtain high-quality data of (buried and exposed) munition at a number of well-chosen test sites.

Task 2.1: Ultra-high resolution 3D-sub-bottom imaging. The multitransducer parametric echosounder (SES-2000 Quattro) will be adapted optimally for cost efficient use in buried munition detection. The array will be made highly flexible with possibility of different transducer configurations. In parallel, a high-res pseudo-3D approach will be developed involving a single transducer and high line density which will ideally be integrated into an autonomous vehicle/platform.

Task 2.2: Magnetometer integration in AUV: Two magnetometers are envisioned to be used with the AUV in a vertical gradiometer setup. We aim at using G-882 cesium-vapor marine magnetometer as these are used by G-tec. G-tec's expertise will be used during the integration testing and validation period. We plan to fix the magnetometers to the AUV frame with a certain distance to electronic bodies, as done during commercial surveys by G-tec. Data will be recorded and provide for real-time analyses through the G-882 electronics.

Task 2.3: Implementing Smart/adaptive mapping and AI application: The ROS-based middleware of the GIRONA AUVs allows direct integration of sensor data into a computing module which will change the mission of the AUV during the survey, depending on the sensor data (smart/adaptive mapping). A predefined survey pattern (crisscrossing and lawn-mowing) will be executed by the AUV. Data will be pre-analysed to provide munition/no-munition information which is used to update a pre-trained AI algorithm with a new ground truth input value.

Tasks 2.4 Field trials & surveys: The new technologies, combined with state-of-the-art techniques such as high-res multibeam, side scan sonar and towed camera, will be tested and verified in 3 different test sites in the Baltic Sea and North Sea. Complementary use of sensors and combination of ship-based and smart AUV-based surveys will be a key factor. In a first stage the techniques/approach will be tested on known sites with suspicious objects or clusters of suspicious objects, exposed on the seafloor in the Kolberger Heide (Site A), afterwards trials will be performed at Site B with buried munition (Lübeck Bay; alternatively or in addition we will select Hooksielplate as test site). Final verification of the approach will happen at Helgoland (Site C) where a complex and also changing pattern of munition occurrences in very different sediment depth need to be expected.

The objectives and resources for each site are as follows:

Kolberger Heide, Site A

Objective: Using existing high res multibeam information we will add AUV-based magnetic surveys and high res subbottom information to acquire a complete data set for training ML methods. It is unknown if and to which extend munition is buried at this site

Resources. We will use GEOMARs ship RV Littorina to acquire data during repeeted surveys as part of a one week exercise. In addition smaller one day cruises with RV Polarfuchs are envisioned to test the implementation of the electro-magnetic instrumentation on GEOMARs AUVs. Additional equipment will come from VLIZ and G-tech these are UHR 3D-sub-bottom profiling (SES-2000 Quattro) and single-transducer pseudo-3D-sub-bottom profiling as well as towed sidescan sonar.

Lübeck Bay, Site B (alternatively Hooksielplate will be used):

Objective: Lübeck Bay has muddy sediment and munition will be buried without giving and surficial expressions. Thus the main objective at this site is to verify our capabilities to detect buried munition and use the AUVs as truly autonomous tools for conclusive data acquisition

Resources: GEOMARs ship RV Littorina will be used during a one week cruise. Additionally equipment will come from VLIZ and G-tech (see above).

Helgoland, Site C

Objective: Helgoland has a widely unexplored dump site and is thus used as final verification site for all used and developed methodologies of *BASTA*. Thus the main objective is to prove that the applied methods are indeed able to perform a fast and correct evaluation of the munition situation.

Resources: We will use again RV Littorina from GEOMAR but also aim at applying for a two weeks cruise with RV ALKOR to perform the survey. All other resources will be the same as stated above, including possible two AUVs from GEOMAR (at least one with the magnetic sensors attached)

Tasks	**Name**	**Description**
Task 2.1	3D-sub-bottom profiling	Step 1 – adaptation of 3D and pseudo-3D-sub-bottom profiling system for efficient buried munition detection. Step 2 – final configuration/approach for UHR 3D SBP imaging
Task 2.2	Integrate magnetometer in AUV	Step 1 – Mechanical, electrical and software integration of magnetometers in AUV, Step 2 – field trials testing survey performance of integration and data quality
Task 2.3	Smart AUV	Step 3 – software integration of real-time data into AUV system and adaptation of system to react on real-time data, Step 4 –Integration of AI in AUV software
Task 2.4	Field trials and surveys	Collection of existing data of sites, planning of cruises, sea trials at Sites A and B

Milestones	**Name**	**WP**	**Lead beneficiary**	**Means of verification**	**Due date**	**Description**
MS6	Fieldwork Site A	2	GEOMAR	Cruise report	9	Ship-based and AUV-based high-res multibeam, side scan, towed

						camera and magnetometer tests at site A.
MS7	3D SBP developments; Phase 1	2	VLIZ	Technical report	18	Adaptation of SES-2000 Quattro for buried munition detection. Optimization of pseudo-3D approach (single transducer), ideally on autonomous vehicle/platform
MS8	Magnetometer integration in AUV	2	GEOMAR	Technical report	18	Mechanical and electrical integration of magnetometers into AUV
MS9	Fieldwork Site B	2	VLIZ	Cruise report	20	Trials of 3D SBP and AUV-integrated magnetometer on test site B
MS10	SBP developments; Phase 2	2	VLIZ	Technical report	30	Final 3D-/pseudo-3D-sub-bottom profiling system
MS11	Smart AUV	2	GEOMAR	Technical report	30	Real-time data acquisition linked with ROS middleware for adaptive mapping based on magnetic readings; implementation of AI models in AUV software framework
MS12	Fieldwork Site C	2	VLIZ	Cruise report	32	Trial of all techniques on test site C

Deliverables	**Name**	**WP**	**Lead beneficiary**	**Type / Dissemination level**		**Due date**	**Description**
D2.1	Cruise report 1	2	GEOMAR & VLIZ	R	Public	10	Digital reports (pdf), English
D2.2	Cruise report 2	2	GEOMAR & VLIZ	R	Public	22	Digital reports (pdf), English
D2.3	Cruise report 3	2	GEOMAR & VLIZ	R	Public	34	Digital reports (pdf), English
D2.4	Technical description UHR 3D-SBP	2	VLIZ	R	Public	36	Digital report (pdf), English
D2.5	Technical description AUV Magnetics	2	GEOMAR	R	Public	36	Digital report (pdf), English

Division of work

Task	**Name**	**Participant**	**Role**	**With help of in-kind contribution/partner organisation**
Task 2.1	3D-sub-bottom profiling	VLIZ	BEN	VLIZ technical department
Task 2.2	Integrate magnetometer in AUV	GEOMAR, G-tec	COO (BEN)	TLZ of GEOMAR and G-tec
Task 2.3	Smart AUV	GEOMAR	COO	engineers of GEOMAR
Task 2.4	Field trials and surveys	GEOMAR (VLIZ, G-tec)	COO (BEN, BEN)	TLZ of GEOMAR, VLIZ technical and research department

Work Package 3	**Multi-sensor database, data integration and visualization**
Duration: Month 1 – 36	Lead: **EGEOS** Partners GEOMAR, VLIZ, G-tec

Objectives

The main objective of this WP is the adaption of the already existing multi-sensor database of AMCUAD.org to fulfil the requirements of including dataset specific quality metrics and methods of artificial intelligence. In addition, a concept will be developed and implemented for visualizing uncertainty based on quality metrics and simplified indicators for rapid situation assessment regarding munition detection.

Task 3.1 Setup interim data compilation platform: An interim data compilation platform will be setup based on the Ocean Science Information System (OSIS – https://portal.geomar.de/web/guest/kdmi) already in place in GEOMAR. The goal of the platform is the fast collection of datasets from stakeholders and partners to be able to start working with real-world datasets before the projected data base can be used.

Task 3.2 Efficient labelling for training datasets and integration of AI modules/methods: A high-quality training dataset is one of the crucial steps towards building AI-based algorithms. Therefore, a system will be developed for an efficient labelling of underwater measurement data to provide training datasets for machine learning algorithms and to be able to continuously improve training datasets over time. The initial training of neural networks itself will be carried out offline based on the data and labels stored in the database. Therefore, an integration of the developed AI modules/methods has to take place and different optimization steps regarding performance, as well as quality and duration of training will be applied.

Task 3.3 Adapt multi-sensor database of AMUCAD.org to include quality metrics: The multi-sensor database of in AMUCAD.org will be modular extended to reflect necessary changes for the calculation of quality metrics. A generalized database model structure will be created for efficient storing and calculation. The design is planned to be open to be able adapt to new types of quality metrics and calculation methods. In addition, algorithms based on GPU processing for large datasets will be developed for extraction and calculation of metrics from the obtained datasets.

Task 3.4 Visualization concept based on already implemented functionality of AMUCAD.org: A visualization concept will be developed for a user-friendly representation regarding uncertainty and quality metrics. This concept will be based on already applied techniques in AMUCAD.org and will technically rely heavily on modern web-based visualization and interaction approaches. Stakeholders as potential end users will be deeply involved in the development process of visualization to include their practical experience in the most useful way.

Resulting functionalities will focus on analysis and interpretation of datasets and visualization of data quality. Therefore, datasets can be interpreted regarding quality metrics on different levels (parameter, sensor and MERGED), weak point analysis can be carried out and different ways for effective visualization data interpretation will be provided (e.g. uncertainty view, raw data view, processed data view). Automatic log entries serve as documentation that will ensure transparent data processing and allow users to track changes. In addition, meaningful parameters (e.g. wave height, line spacing, and spatial resolution) will be made available for the whole datasets and/or areas of specific interest. In addition, the software will provide the possibility to generate a data quality audit report complying with requirements stated in pertinent quality norms, such as DIN EN ISO/IEC 17025:2018.

During the planned stakeholder meetings special (WP5) workshops will be conducted to validate already planned functionality and identify desired features for different stakeholders. Based on the stakeholders' input a visual prototype will be created (e.g. by creating wireframes) and used for iterative feedback rounds. Therefore, the scrum-based methodology of agile software development will be applied which provides highest flexibility in reaction to the user's needs. The work will be linked to WP 5.3 and deadlines will be coupled to milestones 27 and 28.

Tasks	Name	Description
Task 3.1	Interim data compilation platform	Beneficiaries and stakeholders need the ability to provide large amounts of data for further processing and integration. This task focusses on providing the digital infrastructure for the interim data compilation platform
Task 3.2	Efficient labelling for training datasets and integration of AI modules/methods	A system will be developed for an efficient labelling of training datasets and the developed AI modules/methods will be integrated into the database
Task 3.3	Quality metrics integration	Data quality plays a central role for reliable and efficient detection of objects. Therefore, the quality metrics developed in WP5 will be programmatically implemented and verified
Task 3.4	Visualization concept	A visualization concept will be developed regarding uncertainty and quality metrics based on technologies used in AMUCAD.org

Milestones	Name	WP	Lead beneficiary	Means of verification	Due date	Description
MS13	Data platform	3	GEOMAR	Upload of datasets is possible	3	The data platform is established, project beneficiaries and associated organisation can upload datasets
MS14	Data compiled	3	GEOMAR	Initial number of useful datasets are available	6	Uploaded datasets are verified and can be used for further steps
MS15	Database structure	3	EGEOS	Draft of database structure	9	A generalized draft of a database structure reflecting requirements of quality metrics and AI is available
MS16	Data Base alpha version	3	EGEOS	First version (Alpha) in established	18	First version (Alpha) of the application including backend for quality metrics and AI is available for testing of main functionalities
MS17	Data Base beta version	3	EGEOS	Second version (Beta) established	30	Second version (Beta) of the application including backend for quality metrics and AI is available with all planned functionalities
MS18	Demonstrator	3	EGEOS	Demonstrator	36	Demonstrator is available including all functionalities, implemented visualization concept and fixes of known bugs

Deliverables	Name	WP	Lead beneficiary	Type / Dissemination level		Due date	Description *(including format and language)*
D3.1	System use cases and requirement compiled	3	EGEOS	R	Public	9	Description of scenarios and use cases as well as architecture and system requirements; Technical document; Digital report (pdf), English
D3.2	System architecture	3	EGEOS	R	Confidential	12	Analysis of requirements and derivation of design principles and high-level architecture; Technical document; Digital report (pdf), English
D3.3	Design of the application programmin g interface	3	EGEOS	R	Public	24	Design of the application programming interface based on the analysis and concepts in prior deliverables; Technical document; Digital report (pdf), English
D3.4	Visualization concept	3	EGEOS	R	Public	34	Understanding of complex datasets is a key point in transferring data into information; Technical document; Digital report (pdf), English
D3.5	Demonstrator	3	EGEOS	DEM	Confidential	36	Demonstrator is available that includes all functionalities, implemented visualization concept and fixes of known bugs. Software

Division of work

Task	Name	Participant	Role *(COO, BEN, LTP, OTHER)*	With help of in-kind contribution/partner organisation
Task 3.1	Interim data compilation platform	GEOMAR	COO	GEOMAR IT, TenneT, BSH and other stakeholders
Task 3.2	Training dataset compilation and integration of AI modules and methods	EGEOS (G-tec, GEOMAR, VLIZ)	COO (BEN, BEN, BEN)	
Task 3.3	Quality metrics integration	EGEOS (GEOMAR)	COO (BEN)	
Task 3.4	Visualization concept	EGEOS (G-tec)	COO (BEN)	Administrative stakeholders/End-users

Work Package 4	**Data Processing and AI-analytics**
Duration: Month 1 – 36	Lead: **GEOMAR** Partners VLIZ, G-tec, EGEOS

Objectives

The overall objective of this WP is to apply, test and advance data processing methodologies and workflows for (1) SBP and (2) magnetic data and to apply (3) AI methodologies to combined data set. To achieve this objective a number of tasks have been formulated.

Task 4.1 Compile data form other sources than the project partners: The objective is to gather as much already annotated data = data where signals of input data layers have been assigned to be a munition object or not. The task will be to compile data from our supporting partners (TenneT, BSH, …) which will be used as training data for the AI method development in Task 4.4. Data infrastructure is provided through WP3. Info – Data from project field work are compiled as part of WP2.

Task 4.2 Processing of 3D SBP data, develop 3D & pseudo 3D processing workflow: The objective is to optimize and adapt the existing processing routines for pseudo3D- & 3D-sub-bottom data for the high data accuracy that is needed for munition detection and identification. Multibeam data will be integrated with the sub-bottom data to allow precise statistical corrections in order to increase the 3D resolution. Different grid cell sizes will be tested. Smart volume rendering techniques will be applied for optimal visualization of the buried munition.

Task 4.3 Processing of AUV-magnetic data: The objective is to develop processing routines for the AUV acquired magnetic data. Care must be taken to exclude interferences form the AUV induced by its metal parts, power cables and thrusters with magnets. Existing data processing routines need to be adapted to the input data formats of the AUV, data quality and accuracy need to be validated with towed magnetometer measurements to have a precise understanding of data comparability.

Task 4.4 Applying AI methodologies to marine munition data: The objective is to apply and select suitable AI algorithms for munition occurrence prediction including uncertainty evaluation. Several AI methods, e.g. convolutional neural networks, will be tested to run a) as part of the multi-sensor database and b) as pre-trained model on the AUV during surveys. Focus will be given on selecting the most relevant input data layers for different environmental settings and pre-knowledge to prevent the acquisition of redundant layers.

Tasks	Name	Description
Task 4.1	Data compilation	Compile conclusive data from supporting partners that allow training of AI algorithms and their selection
Task 4.2	SBP data processing	Optimize processing and visualization of pseudo 3D- & 3D-sub-bottom data
Task 4.3	AUV-magnetic data processing	Develop processing routines for the AUV acquired magnetic data
Task 4.4	AI development	Determine, test and implement suitable AI methods into the databased workflow and the smart/adaptive mapping by AUV

Milestones	Name	WP	Lead beneficiary	Means of verification	Due date	Description
MS19	Data compilation	4	GEOMAR	Data in database	6	First data of supporting partners available
MS20	SBP processing – alpha*	4	VLIZ	Workflow and test data set reported	18	SBP processing in alpha-version running
MS21	AUV-magnetic processing – alpha	4	G-tec	Workflow and test data set reported	18	AUV-based magnetic data processing in alpha-version running
MS22	AI – alpha	4	GEOMAR	Workflow and first results reported	20	Various AI algorithms tested and test-wise implemented in data base and AUV

*Alpha = first working version

Deliverables	Name	WP	Lead beneficiary	Type / Dissemination level		Due date	Description
D4.1	Processed Data of field campaigns created Part A	4	GEOMAR	DATA	Confidential	12	Data are compiled from partners to train AI methods. The data itself are partly confidential or have been made public by the providers already (BSH)
D4.2	Processed Data of field campaigns created Part B	4	GEOMAR	DATA	Confidential	24	Data are compiled from partners to train AI methods. The data itself are partly confidential or have been made public by the providers already (BSH)
D4.3	Processed Data of field campaigns created Part C	4	GEOMAR	DATA	Confidential	36	Data are compiled from partners to train AI methods. The data itself are partly confidential or have been made public by the providers already (BSH)
D4.4	SBP processing routines and workflows	4	VLIZ	R	Confidential	36	Processing and visualisation workflows described, integration of resulting data into Database (WP3) shown; Digital report (pdf), English
D4.5	AUV-magnetic processing description	4	GEOMAR	R	Confidential	36	Processing AUV-based magnetic data described, integration of resulting data into Database (WP3) shown; Digital report (pdf), English
D4.6	AI method description and software tools	4	GEOMAR	R	Confidential	36	Description of the workflows and used algorithms described, integration of resulting data into Database (WP3) shown; Digital report (pdf), English

Division of work

Task	Name	Participant	Role *(COO, BEN, LTP, OTHER)*	With help of in-kind contribution/partner organisation
4.1	Processed Data of field campaigns created	VLIZ (GEOMAR, G-tec)	BEN (COO, BEN)	GEOMAR & VLIZ students
4.2	SBP processing routines and workflows	VLIZ (G-tec)	BEN (BEN)	
4.3	AUV-magnetic processing description	G-tec (GEOMAR)	BEN (COO)	
4.4	AI method description and software tools	GEOMAR	COO	

Work Package 5	**Facilitate workflow and data quality definitions**
Duration: Month 1 – 36	Lead: **GEOMAR** Partners: VLIZ, G-tec, supporting partners

Objectives

The overarching goal of WP 5 is the definition of best-practice workflows for the data handling process chain, with the aim of expressing the quality of a dataset as a quality value.

Task 5.1 Data quality definition: The first objective is the definition of quality requirements for each of the technologies that are applied for the detection of UXO in WP2. The initial definition is addressing threshold values and cut-off criteria for minimum quality requirements. Subsequently, higher quality levels are defined, leading to the development of a quality metrics for the utilized technologies. A weighting and normalization process is applied, allowing to compare the data quality of different technologies under varying conditions. The highest quality level is determined by the state of technology.

Task 5.2 Best-practice workflow definition: Furthermore, a workflow for the individual steps of data acquisition, integration and processing during multi-sensor application is developed. The goal is the definition of a workflow that is accepted as an industry wide best-practice procedure. During workflow definition the individual process steps will be scrutinized. Both the quality requirements and the best-practice workflow are defined in increments. First, definitions are agreed upon by the involvement of all project partners. Secondly, these are amended and verified through fieldwork campaigns (Task 2.3) by assessing workflows executed during fieldwork activities and by evaluating acquired and processed data.

Task 5.3 Stakeholder involvement: Further verification of results takes place via stakeholder involvement. This is of paramount importance for the industry wide acceptance of the best-practice workflow and the data quality requirements. Before addressing stakeholders, these are first identified and classified for their relevance. Stakeholder involvement mainly takes place by means of workshops, which will be coupled to the annual project meetings. Additionally, results are made available for annotation. Final results are published and disseminated to stakeholders by attending relevant conferences and symposia.

Tasks	**Name**	**Description**
Task 5.1	Data quality definition	The definition of data quality requirements for the different technologies on different quality levels and subsequent generation of a quality metric.
Task 5.2	Best-practice workflow definition	The definition of a workflow for data acquisition and handling that is accepted as a best-practice procedure.
Task 5.3	Stakeholder involvement	The involvement of corporations, authorities, military bodies and other entities that have sufficient knowledge in the application of technology for the technical detection of UXO or will be directly affected by the definition of best-practice workflows.

Milestones	**Name**	**WP**	**Lead beneficiary**	**Means of verification**	**Due date**	**Description**
MS23	Preliminary Quality factors defined	5	GEOMAR	List of quality factors with threshold values and cut-off criteria	6	A preliminary list of quality factors is required before the first fieldwork campaign takes place.
MS24	Preliminary workflow established	5	GEOMAR	Description and graphical depiction of workflow available to stakeholders	9	The workflow of data acquisition and handling as agreed upon by the project partners.
MS25	Data quality described per dataset	5	GEOMAR	Quality factors and preliminary quality metrics available to stakeholders	12	The data quality requirements as agreed upon by the project partners.
MS26	Workflow and quality factor verification 1	5	GEOMAR	Documented annotations to workflow and quality requirements	22	Results of Tasks 5.1 and 5.2 are verified by stakeholder workshops and field campaigns. The results are specified and amended.
MS27	Workflow and quality factor verification 2	5	GEOMAR	Documented annotations to workflow and quality requirements	34	Results of Tasks 5.1 and 5.2 are verified by stakeholder workshops and field campaigns. The results are specified and amended.

Deliverables	**Name**	**WP**	**Lead beneficiary**	**Type / Dissemination level**		**Due date**	**Description** *(including format and language)*
D5.1	Best-practice workflow	4	GEOMAR	R	Public	34	A workflow describing the process of data acquisition and handling as a flow chart (Guideline document), Digital report (pdf), English
D5.2	Quality requirement document	4	GEOMAR	R	Public	34	A glossary of quality requirements and a description of these requirements for different quality levels (Guideline document), Digital report (pdf), English

Division of work				
Task	**Name**	**Participant**	**Role**	**With help of in-kind contribution/partner organisation**
Task 5.1	Data quality definition	GEOMAR (G-tec, VLIZ)	COO (BEN, BEN)	
Task 5.2	Workflow and requirement definition	GEOMAR (G-tec; EGEOS, VLIZ)	COO (BEN, BEN, BEN)	
Task 5.3	Stakeholder involvement	GEOMAR (Stakeholders)	COO (OTHERS)	

3.2 Timetable

The following table displays the pursued timeline of the project in a bimonthly fashion. Milestones are entered in olive and deliverables are entered in blue. The preceding working time is displayed in black.

Activity	**Month** (bimonthly)																	
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Task 1.1	MS1																	
Task 1.2	MS2	D1.2				MS3 D1.5	D1.5					MS4	D1.7					MS5 D1.9
Task 1.3		D1.1																
Task 1.4						MS3						MS4						
Task 1.5																		
Task 1.6			D1.3			D1.4						D1.6			D1.8			
Task 1.7																		
Task 2.1									MS7						MS10			D2.4
Task 2.2									MS8									D2.5
Task 2.3															MS11			
Task 2.4					MS6 D2.1					MS9	D2.2					MS12	D2.3	
Task 3.1		MS13	MS14		D3.1													
Task 3.2					MS15	D3.2												
Task 3.3									MS16			D3.3						M18
Task 3.4															MS17		D3.4	D3.5
Task 4.1			MS19			D4.1						D4.2						D4.3
Task 4.2									MS20									D4.4
Task 4.3									MS21									D4.5
Task 4.4										MS22								D4.6
Task 5.1			MS23			MS25					MS26						MS27 D5.1	
Task 5.2					MS24						MS26						MS27 D5.2	
Task 5.3																		

Milestones listed by WPs

Number	Milestone name	Due date	WP	Lead beneficiary
1	Governance	1	1	GEOMAR
2	Kick-Off Meeting	2	1	GEOMAR
3	1st Annual Meeting	11	1	GEOMAR
4	2nd Annual Meeting	23	1	GEOMAR
5	Final Event	35	1	GEOMAR
6	Fieldwork Site A	9	2	VLIZ
7	3D SBP developments; Phase 1	18	2	GEOMAR
8	Magnetometer integration in AUV	18	2	VLIZ
9	Fieldwork Site B	20	2	VLIZ
10	SBP developments; Phase 2	30	2	GEOMAR
11	Smart AUV	30	2	VLIZ
12	Fieldwork Site C	32	2	GEOMAR
13	Data platform	3	3	GEOMAR
14	Data compiled	6	3	GEOMAR
15	Database structure	9	3	EGEOS
16	Alpha-Version	18	3	EGEOS
17	Beta-Version	30	3	EGEOS
18	Demonstrator	36	3	EGEOS
19	Data compilation	6	4	GEOMAR
20	SBP processing – alpha	18	4	VLIZ
21	AUV-magnetic processing – alpha	18	4	G-tec
22	AI – alpha	20	4	GEOMAR
23	Preliminary Quality factors defined	6	5	GEOMAR
24	Preliminary workflow established	9	5	GEOMAR
25	Data quality described per dataset	12	5	GEOMAR
26	Workflow and quality factor verification 1	22	5	GEOMAR
27	Workflow and quality factor verification 2	34	5	GEOMAR

Deliverables

Number	Deliverable name	Due date	WP	Lead beneficiary
D1.1	Webpage	3	1	GEOMAR
D1.2	Meeting minutes of the Kick-Off Meeting	3	1	GEOMAR
D1.3	1st Periodic Progress Report	6	1	GEOMAR
D1.4	2nd Periodic Progress Report	12	1	GEOMAR
D1.5	Meeting minutes of the 1st Annual Meeting	14	1	GEOMAR
D1.6	3rd Periodic Progress Report	24	1	GEOMAR
D1.7	Meeting minutes of the 2nd Annual Meeting	26	1	GEOMAR
D1.8	4th Periodic Progress Report	30	1	GEOMAR
D1.9	Meeting minutes of the Final Event	36	1	GEOMAR
D2.1	Cruise report	10	2	GEOMAR & VLIZ
D2.2	Cruise report	22	2	GEOMAR & VLIZ
D2.3	Cruise report	34	2	GEOMAR & VLIZ
D2.4	Technical description UHR 3D-SBP	36	2	VLIZ
D2.5	Technical description AUV Magnetics	36	2	GEOMAR
D3.1	System use cases and requirement compiled	9	3	EGEOS
D3.2	System architecture	12	3	EGEOS
D3.3	Design of the application programming interface	24	3	EGEOS
D3.4	Visualization concept	34	3	EGEOS
D3.5	Demonstrator	36	3	EGEOS
D4.1	Processed Data of field campaigns	12	4	GEOMAR
D4.2	Processed Data of field campaigns	24	4	GEOMAR
D4.3	Processed Data of field campaigns	36	4	GEOMAR
D4.4	SBP processing routines and workflows	36	4	GEOMAR
D4.5	AUV-magnetic processing description	36	4	GEOMAR
D4.6	AI method description and software tools	36	4	GEOMAR
D5.1	Best-practice workflow	34	5	GEOMAR
D5.2	Quality requirements	34	5	GEOMAR

4. PARTICIPANTS & PROJECT MANAGEMENT

4.1 Participants

The following table contains participants (without linked third parties) of the *BASTA* project, their short name as utilized in this project proposal and the country they are located in.

Role	Name	Short name	Country
COO	GEOMAR Helmholtz Centre For Ocean Research Kiel	GEOMAR	Germany
BEN	Flanders Marine Institute	VLIZ	Belgium
BEN	EGEOS GmbH	EGEOS	Germany
BEN	G-tec	G-tec	Belgium

Consortium cooperation & division of roles

Two marine science centres, GEOMAR and VLIZ and two industry partners, EGEOS and G-tec, join forces for *BASTA* project presented herein. The group is supported by a number of associated partners who are willing to share data and are interested as stakeholders. Many of them have been involved in other projects with the proponents before. Each of the beneficiaries will be involved in several of the WPs, making sure that the *BASTA* sees substantial contributions from all partners. Beneficiaries' competencies and resources are highly diverse. Cooperation on the different WPs is described in section 4.1. It will lead to the creation of synergies that would not be possible without the joint execution of the project. The following paragraphs outline the division of roles.
In order to ensure complementary work of the beneficiaries, a communication chart will be designed at the beginning of the project in order to document the interface between organizations. It will contain contact information of involved personnel resources, assign responsibilities to these resources and define response times. Furthermore, formats data file and document exchange will be determined. Finally, the communication chart will contain escalation strategies for risk management purposes.
The management structure of *BASTA* is based on the simplified Horizon 2020 Model Consortium Agreement (DESCA). "*BASTA*" will be coordinated by J. Greinert, GEOMAR. The coordinator will serve as the main link between the consortium members and the Research Executive Agency (REA) of the European Commission (EC), monitoring and supporting the Steering Committee (SC). The Steering Committee will act as an advisory decision making committee for issues related to *BASTA*. The SC will be established before the start of the project and consists of one representative of each beneficiary and as an external impartial member Mr Jens Sternheim, Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung of the state Schleswig-Holstein. Decision making will be implemented by reaching a simply priority.

GEOMAR is one of 19 Helmholtz Centres in Germany who undertake research in any aspect of science. GEOMAR is one of three marine centres within Helmholtz, mainly working in the open ocean, but in some cases also close to shore. GEOMAR covers a cacophony of aspects in marine research, ranging from physical oceanography, marine meteorology, geology and geophysics, benthic and pelagic biogeochemistry to biology and microbiology. Research topics include 'Marine Resources', 'The Role of the Ocean in Climate Change', 'Marine Hazards' and 'Human impact on Marine Ecosystems'. GEOMAR has long lasting experiences in coordinating FP7, H2020 and other international and national large scale projects (https://www.geomar.de/en/research/large-scale-research-projects/). Next to its scientific tasks, GEOMAR operates large scale equipment, among them three AUVs, two ROVs and smaller systems like mobile multibeam systems, a large number of lander-based and seafloor deployable camera systems and many others. The main proponent of GEOMAR (Prof. Greinert) is head of the DeepSea Monitoring (DSM) group and is currently coordinating the BMBF funded Project UDEMM (https://udemm.geomar.de/) that deals with investigating WWII munition dump sites in Kolberger Heide and other munition dump sites in Baltic Sea. Six computer scientists are currently employed in the DSM group, who deal with different aspects of data science in the broadest sense, among them the application of artificial intelligence. Prof. Greinert coordinates the GEOMAR part in the infrastructure project MOSES (https://www.ufz.de/moses/) in which two GIRONA 500 AUVs were bought and are continuously developed further. GEOMAR will also employ Torsten Frey, who coordinated the research project OffVali and who is the lead author of the Quality Guideline for Offshore UXO treatment. In this project Mr. Frey has gained major experience in the coordination of stakeholder involvement processes. (www.geomar.de)

VLIZ is Flanders' main centre for marine and coastal research. It has supported the marine science community in Flanders since 1999 and has performed and initiated marine research since 2017. VLIZ will bring its expertise in marine geophysical research into the project, together with its comprehensive marine research infrastructure (including various acoustic systems, autonomous underwater vehicles (AUV, USC) and the research vessel RV Simon Stevin). VLIZ maintains excellent connections with national and European research groups. The project responsible at VLIZ, Dr. Tine Missiaen, has longstanding experience in marine geophysical, geological and geotechnical research with emphasis on very-high-resolution sub-bottom imaging. She has been actively involved over 25 years in munition dumpsite research in the North Sea and Baltic Sea (e.g. EU FP7 MERCW project). She is coordinator of the recently granted project 'DISARM' (2019-2022) on the WW1 Paardenmarkt dumpsite off the Belgian coast. (http://www.vliz.be/en/)

EGEOS is a software development company dealing with high-performance and complex individualized applications, tailored to specific user needs and operational procedures. For development of data intensive IT projects, most up to date OpenSource software and technologies are used. EGEOS has extensive experience in development and management of large database structures incorporating heterogeneous datasets. Projects carried out involve complex spatial and temporal datasets, resulting in deep knowledge about management of geographical data in databases. Besides developing customer specific solutions, EGEOS participates in several national and international research projects focusing on submerged munitions. The results of the projects DAIMON (Interreg Baltic Sea Region), North Sea Wrecks (Interreg North Sea Region) and ErPaD (Investitionsbank Schleswig-Holstein) will be included in the "Ammunition Cadastre Sea" (AMUCAD) developed by EGEOS. (www.egeos.de/)

G-tec is a Belgian based contractor specialized in worldwide geophysical, geotechnical and environmental investigations. With its excellent and suitable equipment and an international team of highly skilled geologists, engineers, biologists and technicians G-tec constantly sets benchmarks for high-quality and safe geo-engineering services in the onshore, intertidal and shallow offshore environment. Founded in 1993 with an academic background, G-tec aims at keeping its scientific rigor and at supporting its clients with feasible and sustainable projects. This is reflected in a continuous R&D scheme and collaboration with leading scientific institutions. G-tec participated in a high number of industrial UXO detection and removal projects, in the EU FP7 MERCW research project (Baltic sea) and was involved in various investigations of the WW1 dumpsite "Paardenmarkt". (http://www.g-tec.eu/en)

Numerous **third parties will be linked** to the *BASTA* project. Confirmed parties are TenneT, Vattenfall, DEME - Dredging International nv, BSH, Schleswig-Holstein's Ministry for the Environment and the World Wildlife Fund. Third parties have been selected carefully in such a way that their input will benefit long-term impact of project results. All of the above will directly benefit from all pursued project results and are therefore inherently interested in project success. Provision of survey data, workshop participation as well as requirements definition for technology advancement and data processing are main contributions that the third parties can make. Over the course of *BASTA* the beneficiaries aspire to link further third parties to the project in order to increase representativeness of results.

4.2 Project management

Critical risks & risk management strategy

Due to the high complexity of the project, numerous risks, uncertainties and difficulties may arise during the execution of the different work packages. The following table lists risks that may arise during *BASTA*, links them to the affected work packages and briefly identifies measures for risk management.

Description of risk	Work package	Proposed risk-mitigation measures
Field survey sites could turn out to be unsuitable for the testing and verification of technology developments.	WP2	Alternative field survey sites will be identified during the first year of project execution; Site A and B are already known to the proponents although sub-bottom studies have not been made yet
Weather may not allow for execution of field surveys.	WP2	Flexibility for the period of field surveys has already been included in timetable.
Human Safety	WP2	Fieldwork will be conducted in parts in closed areas because they are dedicated munition dumping grounds (Kolberger Heide). Human safety is thus highest priority and ships operations will include that no equipment is lowered to the ground. Work on deck will conducted by following strict 'safety first' rules, which is common to all participants. Thus human safety risks will be in the normal range of sea going operations.
Chemical Leakage	WP2	No chemicals will be used during the ships operations, munitions at site A and B are only conventional. Site C might have portions of chemical munition, but physical sampling of the sediment will not be undertaken. Thus chemical leakage risks can be neglected
Marine Life	WP2	Impact on marine live might come from the operation of acoustic equipment. All the used equipment is high frequency and low energy as we are working in shallow water. The degree of interference will be in the range of normal low-level geophysical operations and ambient noise of the marine environment.

Equipment malfunction/ loss	WP2	The risk of equipment malfunction and loss exists. Malfunctioning might occur during the first tests of the magnetic gradiometers on the AUV at Site A. The work at Site A will be day cruises, meaning technical problems can be worked on during the evening or even at sea. Prior testing of the equipment before the cruise will be of course done. All the other equipment is proven technology and will work reliably as all partners are well trained for their operations. Loss of equipment is minimal and includes the normal danger of operating equipment at sea. Highest risks are given during deployment and recovery of equipment when seat state is not ideal. However, the shallow water depth enables a fast recoverey well before sea state is getting problematic. Thus we do not foresee higher risks for equipment malfunction and loss than normal.
Input data may be highly diverse, making it challenging to integrate them into one database.	WP3	Types of input data will be ranked according to their relevance for munition detection, in order to be able to abandon less relevant datasets.
Data availability is lower than expected or stakeholders are unwilling to allow integration of their data into the EGEOS database for tests.	WP 3	Data can be anonymized and no publication of data origin required for testing procedures. A wide variety of stakeholders will be involved to ensure sufficient amount of data for testing.
Performance risk of database and data processing.	WP3, 4	Performance will be a main focus during the concept phase of both WP.
Short innovation cycles in the area of information technologies.	WP3, 4	Agile development will allow for on the fly adaptation of database, data processing and data analytics.
Acceptance in the industry of applied quality measures.	WP5	Transparent process of best-practice workflow design and quality requirements definition.
Industrial stakeholders will not openly discuss pros and cons of proposed workflows by giving a more detailed insight into their workflows.	WP5	Workflows will be anonymized. Trust will be built early on in the project by providing preliminary results to demonstrate potential quality gains.
Highly competitive maritime survey market and uncertain market situation.	WP2, 3, 4	Early involvement of potential customers and contracting authorities.
As technology selection hardly ever a full objective process, conservatism may lead to rejection of project results.	WP2, 3, 4, 5	Early involvement of potential customers and contracting authorities.

Monitoring & evaluation strategy

Performance and timeliness of project milestones and deliverables will be monitored in two ways. First, internal management procedures will be performed by the individual beneficiaries. The scientific work is arranged in four distinct work packages (WP2-5). Each of the WPs contains different tasks with associated deliverables. For each deliverable one partner is assigned to coordinate and follow up the progress. This coordinating partner (COO) ensures the high quality of the accomplished work and realization of the research objectives, and has prime responsibility for good collaboration with other partners involved in the task/deliverable.

Secondly, overall project control (scientific and budgetary) is integrated into WP1 and will therefore be performed by Prof. Greinert (GEOMAR). Main mechanism for progress monitoring will be six-monthly meetings of the beneficiaries (ideally 1 skype meeting and one physical meeting each year). During the meetings, scope verification, schedule control and quality control will be performed for each WP individually. They serve to identify possible gaps or risks, detect possible overlap between the activities or potential adaptions of the timetable. Any decision on changes to the work plan shall require the unanimous decision of all partners. For each WP separate activity meetings will be organized according to the actual need and depending on the timing of the task. Additionally, intermediary reports to funding body.

Outreach will be evaluated in numerous ways. Attendance during stakeholder and final events will be documented and discussion points will be recorded. The outreach of the publication in scientific journals (as outlined in section 5.3) will be evaluated by the impact factor of these journals. Record will also be kept, regarding all those events that project beneficiaries attend, in order to present or introduce the project. The project website will be search engine optimized.

The overall performance of *BASTA* will be evaluated by project indicators defined in the Annex 3. It is possible to divide these indicators into two categories reflecting. Multidisciplinary partnerships and enhanced cooperation are a key element of the project. The exchange between research, business and administration in terms of knowledge, methods and mindsets is given due to the composition of the stakeholders group but also due to the project partners who are working the first time together in this constellation. It is expected that several new cooperations (5-10) can be realized over the project time and in particular the involved SMEs will benefit from access to stakeholders which are partly large and worldwide operating enterprises (e.g. DEME, TenneT, Vattenfall). The field of product development will be affected in several ways. EGEOS is planning for example to transfer the resulting methods and approaches into a long-term sustainable product/service due to the integration into the already existing "Ammunition Cadastre Sea".

In this context two potential patents will be evaluated regarding the dynamic computation of quality metrics and the integration of specific artificial intelligence algorithms into the multi-sensor database. The planned product/service will have positive effects on sustainable use of marine resources due to better identification of munitions and the reduction of munitions-related chemicals in the seas. In addition, new employments will be established already during the project phase and several new jobs are expected during and after the development of a marketable product. The approach itself will be modular and transferable and can therefore be applied worldwide. This will be underlined by the measures carried out to establish standards/guidelines and workflows especially in the industry. Evaluation of this indicator can be done by the number of large enterprises willing to corporate. During the project two sea-basins with most diverse requirements are included (Baltic Sea and Greater North Sea) to facilitate highly generalized project outputs and transferability.

4.3 Dissemination, communication & visibility

Dissemination, communication and visibility of the project are coupled to WP1 and WP5. The organizational setup and maintenance of a project website, the design of a logo and the activities surrounding the organization of stakeholder events are integrated in WP1. The development of workshop content and the dissemination of results are integrated in WP5. The website will be set up by the third month of the project's runtime, thereby ensuring basic visibility from the very start. The website will cover the project, its objects and approaches as well as the pursued impacts. The webpage will serve as a central repository for project information (intranet) and will be updated in accordance with the milestones (section 4.2). We will use the server capacities at GEOMAR and TYPO3 as content management system.

News items on the website will feature videos and photos of fieldwork and of technological developments as well as front end mock-ups of the multisensory database, to communicate tangible project outcomes. Physical dissemination collaterals will be designed (e.g. flyers and posters), containing similar information as the project overview feature on the website. A logo will be designed that will be placed on the project website, websites of beneficiaries, dissemination collaterals and presentation slides. The EU funding through Blue Labs will be highlighted in each of the above. Linked third parties will be invited to use the logo as well. All public information will be available in English.

The project kick-off will be announced via an information email to relevant stakeholders. Mailing lists can be obtained from previous projects (UDEMM, RoBEMM-OffVali, DAIMON) and the client base of G-Tec and EGEOS. Stakeholder events will be announced through the same mailing lists with adequate lead time. The events will feature a combination of results presentation and stakeholder involvement activities. Interims and final results presentation will take place via the following channels:

- Project website
- Beneficiaries websites
- Relevant conferences and events (e.g. Fachtagung Kampfmittelbeseitigung des BDFWT, Fachtagung Kampfmittel der Sprengschule Dresden, international WindEurope, Offshore Wind R&D Conference, Pipeline Technology Conference (PTC) and Offshore Pipeline Technology Conference (OPT))
- Final event (MS 5)
- Scientific publications and industry newspapers

The results of WP5 (data quality requirements and best-practice workflow) will be formalized and publication is aimed to be partnered with an existing standard setting of private and public institutions (e.g. DNV-GL, IMCA, IMO). Other results will be published in appropriate scientific journals on marine research (e.g. Marine Geology, Continental Shelf Research) or quality management (e.g. Journal of Quality Management, Environmental Quality Management, Measuring Business Excellence). Addressees of all the mentioned dissemination, communication and visibility activates will be maritime surveyors, munitions clearance specialists, relevant EU, national and regional authorities (e.g. for shipping, offshore construction, maritime environment, occupational health and safety), offshore construction and dredging companies and operators of offshore structures (e.g. wind parks, pipelines and cables).

4.4 Ethics, environment & security

Environment

Increasing the energy efficiency in buildings and infrastructure is already common practice for all partners. The number of physical meetings will be kept to a strict minimum. Meetings will happen by web- or telephone-conference with the aim of reducing the environmental footprint as much as possible. Most partners have strict public transport policies. Therefore, generally environmentally friendly transport – trains instead of planes or cars - will be chosen. E.g. at VLIZ, for meetings that can be reached by train journeys of less than < 6 h, trains must be taken. EGEOS compensates the carbon footprints of business trips via a specific offset program (www.atmosfair.de). If car transport is needed (e.g. for field work) this will take place with environmental friendly (electric) cars when possible (e.g. VLIZ has electric cars for this purpose).

In order to minimize travelling both for beneficiaries and for linked third parties it is intended to link stakeholder involvement to other, already established events. Opportunities arise during meetings of munitions working groups of HELCOM (SUBMERGED group) and OSPAR, or workshops taking place as part of the JPI Oceans Joint Action Munitions in the Sea. Other feasible events are conferences of munitions specialists and offshore developers (such as the ones outlined in section 5.3).

Field work campaigns will be reduced to a minimum, as the majority of necessary data is already available from past surveys among others conducted by GEOMAR and G-TEC. Other data will be acquired from linked third parties. The two initial field work campaigns serve to test/optimize the new techniques and complete the dataset for enabling more representative multi-sensor data integration. The third field work campaign will verify the approach. During the field work, the preliminary workflows will be verified, thereby inherently balancing quality requirements and economic efficiency.

Possible survey sites have been selected to be situated close to GEOMAR and G-Tec maritime resources, which reduce travel distance during field work. Finally, since data acquisition is automatically monitored and recorded during the survey, crew numbers as well as ship size and therefore fuel consumption will be kept at a minimum. G-TEC has a QSHE policy (plus ISO 14001 certification) which addresses the reduction of environmental impact during survey work and the use of sustainable techniques.

The proposed hydroacoustic technical equipment such as multibeam, side scan and sub-bottom profiling (SBP) systems are all very high frequency systems in their specific type of systems. Multibeam and side scan systems range from 200 kHz to 1600kHz and are thus very high frequent, causing no harm to mammals with the used pressure level. The applied SBP techniques operate in a frequency range roughly between 8kHz and 100kHz and at low pressure levels which do not harm mammals. Magnetometers are passive sensors, measuring the earth magnetic field and do not emit energy in the form of acoustic or electromagnetic signals. Electromagnetic systems emit electromagnetic pulses, which do however only range few meters.

Ethics

Data of providers will only be used with informed consent, which means that they understand the aim of the research, know that they can stop participating at any time and that their information is kept secret. In addition, only data is used that is truly needed for achieving the desired project results and irrelevant data is immediately deleted. All data collections and participation of project partners and stakeholders will be conducted in full agreement to the General Data Protection Regulation (GDPR) of the European Union.

5. DECLARATIONS

Other EU funding	
Information concerning other EU grants for this project *Please note that there is a strict prohibition of double funding. It is important that you provide full and complete information on all other EU funding for the project.* *Give information on any other grant applications pending or similar projects submitted by your consortium. Name the EU programme, project reference number and title. Include EU funding managed by authorities in EU Member States or other funding bodies.*	**YES/NO** (if NO, add details)
We confirm that to our best knowledge neither the project as a whole nor any parts of it have benefitted from any other EU grant.	YES
We confirm that to our best knowledge neither the project as a whole nor any parts of it are (nor will be) submitted for any other EU grant.	YES
Information concerning other funding for this project	
Will the project get any funding from other public sources (EU, national, international)?	NO
Will the project be part of a set of coordinated/complementary/joint projects which get funding from other public sources (EU, national, international)?	NO

Information concerning other EU funding in the same policy area

Have any of the participants already benefitted from funding under this EU programme (or previous programmes)? Include EU funding managed by authorities in EU Member States or other funding bodies (e.g. EIB loans etc).

The labels used mean: COO — Coordinator; BEN — Beneficiary; LTP — Linked third party/affiliated entity.

Participant	Name of EU Programme	Reference number and title of the project	Role (COO, BEN, LTP, OTHER)	Amount (EUR)	Project website (if any)
VLIZ	EU - EMFF (BlueEconomy Call, Strand 2: Marine Litter)	AQUA-LIT	BEN	72,396	

Information concerning other EU funding in other policy areas

Have any of the participants benefitted from EU funding in other policy areas in the last 4 years? Include EU funding managed by authorities in EU Member States or other funding bodies (e.g. Regional Funds, Agricultural Funds, EIB loans etc).

Note: *If the funding was awarded to a group of beneficiaries, mention only the amount awarded to the participant.*

Participant	Name of EU Programme	Reference number and title of the project	Role (COO, BEN, LTP, OTHER)	Amount (EUR)	Project website (if any)
GEOMAR*	H2020	690416 ROBUST	BEN	549,000	http://eu-robust.eu
GEOMAR*	H2020	654182 ENVRI+	BEN	91,000	http://www.envriplus.eu/
GEOMAR*	H2020	603418 MIDAS	BEN	660,240	http://www.eu-midas.net/
VLIZ	H2020	730960 SeaDataCloud	BEN	208,000	https://www.seadatanet.org/About-us/SeaDataCloud
VLIZ	H2020	633211 ATLANTOS	BEN	40,000	https://www.atlantos-h2020.eu/
VLIZ	INTERREG North Sea Region	North Sea Wrecks	BEN	363,850	https://northsearegion.eu/nsw/about/
EGEOS	INTERREG North Sea Region	North Sea Wrecks	BEN	221,425	https://northsearegion.eu/nsw/about/

*Only those with participation of the proponent Prof. Greinert are listed for GEOMAR; GEOMAR e.g. coordinates ATLANTOS.

6. APPENDIX

6.1 References used in the proposal

Arbeitskreis Arbeitshilfen Kampfmittelräumung (2014). Arbeitshilfen Kampfmittelräumung. Baufachliche Richtlinien zur wirtschaftlichen Erkundung, Planung und Räumung von Kampfmitteln auf Liegenschaften des Bundes. 2. Auflage. Berlin, Bonn: Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB), Bundesministerium der Verteidigung (BMVg).

Beck A.J., Gledhill M., Schlosser C., Stamer B., Böttcher C., Sternheim J., **Greinert J.**, Achterberg E.P. (2018). Spread, Behavior, and Ecosystem Consequences of Conventional Munitions Compounds in Coastal Marine Waters. Frontiers in Marine Science 141 (5). (doi: 10.3389/fmars.2018.00141).

Bundesministerium der Justiz und für Verbraucherschutz (1996). Gesetz über die Durchführung von Maßnahmen des Arbeitsschutzes zur Verbesserung der Sicherheit und des Gesundheitsschutzes der Beschäftigten bei der Arbeit (Arbeitsschutzgesetz). ArbSchG.

Bundesministerium der Justiz und für Verbraucherschutz (2002). Gesetz über explosionsgefährliche Stoffe (Sprengstoffgesetz). SprengG.

Bundesministerium für Wirtschaft und Energie (w.Y.). Munitionsaltlasten. Available at: http://www.erneuerbare-energien.de/EE/Navigation/DE/Forschung/Windenergie-auf-See/Munitionsaltlasten/munitionsaltlasten.html. Last checked: 15.01.2019.

Cooper, N.; Cooke, S. (2015). Assessment and management of unexploded ordnance (UXO) risk in the marine environment. London: CIRIA.

DIN EN ISO 9000 (2015). Qualitätsmanagementsysteme - Grundlagen und Begriffe (ISO 9000:2015); Deutsche und Englische Fassung.

European Commission (2017). Report on the Blue Growth Strategy Towards more sustainable growth and jobs in the blue economy. final. Commission Staff Working Document. 128. Brussels. Available at: https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/swd-2017-128_en.pdf. Last checked: 19.01.2019.

Federal Ministry for Economic Affairs and Energy (BMWi) (2015). Offshore wind energy. An overview of activities in Germany. The energy transition - a great piece of work. Hg. v. Federal Ministry for Economic Affairs and Energy (BMWi). Berlin. Last checked: 25.09.2018.

Frey, T., Holländer, R. (2019). Qualitätsleitfaden Offshore-Kampfmittelbeseitigung. v 1.0. Leipzig: Universität Leipzig - Wirtschaftswissenschaftliche Fakultät - Institut für Infrastruktur und Ressourcenmanagement, in press.

Gutowski, M., Bull, J., Dix, J., Henstock, T., Hogarth, P., Hiller, T., Leighton, T., White, P. (2008). Three-dimensional high-resolution acoustic imaging of the sub-seabed. Applied Acoustics, 69, 412–421.

International Marine Contractors Association (IMCA) (2016). Entry level requirements and introductory modular course outline for new remotely operated vehicle (ROV) personnel. Rev. 3. Remote Systems & ROV Division. R 002.

International Maritime Organization (1975). Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter.

International Organization for Standardization. (2016). How to write standards. Vernier: ISO.

Missiaen, T. (2005). VHR marine 3D seismics for shallow water investigations: some practical guidelines. Marine Geophysical Researches, 26, 145-155. (doi:10.1007/s11001-005-3708-7).

Missiaen, T., Feller, P. (2008). Very high resolution seismic and magnetic investigations of a chemical munition dumpsite in the Baltic Sea. J. Applied Geophysics, 65, 142-154. (doi: 10.1016/j.appgeo.2008.07.001).

Missiaen, T., Evangelinos, D., Claerhout, C., De Clercq, M., Pieters, M., Demerre, I. (2017). Archaeological prospection of nearshore and intertidal area using ultra-high resolution marine acoustic techniques: Results from a test study on the Belgian coast at Ostend-Raversijde. Geoarchaeology, 1-15. (doi: 10.1002/gea.21656).

OECD (2016). The Ocean Economy in 2030. Paris: OECD Publishing.

United Nations (1994). United Nations Convention on the Law of the Sea. UNCLOS. United Nations Treaty Series 1833 (31363), 397–581.

6.2 References of proponents

Abbondanzieri, M., Klein, T., **Frey, T.**, Müller, P. (2018). RoBEMM. Robotisches Unterwasser-Bergungs- und Entsorgungsverfahren inklusive Technik zur Delaboration von Munition im Meer, insbesondere im Küsten- und Flachwasserbereich. In: Tagungsband der Statustagung 2018. Statustagung Maritime Technologien 2018. Berlin. 13.12. Forschungszentrum Jülich GmbH (ed). Jülich: Zentralbibliothek, Verlag (Schriftenreihe Forschungszentrum Jülich), 159–167.

Beck A.J., Gledhill M., Schlosser C., Stamer B., Böttcher C., Sternheim J., **Greinert J.**, Achterberg E.P. (2018). Spread, Behavior, and Ecosystem Consequences of Conventional Munitions Compounds in Coastal Marine Waters. Frontiers in Marine Science 141 (5). (doi: 10.3389/fmars.2018.00141).

Chademenos, V., Stafleu, J., **Missiaen, T.**, Kint, L. & Van Lancker, V. 2019. 3D subsurface characterization of the Belgian Continental Shelf: a new voxel modelling approach. Netherlands Journal of Geosciences (NJG), in press.

Frey, T. (2018). Ansätze zur Risikobeurteilung für die Beseitigung von Kampfmittelaltlasten im Meer. In: Deutsche Gesellschaft für Abfallwirtschaft e.V., Tagungsband. 8. Wissenschaftskongress "Abfall- und Ressourcenwirtschaft". Wien: innsbruck university press.

Frey, T. (2018). Generation of a Quality Guideline for the Treatment of Unexploded Ordnance Faced During Offshore Wind Park Construction. In: Proceedings. WindEurope 2018 Conference at the Global Wind Summit. Hamburg. 25.-28.10. WindEurope asbl/vzw.

Frey, T., Holländer, R. (2019). Qualitätsleitfaden Offshore-Kampfmittelbeseitigung. v 1.0. Leipzig: Universität Leipzig - Wirtschaftswissenschaftliche Fakultät - Institut für Infrastruktur und Ressourcenmanagement, in press.

Missiaen, T., Henriet, J.-P. (eds) 2002. Chemical munition dump sites in coastal environments. Brussels: OSTC Special Publication.

Missiaen, T., Henriet, J.-P., Paardenmarkt Project Team (2002). Chemical munitions off the Belgian coast: an evaluation study. In: T. Missiaen & J.-P. Henriet (eds.), Chemical munition dump sites in coastal environments, 65-79.

Missiaen, T. (2005). VHR marine 3D seismics for shallow water investigations: some practical guidelines. Marine Geophysical Researches, 26, 145-155. (doi: 10.1007/s11001-005-3708-7).

Missiaen, T., Feller, P. (2008). Very high resolution seismic and magnetic investigations of a chemical munition dumpsite in the Baltic Sea. J. Applied Geophysics, 65, 142-154. (doi: 10.1016/j.appgeo.2008.07.001).

Sanderson, H., Fauser, P., Thomsen M., Vanninen P., Soderstrom M., Savin Y., Khalikov I., Hirvonen A., Niiranen S., **Missiaen, T.**, Gress A. et al. (2010). Environmental Hazards of Sea-Dumped Chemical Weapons. Environmental Science and Technology, 44**(**12), 4389-4394.

Missiaen, T., Söderström, M., Popescu, I., Vanninen, P. (2010). Evaluation of a munition dumpsite in the Baltic Sea based on geophysical and chemical investigations. Science of the Total Environment, 408 (17), 3536-3553.

Missiaen, T., Evangelinos, D., Claerhout, C., De Clercq, M., Pieters, M., Demerre, I. (2017). Archaeological prospection of nearshore and intertidal area using ultra-high resolution marine acoustic techniques: Results from a test study on the Belgian coast at Ostend-Raversijde. Geoarchaeology, 1-15. (doi: 10.1002/gea.21656).

Missiaen, T., Sakellariou, D., Flemming, N. (2017). Survey strategies and techniques in underwater geoarchaeological research: an overview. In: Bailey, G., Harff, J. & Sakellariou, D. (eds), Under The Sea: Archaeology and Palaeolandscapes of the Continental Shelf. Elsevier Coastal Research Library, 21-37.

Missiaen, T., Slob, E., Donselaar, M.E. (2008). Comparing different shallow geophysical methods in a tidal estuary, Verdronken Land van Saeftinge, Western Scheldt, The Netherlands. Netherlands Journal of Geology (NJG), 87 (2), 151-164.