Networked Enabled Combat for the Enhancement of the Underwater Common Operating Picture

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Abstract – Defence R&D Canada – Atlantic’s Networked Underwater Warfare technology demonstration project is conducting a trial to investigate the potential for enhanced effectiveness in producing an underwater common operating picture under field conditions. The trial consists of nodes including ships, aircraft, submarines and additional reach back to shore support centres. The trial objectives are threefold; as a vehicle to develop fusion technologies, as a means to improve underwater warfare effectiveness and to demonstrate that faster formation of the underwater common operating picture can be produced using networked shared information. One of the products that has been developed is the Networked Enabled Combat System (NECS).

Keywords: Net-centric warfare, data fusion, reach-back analysis, command and control, communication, integration and collaboration.

1 Introduction

In order to provide enhanced effectiveness to underwater warfare that uses new sensors and platforms to maximum effectiveness, networking of platforms is required. Currently, Defence R&D Canada - Atlantic has been engaged in a demonstration project of a Networked Underwater Warfare system as shown in Figure 1. The system utilizes sensors on a distributed multi-platform ad-hoc network to establish a local common operating picture [1]. A reach back capability to a Shore Support Centre (SSC) via satellite using the Canadian Forces Experimental Network (CFXNet) will demonstrate the engagement of a virtual team using reach-back analysis provided by Subject Matter experts.

Figure 1: Networked Underwater Warfare Concept

The development of a virtual team environment is one of the key concepts stipulated for the conduct of Net-Centric Warfare (NCW). A Net-centric warfare definition is as follows [2]; “Network-centric warfare is the linking of platforms into one shared-awareness network in order to obtain information superiority, get inside the opponent's decision cycle, and end conflict quickly.”

In business, as in other areas of collaboration such as collaborative engineering, the use of distributed teams means the footprint of resources required at one site has been eliminated in favour of an ad-hoc and flexible team approach that results in a fundamental organizational transformation [3]. Defence models still retain command and control structures but require this flexibility. Other examples exist currently within Defence R&D Canada (DRDC), and the Collaborative Capability Definition, Engineering and Management (CapDEM) project is an example of the necessity to move towards a flexible team approach [4].
Knowledge management as expressed by the Harvard business school [5] have been promoting for a number of years the use of different structures for business that allow better knowledge management by bring together Subject Matter experts (SME) as required in order to facilitate a particular project or business venture. Recently the net-centric warfare construct is also taking advantage of this approach and the development of the NUW project is one demonstration of the future collaboration in this area.

The NUW project objectives are three fold:

- Develop and demonstrate technologies to fuse tactical sensor information to form and maintain an improved ASW portion of the Common Tactical Undersea Picture
- Improve the effectiveness of Underwater Warfare by investigating a flexible information/knowledge management architecture that can support several sonar systems and include land/air based sensors
- To demonstrate that the formation of the underwater portion of the COP (Common Operating Picture) can be done faster and more accurately by sharing information

### Table 1. NUW Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>At-Sea Analysis</th>
<th>Post-Trial Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Contact Validity</td>
<td>No contact info available to operator</td>
<td>Requires ground truth – needs validity definitions</td>
</tr>
<tr>
<td>2. Time in Contact</td>
<td>Yes- can use normalize or actual TIC</td>
<td>Yes- can be implemented for each system and for whole network</td>
</tr>
<tr>
<td>3. Detection Range</td>
<td>No- needs ground truth</td>
<td>Yes- if ground truth available-for each trial segment</td>
</tr>
<tr>
<td>4. Probability of Detection as a function of Lateral Range &amp; Cumulative PD</td>
<td>No ground truth</td>
<td>Post- trial segment – Can use a running metric as a possible metric for at-sea analysis</td>
</tr>
<tr>
<td>6. Initial detection range &amp; Distribution</td>
<td>No- No Ground Truth- but can plot reported ranges</td>
<td>Yes- if ground truth is available. Distribution limited to time segments</td>
</tr>
<tr>
<td>7. Time History Plots</td>
<td>Yes- TIC with normalized metric</td>
<td>Yes- TIC plots for each sensor in network and for entire network</td>
</tr>
<tr>
<td>8. Percentage of Contacts with range</td>
<td>No- unless using only contact reports</td>
<td>Yes- with Ground truth</td>
</tr>
<tr>
<td>Cumulative Pd with Range</td>
<td>No</td>
<td>Yes- per trial segment</td>
</tr>
<tr>
<td>9. Average Contact range</td>
<td>Yes- for active sonar contacts- reported range only</td>
<td>Yes- actual range</td>
</tr>
<tr>
<td>10. Coverage</td>
<td>Yes- Temporal given by TIC; Spatial given reported Ranges</td>
<td>Yes- temporal and spatial for trial segment per sensor and network</td>
</tr>
<tr>
<td>11. Contact validity</td>
<td>Yes- for reporting false contacts</td>
<td>Yes- for reporting actual contacts</td>
</tr>
<tr>
<td>12. Percentage of False Contacts</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 2 Trial Overview

Figure 1 shows the 6 nodes that are part of the network. The network is established using a Sub-Net Relay (SNR) over a UHF radio link between the platforms. In addition, a satellite link allows use of reach back to CFXnet and the Maritime Command Operational Information Network (MCOIN). Through CFXNET, a reach back is estabilish to the Canadian Forces Maritime Warfare Centre.
There are several expectations from the trial. The focus of the trial is on networking and the expected benefits that result from sharing information. It is expected that collaboration among the units will enhance the overall effectiveness in the conduct of this particular application, which is Anti-submarine warfare (ASW). By using the systems provided to interact with other platforms and users, the situational awareness will generate an underwater common operating picture (COP). User will be able to extract information from the systems to help in their work or analysis.

Overall, the demonstration would show that the force would be able to detect, track and localize an underwater target more effectively by networking than by the use of stand-alone or non-networked systems.

From the perspective of measurement, it is less apparent how in fact the effectiveness of such systems can be demonstrated. The NUW TDP is making use of a double blind experiment in which a networked operator on the Canadian Forces Auxiliary Vessel (CFAV) QUEST is compared to a stand-alone system operator who has access to radio and conventional communications to determine the effectiveness at one node of the system. Measurement of the effectiveness of the system overall is more problematic.

A number of metrics have been developed that extend the use of Intelligence, Surveillance and reconnaissance (ISR) to the NUW project and also utilize the sensor effectiveness measures that are traditionally used in antisubmarine warfare [6].

One of the biggest challenges will be to measure in some form the situational awareness of the reach back cell and of the network in total. Situational awareness can be measured through operator observations and recorded by observers but is deeply complex as it pertains more to what the operator, SME or commander perceives rather that a demonstration of events and times that these were recorded or noted. Perception has been a troublesome prospect and delves more into the physiology and mindset of the participants. This type of Human factors is a level of analysis that is undergoing development.

**3 Networked Enabled Combat System (NECS)**

Figure 2 shows a picture of the Net-Enabled Combat System (NECS) at different nodes including the aircraft, ship, and at the Shore Support Centre. The NECS system is based upon the System Test Bed architecture that was originally developed for the Towed Integrated Active Passive Sonar (TIAPS). The latest system provides both sensor processing and an integrated data management with display extensions for a networked environment. [7]

Some of the features of the NECS system are the chart display that is based on the Global Command and Control System – Maritime (GCSS-M) architecture used by the Canadian Navy. The system can display both organic and other platform sensor information including active and passive acoustic sonar, Automatic Identification System (AIS) information from ships and aircraft, radar contact information, and a blue force tracking system to allow other platforms to convey their positions.
In addition, each node will have automatic web-page publishing facilities from their combat systems for enhanced situational awareness and relay historical information. This information will be available both within each platform or accessed from other nodes so that off-platform pages can viewed.

The NECS system produces a COP from these disparate sensors types as shown in Figure 3. The chart display lies underneath and has features that can be turned on individually. Information includes lines of passive sonar bearing contacts, Passive Target Motion Algorithms (TMAs), active sonar return positional information, and incorporates various data association and fusion algorithms. Some tactical decision aids are included and acoustic prediction, radar tracks and of course bathymetry can also be displayed.

For example, Figure 4 shows the typical passive sonar board band display of a time series, while Figure 5 shows the display of Bearing Time Intensity (BTI). Figure 6 shows how the active contacts can be displayed on the chart. Figure 7 shows the bearing range indicator and the plan position indicator displays. Each of these displays can be opened as separate windows from any of the nodes.

4 Web Pages and Chat Windows

As mentioned each node produces a set of web pages with automatic displays of information from the network. For example, Figure 8 shows the summary web page for the Maritime Patrol Aircraft (MPA) node. Each node has a list of specially designed and generic web pages. The summary page for the node contains a summary of information of tracks, chat contacts and so forth.
Chat is a particularly useful tool for communication and was shown to be of significant potential benefit for collaboration and integration for situational awareness. Figure 10 shows a web page that contains a chat window and a chat history. Chat provides a significant augmentation of communication over legacy and current systems.

Table 2. NECS System Functionality

<table>
<thead>
<tr>
<th>Location</th>
<th>Number</th>
<th>Description</th>
<th>Chart</th>
<th>Chat</th>
<th>Web page</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Viewing</td>
<td>Publish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFAV QUEST</td>
<td>1</td>
<td>Stand-alone</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Full - operator</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Networked</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Terminal</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Full - operator</td>
</tr>
<tr>
<td>CORNERBROOK</td>
<td>1</td>
<td>Headless</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Terminal</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>(internal)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SUMMERSIDE</td>
<td>1</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Terminal in Ops room</td>
</tr>
<tr>
<td>NRC Convair</td>
<td>1</td>
<td>IMPACT</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>In VP2 Container and terminal placed in Ops room</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Laptop</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Sonobuoy processing</td>
</tr>
<tr>
<td>CFMWC</td>
<td>2</td>
<td>Solaris</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Terminal</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>PC</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td></td>
</tr>
</tbody>
</table>
5  NUW At-Sea Network

The underlying network is a TCP/IP network that uses a “wireless” UHF radio link with Sub-Net Relay (SNR). Because of the use of UHF radios, the network is only available for Line of Sight (LOS) that can vary with propagation conditions and antenna height. When the aircraft is available and on-station, the network can be promulgated for up to 50 kilometres due to the height of the aircraft. The implication is that the network is tactical.

There are limitations in using this type of system, primarily in the bandwidth that is limited to 64 kilobits per second. Because of this operation protocols may be emplaced as web surfing will impact the network and use must be managed. The network uses a slotted time management system where slots are dynamically allocated depending on the load on the network. This cycle is 640 milliseconds per slot with 17 slots per cycle hence response may be delayed.

GPS is used for timing between the nodes and this timing is accurate time base on the submarine node, as it is not accessing the GPS signal while submerged. Automatic connection after disconnection is handled by the SNR. The entire network is encrypted for security purposes.

A seamless connection to the Shore Support Centre is achieved through a satellite connection from CFAV Quest as a node to the CFXnet that provides a direct connection to the at-sea network. Figure 11 shows an overview of the system.

5.1  CFAV Quest

For the NUW trial the main ship being used is the research vessel CFAV Quest shown in Figure 12. Quest has many special capabilities and in actual fact represents the naval combatant. For demonstration purposes the trial did not request the use of an actual frigate such as the Halifax Class frigates as these require special technology insertion processes in order to achieve engineering changes on the ships. Having a research vessel for this purpose allowed rapid testing of the technology.

Figure 12. Canadian Forces Auxiliary Vessel QUEST

For this demonstration Quest is equipped with numerous sensor and systems including the towed acoustic array system, an Automatic Identification System (AIS), commercial radar, Experimental Bathymetric buoys, and acoustic ship deployed sonobouys. There will be 2 full NECS systems deployed each with 2 workstations for a total of 4 operators.

The purpose of having 2 sets of operators is to have one set of operators operating in “stand-alone” mode with access only to organic systems, sensors and communication links. The second set of operators will use the networked NECS system with both organic and inorganic information to form the COP.

The role of the Quest is as a Blue Force member. As part of a test of the at-sea Command and Control (C2) there will be a Task Group Commander deployed who will act as tactical authority for the deployment of the blue force. The Quest will also control the acoustic sonar active signal transmissions. It will act as the key node for the formation of the COP as well as a relay for information from the at-sea group to the shore network. For data collection it will act as an at-sea repository of trial data. The Quest will also deploy a number of moored acoustic sources.

5.2  Convair 580

As a representation of a Maritime Patrol Aircraft or MPA, the National Research Council operates an aircraft out of Ottawa, Canada that is similar to the Quest. The aircraft
is a CONVAIR 580 shown in Figure 13 and is a key team member in the network. The sensors that will be deployed are acoustic sonobuys.

For a combat system, the experimental Integrated Multistatic Passive Active Concept Testbed (IMPACT) system will be deployed with NECS and will support both an information management and display and supports the COP chart display. Sonar operators will use IMPACT and tactical personnel will be at an additional terminal for navigational displays.

The CONVAIR will act as a blue force member and may also be able to control some of the active acoustic pings during some of the trial components. Tactical input will be provided from Tactical Navigation and the aircraft will be able to deploy and monitor an acoustics sonobouy field. The aircraft will as a result help to build the underwater COP.

5.3 Maritime Coastal Defence Vessel
HMCS Summerside

The Maritime Coastal Defence Vessel (MCDV) as shown in Figure 14 is a smaller Canadian Naval ship used for reserves and coastal patrols. The MCDV HMCS Summerside will be the active sonar tow ship. It will deploy a vertical projector as well as bathymetric buoys. A simplified NECS system will be onboard and it will support the active sonar ping control. It will have tactical displays and be operated by technicians instead of sonar operators.

The MCDV will act as a Blue force member and support multistatic activity with possible manoeuvres during the free-play portion of the trial. It should be noted that while CFAV Quest will control the types of active signals and their timing, the control and responsibility rests with HMCS Summerside.

5.4 Submarine: HMCS Cornerbrook

The conventional VICTORIA class submarine pictured in Figure 15 will provide two roles for the trial; first as a target and secondly as a Blue Force team member. The latter represents a significant operational capability that will maximize the use of a submarine as part of a Task Force. Submarines normally operate independently and in areas where they will not be confused with potential targets. As a result, integration of a submarine into the network has a potential for enhancing the overall effectiveness of the task force.
with other platforms. A simplified NECS system will be used to display the COP but sensors are not directly connected to the network due to the project scope.

The submarine will act as a target when no other target is present. It will also connect to the network to test the network configuration and to update information during work ups and during the free-play portions of the trial. During free-play, the submarine will act as a Blue force member when another target is present and will work with surface elements to build the underwater COP. By interacting with the shore support centre, assistance will be obtained and information will be provided to demonstrate the ability of the shore support centre to assist and maintain situational awareness of the underwater COP.

5.5 Shore Support Centre

The Shore Support Centre (SSC) represents the reach back capability to the Visualization laboratory of Canadian Forces Maritime Warfare Centre’s (CFMWC) Development Laboratory. This presents a new opportunity to investigate collaboration between the at-sea units during the NUW trial and personnel on-shore who can monitor the trial. The establishment of the trial SSC at CFMWC would enable the investigation of a number of objectives.

The SSC will demonstrate the use of net-centric constructs by the virtual team partnership of shore units with at-sea platforms. Especially during the free play portion of the exercise, the Reach Back Team would test the interaction, collaboration and communication in a SSC-like setting to determine the ability to generate common situational awareness of a tactical operation.

The SSC represents a focal point for the shore support of the trial. Shore support can be provided in a number of ways and for example has been provided in the form of engineering support, scientific and intelligence reach back analysis. The visualization lab as depicted in Figure 16 consists of a 3-screen display at the front of the room and terminals located on desks in the room. The Reach Back Coordinator and team members can monitor the disposition of the platforms during the trial, as well as the trial progress and interact with personnel representing each of the nodes at the SSC as well as with other platform nodes and shore centres.

The ability to monitor the trial progress in real-time from shore means that operations that are conducted can benefit from the on-shore support. This can include analysis support, policy response, environmental support and other subject matter expertise. In this sense, the reach-back capability has more potential applications than the current trial emphasis on underwater warfare. For this reason, the reach back represents a demonstration of a necessary component for conducting net-centric warfare.

![Figure 16. Shore Support Centre Battle Laboratory](image16)

The SSC has a number of defining characteristics that enable it to provide support to the at-sea mission. These are as follows:

- **Replication of Combat System** – SSC personnel will have access to the same tools and features in the NECS as the at-sea operators, though not direct control of sensors;
- **Reach Back Analysis Capabilities** - a number of personnel will provide a demonstration of the reach back analysis support. This will include the use of multistatic sonar analysis programs and potential shore-based sonar operator support;
- **Situation Awareness** - due to the near real-time nature of the CFXnet network configuration, the SSC will have the same picture and hence the same level of situational awareness as the at-sea platforms;
- **Collaborative Team** – given the situation awareness and analytical support, the team at the SSC will have the ability to collaborate with the at-sea platforms and at-sea operators;
- **Intelligence Support** – given the links to other shore-based networks and agencies, the SSC would be ideal for providing intelligence;
- **Shore-side Focal Point** – the SSC will be a natural focus point for the mission and access to co-ordination of external assets and agencies.

The establishment of the reach back at the CFMWC Synthetic Visualization lab offers the opportunity to collaborate with Subject Matter Experts (SME) during the NUW trial at a shore-based facility. The suggested personnel and responsibilities are as follows;

- **Reach Back Team Leader/ Senior SSC Watch Officer** – the Project Leader will conduct trial coordination of the SSC and co-ordination with the Chief Scientist at sea. Represents the Senior
Watch Officer in a SSC and co-ordinates the Battle space SME Team.

- Sub-surface Ops - Principally, these experts represent the submarine and the use of a Blue-Force submarine. Representatives are expected from the Submarine Squadron.
- Surface Ops - representatives would be concerned with the operation of surface assets, in this case the QUEST and the MCDV.
- Air Ops- originally conceived as representatives of the MPA community.
- Analysis Experts – analytical support includes scientific and shore-based operator support.
- Technical Support – network technical support will be present; other technical support could utilize the reach back facility.
- Observers - observers from other projects, agencies, and nations offers the opportunity to collaborate and liaise.

6 Conclusions

The NUW TDP represents a significant research initiative to build a practical and working at-sea network that will demonstrate many of the net-centric warfare constructs and provide evidence of the enhancement in effectiveness that can be brought to a conventional type of warfare by using the synergistic collaboration and interaction of a virtual team.

References


