An Operator Perspective on Net-Centric Underwater Warfare

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Abstract - In March 2007, the Networked Underwater Warfare Technology Demonstration Project at Defence R&D Canada – Atlantic conducted an at-sea anti-submarine trial utilizing Net-centric Warfare (NCW) constructs to demonstrate improved technologies for underwater warfare. User feedback was solicited during and after the trial for the purpose of documenting the manner in which the systems were used during the trial and gaining insight into their potential future usage in NCW activities. This paper describes some of the key issues raised and how they might be addressed in the future. Although some of the issues raised can be addressed through adjustments in the communications strategy, the way ahead for NCW will require a redefinition of the concept of operations for each platform and for the team in order to balance the advantages of the team and platform-centric approaches.

Keywords: Net-centric warfare, networked underwater warfare, subnet relay, anti-submarine warfare.

1 Introduction

The concept of net-centric warfare (NCW) is built on the premise that improved communications and the increased availability of information will improve the effectiveness of an operation. Anti-submarine warfare (ASW) is a good example of the type of activity that can be pursued by a variety of platforms, each of which brings a different mix of capabilities to the table. NCW offers a means to fuse these platforms into a more effective and efficient force.[1][2][3]

As part of its Technology Demonstration Project (TDP), the Networked Underwater Warfare Group (NUW) at Defence R&D Canada - Atlantic (DRDC Atlantic) held a sea trial in March 2007 to evaluate the application of several NCW constructs during an ASW operation.[4][5]

As shown in Figure 1, the sea trial involved a variety of the types of platforms which are capable of contributing to an ASW operation including a surface ship towing a line array, a fixed wing maritime patrol aircraft, a second surface ship towed an acoustic source and a submarine. A shore-based reachback cell was also included and is also considered to be a platform for the purposes of this discussion. Each of the platforms involved had its own capabilities and most had organic acoustic sensors. The platforms were connected by a Subnet Relay (SNR) network.

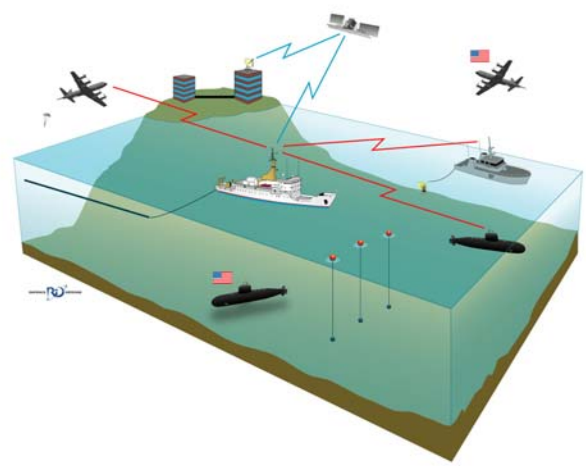

Figure 1 The NUW sea trial configuration

One of the key aspects of the trial was the deployment of technologies for the fusion of tactical sensor information and the formation of a common tactical picture. A second key aspect of the trial was the deployment and evaluation of a flexible information / knowledge management structure capable of supporting a variety of land, sea and air based sensors. The final key aspect was a demonstration of improved speed and accuracy in the development of the underwater portion of the Common Operating Picture (COP) as implemented under the aforementioned architecture and shared by all of the platforms involved in the ASW exercise.

The preliminary results of the trial were a demonstration of the effectiveness of both the sensor data fusion technologies and the information/knowledge management architecture, as well as a noticeable improvement in the speed and accuracy with which the COP was developed.

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2 Network Applications

The at-sea platforms were connected as peers on an SNR network, while the reachback cell was connected via a dedicated satellite link to the primary surface ship. Each of the nodes had the same, 64 kbps, bandwidth to the network and each of the at-sea platforms was also capable of acting as a relay between distant nodes. The entire network was securely encrypted.

A suite of applications was available across the network. The applications were hosted and provided by a local data server and Network Enabled Combat System (NECS) on each platform. The applications both provided and made use of information shared across the network and were accessible simultaneously by multiple operators on each platform. The applications included a chart-based display of the COP, chat, web browsers and web servers.[6]

The COP provided a visual summary of the local tactical picture, and was a composite of feature[1] data that was provided by local sources and received over the network from other platforms. This data included sonar and radar tracks, Automatic Identification System (AIS) information, and positional information from each of the platforms. The COP display used the familiar Defense Information Infrastructure (DII) Common Operating Environment (COE) architecture.

Each data server also served web pages. Each platform had its own summary page which could be accessed from anywhere on the network. The web page provided a means to review the current status and past history of that platform and included a track summary, a record of recent chat messages, network status summary, archival snapshots of the COP, and several web logs.

Messaging was available to all network users through both a dedicated chat application and a chat web page. Longer messages and files, such as pictures, could be shared by making an entry in a web log and then referring to it in a chat message. The display of information on the COP was controlled through data subscriptions which could be modified through a web page.

In general, the SNR-based network operates much like an IP-based Ethernet network, albeit at slow speed and with increased delays relative to a wired network, and like those networks can be remotely administered and supported from anywhere on the network. This can both improve the reliability of the network and reduce the number of personnel required for its support.

[1] In this discussion, a feature is defined for passive sonar as "… a distinct anomalous event that produces a positive signal excess …"[7] and similarly for other sensor types.

3 Networked Platforms

3.1 CFAV Quest

The primary surface vessel in this sea trial was the DRDC Atlantic's research vessel, the Canadian Forces Auxiliary Vessel (CFAV) Quest. The Quest was equipped with both an SNR network node for communication with the rest of the at-sea nodes, and a satellite link to communicate with the shore-based reachback cell. It also had other communication capabilities which could be utilized during the trial but were not connected to the SNR network.

The ship was equipped with a towed array acoustic receiver during the trial as well as a multi-channel sonobuoy receiver. Effective range of the sonobuoys, however, was limited by the height of the ship's mast. The received data from the towed array was processed using sonar processing and display extensions on the local NECS. One of the other applications running on the NECS was a chart display showing the COP. Underlying the COP was a chart of the local bathymetry.

Towed array data was of particular interest on this platform and a full set of processing options was available for the various apertures of broadband and narrowband data. Bearings-only passive signal followers could be generated automatically or manually from the acoustic data and markers indicating the current bearings of those signal followers relative to the ship were shared over the network and displayed on the COP. The Quest was equipped with AIS and surface radar and contributed both types of information over the network.

One of the ASW tools used in this exercise was multistatic sonar. Multistatic sonar is a variation of active sonar that uses multiple, geographically separate receivers and a source to look for echoes off a target. In this trial the source, VP2, was being towed by the HMCS Summerside and the line array towed by the Quest was used as a receiver. Returns from the multistatic sonar were also shared over the network and displayed on the COP.

3.2 Convair 580

The air platform in this trial was a leased Convair 580 which was used as a surrogate for a Maritime Patrol Aircraft (MPA). The MPA was equipped with an SNR network node and, due to its higher altitude, was able to act as a relay between the surface and sub-surface platforms. Operators on the Convair were able to subscribe to network data, such as that available from the

Quest, as well as share their own data with the rest of the network.

The Convair deployed and monitored sonobuoys during the trial using a dedicated sonobuoy processor attached to the local NECS. Data received from the sonobuoys could be processed passively, with the assumption that the received signal originated from the target, or actively, using the signal from VP2 and looking for echoes from the target. In the passive processing case, the information shared over the network could be either bearings from individual sonobuoys or cross-fixes from multiple buoys. In the active processing case, the shared information could include target location. In both cases, subscribers to the shared data could drill down to retrieve additional details, such as the area of uncertainty of a location estimate.

3.3 HMCS Summerside

The second surface vessel in this sea trial was the HMCS Summerside, a Maritime Coastal Defence Vessel (MCDV). It was used primarily to tow the acoustic source, VP2, used in the multistatic sonar operations. The MCDV was equipped with an SNR network node for communication with the rest of the at-sea nodes. It was able to display the COP and report the ship's position but had no other organic sensing or processing capability. Nevertheless, its crew and scientific staff were able to view navigation aids such as AIS data and radar tracks from the Quest and were able to use chat and web logs to communicate with the other platforms.

3.4 HMCS Corner Brook

The sub-surface platform on the SNR network was the HMCS Corner Brook, a Victoria class diesel electric submarine. It was used both as a target and as a blue force member when an alternate target was available.

A simplified version of the NECS without any processing capability was deployed aboard the submarine due to space limitations and project scope. It was able to record and report the platform's position and depth but did not otherwise directly interface with the boat's organic systems.

The lone human interface for this system was located in the control room, where it was used by a variety of crew and staff to, among other things, participate in chat, submit and read web logs including bathymetry data and photographs, display track information, display the COP, and provide information on upcoming and recent signals for multistatic sonar. The SNR network also provided AIS data and radar tracks.

The inclusion of a submarine in the SNR network presented a unique challenge in that the platform is necessarily out of contact with the rest of the network when it is at depth. This was accommodated to some extent on the network side by mirroring its web pages on the Quest. For the platform itself, however, this meant that there would be an abrupt update whenever the boat returned to a depth at which it could communicate.

3.5 Shore Support Centre

Although the Shore Support Centre was not itself on the SNR network, it was able to maintain connectivity with the network through a satellite link to the Quest. As this platform had no organic sensors, its NECS was not configured for the processing of data, only for display and communications.

The Shore Support Centre served two main functions, to provide remote awareness of the at-sea situation to interested parties, and to provide a means for the at-sea platforms to obtain support from shore-based assets. The types of support provided varied from system-specific hardware support to intelligence and environmental prediction support.

4 Discussion

4.1 Building a Network-Centric Team

ASW is a good example of the type of activity that can be pursued by a variety of platforms, each of which brings a different mix of capabilities to the table. NCW offers a means to fuse these platforms into a more effective and efficient force. One of the key objectives of this technology demonstration program has been to demonstrate improved effectiveness, i.e. increased speed and accuracy, in the formation of the underwater portion of the COP through the sharing of information. Preliminary results from this sea trial indicate that this is indeed the case. It has also achieved the objectives of demonstrating improved tactical sensor fusion technologies, and the development of a robust, dynamic tactical network. That said it is useful to consider some of the aspects of this trial that may take on greater significance as this technology is advanced.

The provision of a robust tactical network can provide a significant information advantage in that it can increase both the speed and the volume of data moving among platforms and both advances are significant. In this trial we saw that the operators made good use of both organic, locally processed, sensor data and the processed sensor data available from other platforms. It was interesting, however, to observe how the different types of data were used.

The operators in this trial were familiar with the traditional, platform-centric and sensor-specific approach to sonar operations. The majority of the processing in this trial was also sensor-centric, in that data from each type of sensor required a minimum level of refinement before it was in a format, typically at the feature level, at which could be shared. It was not surprising therefore to see that, when faced with the choice of processing local sensor data or analyzing data from the network, operators tended to begin by processing local data. At a point, however, the focus of the operator broadened, often in conjunction with a lack of significantly useful local data, and he began looking for cues from the network data to indicate likely regions of interest in the local data.

The pair of operator positions onboard the Quest rapidly evolved into a tiered configuration wherein one operator processed data from the towed array into features and tracks while the second dealt with the refined data from both local and network sources. This evolution was possible because, since the highly networked configuration was relatively novel, the concept of operation for the operators in this trial was intentionally left fluid. It reinforces, however, the expectation that effective use of the increased amount of information available in a network-centric configuration will require both a different operator workflow and an increased level of automation.

4.2 Centralized Data Fusion

Sensor data can be exchanged among platforms at various levels of refinement. Traditionally, due to the limited amount of communications bandwidth between platforms, sensor data was not exchanged until it had been processed to the contact level where it had a very high probability of representing a target. In a highly networked scenario, such as that described here, in which major nodes maintain continuous links with each other, it is possible to share sensor information at the feature level or below, where it has a significant but not high probability of representing a target. This presents the opportunity for a centralized data fusion engine to operate on data from diverse sensors at diverse locations.

As multiple sensors of multiple types become interconnected, the potential for improved information extraction increases. An initial challenge may be determining the most useful level at which to fuse the sensor data.

4.3 Chat and Web logs

A form of communal instant messaging called chat was available to all users across the SNR network. Chat has many advantages relative to voice communication over a radio channel, not the least of which is that it is secure at the level of the network and there is no ambiguity between what is typed and what is read from the screen. Furthermore, since each message is preceded by a user name, a chat log can provide a ready record of recent communications. Once an SNR network was established communication between platforms on the network was rarely, if ever, handled outside the network.

The web servers at each platform also hosted several web logs for the recording and exchange of operator and maintenance messages. Files could also be attached to log entries for the exchange of other types of information, such as photographs. Since chat messages were limited to a single line, these logs were used as a method of distributing longer text messages in a format similar to email.

Chat is very dynamic in that its style and content are not necessarily predictable. A pair of familiar users might assume a high degree of shared context and provide only the minimal information that they believe is relevant to their communication. While this might work well in a private chat session, it can be confusing in a shared environment, especially when multiple concurrent chat streams and their messages are interwoven.

One of the advantages of chat is its flexibility such that it can be used to work around the lack of a potentially useful network application. On the other hand, the lack of sufficient structure may be keenly felt when chat itself becomes difficult or confusing to use. Especially on a dynamic, low-bandwidth network such as the one deployed during this experiment, network congestion can cause chat messages to be delayed or lost. If insufficient contextual information is included in each message, its content may be misconstrued. This may require as little as the loss of a single message.

4.4 Data Availability

The SNR network used in this trial used line-of-sight radio channels for communication. The range of those channels is strongly dependent on antenna elevation and it was therefore not surprising to see that the surface and sub-surface platforms could communicate directly at much greater ranges with the aircraft than with each other. All nodes had the ability to relay network traffic.

The submarine spent a significant amount of the trial submerged and, during these times, was out of communication with the rest of the network. Once it had returned to communications depth, however, it immediately rejoined the network and was able to benefit once again from the COP information provided by the rest of the network. New information from the submarine was also immediately available to the rest of the network. The intermittent availability of the submarine node was anticipated and its web pages were cached on the Quest for use during those time when the boat itself was unavailable.

The periodic lack of communications with the submarine was not due solely to its submergence, as its antenna height also limited its ability to communicate. This problem, which also impacted, though not as strongly, the surface platforms could be addressed in future through the use of a lower frequency radio channel or the presence of a continuous aerial relay, such as an unmanned aerial vehicle (UAV).

The repeated joining and leaving of the submarine raises the question of whether an operator can count on the arrival of new or updated data from a platform. In a scenario where a platform is assigned responsibility for using specific sensors to monitor a specific region, lack of communication with that platform would immediately begin to degrade situational awareness in that region. The question of how best to address this situation is best addressed as a concept of operation issue.

The presence of a submarine on the network also raised another question, that of stealth. Much like operating an active sonar, any platform which is regularly updating information on a radio network is also potentially indicating its position to the opposing force.

As stealth is a significant concern to submarine operations, the ability to cooperate while maintaining an appropriate emissions control (EMCON) state is a concern. This concern may be partially addressed by enabling a passive-only or “sniffing” participation in the network which does not transmit message acknowledgements.

4.5 Tempo

A communications network capable of providing up-to-the-minute data is also capable of providing up-to-the-minute direction and this was a concern to many users. The potential for fleet staff to observe the trial from the reachback cell and, based on their personal experience and recently acquired situational awareness, make recommendations to the personnel at sea was present (the “5000 mile screwdriver problem”) and a concern.

Experience in allied forces has shown that this situation is unlikely to come to pass as there are requirements for action at all levels. While the risk continues to be present, fleet staff are generally aware that micromanaging platform operations means that insufficient attention is being paid to the strategic and tactical for which they are themselves responsible. An effective concept of operations would limit direction to that provided in the form of Commander’s Intent.

4.6 Workload versus Effectiveness

The intent of net-centric warfare is to increase the effectiveness of platforms by improving their situational awareness and decreasing their response time. In this trial we deployed a very capable network to provide additional inorganic information to operators which we believed would improve their effectiveness. We must also consider that, if we hadn’t modified their original workflow, the presence of this additional information would have significantly added to the workload of the operator. The additional information has the potential to reduce the operators’ workload, but that could only be the case if the shared data replaces information that would otherwise be extracted from the local sensor data.

The presence of the shared data in this trial had two effects. First, it cued the operators to the presence of a target and then provides initial information on the characteristics of the target or, if a target had already been suspected, increased the operator’s confidence in the presence of that target. Second, it reduced the size of the region in which additional targets might be found. The workload of the team did not need to change, only its workflow.

During the trial, operators found that the use of chat and web logs in lieu of voice communications increased the reliability and security of interactions among the users but that it also required the operators to visually monitor an addition computer window. Traditional voice communications, on the other hand, made use of other senses which could be employed simultaneously. Much of the distraction of using text communications in this case could be reduced by implementing a more structured chat format and establishing separate sessions for different user groups.

The additional information available through the network, although it doubtless improves the effectiveness of the platform or group, will require increases in either automation or changes in workflow and possibly both.

5 Conclusions

This sea trial demonstrated the ability of a diverse variety of platforms to operate as a net-centric team in an ASW operation. The performance of the team also demonstrated the effectiveness of improved sensor data fusion technologies and the information/knowledge management architecture under which they were implemented. A marked improvement was also observed in the speed and accuracy with which the COP was developed.

In the process of conducting the trial a number of comments and observations were made regarding the operation of the trial and NCW in general. Most significant is the recognition that effective implementation of NCW constructs will require a greater awareness on the part of the operators and a different level of thinking. The increased amount of shared information will require that a greater percentage of the local team’s time will be spent dealing with incoming data. As the local data processing requirements are unlikely to decrease, there is a need for either increased automation or increased staffing and possibly both.

An effective NCW scenario must be designed to accommodate situations where some or all of the networked platforms or their data are unavailable. This could include platforms with limited endurance, such as aircraft, with roles in which they are incommunicado, such as submarines, or suffer operational failures. This will require that each platform be able to operate flexibly both collaboratively and independently.

The way ahead for NCW will require changes in the concept of operations for each platform and team to accommodate these changes and to make best use of the opportunities available.

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