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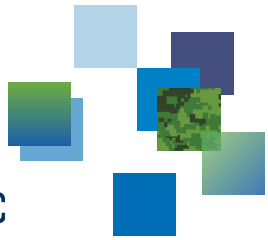

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Battlespace Characterization Work Breakdown Element Plan

Project 01cf—Emerging Techniques in Naval Mine Countermeasures

Anna Crawford
DRDC – Atlantic Research Centre

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Abstract

This report summarizes future planning for the Battlespace Characterization Work Breakdown Element (BC WBE) of project 01cf—Emerging Techniques in Naval Mine Countermeasures (EmTechNMCM). In the EmTechNMCM project, the BC WBE addresses collection of environmental data supporting NMCM areas such as mission planning, sensor performance prediction/assessment and Rapid Environmental Assessment (REA) and how best to present environmental data to operators in useful format. The WBE leverages the availability of DRDC's small Unmanned Underwater Vehicles (UUVs) to examine employment of this type of asset in Intelligence Preparation of the Operational Environment (IPOE) activities.

Significance for defence and security

The RCN has, or will very soon have, UUVs in service, as a procurement is currently finalizing. DRDC can position itself to be an advisor on best practices for effective usage of these platforms in NMCM and other roles.

Résumé

Le présent rapport résume la planification future de l'élément de répartition du travail Caractérisation de l'espace de bataille (ERT CEB) du projet 01cf - Techniques émergentes de lutte contre les mines navales (TechEmLCMN). Dans le cadre du projet TechEmLCMN, l'ERT CEB traite de la collecte de données environnementales à l'appui de domaines de LCMN tels que la planification de missions, la prédiction/l'évaluation du rendement des capteurs et l'évaluation environnementale rapide (EER), ainsi que la meilleure façon de présenter les données environnementales aux opérateurs dans un format utile. L'ERT tire parti de la disponibilité des petits véhicules sous-marins sans équipage (VSSE) de RDDC pour examiner l'utilisation de ce type de ressources dans le cadre des activités de préparation de l'environnement opérationnel fondée sur le renseignement (PEOR).

Importance pour la défense et la sécurité

La MRC a, ou aura très bientôt, des VSSE en service, car un processus d'acquisition est en voie de finalisation. RDDC peut se positionner comme conseiller en matière de pratiques exemplaires pour l'utilisation efficace de ces plates-formes dans le cadre de la LCMN et d'autres rôles.

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1 Introduction

This report summarizes future planning for the Battlespace Characterization Work Breakdown Element (BC WBE) of project 01cf – Emerging Techniques in Naval Mine Countermeasures (EmTechNMCM). The overall EmTechNMCM project aims to address six areas (serials) specifically identified with Naval Mine Warfare in the Underwater Warfare component of the Maritime Science and Technology Program Guidance (MSTPG) document [1, Annex A]. Of these six, serial UW06 is specifically associated with a Battlespace Characterization project element, and the BC WBE also intends to address subject areas identified in serials UW18, UW07 and UW19. These four serials are listed below in Table 1, with descriptions as stated in the MSTPG. The EmTechNMCM WBEs that were developed to address particular serials are listed in bold type following the descriptions of the serial objectives. The EmTechNMCM project also includes **Ship-Mine Interaction** and **Explosive Ordinance Disposal (EOD) Support** WBEs which have very little linkage to the BC WBE and are not listed in Table 1.

It is widely accepted that knowledge of the operating environment is critical to mission success in almost all operational scenarios. Battlespace Characterization as a general topic is wide ranging, dealing with the provision of environmental background context information and situational awareness of an Operational Area. In the case of NMCM operations, the environment directly affects sensor (in this case, high frequency sonar) performance and must be considered in the planning of missions in order to achieve mission risk objectives specified in part by clearance or coverage criteria. In the EmTechNMCM project, the BC WBE addresses collection of environmental data supporting NMCM areas such as mission planning, sensor performance prediction/assessment and Rapid Environmental Assessment (REA). The WBE leverages the availability of DRDC's small Unmanned Underwater Vehicles (UUVs) to examine employment of this type of asset in Intelligence Preparation of the Operational Environment (IPOE) activities.

The number of environmental variables of possible relevance to NMCM operations is large. Collaborative activities within TTCP that formed part of the previous NMCM project (01cb) resulted in a comprehensive accounting of many NMCM–relevant environmental variables [2], with solicited input from the participating nations' operational communities. Though not specifically prioritized, the variables in the list identified as having the highest potential impact on mission success were: bathymetry (depth and slope), seabed composition and type (including clutter density), currents, water temperature and salinity, and other properties such as clarity or pollutants.

Table 1: *Serials in Annex A of the MSTPG document to be addressed by the BC WBE.*

Serial	Objective	Sponsor	Due
UW06	Develop tools, tactics and procedures for characterizing the NMCM battlespace and its effects on NMCM performance and remaining risk, including route survey and change detection operations as well as the employment of unmanned systems. Investigate methods for quantifying and exploiting knowledge of the battlespace during mine hunting and route survey operations. **(Battlespace Characterization)**	DNR 3	2023
UW18	Develop analysis methods to determine the operational effectiveness of the NMCM detect-to-engage sequence, as well as contribute to Allied efforts on next generation Tactical Decision Aids **(Tactical Decision Aids and Operations Analysis)**	DNR 3	2023
UW07	Investigate and evaluate existing as well as next-generation mine hunting sensors and sensing techniques. Investigate and develop new processing methods and data fusion techniques to improve the detection, classification and identification of legacy and evolving mine threats in the NMCM battlespace **(Mine hunting Sensors and Processing)**	DNR 3	2023
UW19	Investigate and develop technology for next-generation unmanned systems to improve the full detect-to-engage sequence of naval mine countermeasures operations by adapting to changes environment, mission parameters, and the systems themselves. Development of new methods and tools that support the interoperability with other unmanned as well as manned systems and the command and control of autonomous missions **(Unmanned Systems)**.	DNR 3	2023

2 WBE Structure

As stated above, the purpose of this WBE is to investigate collection and use of environmental data in support of NMCM operations, with focus on use of UUVs to accomplish the task of data collection. The bulk of the work will be split between two main areas, each with two subelements, as follows:

1. Use of UUVs for environmental Battlespace Characterization
   (a) Autonomous behaviours for collection of environmental data
   (b) Current measurement using UUVs
2. Effective use of environmental information for improved success in NMCM Operations
   (a) Frequency of re-survey to maximize effectiveness of change detection
   (b) Development of environmental data products for operators

These areas will be elaborated on in the subsequent sections.

Use of UUVs for environmental Battlespace Characterization

UUVs are seeing increased usage by military operational units worldwide, and indeed within the RCN since recent acquisition processes have come to a successful conclusion. When UUVs are to be used for NMCM surveys, prior knowledge of the operating environment is particularly critical as autonomous behaviours allowing on-the-fly mission replanning have not yet reached maturity. Factors as basic as water depth across a littoral operating area, currents or water density (salinity and temperature), can have critical impact on mission success. Small UUVs offer the tactical advantage of covertness and can be an ideal platform for performing REA surveys, particularly in the case that these are the assets in theatre already for follow-on NMCM missions. Survey missions intended for the collection of environmental data are planned with different parameters than missions designed for mine hunting. Water properties such as temperature and salinity, for example, are only sampled in the water that the UUV directly travels through, so that measurement of water column profiles extending from seabed to surface require the UUV to transit that entire vertical water space.

1a. Autonomous behaviours for collection of environmental data: Autonomous behaviours can be designed for collection of environmental data that is appropriate for NMCM mission planning and performance evaluation. For example, TTCP collaborators have developed behaviours for mapping bathymetric depth contours and OceanServer Technology Inc, supplier of the Iver3 UUVs, includes an “undulate” mission pattern as a built–in feature of the UUV for water column profiling.

The intention in this part of the WBE is to leverage TTCP and other collaborations (potentially a University) to obtain some existing environmental sampling behaviours to examine

effectiveness during local trials. These will be evaluated for suitability of the environmental data outputs. This work relies on the expertise and outside collaborations in the Unmanned Systems WBE. Expertise in programming will also be required to implement new behaviours on DRDC's UUVs. Some prior testing can be performed on DRDC's UUV simulator.

1b. Current measurement using UUVs: Of the top rated environmental parameters with the potential to affect execution of NMCM operations, accurate measurement of water currents is one of the most challenging. Bathymetric measurements and procedures for performing the required surveys are well understood and UUVs are well suited for this task. Similarly with measurement of water properties (e.g. temperature, salinity). The measurement of currents, on the other hand, poses a challenge. The UUV primary current sensor is the Doppler Velocity Log (DVL), which is part of the on–board suite of navigation sensors. Water currents measured by acoustic (Doppler) methods are inherently noisy, particularly from a moving platform, and the data products that result can be difficult to interpret. There are existing techniques in scientific literature addressing this issue for hull–mounted (ship) ADCPs.

The intention for this part of the WBE is to conduct local trials using DRDC's UUVs to measure currents that can be compared to bottom–mounted ADCP measurements and model outputs. Preliminary trials have already been conducted (DRDC's BOOTUP trial, fall 2017), during which UUV missions were run in the Narrows of Halifax Harbour, with an ADCP deployed nearby providing ground truth measurements. Current modeling support will be sought for this work, with discussions underway now with Queens University, Royal Military College (both in Kingston, Ontario) and OGD.

Effective use of environmental information for improved success in NMCM Operations

Environmental information can be critical to mission success, but is not useful if presented in a way that is not accessible to NMCM planners. In some cases, useful products can be made from one data source, e.g. bathymetric charts, and in other cases, products can be synthesized from multiple inputs, as would be the case with the eventual Change Detection Bottom Type product described below. This sub–element of the WBE examines products made from environmental measurements.

2a. Frequency of re-survey to maximize effectiveness of change detection: This work carries on from groundwork laid during the previous NMCM project (01cb) [3]. The intention is to implement a model for a "Change Detection Bottom Type"—this parameterizes the likelihood that there will be changes to the seabed that adversely affect performance of a change detection approach to Route Survey[1]. Model inputs will include bathymetry, seabed composition, local currents and tides, and vessel traffic. Output would be a chart–like product that assists Route Survey planners in assigning time and effort to areas where

[1] Route Survey is included as a part of NMCM practice.

it is most needed, to areas where changes are most likely to occur, requiring more frequent re–survey to maintain a viable background database against which to detect changes. The concept for this model has been taken up by the CUMID collaboration (described in the next section) as a means of encapsulating into an Operator Aid the three nation's research efforts in improved change detection methods. The inputs to the model will largely be environmental parameters, with the notable exception of vessel traffic. Linkages with DRDC – CORA are being explored to provide expertise in this area. The development of an ArcGIS framework for the future development of the model and operator aid will be contracted out. Current modeling work that supports the WBE sub–element "Current mapping using UUVs" (1b, above) can also support this sub–element.

2b. Development of environmental data products for operators: This element of the WBE encompasses research into what the environmental data requirements are for NMCM mission planning and performance evaluation, which of these can be effectively collected using UUVs and how best to do this, and what formats of data presentation are effective for transferring the knowledge to NMCM planners. In effect, this is a catch–all element that covers preparations and necessary ground work for the other elements, including assessment of results, in particular from 1a and 2a (described above). It carries on from research done in the previous NMCM project (01cb), including post–analysis and documentation of the experiences gained from participation in the three Hell Bay trials, enabled through TTCP collaboration. Future plans for the TTCP BC KTA are of interest, specifically collaborative trial activities (with other KTAs in TP13), development of operator aids and useful environmental data products, and investigation of UUV performance surfaces.

3 Project Execution

3.1 Team Structure

This WBE has been planned for one scientist, with required support from other team members in the DRDC Mine Warfare group in areas where other expertise is needed. For example, the Autonomous Behaviours subelement (1a) will require expertise from the Unmanned Systems WBE, as well as programming (Computer Scientist) and trial support from the DRDC Technical Services groups that operate and maintain the UUVs. Aspects of the work proposed in areas 2a and 2b could benefit from expertise within other DRDC Atlantic research groups working with operator displays and human–machine interfaces.

3.1.1 External Collaboration

External collaboration is required in several areas of the WBE, itemized as follows:

1. Programming expertise in development of a framework for the Change Detection Bottom Type model, expected to be contracted out, and for implementation of autonomous behaviours on UUVs.

2. Current modeling expertise—University or OGD support will be sought out to provide this input, perhaps under contract.

3. Vessel traffic mapping expertise: DRDC – CORA have been approached on this topic.

The specific collaborative efforts which will be leveraged to bring in outside input are:

1. TTCP: Within Technical Panel 13 (Mine Warfare), the Battlespace Characterization Key Technical Area (BC KTA) has participated in the Hell Bay series of trials by performing pre-trial environmental characterizations using UUVs ahead of the follow-on NMCM exercises. Canada is a participating member of this KTA and this has resulted in a wealth of relevant data, experience and access to an international network of like–minded researchers working in this area.

2. The Coalition Underwater Mine and IED Defeat (CUMID) project is a trilateral scientific research agreement between Canada, Norway and the US, the focus of which is improvement of change detection methodologies.

3. Universities: The DRDC Mine Warfare group has close ties with Dalhousie University, a source of expertise in autonomy, unmanned systems and oceanographic modeling. Dr Crawford is an adjunct faculty member at Royal Military College (Physics Dept.), which also has expertise in ocean modeling and agreements with Queens University. Aspects of the WBE research plan are well suited for final year undergraduate and MSc level projects.

4. DRDC – CORA: CORA has been consulted regarding their work in vessel traffic prediction and mapping, which is a required input to the model for Change Detection Bottom Type. CORA in turn has links to researchers at the NATO Centre for Maritime Research and Experimentation (CMRE) in this area.

5. OGD: In particular, Fisheries and Oceans Canada (DFO) is where most expertise in oceanographic modeling of currents resides. Collaboration may fall under an existing MOU, or it may be possible to enable this through the Facility for Intelligent Marine Systems (FIMS) in the future.

3.2 Prerequisites and Dependencies

There are no identified prerequisites beyond the availability of identified platforms (DRDC assets), and technical/logistical support for trials operations, discussed further below. This program builds on the existing previous work done in the former NMCM (01cb) project.

The following WBE dependencies within the EmTechNMCM project (01cf) have been identified:

1. Unmanned Systems WBE

2. Sensors and Processing WBE

3. Tactical Decision Aids WBE

Execution of the WBE plan of work depends on the following DRDC assets for testing and experimentation:

1. Small UUVs (OceanServer Technologies Inc. Iver2 and Iver3s): These support the research in WBE areas 1a, 1b and 2b, for collection of specific environmental data types, and for testing implementation and effectiveness of autonomous behaviours.

2. Unmanned Surface Vehicle (SeaRobotics USV2600): Although an unmanned surface vehicle (USV) is not being researched directly, it provides an alternate platform for the testing of autonomous behaviours, in conjunction with the Unmanned Systems WBE.

3. Acoustic Doppler Current Profilers: DRDC has several in inventory, including 2 attached to the Mine Warfare group.

Trial activities may benefit from access to DRDCs Calibration Barge facility, as an on–water platform.

The following **external** dependencies have been identified: in order to successfully execute field trials, external resources will be needed for logistical and trials support, including transportation and support craft. In the past, local trials have been staged out of the Bedford Institute of Oceanography, with assistance from OGD (NRCan and DFO) and the

RCN (Fleet Diving Unit Atlantic). It may be possible in future to access support services through the Facility for Intelligent Marine Systems (FIMS), Centre for Ocean Ventures and Entrepreneurship (COVE) or other local centres of oceanographic expertise. Coordination between the project WBEs, in particular Unmanned Systems, is essential, to maximize return for solicited support of trials efforts.

3.3 Planning assumptions

The following are assumptions made in the formulation of the described program of work:

1. Funding is available, accessible and adequate.
2. Procurement processes can be executed in a timely manner, for goods, services and software required for completion of the planned work.
3. Trials can be completed, with access to the UUV platforms and the technical support services required for their maintenance and operation.
4. Collaborators can be found and appropriate agreements can be arranged to bring in required expertise in areas already identified in the plan (current modeling, vessel traffic mapping), as well as others that may arise through the course of the research.

3.4 Monitoring and control—scope, change and risk management

Monitoring of the progress and effort will be through maintenance of a schedule of milestones, which will be assessed and reviewed periodically, in coordination with the other project WBE leads. Technical scope will also be assessed and any changes in WBE scope will be affected in accordance with DRDC processes, in consultation with the project lead, project manager and client. An initial risk assessment is included in Section 3.7, Table 4 – risks will also be re–evaluated periodically.

3.5 Proposed budget

The overall budget for the EmTechNMCM project (01cf) is $500k per year. There are no large capital expenditures foreseen for the BC WBE that are not already accounted for by other projects or WBEs within the EmTechNMCM project, for example possible upgrade of one of DRDC's Iver UUVs. The bulk of the spending for this WBE will cover contracted development of operator tools and vehicle behaviours. Table 2 details yearly cost estimates.

3.6 Milestones and deliverables

The primary deliverable of the WBE will be a DRDC Scientific Report summarizing the findings and results, which will distill the contents of the several smaller Letter and Trial Reports that are identified as project milestones and will propose recommendations for the

Table 2: *Planned budget for the BC WBE, 2018–2021.*

Fiscal Year	Activity	Cost
2018-19	Contract for ArcGIS operator display framework development	$40k
	Software licensing	$15k
2019-20	Continuation of ArcGIS contract	$50k
	Software licensing	$15k
2020-21	Contract for development of UUV behaviours	$50k
	Software licensing	$15k

client. Unclassified conference presentations and papers in open literature are expected to come out of this work as well. Supervised work by contractors or students will also result in reports. The duration of the project is expected to be 2018–2021. The planned BC WBE milestones, largely Letter or Trial Reports, are listed in Table 3.

Table 3: *Planned milestones for the BC WBE, 2018–2021.*

Milestone	Research Area	Estimated Date
WBE Plan document (RD, this report)	BC WBE	Summer 2018
Summary of TTCP BC KTA experiences and lessons (SR)	2b	Fall 2018
Trial plan, UUV current measurements during Re-BOOT'18 (LR/RD)	1b	Summer 2018
Trial report, ditto (SR)	1d	Summer 2019
Contract report on ArcGIS development work (CR)	2a	2019-2020
Letter report on current measurement using UUVs (LR)	1b	Winter 2020
Final report (SR)	BC WBE	Spring 2021

3.7 Risks

At time of planning, identified risks are listed below in Table 4. The principle risk, not articulated in Table 4, is the heavy reliance on a single scientist. The risk assessed as most impactful is delay in contracting of goods and services.

Table 4: *Risks identified initially for BC WBE program.*

Risk	Likelihood	Impact	Mitigation Strategy
Platform (UUV), or support to operate it, is unavailable	L	H	Coordination between WBEs, use of simulators for some preliminary work, advance planning
Collaboration agreement failure	L	H	Leverage pre-existing collaborations if possible, explore other options to provide missing expertise
Delayed contracting of goods/services	H	H	Continue work at DRDC up to point where contracted work or item fits in, reschedule project milestones and rescope

4 Exploitation

The RCN has, or will very soon have, unmanned systems (UUVs) in service, as a procurement for small UUVs has very recently finalized. DRDC can position itself to be an advisor on best practices for effective usage of these platforms in NMCM roles, including as IPOE or covert REA assets. The best means for socializing the concepts of using UUVs for environmental measurements with the RCN operators will be in coordination with the Unmanned Systems WBE work, and by presentation of useful, easy-to-interpret, environmental data products that demonstrate the benefits.

References

[1] DGNFD (2016), Maritime Science and Technology Program Guidance, Version 4.0, June 2016.

[2] Crawford, A. (2016), Comments from Canadian Operators on the Table of Environmental Parameters, Defence Research and Development Canada, Reference Document, DRDC-RDDC-2016-D028.

[3] Crawford, A. and Renaud, W. (2016), Development of an ArcGIS model for prediction of seabed changeability, Defence Research and Development Canada, Reference Document, DRDC-RDDC-2016-D014.

List of symbols/abbreviations/acronyms/initialisms

ADCP	Acoustic Doppler Current Profiler
BC	Battlespace Characterization
CMRE	Centre for Maritime Research and Engineering
CORA	Centre for Operational Research and Analysis
COVE	Centre for Ocean Ventures and Entrepreneurship
CR	Contractor Report
CUMID	Coalition Underwater Mine and IED Defeat
DFO	Department of Fisheries and Oceans
DRDC	Defence Research and Development Canada
DNR	Director of Naval Requirements
DVL	Doppler Velocity Log
EmTechNMCM	Emerging Techniques in Naval MCM
EOD	Explosive Ordinance Disposal
FIMS	Facility for Intelligent Marine Systems
IED	Improvised Explosive Device
IPOE	Intelligence Preparation of the Operational Environment
KTA	Key Technical Area
LR	Letter Report
MCM	Mine CounterMeasures
MOU	Memorandum of Understanding
MSTPG	Maritime Science and Technology Program Guide
NATO	North Atlantic Treaty Organization
NMCM	Naval MCM
NRCan	Natural Resources Canada
OGD	Other Government Departments
RCN	Royal Canadian Navy
RD	Research Document
REA	Rapid Environmental Assessment
SR	Scientific Report
TP13	Technical Panel 13 (Mine Warfare)
TTCP	The Technical Cooperation Program
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
UW##	Underwater Warfare serial numbers, in the MSTPG
WBE	Work Breakdown Element

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