Copy No. _____

Defence Research and Development Canada | Recherche et développement pour la défense Canada

DEFENCE DÉFENSE

Environmental Modeling Packages for the MSTDCL TDP

Review and Recommendations

Robert Trider, Peter Giles and Bruce Martin
General Dynamics Canada Ltd.

General Dynamics Canada Ltd.
3785 Richmond Road
Ottawa, Ontario K2H 5B7

GDC Document Number: 979392

Contract Project Manager: Beatrice Chappaz, 902-406-3707

Contract Number: W7707-053008

Contract Scientific Authority: Dr. Mark Trevorrow, 902-426-3100 ext 315

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2009-004
September 2009

Canada

Environmental Modeling Packages for the MSTDCL TDP

Review and Recommendations

Robert Trider
Peter Giles
Bruce Martin
General Dynamics Canada Ltd

General Dynamics Canada Ltd
3785 Richmond Rd.
Ottawa, Ontario K2H 5B7

GDC Document Number: 979392
Contract Project Manager: Beatrice Chappaz, 902-406-3707
Contract Number: W7707-053008
CSA: Dr. Mark Trevorrow, Scientific Advisor MSTDCL TDP, 902-426-3100 x315

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2009-004
September 2009

Principal Author

Peter Giles

General Dynamics Canada

Approved by

Original signed by David Hazen

David Hazen

Head, Technology Demonstration

Approved for release by

Original signed by Ron Kuwahara for

Dr. Calvin Hyatt

Head, Document Review Panel

Abstract

Since 2005 DRDC Atlantic has been conducting the Multi-Sensor Torpedo Detection, Classification, and Localization (MSTDCL) technology demonstration project aimed at improving the torpedo detection, classification, and tracking capabilities on Halifax-class frigates. This document examines the advantages to the MSTDCL project of adding a capable Environmental Analysis package for detection performance prediction. Three levels of complexity were examined: a basic level based on the Networked Underwater Warfare (NUW) developed analysis package, an intermediate level package building on the NUW package to provide improved functionality and displays while reducing operator interaction, and an Advanced Environmental Analysis package that improves the accuracy of the performance predictions by more accurately representing range-dependent environments. The advantages of each level to the MSTDCL system are compared, along with estimates of the work level required to implement the package. A low-risk approach beginning with the NUW package and advancing through the intermediate levels is recommended.

Résumé

Depuis 2005, RDDC Atlantique mène le projet de démonstration de la technologie de détection, de classification et de localisation des torpilles à partir de capteurs multiples (DCLTCM), qui vise l'amélioration des capacités de détection, de classification et de poursuite des torpilles à bord des frégates de la classe Halifax. Le présent document examine les avantages, pour le projet DCLTCM, de l'ajout d'une trousse satisfaisante d'analyse environnementale en vue de la prédiction du rendement de la détection. Trois niveaux de complexité ont été examinés : un niveau de base, fondé sur la trousse d'analyse élaborée dans le cadre de la guerre sous-marine en réseau (GSR); une trousse intermédiaire, qui fait fond sur la trousse GSR pour permettre l'amélioration de la fonctionnalité et les affichages, tout en réduisant l'interaction de l'opérateur; et une trousse d'analyse environnementale avancée, qui permet d'améliorer la précision des prédictions du rendement grâce à une représentation plus précise des milieux dépendants de la distance. Les avantages de chaque niveau pour le système DCLTCM sont comparés, et le niveau de travail requis pour la mise en œuvre de la trousse est estimé. On recommande une approche à faibles risques, qui commence par la trousse GSR et se poursuit par les niveaux intermédiaires.

This page intentionally left blank.

Executive summary

Environmental Modeling Packages for the MSTDCL TDP: Review and Recommendations

Robert Trider; Peter Giles; Bruce Martin; DRDC Atlantic CR 2009-004; Defence R&D Canada – Atlantic; September 2009.

Introduction: Since 2005 DRDC Atlantic has been conducting the Multi-Sensor Torpedo Detection, Classification, and Localization (MSTDCL) Technology Demonstration Project (TDP) aimed at improving the torpedo detection, classification, and tracking capabilities on Halifax-class frigates. The basic thrust has been the integration and display of sonar data from the SQR-19 towed array, the SQS-510 sonar, sonobuoys, and the ship's command and control system, resulting in a sea-going system known as PLEIADES. As part of MSTDCL the feasibility of developing a near-real-time underwater acoustic sensor performance prediction capability was explored. Previously, the Networked Underwater Warfare (NUW) project had developed an underwater environmental modeling package, based on earlier work at DRDC Atlantic.

Results: The capabilities provided by the NUW acoustic modeling system define a *basic* environmental modeling package for the purposes of this study. This study reviews this basic package, discusses its potential advantages to the MSTDCL TDP and PLEIADES system, and then considers expanded capabilities. Specific suggestions are made for improving this basic package by adding improved environmental databases and tools, improving the prediction accuracy through addition of a parabolic-equation model for low-frequencies, and improving operator tools. This study discusses some shortcomings of the basic package for littoral operations, and then reviews some of the latest adaptive modeling techniques which could be employed. A graduated approach beginning with the basic NUW capability is recommended.

Significance: The performance of underwater acoustic sensors is heavily dependent on local environmental conditions, especially in littoral regions, thus it is essential to be able to predict sensor performance in near real time. Considerable work on development of accurate underwater acoustic performance models has been done by DRDC in the past decades. This study proposes a graduated suite of environmental prediction capabilities that should be implemented within the PLEIADES sonar processing system. Ultimately this will provide a sophisticated sonar performance modeling capability that is integrated with the sonar processing and automated detection and classification functions.

Future plans: This study was completed in late-2007, and since then work to integrate the basic NUW sonar performance capability into the PLEIADES system has been performed; specifically implemented on HMCS Ottawa during Westploy and RIMPAC exercises in mid-2008. Continued development of environmental modeling capabilities at DRDC Atlantic is being conducted under project 11ch "Assessing Sonar Performance in a Realistic Environment".

Sommaire

Environmental Modeling Packages for the MSTDCL TDP: Review and Recommendations [Trousses de modélisation environnementale pour le PDT DCLTCM: Revue et Recommendations]

Robert Trider; Peter Giles; Bruce Martin; DRDC Atlantic CR 2009-004; R & D pour la défense Canada – Atlantique; Septembre 2009.

Introduction : Depuis 2005, RDDC Atlantique mène le projet de démonstration de la technologie (PDT) de détection, de classification et de localisation des torpilles à partir de capteurs multiples (DCLTCM), qui vise l'amélioration des capacités de détection, de classification et de poursuite des torpilles à bord des frégates de la classe Halifax. Le projet visait essentiellement l'intégration et l'affichage des données du sonar remorqué SQR-19, du sonar SQS-510, de bouées acoustiques et du système de commandement et de contrôle du navire, ce qui a donné un système de mer appelé PLEIADES. Dans le cadre du DCLTCM, on a étudié la faisabilité de la mise au point d'une capacité de prédiction du rendement de capteurs acoustiques sous-marins en temps quasi réel. Plus tôt, dans le cadre du projet de guerre sous-marine en réseau (GSR), on avait mis au point une trousse de modélisation environnementale sous-marine, d'après des travaux antérieurs menés par RDDC Atlantique.

Résultats : Les capacités fournies par le système de modélisation acoustique GSR définissent une trousse de modélisation environnementale *de base* aux fins de la présente étude. Dans la présente étude, on examine la trousse de base, on discute de ses avantages possibles pour le PDT DCLTCM et le système PLEIADES, puis on considère les capacités élargies. Des propositions précises sont faites en vue de l'amélioration de la trousse de base par l'ajout de bases de données environnementales et d'outils améliorés, l'amélioration de la précision des prédictions par l'ajout d'un modèle d'équation parabolique pour les basses fréquences, puis l'amélioration des outils de l'opérateur. Dans la présente étude, on discute de certaines lacunes de la trousse de base pour les opérations littorales, puis on examine certaines des dernières techniques de modélisation qui pourraient être employées. On recommande une approche progressive qui commence par la capacité GSR de base.

Portée : Le rendement des capteurs acoustiques sous-marins dépend énormément des conditions ambiantes locales, en particulier dans les régions littorales. C'est pourquoi il est essentiel d'être en mesure de prédire le rendement des capteurs en temps quasi réel. Au cours des dernières décennies, RDDC a mené beaucoup de travaux en vue de la mise au point de modèles du rendement des capteurs acoustiques sous-marins précis. Dans la présente étude, on propose une suite progressive de capacités de prédiction environnementale qu'il faudrait mettre en œuvre à l'intérieur du système de traitement sonar PLEIADES. En fin de compte, cela donne une capacité perfectionnée de modélisation du rendement du sonar qui est intégrée au traitement du sonar et aux fonctions automatisées de détection et de classification.

Recherches futures : La présente étude a été complétée à la fin de 2007. Depuis, on a mené des travaux pour intégrer la capacité de rendement du sonar GSR de base au système PLEIADES. En particulier, la capacité intégrée a été mise en œuvre à bord du NCSM Ottawa durant les exercices *Westploy* et *RIMPAC*, au milieu de l'année 2008. La poursuite du perfectionnement des capacités de modélisation environnementales à RDDC Atlantique se fait dans le cadre du projet 11ch, qui porte sur l'évaluation du rendement des sonars dans des conditions réalistes.

This page intentionally left blank.

Table of contents

List of figures

1 Overview

This work was performed by General Dynamics Canada (GD Canada) to investigate the benefits and costs associated with incorporating integrated environmental analysis as part of an automated threat detection system within the PLEIADES sonar system. This work was performed under the MSTDCL TDP contract, W7707-053008.

1.1 Project Background

For the Multi-Sensor Torpedo Detection, Classification, and Localization (MSTDCL) TDP, Defence Research & Development Canada (DRDC) Atlantic and GD Canada are developing an integrated, multi-sensor system for automatically detecting and classifying torpedoes. The TDP includes a number of sea trials where the prototype sonar processing system (named PLEIADES) is deployed on Halifax-class Frigates.

Torpedo detection, by necessity, relies heavily on underwater sensors (sonars) and their processing systems. Acoustic detection, classification, and localization, whether performed automatically or not, require some understanding of the capabilities of each sensor. Therefore an ability to predict sonar performance is essential. Unfortunately, the detection performance of these systems can be strongly dependent on frequency, direction, depth, and environmental conditions. This is especially true in littoral waters.

Given these considerations as a starting point, it is natural to ask whether a fast, accurate acoustic prediction capability could be used to improve the performance of the MSTDCL system. The purpose of this study is to discuss the advantages of incorporating an environmental analysis package as an integral part of this system.

1.2 Scope

The guidelines for the study were to assume a starting point based on the environment package being developed by the NUW TDP. The NUW package (see Ref. [1]) is therefore defined as the 'basic' environmental analysis package, although it provides a significant and highly useful capability. Those capabilities are first defined as a reference for further discussions. We then define an intermediate package that provides more information to the operators and command, proposes to automate some data input requirements, and adds a low frequency (<1 kHz) acoustic model for improved predictions in this region of the spectrum. Finally we considered the variability of the littoral region of operations and propose an advanced environmental analysis package. The capabilities in the advanced package should provide improved sonar performance prediction accuracy, or at least provide the operational team with good insight as to the variability in the performance predictions that could exist.

Another important feature for any seagoing environmental analysis package is to provide results in a timely and efficient manner. The limiting factor in providing timely results is usually the underlying acoustic propagation model. The NUW package has selected the Bellhop acoustic model, which has been shown to provide good acoustic predictions in a very reasonable timeframe. However as currently configured this package does require some operator experience and attention to produce the desired output products. The proposed advanced package makes every attempt to reduce the amount of operator interaction and to provide even more timely updates of the predictions. Features such as oceanographic and seabed modeling that produce updated acoustic model inputs can reduce operator interaction and improve the accuracy of the results. Such a system can obtain the necessary inputs from databases, *in situ* measurements and ambient noise measurements. The goal with this advanced package is to provide guidance to the tactical team on the variability that can be experienced due to the range-dependent environment and at the same time, indicate sonar deployments that try to minimize this effect.

1.3 Document Organization

The report begins with three sections describing the three proposed levels of environmental package and how they would interface to the MSTDCL system. In each case, the advantages of the different packages are compared. The report also discusses the amount of effort required to incorporate each package into MSTDCL. The report then describes the general advantages of environmental analysis to MSTDCL, and concludes with a set of study recommendations.

2 Basic Environmental Analysis Package

We selected the package currently being developed by the NUW TDP at DRDC Atlantic as the starting point for our analysis of the benefits of environmental modeling for MSTDCL. This section will describe the high-level capabilities of that package. For further insight into the NUW package reference [1] should be consulted.

While labelled as the basic analysis package, this tool is really a significant advance over many other products readily available. For example, the operator can choose to view the results of the modeling in many ways through a variety of displays. A typical operator display from this product is shown in Figure 1 below. The higher level displays are chart-based with overlays of sonar positions and predicted detection ranges if desired by the operator.

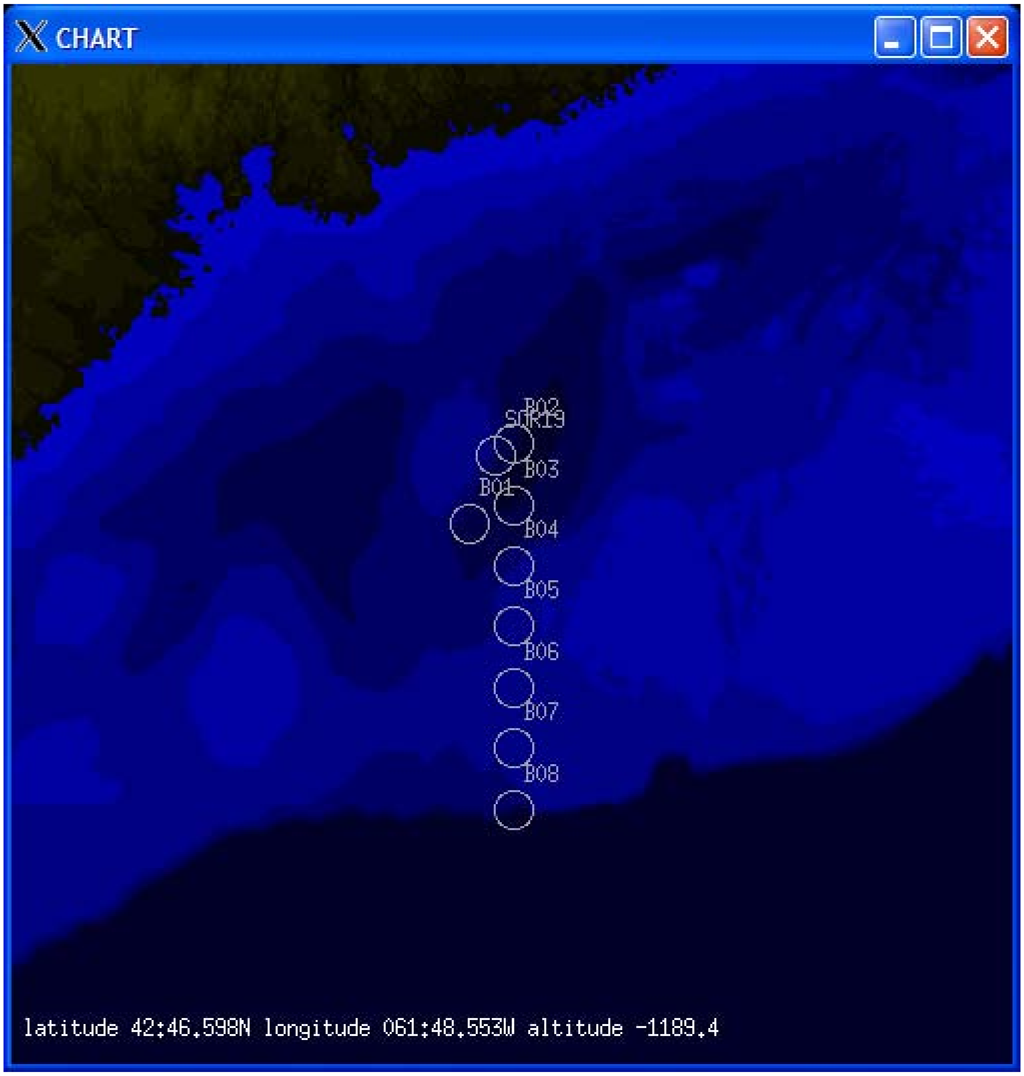

Figure 1. Chart Display with Sensor/Track Overlay

The operator interfaces with this package by editing a work sheet. An example of this worksheet is shown, with some of the typical data values used, in Figure 2 below. The setup of the work sheet inputs does require a certain amount of oceanographic expertise and experience, but this is the case with most environmental analysis packages.

Figure 2. Environmental Analysis Worksheet with Data Shown

The operator interaction is quite extensive. This is not significant when using the package as a planning tool, but can be quite a strain on the operator resources when engaged in an operational scenario. Of course a number of the inputs will be constant for the scenario at hand, but with other inputs (such as the temperature profile) more detailed actions are required.

In Figure 3 below we show a general flow diagram for this basic environmental analysis package, including the operator interaction that must occur in order to develop certain data inputs for the model.

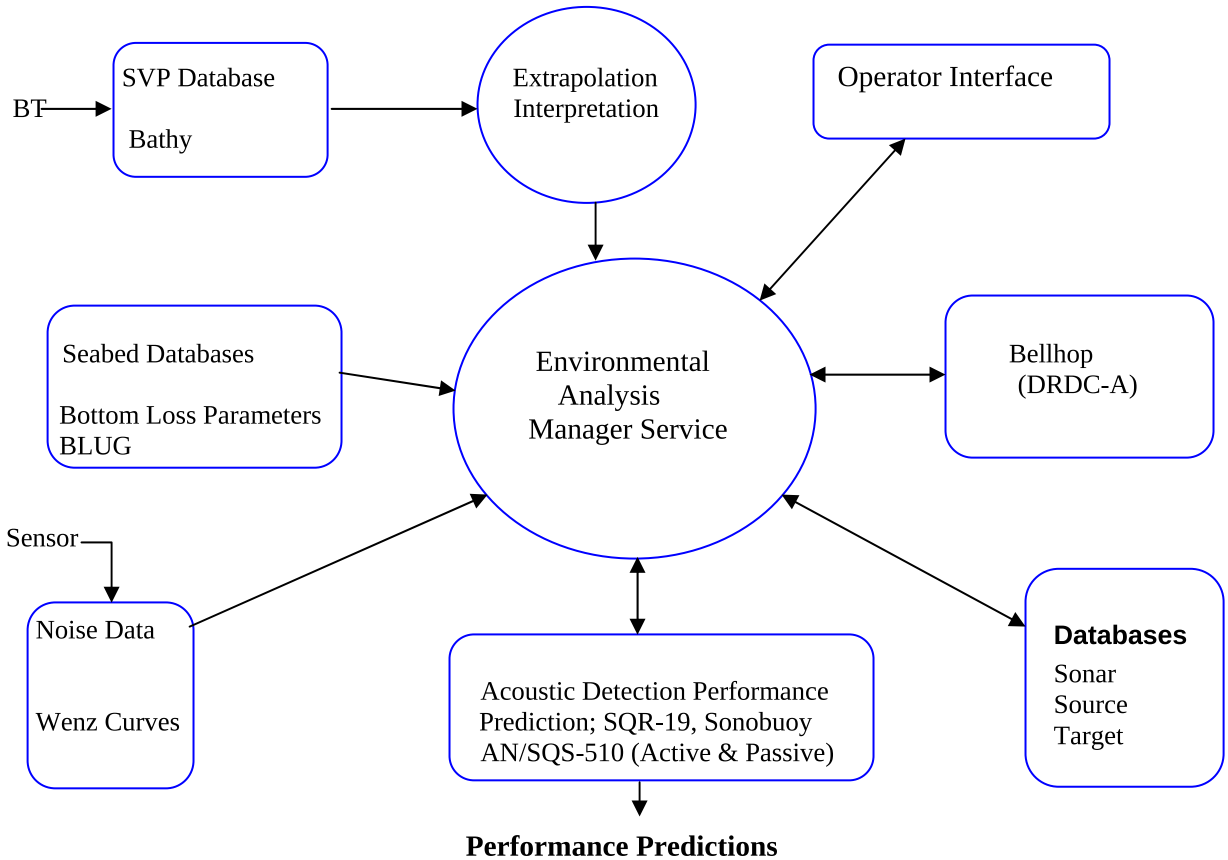

Figure 3. The Data-flow Structure for the NUW Developed Environmental Analysis Package

The fundamental acoustic model behind this analysis package is the BellhopDRDC model [2]. This BellhopDRDC Gaussian Beam ray model has had some additions and refinements added as part of the NUW project and this improved version is being embedded in the Environmental Analysis tool package. The Bellhop model is well suited to both the NUW and MSTDCL applications since it offers timely, accurate results over most of the frequency bands of interest and accommodates range-dependent bathymetry.

To begin an environmental analysis, the user must select a location and provide a temperature profile. The tool allows temperature profile inputs from measured BT data or historic profiles that in turn can be blended with the observation if required. Because the BT data must be manually edited, the package is prone to error in a tactical environment unless an experienced acoustic operator is available to periodically carry out this important input task. It is more suited to use as an off-line pre-mission guide. The selection of the measured points to employ and the merging with other data can affect both the speed of operation and the accuracy of the predictions. An example of the profile editing display and functionality is shown below in Figure 4. The operations allowed with this editor are:

- Add temperature point;
- Move temperature point;

- Save profile;
- Load profile;
- Truncate down;
- Truncate up; and
- Down sample temperature profile.

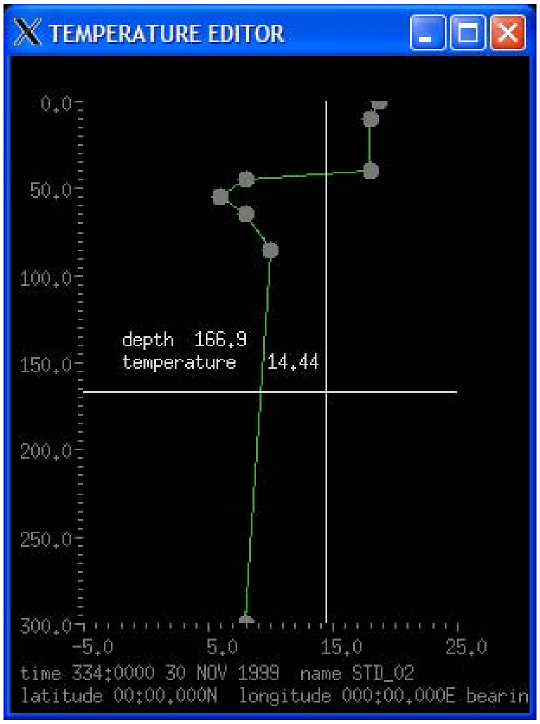

Figure 4. Temperature Profile Editor

There are background software tools provided to assist the operator in the data point selection such as the "broken pipe" algorithm which provides a guide for the down sampling process.

The NUW environmental package contains databases (or spaces to insert databases) for historic temperature and sound velocity profiles, bathymetry, bottom province and bottom loss data. It allows access to the bathymetry database via latitude/longitude co-ordinates and then along a specific operator selected bearing or look direction. The acoustic model outputs are propagation loss and ray plots for the specified conditions. Examples of the currently provided displays for the propagation paths and propagation loss results for the direction selected are shown in Figures 5 and 6 below.

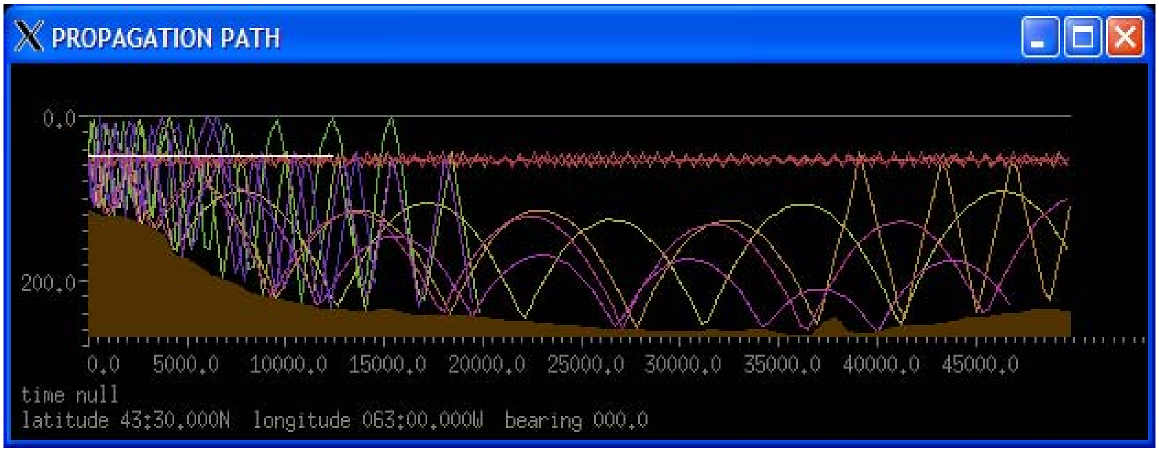

Figure 5. Propagation Ray Path Display

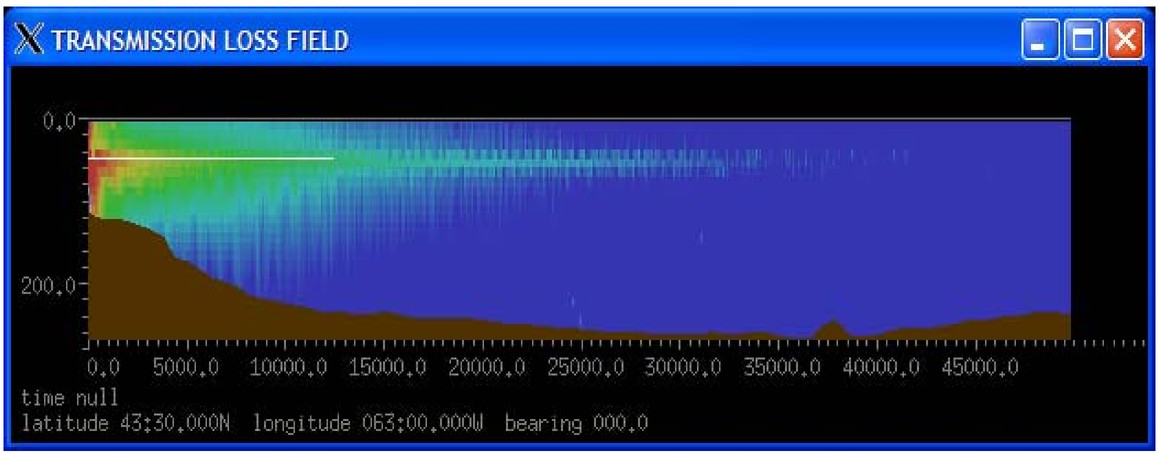

Figure 6. Transmission Loss vs. Range and Depth Display

The propagation loss predictions are converted to detection predictions using noise data, sensor performance inputs and target characteristics. The sensor and target parameters are taken from a stored database of known values, along with operator-entered values for the receiver depth. Noise levels can be taken from through-the-sensor measurements, historic data or Wenz curves for ambient noise. In the active case, the NUW package has attempted to provide a reverberation model for pre-mission planning purposes, or it can use through-the-sensor measurements to obtain these values. The detection prediction results can be shown to the operator on a chart display, as overlays on the sensor positions. While the calculations are for one receiver depth the full field of target depths is computed and a 2-D plot of this data is planned.

One of the strongest features of this NUW Environmental Analysis package is the chart display. It allows the operator to work at a high level to view the expected detection ranges and the deployment of the sensors. It gives the package an excellent planning tool capability as well as an operational overview of how well the deployed resources are functioning against the specified targets. The areas of coverage for each sensor are clearly visible to the operator. When variable detection ranges exist within the water column, they are displayed as maxima and minima for the receiver depth selected. These are indicated by the two colour overlays as seen in Figure 7 below.

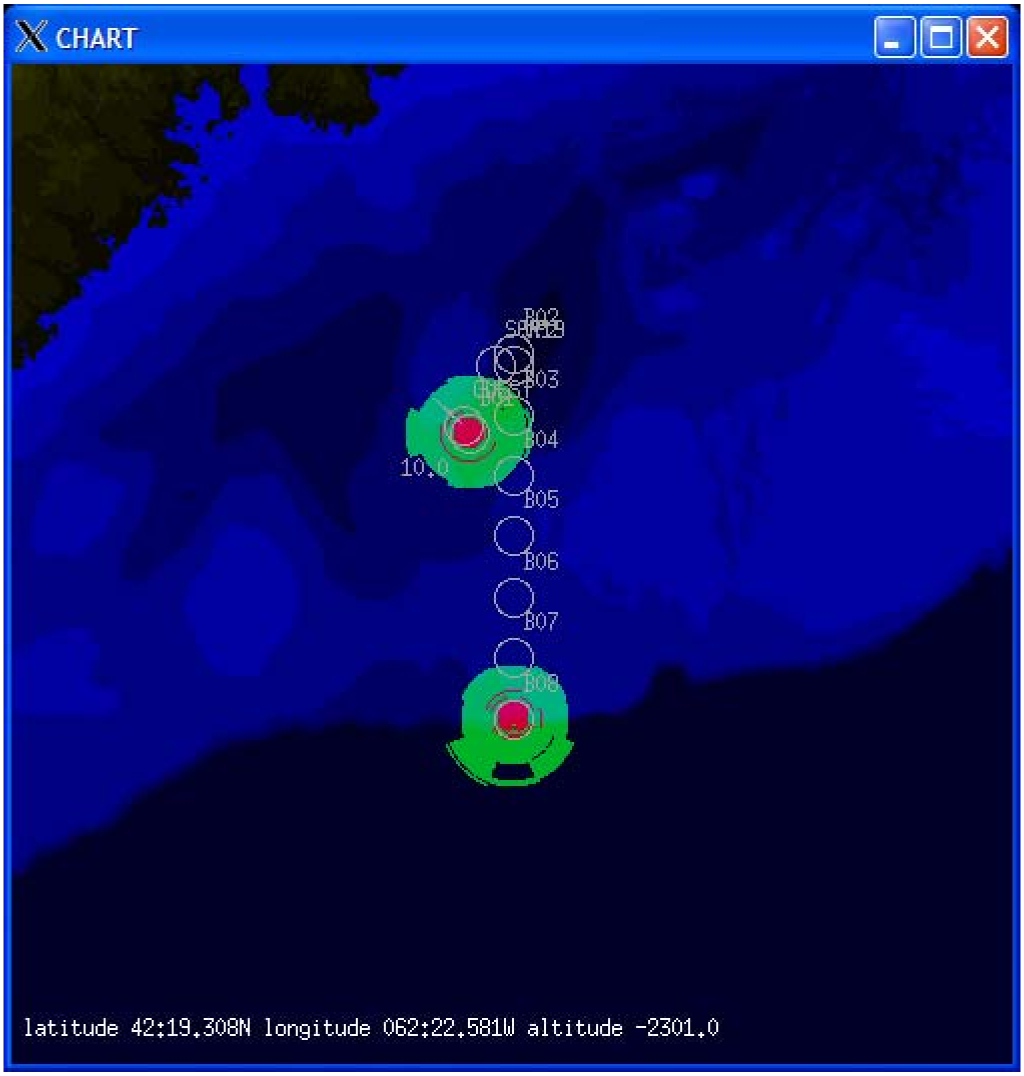

Figure 7. Chart Display with Detection Range Overlay

There were several other features planned for the NUW Environmental Modelling Manager (EMM) package, for example optimum sensor placement in the water column, optimum ping selection, etc. which were not completed. These Functions, along with the absence of certain database information, are some of the components of the NUW EMM package that will need to be addressed in the MSTDCL *Intermediate* level environment package if full advantage of this analysis capability is to be achieved. An overview of the NUW package functionality is shown in Figure 8 below.

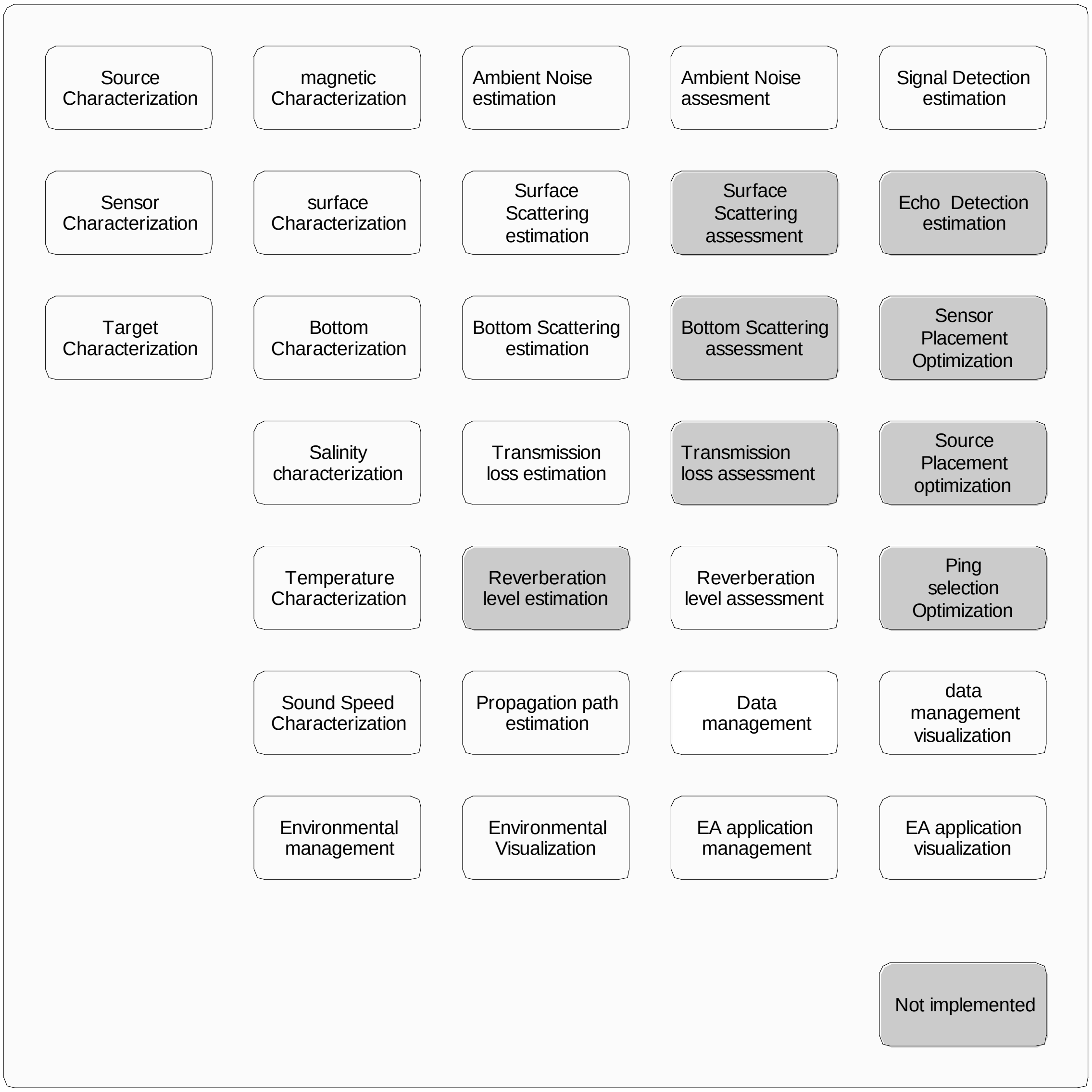

Figure 8. Environmental Analysis Functionality

There are three assessment blocks which are shown as not completed, and these involve the further analysis of the through-the-sensor measurements to provide the additional information that is required. Some additional processing of the received signals will be required to complete the information gathering intended by the functionality illustrated. For example, the surface scattering assessment provides a measure of the frequency spreading, which in turn will be used to provide guidance to the operators on the minimum target speed for good Continuous Wave (CW) detections.

In some cases this assessment information may be required as part of the inputs for the optimization calculations and for the echo detection estimation. The associator, tracker and classifier can have improved acoustic path prediction data, better range estimates for bounds on possible tracker solutions, and improved target parameter estimates. These will be discussed further below.

2.1 Advantages of the Basic Environmental Analysis Package

While other environmental analysis packages do exist and could be purchased, they tend to be very much stand-alone sonar performance prediction packages. The NUW package has evolved to include some of the more in-depth displays included in these other models, but goes well beyond this capability. For example the chart display with overlays and sensor positions gives the operator a higher-level view of the acoustical situation that is much more tactically relevant. The NUW package also includes the use of through-the-sensor measurements to update the performance predictions based on local, current environmental measurements. While some degree of operator input is required by the NUW package during the data preparation and selection of acoustic model inputs, this can be much less than that required by some of the competing packages. The NUW package was also constructed with operational employment in mind so that the time to update and achieve a new set of acoustic predictions is much faster than that of other acoustic modeling packages. The NUW package has already worked out the Calibration Factors (CF) applicable to CF sonars, i.e. the SQR-19 array, the SQS-510 sonar, and Directional Frequency and Ranging (DIFAR) sonobuoys, so that their through-the-sensor measurements can be readily incorporated into the performance predictions. This provides the MSTDCL automatic processing, associators, and trackers with a valuable second source of possible target detection ranges, as well as possible overlapping detection areas, which are important parameters in the fusion of contacts on multiple sensors to the same target.

On a more pragmatic level, the technology developed for the NUW TDP is wholly owned by DRDC and was developed by the local office of GD Canada. Furthermore, it was developed using the same System Test Bed (STB) architecture that forms the basis of the PLEIADES system. All of this means that the NUW package has strong local support and can be transferred to MSTDCL with a relatively small amount of cost and effort. For these reasons the NUW approach to performance prediction and environmental modeling is recommended as the basic starting package for the MSTDCL requirement.

It is worth noting, however, that GD Canada has also been developing its own environmental prediction capability. The development of the Sensor Performance and Acoustic Detection Evaluation System (SPADES) and its primary user interface, the Integrated Coverage Editor (ICE), has been funded as an internal research and development project at GD Canada, led by Dr. Gary Brooke and Steve Kilistoff in Victoria. The SPADES/ICE system was deployed on a CPF during an MSTDCL sea trial in February 2007. It provides a very efficient, advanced environmental prediction capability, similar to that provided by NUW. In fact, although it lacks some of the advantages identified above, it does include some features proposed for the intermediate environmental package as described in Section 3. Therefore, the extra cost of integrating SPADES into the STB should be balanced against the cost of upgrading.

2.2 Effort to Implement Basic Package for MSTDCL

Since NUW has implemented its Environmental Manager as a set of STB components, there is minimal effort required to add this functionality to MSTDCL. The tasks required include:

- Adding the display tools to our Chart display;
- Adding the necessary operator inputs as Java panels (vice the current X-Windows tools);
- Modifying the signal processing to provide calibrated outputs for through-the-sensor noise estimates (the NUW TDP has defined the algorithm);
- Completing the Mk8 interface; and
- Configuration, integration, and testing.

In total approximately 40 days of effort is estimated to be required for these tasks.

3 Intermediate Environmental Analysis Package

The proposed Intermediate Environmental Analysis package builds on the NUW package to provide the operator with several major refinements and improvements. These are:

- A more detailed evaluation of the environment through more extensive use of databases, automation of the environmental assessments, and more comprehensive combined displays;
- Completion of the sensor placement optimization to assist operators and command in the optimum sensor placement;
- Including a Parabolic Equation (PE) acoustic model in the environmental package for frequencies below 1 kHz;
- Extending the system to provide continuous updates to the detection predictions based on the current geographic location;
- Automation of model parameter selection;
- Automation of Sound Velocity Profile (SVP) data preparation; and
- Completion of the database population.

An example of more detailed environmental assessment is shown in Figure 9 below, where the ray-plot and the full field propagation loss have been combined into one display. While based on a single Bathythermograph (BT) assumed constant over range, the model run blends the measured and historical BT data to accommodate the variable bathymetry automatically.

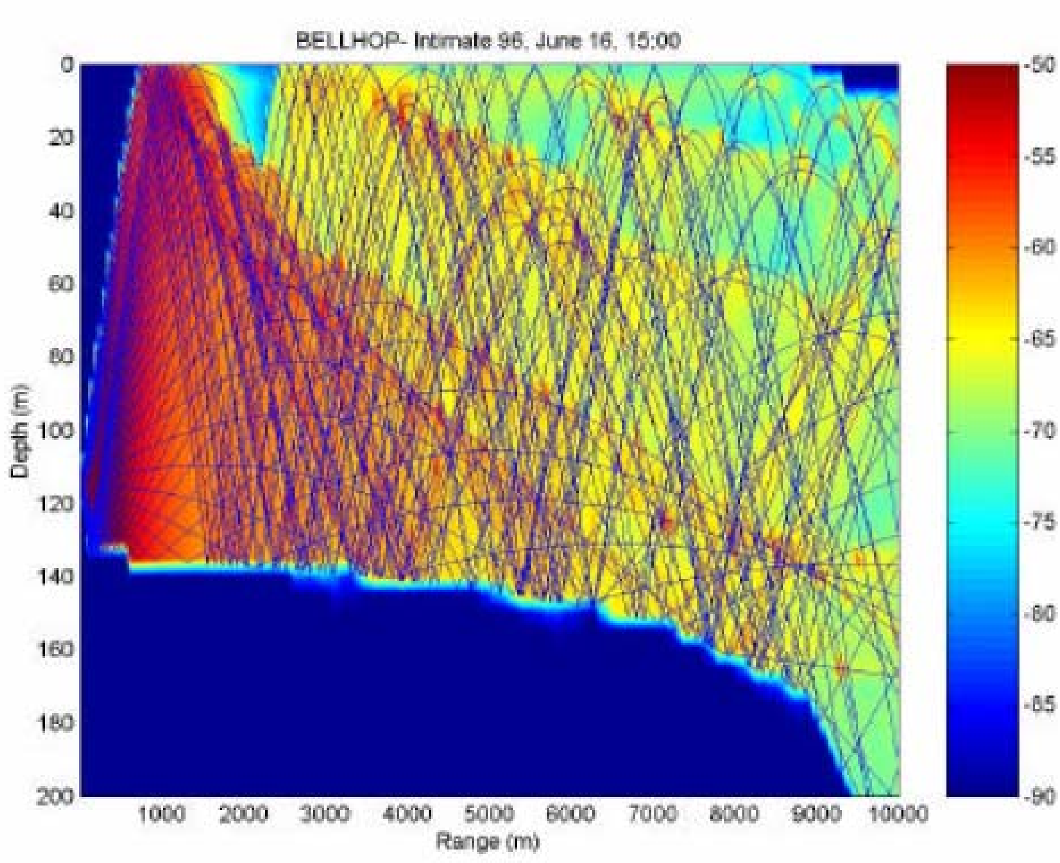

Figure 9. Combined Ray-Plot and Propagation Loss Display

A second feature of the intermediate package is provision of outputs to assist command and the sonar operators in a coarse estimate of the optimum placement of the receivers; for example, where to deploy sonobuoys, and what depths to choose for the sonobuoy hydrophone. In the case of the towed array the tool would allow the operator to input the desired speed of advance and cable scope range. This will be converted to a range of depths available, and the model runs will be used to select a couple of options. These will guide the placement of this important sensor for best water column coverage. Most of the calculations are already done for this type of analysis within the model. The intermediate package will need an operator interface to perform the 'what-if' analysis.

The Bellhop model uses ray-path predictions that have had some error problems, especially below 1 kHz. In the intermediate level package it is proposed to include the ability to run a second model suited to low-frequency passive propagation problems. A reasonable choice would be a PE model. These models are reasonably efficient for low frequency shallow water scenarios, and DRDC has ready access to a well-established PE model (PECan). In those spectral areas below 1 kHz, where the PE results and the Bellhop results differ by more than a few decibels, then this package would select and use the PE results in the computations for system performance and coverage indications.

Another proposed change for the intermediate level package would be to have the environmental analysis system running in the background using the current location and through-the-sensor noise measurements to update the detection performance. This would alert the system operators to any look directions or sensor types whose performance may have changed from the time of the initial environment analysis runs. We further propose to automate the calculations for all sensors in the task group, which generally includes the SQS-510, AQAP-3 (helicopter dipping sonar), Canadian Towed Array Sonar System (CANTASS) and sonobuoys. We would also automate the calculation of counter detection ranges for our own signatures at the current speed, and for the SQS-510 hull-mounted sonar. There are no significant technical hurdles preventing real-time operation of the NUW package.

One final improvement that has high importance in the intermediate level package is automating the preparation of the SVP data and the geoacoustic data for input into the acoustic model. Currently in the basic package this requires operator intensive effort, but the knowledge exists to automatically configure this data. There already exist bathy launchers with computer interfaces for data transfer, and MSTDCL has partially implemented an interface to the Mk.8 Bathythermograph on the Halifax-class ships. We require smoothing of the data received, a decision on the actual water depth, and reconciliation of this measured data with historical database data for extensions where the depth profile has deeper water than the point at which the measurement was taken; i.e. a down slope look direction. Also we require merging of the BT data with satellite or ship's surface measured surface temperature to more accurately represent the first 10 m of profile data.

It is important to note that these latter improvements are not aimed at improving the fidelity of the propagation model (Bellhop), which appears to be adequate for most scenarios. In the basic package, however, the accuracy of the model results is limited by inaccurate and out-of-date environmental data-base parameters. Many of the upgrades proposed for the intermediate package, by automating measurements and data synthesis, would improve the reliability of the environmental specification, and by extension would result in more accurate and reliable acoustic performance predictions. The operators and command would have constantly up-to-date information with very low operator involvement, which is a significant advantage for the intermediate level environmental analysis package.

3.1 Advantages of the Intermediate Environmental Analysis Package

The intermediate level of acoustic environmental analysis package represents a significant engineering upgrade to the basic package provided by NUW. In the intermediate level analysis package all the advantages attributed to the basic package currently being developed by the NUW TDP are applicable, along with the added advantages of:

- Reduced operator intervention;
- Completed database population;
- Completed optimization for ping selection and sensor placement;

- More frequent updates via automatic model parameterization;
- More accurate predictions for frequencies below 1 kHz; and
- Improved operator/command communications via the updated displays and additional outputs provided.

In the case of MSTDCL operations in littoral waters, where the acoustic environment can be changing rapidly, it is a significant advantage to have more frequent updates. At a minimum the operator is alerted to the changes in the sonar coverage and has the potential to adjust the sensor depth in the case of the towed array, deploy additional sonobuoys to the new optimum depths, and to inform command of the changing detection coverage available from the deployed sensors.

The more frequent updates can only be considered viable in the operational context if the process of editing the bathy information is automated. This involves potentially changing the bathy launcher on the frigates to include an updated multi-chamber launcher and the elimination of operator intervention in doing the editing and preparing the profile for input to the acoustic model. This automation provides for more timely updates of the environmental picture and is viewed as a significant advancement for this MSTDCL intermediate level package.

The inclusion of the PE acoustic model in this package for frequencies below 1 kHz improves the performance prediction accuracy in this region of the acoustic spectrum for environments where ray path analysis has been shown to have some weaknesses. The addition of this acoustic model to support the Bellhop model is a small step that NUW may implement before MSTDCL imports this functionality. The addition of this low frequency model is a prediction accuracy advantage for MSTDCL since most signals of interest for the CANTASS and sonobuoys are below 1 kHz.

This intermediate level environmental package will provide improved inputs for the MSTDCL automatic processing components, the associator and the tracker. With the basic package the accuracy of the detection range estimates — which may be based on the SVP from a few hours ago — can at best provide a generalized “range of the day” sort of estimate. Even though the bathymetry and noise backgrounds would be updated in the basic package, the rapidly changing environments of the littoral region can often require more frequent SVP updates which this intermediate package proposes to make available. This provides the associator and tracker processing more current and reliable estimates on which to base the solutions.

One additional advantage for this intermediate level package is the improved communication options provided by the additional displays and processing. This would provide the PLEIADES operator the additional knowledge on how to deploy the sensors to achieve the best performance against a particular threat. In some environments one sensor placement may not be as viable as another, and the consequence of this may be reduced detection ranges regardless of the sensor depth selected. However, having an operator informed of the sonar environment, through the additional displays of the detection coverage possible with differing deployments, increases the effectiveness of the PLEIADES system.

3.2 Effort to Implement Intermediate Package for MSTDCL

This section contains very rough estimates of the order of magnitude of effort that would be required to implement the Intermediate Environmental Package. As a first step, the Basic Environmental Package must be implemented. If DRDC is interested in pursing these capabilities, then GD Canada recommends performing a design investigation to better define the scope, solution, and projected costs. GD Canada views this effort as a natural extension of this study. If directed by DRDC, GD Canada will propose how to conduct such an investigation within Option Phase 3 of the MSTDCL contract.

The tasks required and their rough order of magnitude estimates are:

- A more detailed evaluation of the environment (new display formats): 20 - 40 days;
- Coarse outputs to assist command in the optimum sensor placement: 15 – 30 days;
- Including a PE acoustic model for frequencies below 1 kHz: 15 – 30 days;
- Extend the system to provide continuous updates to the detection predictions based on measured noise and the current geographic location; 60 – 80 days (includes automating performance of all models of interest to the task group);
- Add sensor coverage inputs to the tracker, associator and classifier to provide more reliable system outputs: 30 – 60 days; and
- Automate SVP data preparation: 10 – 20 days.

The total estimate is on the order of 200 days, +/- 50. Clearly this is a significant investment; however, it is the type of functionality that is required to significantly boost the operational performance of our sonar systems in realistic at-sea environments.

As an alternative approach, note that GD Canada's SPADES tool already provides some of the Intermediate capabilities described above. Therefore, the cost of upgrading from the Basic package to the Intermediate package would be reduced. This must be balanced against the higher initial cost of integrating SPADES with the STB.

4 Advanced Environmental Package

In the basic and intermediate environmental packages we assumed databases of sufficient accuracy were available so that the acoustic model was provided with inputs that would describe the range independent environment. In deep water the resulting predictions would be sufficiently accurate over long ranges. In the littoral regions we cannot make that assumption. The main thrust of the proposed advanced environmental package for MSTDCL is to enable more accurate and detailed environmental assessment, using *in situ* and through-the-sonar measurements.

In littoral environments one SVP will not apply over all ranges and areas for which predictions are required. Another difficulty is that under typical situations the Frigates usually only acquire a few SVP per day. In a littoral environment the SVP may change on spatial scales of a few miles, so this level of sampling is inadequate. In addition the bottom parameter databases are, in many cases, actually holdovers from deepwater applications. One of the current geoacoustic databases, the Bottom Loss Upgrade (BLUG) database, is an extrapolation from deep-water provinces to shallow water bottom types and is rarely based on local acoustic measurements.

For these reasons and the complexity of littoral waters, it is not uncommon for model predictions of propagation loss, and hence detection range estimates, to be in disagreement with measurements by 5 – 10 dB or more. Computing the full range-dependent environment is desirable, but this is a challenging problem. For the ranges of interest to the MSTDCL project it is still very worthwhile to consider an advanced acoustic environment analysis package that accurately handles a range-independent SVP and geoacoustic properties along with the range dependent bathymetry. This is similar to the approach used in the basic and intermediate packages. However in the advanced package we propose automated tools that can update the model inputs based on sensor measurements, producing an ensemble average for the SVP and geoacoustic inputs, more representative of the true environmental complexity. That is, the ensemble average is representative of the range-dependent environment and accurately reflects the expected variability that could exist in the environmental parameters over the ranges of interest.

In an advanced environmental analysis package the goal is to reduce disagreements between the performance prediction and measurements, where possible through in situ geoacoustic inversions (single sensor), environmental measurements with tomography (SVPs), and ambient noise measurements. It is assumed that an initial mean environment that is close to reality can be estimated from databases and measurements. These include the SVP and a geoacoustic profile that includes sediment sound speed, density and attenuation versus depth. Multi-path propagation in a shallow water environment leads to coherent structure in the sound field both spatially and temporally. The nature of this coherent structure is strongly dependent on the geoacoustic parameters of the sediment and is the physical basis for the modeling approach to the extraction of the geoacoustic parameters.

The goal of the advanced package is to predict the actual range dependence for both the water column and the seabed properties. Two methods for generating and handling the inputs are addressed in this advanced environmental package. The first is an interpolating scheme for the SVP and the geoacoustic parameters to be used in the acoustic model. We will need to impose a time constraint to ensure this converges in time to provide useful outputs. If it does not, or if we cannot use this approach because the range-dependent SVP is not known, then a second statistical approach can be used where a mean profile is perturbed based on observation. This allows the acoustical model, and hence the operator, to see a meaningful range of performance estimates which can then be used to guide the deployment of resources and the interpretation of sonar results.

The approach is comprised of five basic steps:

1. An analytical estimate of the critical environmental parameters is performed. Beginning with a mean SVP it can be predicted which of the environmental parameters would have the most influence on the propagation paths at hand.

2. A measurement of these critical environmental parameters is performed, along with statistical uncertainties.

3. Generate an ensemble of possible environments. Here we consider a range dependent environment with one possible SVP perturbed slightly, to describe variability over the entire path length. Similarly for the geoacoustic features to be passed to the acoustic model, we consider an ensemble of possible parameters.

4. Compute the transmission loss and ray paths for an ensemble of environmental parameters.

5. Communicate the acoustic uncertainty to the operator in a meaningful way.

The proposed advanced environmental analysis package is illustrated in block diagram form in Figure 10 below.

One attribute of this advanced system is that the mean SVP will be used to guide the selection of the environmental parameters that have the most effect on the model results. For example, it is well known that steep propagating acoustic rays (high normal modes) refract little and are insensitive to details of the sound speed. We also know that sound channel or trapped acoustic energy as well as surface reflected-bottom refracted rays are insensitive to geoacoustic parameters.

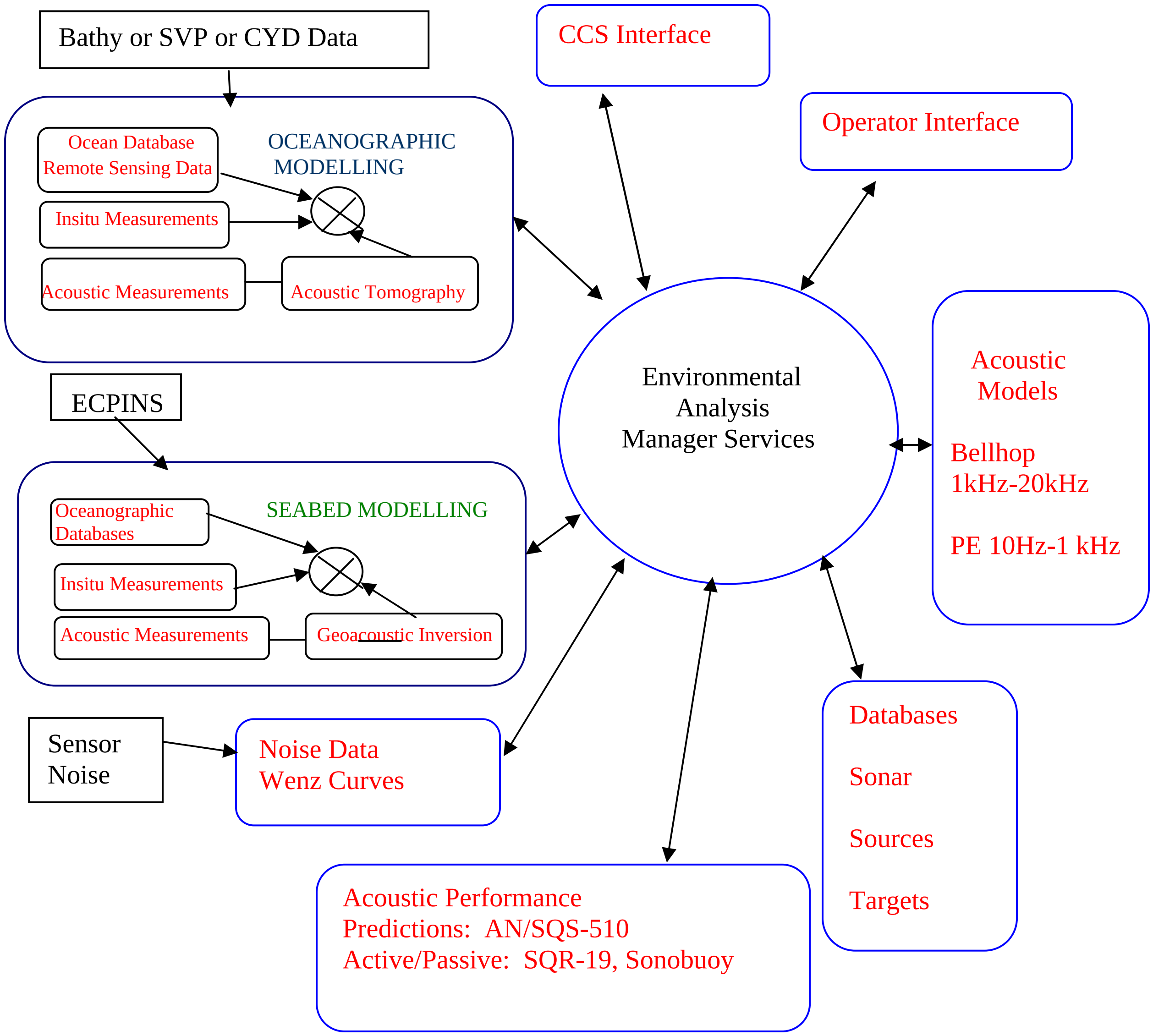

Figure 10. Advanced Environmental Analysis Package

We must consider the source and receiver depths when dealing with environmental parameter classifications that are derived from the sound velocity profile. Acoustic field measurements made at different depths will be sensitive to different environmental parameters. For example we can classify paths as downward refracting, upward refracting, surface duct, sound channel, etc. Analysis in Ref[2] indicates how the model can use these classifications. For example, downward refracting rays or modes (acoustic rays/modes with phase speed at the source that are less than the surface sound speed) will be refracted away from the surface and can be considered examples of surface-reflected-bottom reflected paths. These paths are sensitive to the SVP and to internal wave activity in the mixed surface layer. The energy will also interact with the bottom though with lower grazing angles. For hard sediments with high sound speed ratios and high critical angles all the bottom interaction will be sub-critical and propagation will be sensitive to the sediment attenuation but not the sediment sound speed. Similar analysis can be derived at other source depths for the same SVP where the phase speed is greater than the surface sound speed and these produce surface reflected-bottom reflected paths. All this energy will be at relatively high angles and will therefore refract little as they propagate.

This analysis is meant to generate an appreciation of the variability that may be encountered in the acoustic model outputs based on the level of confidence that can be placed on the database type and the sampling resolution. This analysis in turn will lead to an automatic input and update system for the parameters required by the acoustic model. This automatic input system will track the ship movement and update the operator performance prediction displays on a periodic basis.

The advanced acoustic environmental analysis package relies on the ability of the model to incorporate local measurements from passing ships of opportunity. When these contacts exist, we can develop a scissorgram, a measure of the received acoustic power level as a function of radar range. Through analysis we can invert these power levels to provide more reliable estimates of the local environmental parameters, the geo-acoustic parameters and the modified SVP, than can be supplied to the acoustic model, by databases alone. When the input parameters have been derived from such measurements the results of the performance predictions can be presented in a different color on the predictions chart, to clearly indicate to the operator that these results are based on 'reliable' local data measurements.

In this advanced environmental analysis package an effective parameterization of the environment is sought which permits the accurate prediction of the features of the acoustic field that are relevant for the sonars involved and the range dependent environment they are working in. A second aspect of this advanced package is rapid computation for timely availability of the desired sonar performance predictions. This means that the generally very large geoacoustic parameter search space is significantly reduced by using a simple geoacoustic model with a single layer, single grain size sediment, overlaying a hard acoustic half-space. This model is based on the work of Hamilton [4] and Buchmann [5].

In this advanced model the uncertainty of the input data will depend on the area of operations, the databases available for that area, and the operational conditions encountered. When we encounter contacts of opportunity that allow us to estimate the environmental parameters, we can compare the results to the uncertainties. As we develop a statistically significant set of measurements, we can better quantify the uncertainty, which leads to better ensembles and better bounds on the possible environmental conditions.

4.1 Advantages of the Advanced Environmental Analysis Package

In the previous two levels of acoustic environmental analysis and prediction packages a number of the input parameters were obtained from either historical databases or from generalized geoacoustic tables. However variability in the coastal ocean environment spans a wide range of spatial and temporal scales and these can lead to poor acoustic predictions. The key advantage of this advanced acoustic environmental analysis package is that it addresses the uncertainty which may be present in the input environmental parameters and alerts the operator to the potential variability which may exist in the results obtained from the performance prediction tools due to these environmental uncertainties.

The improved transmission loss accuracy and accompanying uncertainty bounds presented to the operator and command can have significant impact on all sonar operations. For MSTDCL, one key advantage would be the inclusion of this prediction information into the signal/data processing stream of the system. The associator, tracker and classifier can have improved acoustic path prediction data, better range estimates for bounds on possible tracker solutions and improved target parameter estimates. These advances in the environmental parameter representation are the result of the improved understanding and reliability of the true acoustic path as a function of range, bearing and depth; i.e. the three dimensional picture.

The improved knowledge can also provide improved sonar operations for PLEIADES by determining regions of coverage overlap for the various sensors. Ensuring sonar coverage overlap is a significant safety feature for ship operations in littoral waters. Not only will the potential for initial detections be improved but the target associator and tracker operations are also improved. Improved detections will also result in reduced times to develop accurate solutions and hence more time to prepare a defence in the event of a weapon firing. The associator is better able to predict when the contact on two sensors may be the same target, based on the improved sensor coverage predictions. The tracker benefits from having more than one sensor in contact, yielding a full solution vice the underdetermined case that often exists when only one sensor is deemed to be in contact.

In the case of MSTDCL, having accurate or at least reliable bounds on possible detection ranges for each sensor and knowledge of the possible coverage overlap can be of significant system performance benefit. This is as opposed to the general guidelines and possibly unreliable performance predictions that could be experienced by using the model predictions that have been derived from input parameters obtained from historical and generalized environmental databases.

4.2 Effort to Implement Advanced Package for MSTDCL

The effort required to implement the advanced package is very large, likely on the order of 2 to 4 person years, and requiring a number of at-sea trials to validate the performance. GD Canada is prepared to develop a preliminary design and cost estimate for this package if DRDC requests this information, however, we believe that such a large project is very much outside the scope of MSTDCL.

5 Advantages to MSTDCL of Including an Environmental Analysis Package

Acoustic predictability is critical to the deciBel budget for effective sonar operations and significantly affects the probabilities of detection and false alarm. Communicating this information in an effective manner to the sonar operator(s) and the command is equally as important as the acoustic predictions themselves. To be useful to the operators the information must be available in a timely manner and must be responsive to changing oceanographic conditions. The NUW project at DRDC-Atlantic has undertaken the development of an environmental analysis package which we have briefly described as our basic analysis package. While primarily aimed at submarine detection and tracking, this package offers significant advantages for the MSTDCL project as well. By including torpedo threat parameters in this prediction package, the algorithms, interfaces and displays provided offer a significant advance in acoustic prediction capability that can be ported to the MSTDCL project team for very low cost.

This package contains the tools, databases, interfaces, models, calibration data and output displays to provide the MSTDCL operator with a good understanding of how the sonar systems can perform under the conditions input to the model. This is especially important when it comes to detection range estimates and water column coverage. The chart view is a unique feature of this environmental package as is the ability to accommodate range-dependent bathymetry for the various sectors.

The through-the-sensor measurement capability for background noise estimation is another key feature of this environmental analysis package. This capability means that the operator will be provided with a more accurate view of the expected detection ranges on a sector- by- sector basis which in turn can allow the command to better deploy their sonar resources. This information can be an important factor in sonobuoy deployment, providing spacing and expected detection range and coverage overlap with other sensors. This capability is especially valuable to the MSTDCL system.

The knowledge of detection coverage overlap is an important input parameter for the association and tracker algorithms. Here having the knowledge of two sensors in contact on the same target, can yield a rapid accurate tracker solution, solving the underdetermined case and reducing the effect of errors for the “intercept” and “pursuit” assumption cases.

In the consideration of safely completing a tactical mission, an environmental analysis package can be a vital tool for command. The basic package being developed by the NUW TDP is the result of understanding the importance of this tool in the employment of co-operating assets. Here detection performance predictions are a key to unit spacing for optimal sonar coverage. In deciding on where to deploy resources such as the towed array and sonobuoys, a 3D view of predicted detection performance is also vital if full water column coverage is to be attained. In the MSTDCL project this water column view of estimated detection performance is also critical since it is well known that different weapons operate most effectively at different depths; e.g. wake homing vs. passive acoustic torpedoes. The displays provided by the combined ray path and propagation loss presentation will clearly alert the operator to possible gaps in sonar coverage, should they exist at the ranges of interest for the MSTDCL system.

Then building on this capability the intermediate package would extend the timeliness and accuracy of the prediction results via the automation of the preparation of the model inputs. Where the basic package update information can be skewed by the time since the last SVP calculation and/or geoacoustic data input, the intermediate package, through the automation process could provide for more frequent acoustic model updates. These more frequent model runs could even be event driven updates based on ship, sensor or remote input of environmental measurements.

Realizing that the littoral region can often present the sonar suite with a complex range dependent environment, the advanced environmental package proposes the use of state-of-the-art modeling techniques to more accurately reflect in the acoustic model inputs, the variability in the acoustic path which environmental measurements have shown are being encountered. That is, the advanced package proposes to use *through-the-sensor* acoustic measurements to resolve the differences between the model predictions and the measurements via the use of the measurements to more accurately predict the environment parameters input to the acoustic model. In this way the sonar operators and the automatic processing of the MSTDCL system will have available the most accurate and up-to-date sonar performance predictions.

6 Conclusions and Recommendations

In this note we have described three acoustic environmental analysis packages and noted the advantages to MSTDCL that each could provide. The starting point was the package developed by the NUW TDP, and represents an excellent capability with significant improvements over many other operational analysis packages. The intermediate level package proposed represents mainly engineering and operational improvements to the NUW package that will help to improve the effectiveness of environmental analysis in the MSTDCL system. The advanced analysis package proposed represents a scientific advance to the basic and intermediate packages by incorporating the latest environment sampling techniques to produce more accurate sonar performance estimates or when all the inputs are not available, provides a measure of the uncertainty that may be encountered and how this could affect the sonar performance.

It has been fairly well documented in several recent DRDC-A trials on the North Sea, Mediterranean, and Scotian Shelf that the acoustic performance predictions were quite far off from the performance actually achieved. In one case, Q268 - the TMAST trial in the Irish Sea, the bathy conditions indicated a downward refracting environment and thus poor propagation conditions were predicted, mainly influenced by the geoacoustic parameters assumed. However, the sonar results achieved were much better than predicted and this type of experience gives a negative bias to some existing environmental analysis packages. These observations were confirmed by Jensen and Ferla in a paper presented at the Environmental Variability Conference in La Spezia [6].

The first recommendation would be to do the small amount of engineering required to adapt and incorporate the basic NUW environmental analysis package into the MSTDCL system. This allows experience to be gained with this type of product. Although there is currently no allocation for this work in the MSTDCL budget and schedule, the work could be completed for a relatively small cost (approximately 320 hours as described in section 2.2) if additional financial resources were available.

Once the Basic package is implemented and fully understood, we recommend performing an estimate of the engineering required to implement the intermediate level of environmental analysis package. If desired, GD could implement this package as part of Option Phase 3, if this option is exercised by DRDC.

As an alternative, GD Canada has its own environmental prediction package (SPADES), which could be integrated with the STB. This option has not been recommended because the NUW environmental package will require less integration effort, thus providing the MSTDCL TDP with a Basic environmental capability at the lowest possible cost. However, SPADES already offers some of the capabilities proposed for the Intermediate package described in this report. Therefore, the increased cost of integration would be partially offset by an increase in capability, and a decreased cost of upgrading to the Intermediate package. If so directed, GD Canada could perform a more detailed costing estimate for these two alternative ways of reaching the Intermediate package capability.

Our third recommendation is to explore the costs associated with implementing the oceanographic model and the seabed modeling, which are the main features of the advanced environmental analysis package, and the incorporation of these into the NUW acoustics model. This would allow for further elaboration of the two models advancements. We would also propose to develop the necessary structure to link the acoustic *through-the-sensor* measurements with radar tracks so that the inversion calculations can be performed. It is expected that the MSTDCL CCS interface could provide the necessary data. Assuming that funding is available, it would then be recommended that the advanced acoustic environmental analysis package be progressed to a demonstrable product. Given the large scope and uncertain costs, the algorithm development and implementations for the Advanced Package would likely occur under a separate research project.

The timely implementation of these recommendations would then ensure that any operational deployment of the MSTDCL system could benefit from the availability of a world class acoustic environmental analysis package providing true multi-sensor target association, tracker solutions and classification in a timely manner consistent with the high speeds of the torpedo threat.

7 References

[1] G. Inglis, et al., "NECS Environmental Analysis Application," DRDC Atlantic CR 2007-204.

[2] D. McCammon, "BellhopDRDC Users Guide, Version 3: Covering Transmission Loss, Ray Tracing, Bottom Loss and Surface Loss," DRDC Atlantic CR 2006-067.

[3] K. Heaney and H. Cox, "A Tactical Approach to Environmental Uncertainty and Sensitivity", IEEE *J. Ocean Eng.* Vol. 31(2), pp 356-367, April 2006

[4] E. I. Hamilton, "Geoacoustic Modeling of the Seafloor", *J. Acoust. Soc. Am*. vol. 68, pp 1313-1314, 1980.

[5] R. T. Bachman, "Parameterization of Geoacoustic Properties", San Diego, Cal., Scripps Institution of Oceanography, 1989

[6] E. B. Jensen and C. M. Ferla, "Mismatch Between Navy Bottom Loss Databases and measured Results", presented at the Environmental Variability in the Littoral Ocean, LaSpezia, Italy, 2002.

List of acronyms and initialisms

ARP	Address Resolution Protocol
BLUG	Bottom Loss Upgrade (environmental database)
BT	Bathythermograph
CANTASS	Canadian Towed Line Array Sonar System
CASS	Comprehensive Acoustic Simulation System
CCS	Command and Control System
CF	Calibration Factors
COTS	Commercial Off-the-Shelf
CPF	Canadian Patrol Frigate (Halifax-class ship)
CW	Continuous Wave
dB	Decibel
DIFAR	Directional Frequency and Ranging
DRDC	Defence Research & Development Canada
EMM	Environmental Modelling Manager
ETOP02	Global 2' Elevation Database
FM	Frequency Modulated
GD Canada	General Dynamics Canada
GDPE	General Dynamics Parabolic Equation
GRAB	Gaussian Ray Bundle
MSTDCL	Multi-Sensor Torpedo Detection Classification and Localization
NUW	Networked Underwater Warfare
ONR	Office of Naval Research
PCs	Personnel Computers
PE	Parabolic Equation
PECan	PE Model developed by DRDC
SPADES/ICE	Sensor Performance and Acoustic Detection Evaluation System / Integrated Coverage Editor
STB	System Test Bed
SVP	Sound Velocity Profile
TDP	Technology Demonstration Project
TL	Transmission Loss
TMAST	TTCP Multi-Static Active Sonar Technology project

This page intentionally left blank.

Distribution list

Document No.: DRDC Atlantic CR 2009-004

LIST PART 1: Internal Distribution by Centre:

3	DRDC Atlantic Library
1	Erin MacNeil, PM/MSTDCL TDP
1	David Hazen, H/TD
1	Mark Trevorrow
1	Art Collier
1	John Osler, GL/MEA
8	TOTAL LIST PART 1

LIST PART 2: External Distribution by DRDKIM

1	NDHQ / DRDKIM 3
1	Library & Archives Canada, Attn: Military Archivist, Government Records Branch
1	Peter Giles, General Dynamics Canada, 31 Millbrook Ave, Dartmouth, NS B2V 0A2
1	DSTM 4, DRDC HQ, Constitution Bldg, 305 Rideau St., Ottawa, ON K1A 0K2
1	DMRS 5-3, NDHQ Ottawa, 101 Colonel By Dr., Ottawa, ON K1A 0K2
1	DMRS 5-2, NDHQ Ottawa, 101 Colonel By Dr., Ottawa, ON K1A 0K2
1	DMSS 7-2, NDHQ Ottawa, 101 Colonel By Dr., Ottawa, ON K1A 0K2
7	TOTAL LIST PART 2

15 TOTAL COPIES REQUIRED

This page intentionally left blank.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) General Dynamics Canada Ltd 3785 Richmond Rd., Ottawa, Ontario K2H 5B7	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Environmental Modeling Packages for the MSTDCL TDP: Review and Recommendations

4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used)

Trider, R., Giles, P., and Martin, B.

5. DATE OF PUBLICATION (Month and year of publication of document.) September 2009	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 42	6b. NO. OF REFS (Total cited in document.) 6

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Contract Report

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

Defence R&D Canada – Atlantic
9 Grove Street
P.O. Box 1012
Dartmouth, Nova Scotia B2Y 3Z7

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.) 11cw02	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.) W7707-053008
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.) 979392	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.) DRDC Atlantic CR 2009-004

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

Unlimited

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

Since 2005 DRDC Atlantic has been conducting the Multi-Sensor Torpedo Detection, Classification, and Localization (MSTDCL) technology demonstration project aimed at improving the torpedo detection, classification, and tracking capabilities on Halifax-class frigates. This document examines the advantages to the MSTDCL project of adding a capable Environmental Analysis package for detection performance prediction. Three levels of complexity were examined: a basic level based on the Networked Underwater Warfare (NUW) developed analysis package, an intermediate level package building on the NUW package to provide improved functionality and displays while reducing operator interaction, and an Advanced Environmental Analysis package that improves the accuracy of the performance predictions by more accurately representing range-dependent environments. The advantages of each level to the MSTDCL system are compared, along with estimates of the work level required to implement the package. A low-risk approach beginning with the NUW package and advancing through the intermediate levels is recommended.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Acoustics; Environmental Modeling; PLEIADES; sonar; Halifax-class

Defence R&D Canada

Canada's leader in defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca