Networked Underwater Warfare TDP - A Concept Demonstrator for Multi-Platform Operations

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Abstract

The Networked Underwater Warfare Technology Demonstration Project (NUW TDP) is a Defence R&D Canada activity that will spend approximately $6.2M over four years to investigate, via simulation and real-time demonstration, future capabilities for the Canadian Navy and Maritime Air to carry out integrated, single- and multi-platform UnderWater Warfare (UWW) in national operations and coalition operations with our allies. It will utilize information from a variety of acoustic sensors to build the local-area UWW picture and subsequently provide it to the command system for merging into the overall tactical picture. Included in the project will be an investigation of other acoustic-related applications that emphasize complete visualization of the tactical scene, including tactical oceanography, and classification and decision aids to optimize the employment of UWW resources.

1. Background

Within Canada, initiatives are underway that should lead to a range of new acoustic (sonar) systems being installed on virtually all Naval and Maritime Air platforms. These programs are already benefiting from extensive research and development carried out by Defence R&D Canada, and the resulting new systems will incorporate the latest in wet-end sensors and dry-end signal and data processing.

Each of these programs is independently addressing the fundamental issues of information analysis, fusion, distribution, and decision support. But there is now an opportunity to improve effectiveness by creating a flexible information/knowledge management architecture that can support each specific sonar application, and that can also be generalized to include land- and air-based sensors.

Due to the current focus on multi-platform, multi-threat warfare in confined littoral waters, and the advent of low-frequency active sonar and its attendant acoustic impact over large ocean areas, it has become increasingly important that all co-operating platforms operating in the affected areas be tightly managed in near real-time. This in turn requires an infrastructure where individual platforms act as nodes within a networked environment, able to acquire and publish sensor and tactical information in order to co-operatively build an accurate local-area tactical picture.

Torpedo defence and mine avoidance capability can also be heavily leveraged through real-time multi-platform coordination. These requirements are made more urgent by the rapid evolution in computing and communications, and the US Navy's push towards network-centric warfare. This in turn demands that this activity be carried out in a context of coalition and joint interoperability. Consequently, there is an urgent need to accelerate current activities to further investigate concepts and develop solutions for multi-platform, net-centric systems for Canadian warships operating within a coalition scenario. Core concepts and capabilities for other key participants in littoral UnderWater Warfare (UWW) also need to be addressed, including the CP-140 Maritime Patrol Aircraft (MPA) and the Maritime Helicopter. This project constitutes the first venture by the Canadian maritime R&D community into net-centric warfare. Using anti-submarine warfare as a focus, this technology demonstrator will evaluate and validate concepts in networked cooperative operations in a maritime environment.

2. The Technology Demonstrator Model

Defence R&D Canada – Atlantic has assisted the naval community with a range of technology demonstrators that in the past have concentrated on the surface ship towed array sensor. In fact, the current primary anti-submarine sensor on board the Halifax Class Frigate, the Canadian Towed Array Sonar System (CANTASS), is a direct result of research and demonstration at this laboratory. The current emphasis is now directed towards integrating information from a variety of acoustic sensors and investigating strategies for the utilization of this information at the command and control level.

Concept demonstration projects at DRDC Atlantic emphasize algorithm research and development. The hardware is commercial-off-the-shelf (COTS), although some special-purpose hardware is used if necessary, and the software is written to a relaxed standard that emphasizes functionality and demonstrability. The final demonstration system is designed to meet real-time requirements in order to provide a vehicle for exhaustive assessment on board either naval or air platforms. The philosophy is to follow the build-a-little-and-test paradigm, allowing for incremental improvements as they become available.

The lab's sonar research effort has been focused by a series of concept demonstrators that have the capability to process and display the outputs of acoustic arrays and sonobuoy fields in real time aboard operational platforms. Two of the current sonar technology demonstrators, the Towed Integrated Active-Passive Sonar (TIAPS) [NSS0199, 1999] [LFA, 2002] and the Integrated Multistatic Passive Active Concept Testbed (IMPACT[1]) [MIS0200, 2000], support the Navy and the Maritime Air community, respectively, in developing an integrated passive and low frequency active sonar capability. As the signal processing and human-computer interface (HCI) research in these systems has reached maturity, the NUW TDP will seek to improve solutions in the domain of combat systems that must operate in a multi-platform, multi-threat littoral environment.

[1] The Modular VME Acoustic Signal Processor (MVASP), largely based on the multistatic capabilities of IMPACT, is currently being fitted into the MPA fleet.

3. Objectives

Motivated by the trend toward multistatic low frequency active sonar, and the drive towards the US-inspired Joint Vision 2010 [JV2010] with its focus on net-centric warfare, the NUW technology demonstrator will demonstrate improvements in UWW by utilizing multiple cooperating platforms and a common networked infrastructure. This will be realized by building a networked underwater warfare system with a focus on anti-submarine warfare (ASW). NUW will leverage upon technologies generated by other concept demonstrators, including:

- TIAPS – an integrated passive/low frequency active system with both a source and active receive towed array, and a wide-aperture passive towed array,
- IMPACT – an airborne sonobuoy signal and data processing system capable of target localization in a multistatic operations environment, and
- SIMS – the Sonar Information Management System, an integrated active and passive acoustic data management system focused on the requirements of a single ship [MIS0199, 2001].

In order to demonstrate improvements by using net-centric capabilities and multiple sensor inputs, the NUW TD has the following objectives: First, to design, build and demonstrate a networked information and decision management system that generates the multi-platform UWW component of the local tactical picture. Second, to develop a simulation environment for system development and testing. Third, to develop a radio frequency communications network based on Internet Protocols. Finally, to provide a sea-tested, systems-oriented database to support the development and acquisition of future systems for Canadian Forces surface, subsurface, and maritime air platforms.

4. Major Activities

The project is composed of a number of activities that includes both construction of the required infrastructure and testing facilities, and the development of capabilities to address aspects of networked underwater warfare. The following sections provide an overview of the general areas that will be addressed over the course of the project.

4.1 *Concept Demonstration and Design*

In order to keep pace with the changing operational requirements and to take maximum advantage of COTS technologies, the emphasis is now on the data, information and knowledge processing, and display requirements. Especially in the area of research-level concept demonstrators, it is important to maintain a flexible “plug-and-play” architecture to allow for the quick insertion and replacement of candidate combat system technologies when assessing capabilities and recent innovations.

The open standard called the Common Object Request Broker Architecture (CORBA) [CORBA] forms the underlying infrastructure that will provide a transparent data communications capability within a client/server paradigm. The mechanics of data distribution are handled transparently by CORBA through a publish/subscribe environment, including translation between different hardware systems. The second middleware software system is the US Navy’s Common Operating

Environment (COE)[2] [COE] that forms the foundation for the Global Command and Control System – Maritime (GCCS-M), among other variants. This will provide the services related to the display of the local tactical picture, as well as provide database management services for the tracks of platforms detected on acoustic, non-acoustic, and off-board sensors. The third middleware package is the NATO acoustic prediction tool called AESS, for the Allied Environmental Support System. This will provide acoustic models that assist in the estimation of the surrounding ocean environment, including signal propagation loss through the medium, and the level of reverberation to be expected when employing active sonar.

4.2 *Simulation Testbed*

Within this project a modeling and simulation facility will provide a powerful means to both evaluate candidate combat system technologies in a controlled environment, and provide a testing environment prior to sea trials. Rather than building an entire infrastructure, Canada will be utilizing a sophisticated simulation package obtained through an international agreement called The Technical Cooperation Program (TTCP) [TTCP]. Based on the Virtual Ship Project [CSRC] currently under development at the Australian Defence Science and Technology Organisation (DSTO), this facility will simulate the data stream from a series of virtual acoustic sensors operating in a littoral environment. The initial focus will be on towed arrays and sonobuoys, with signal processing that enhances both the passive emanations from the surrounding ocean traffic, and the returns from virtual low-frequency active sonars. The underlying architecture of the Virtual Ship is the open standard called the High Level Architecture, or HLA, which provides an infrastructure within which models interact in a consistent manner and allows federations of simulations to communicate.

The final purpose of the simulation facility is to mimic a sea trial in order to stress test both the MPA and surface platform variants of the concept demonstrator. A virtual surface vessel and aircraft hosting a suite of sensors and a track database system will provide the necessary inputs to the combat system algorithms. Scenarios of advancing complexity will allow an evaluation of the system before actual trials at sea.

4.3 *Acoustic Sensor Integration*

Due to the reduction in radiated noise of modern submarines and the focus on littoral/shallow water environments with large numbers of vessels, the detection, classification, and localization of the local ocean traffic using acoustic sensors has become increasingly difficult. In addition, modern acoustic sensors provide such a quantity of data that the sheer volume can overwhelm the operator. The solution lies in the concepts of sonar information management that support cooperative UWW by distilling the data into meaningful information.

This project will demonstrate the integration of active and passive sensor data with full utilization of non-acoustic and off-board data sources. Past research has concentrated on association and localization algorithms for the towed array from a single ship perspective, and for fields of

[2] Previously termed the Defence Information Infrastructure Common Operating Environment (DII COE). Defence R&D Canada – Atlantic is Canada's primary R&D facility for the COE.

sonobuoys. Investigations will now concentrate on the issues involved with multiple cooperating platforms utilizing a networked approach.

The COE will provide the tactical plotting capability upon which information from the acoustic sensor suites will be built. Lines of Bearing and Target Motion Analysis (TMA) solutions from passive sensors on cooperating platforms will be layered on top of an ocean bathymetry map. Detected echoes from active sonar will be added to the same display to allow both automatic and manual association between active and passive contacts. Correlation with non-acoustic track information will be available through the COE's tactical database management system, and these other tracks will be displayed alongside the acoustic sensor information. The layering of navigation and tactical data will provide the context for the sensor information and provide situational awareness.

4.4 *Tactical Oceanography*

The current acoustic prediction tool within the Canadian Naval community is the Allied Environmental Support System. This software package requires manual requests from the operator, issues a set of calls to the underlying sonar prediction engine, then returns the results for operator viewing. Within a previous project, DRDC Atlantic began developing a CORBA-based infrastructure that utilizes the underlying prediction engine for distributing sonar model information to a variety of client applications whose performance would be enhanced by knowledge of the current acoustic conditions. This work will be extended to allow assessment and validation of increased system functionality and situational awareness resulting from access to prediction information and high-resolution bathymetry charts. In particular, tactical decision aids on sonar sensor deployment and effectiveness will benefit from instant access to estimates of the surrounding acoustic environment. Some of the features of this system include:

- A CORBA-compliant server whose front end handles client requests through a consistent interface, and a back end that can connect to one or more acoustic prediction models. This will ensure that the full range of environmental information is available to client programs utilizing both passive and active sonar sensor data.
- A scheduling system where CPU-intensive processing will be performed in the background on a scheduled basis. Using results from the latest run will provide an almost instant response to requests by the operator or automated client programs. The CORBA publish/subscribe capability allows client programs to receive updates on a regular basis, and;
- Automatic provision of readily available information, such as ownship location and water depth, to minimize manual input by the operator.

4.5 *Tactical Decision Aids*

In order to facilitate the effective use of the tremendous amount of information available to the command team, the use of tactical decision aids will be investigated. A typical example of such an aid is the evaluation of user-specified scenarios, permitting an operator to investigate the potential risks and benefits of a course of action, the outcome of which would be influenced by conditions at hand. These scenarios often require tradeoffs among multiple competing objectives and

typically lack a clearly defined decision-making structure. In some cases, the conflict may be between the levels of risk and reward while in others the conflict may be between short and long-term objectives. The tactical decision aid's greatest value lies in its ability to communicate the impact of a proposed course of action within a complex environment.

Selection of a cost function, by which the results of a series of potential scenarios could be evaluated, further enhances the value of a tactical decision aid. An operator could request a decision recommendation from the decision aid, at which point the aid could provide one or more minima from the cost surface. Alternatively, the operator may be more interested in which scenarios to avoid, in which case the aid may indicate the surface maxima. In either case, the operator is provided generalized information that has been specialized to the current circumstances and is free to further investigate additional cases that may better fulfill requirements or expectations unknown to the aid.

4.6 *Experimentation and Trials*

The NUW TDP plans to participate in a number of trials and experiments that will demonstrate the developed technologies at increasing levels of integration. Significant sensor data has already been acquired from a TTCP-sponsored scientific ocean experiment that emphasized both passive and active sonars in a series of multiplatform scenarios. This data will be utilized to critically test the concept demonstrator as new capabilities are incorporated.

Again through TTCP, the project will be participating in annual experiments conducted by the US Navy, called Fleet Battle Experiments [FBE]. These experiments comprise a combined live and simulation environment that employs a coalition wide area network to investigate net-centric undersea warfare concepts, utilizing a large international infrastructure of labs, ranges, ships, and aircraft. The NUW TDP will use these experiments to investigate multiplatform data fusion concepts and information management agents on an increasing scale as new algorithms and tools become available within the concept testbed.

During the four-year timeframe of the NUW project, a number of trials using virtual sensors within the simulation testbed will provide focused testing of concept demonstrator components within a controlled environment. In addition, there is likely to be an opportunity to combine simulations with other TDPs that are exploring complementary issues. For example, the Maritime Air Littoral Operations (MALO) TDP is a simulation-based MPA testbed for investigating multistatic tactics, and the Command Decision Aid Technologies (COMDAT) TDP is developing a command decision support concept demonstrator for the CPF.

The last year of the project will involve two sea trials to demonstrate the final concept testbed. A single surface platform working in concert with an MPA will provide insights into the capabilities in a larger context. The research vessel attached to DRDC Atlantic, CFAV QUEST, will be towing the array system developed under the TIAPS project and sharing acoustic, track, and tactical information with the MPA in order to develop an accurate local tactical picture. The first trial will serve as a rehearsal and lessons-learned vehicle to detect deficiencies in the testbeds and connecting wireless local area network, providing an opportunity to rectify deficiencies before a full demonstration in the final sea trial.

4.7 *Multiplatform Integration*

The requirement to examine UWW in a networked environment precludes the use of any legacy data link protocols based on polling, including systems such as Link 11. Consequently, the NUW TDP intends to employ an HF/UHF Internet Protocol network based on technology developed for the Joint Warrior Interoperability Demonstrations (JWID) [JWID, 2001] involving the five countries Australia, Canada, New Zealand, the United Kingdom, and the United States (AUSCANNZUKUS). Employed on a minimum of two platforms, such as a surface ship and an MPA, the network will be configured to allow the examination of net-centric concepts in conducting UWW.

This requirement changes the traditional design paradigms used in stand-alone sonar systems. As discussed in Sections 4.1 and 4.3, the COE will host common services for the sensor systems and provide the underlying data connectivity protocols to facilitate interoperability. The initial surface testbed based on previous work utilizes COE services and is thus "network aware", and the IMPACT system is currently being interfaced into the COE environment to enable data sharing.

It is intended that the Internet Protocol-based RF network architecture will use one or more of the following technologies that have been demonstrated in JWID and continue to be developed and improved. DRDC Atlantic will work with the Communications Research Centre (CRC) in Ottawa to implement the required functionality:

- HF Extended Line of Sight (ELOS): a multi-member subnet currently capable of 9.6 Kbps via commercial modems. Development continues at CRC to achieve 16 Kbps in a single 3KHz channel or 32 Kbps in ISB (6 KHz channel).
- HF Beyond Line Of Sight (BLOS): currently capable of 9.6 Kbps from commercial modems. Development continues at CRC in an attempt to achieve a rate of 19.2 Kbps using novel modem waveforms.
- UHF Line Of Sight (LOS): currently capable of 16 Kbps with potential future capability of 64 Kbps and 128 Kbps under new modems currently being developed at CRC.

The existence of a low bandwidth network that enables the exchange of sensor information and a resulting common tactical picture produces its own inherent constraints. First, it demands that Information Exchange Requirements (IER) must be carefully articulated in order to benefit from the networked capability. Secondly, procedures and protocols must be enforced to ensure a consistent tactical picture is available to all participants. This is important because the inherent mobility of the participating units coupled with RF propagation variations will cause numerous disconnects. Therefore, the network must handle these occurrences and provide robust self-synchronization upon re-connection. This implies an inherent data replication ability within the constraints of IER and available bandwidth. It is the intention of the NUW TDP to examine some of these issues under the forum of the Fleet Battle Experiments. Technologies that will be investigated to mitigate these problems include COP Synchronization Tools provided by the COE, and software agents.

5. Summary

The Networked Underwater Warfare Technology Demonstration Project will evaluate and validate the use of network-centric concepts to provide an enhanced local tactical picture from the UWW perspective. It will utilize both simulation and at-sea trials to evaluate the impact of integrating both signal and target data from a variety of sonar sensors, in conjunction with information from non-acoustic sensor systems, to build an accurate tactical picture. The project will also assess the contribution from ocean prediction models used in a tactical context, as well as tactical decision aids that utilize both measurement and prediction to assist the command team to attain mission goals. A radio-based local area network will provide the communications infrastructure upon which co-operating Naval and Maritime Air platforms can build an accurate tactical picture through information sharing. This project will provide the Canadian Navy with a view into next-generation UWW concepts in both national and coalition task group environments.

6. References

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