# Investigating The Network Enabled Conventional Submarine: An Australian Perspective

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**Abstract**

Australia's Defence Science and Technology Organisation (DSTO) has established a research and experimentation program investigating network enabling of the Royal Australian Navy's Collins Class submarines (SSG). A focus of this program is to understand the combat system functions required to support network centric warfare operations. Then to research and develop prototype applications that will support an experimentation and sea-trialing program. This paper reviews the experimentation program established to support the research and development of network enabled RAN submarines.

## Introduction

Australia's Defence Science and Technology Organisation (DSTO) has established a research and experimentation program investigating the network enabling of the Royal Australian Navy's Collins Class submarines (SSG). Key objectives of this program are to examine the utility of network enabling conventional submariners and research the combat system functions required to support network centric warfare operations. To achieve these outcomes a mix of Operations Research, BattleLab experiments and at sea experiments are planned.

Initially, this experimentation program is providing a better understanding of what is required to network enable a conventional submarine, and guide Network Centric Warfare (NCW) technology R&D. In trialing some of the research applications designed to facilitate NCW operations in the Undersea BattleLabs and FBE-Juliet, DSTO will gain an even better understanding of our technology gaps. The results of these trials will be used to provide a measure of the value of information given the type of NCW operation, communication method and bandwidth, the capabilities of cooperating platforms, and information processing capability.

Ultimately, this experimentation program, along with a wider operations research study, will:

- determine the effects to be achieved, constraints on achieving them, and measures of effect.

- examine key data to be exchanged and identify any scenario based dependencies.
- explore the importance of different transmission rates of key data types.
- assess the value of network enabling conventional submarines.
- determine the technical requirements to effectively network enable conventional submarines.
- examine the key submarine issues of stealth, burst transmission/reception, and amalgamating received historical data with the submarine's tactical picture.
- recommend changes to the concept of operation that would facilitate more effective employment of a NCW conventional submarine

A key aspect of exploring the network enabling of the Collins class submarines is the establishment of a broad experimentation program covering both technology and concept of operations issues. The activities being undertaken by DSTO fall into the hierarchy of experimentation and research methods described in Figure 1. (This hierarchy of experimentation and investigation is described in more detail in [1]).

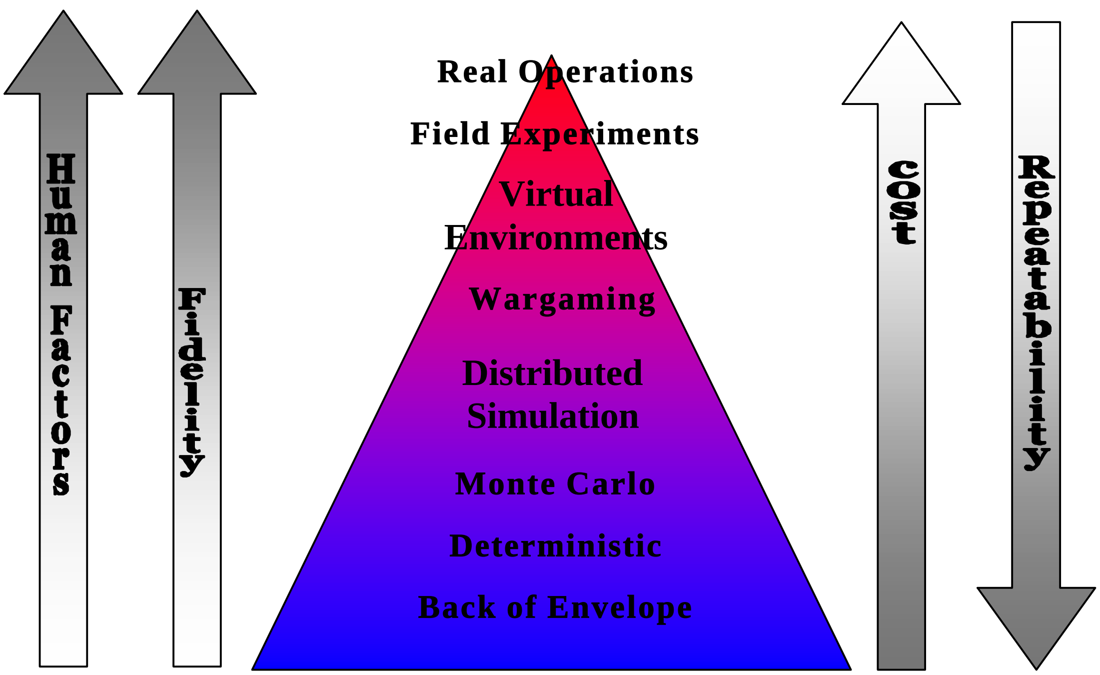


**Figure 1: A hierarchy of experimentation and research methods.**

To support the investigation into the network enabling of RAN submarines, DSTO has established an experimentation program drawing on programs within DSTO, the RAN and external international organisations. Specifically, the following assets and activities are being utilised.

1. **Royal Australian Navy's Experimentation Program (HEADMARK)**. The impact of network centric warfare on the RAN is being evaluated as part of the RAN's

forward looking experimentation program called HEADMARK. DSTO will participate in, and utilise the results from, operations research and analysis studies, wargames and operational exercises.

2. **DSTO Undersea BattleLabs Trials**. The two Undersea Battlelabs provide a controlled environment where individual submarine combat system functions or full combat systems can be put under test. A wide range of simulation and stimulation components are utilised to generate known and controlled inputs or recorded sea data. Further, the system outputs and operator actions may be readily recorded for analysis. The Undersea BattleLabs can also interact with other virtual NCW capable partners (eg the DSTO Virtual Ship) and adversaries.

3. **The Technical Cooperation Panel (TTCP) experiments**: DSTO are key contributors to the coalition based network centric warfare experiments being conducted by *TTCP Maritime Group Technical Panel 1: Maritime Command, Control and Information Management*. This long-term experimentation program is focused on unearthing the problems and achieving a network enabled maritime coalition force. DSTO are using this program to better understand the problems associated with interoperating with coalition platforms of varying capability in a NCW environment. (While this paper focuses on network enabling Australias' conventional submarines, DSTO are also experimenting with a virtual ship in this TTCP experimentation program.)

4. **Australian participation in USN Fleet Battle Experiments**: DSTO have recently embarked on a 3 year plan to utilise the USN coordinated Fleet Battle Experiment (FBE) program to support this research into network enabling RAN submarines. DSTO will initially provide a Virtual Augmented Collins class submarine represented by a high fidelity combat system enhanced with a number of DSTO developed network enabling applications. This virtual augmented Collins Class submarine will be manned by RAN submariners and DSTO scientists, operating as part of a coalition force compromising live and virtual platforms. DSTO's participation in the FBEs will be used to further develop and trial network centric warfare technology in a coalition environment.

This paper will discuss how these experimentation programs are being applied to explore the network enabling of Australia's submarines.

As network enabling the Collins Class submarines extends well beyond the technology issues, this research program is being conducted under the backdrop of the current and future (1) RAN force structure, (2) operational concepts for combined and coalition operations, (3) RAN communications plans, and (4) Australian government strategic guidance (as described in the Defence White Paper 2000).

## Framing the Problem

One key to a successfully experimentation program is (1) identifying a question that best captures the problem or decision under investigation, (2) establish one or more hypothesis or assumptions forming the basis for an argument (2) decomposing this question into a number of observable and measurable entities, and (3) determining the correct experimentation methods to be applied.

In identifying a question that best captures the problem under investigation, DSTO has investigated a number of Measures of Effectiveness (MOEs) that characterise an overall outcome of an NCW engagement or activity. Examples of MOEs considered for this study include, probability of mission success, reduced blue on blue engagements, successful prosecutions of red contacts, ownship survival, percentage of contacts correctly identified, and percentage of contacts correctly localised.

Initially studies are focused on the MOE: Percentage of contacts correctly localised. Described in the table below:

| | |
|---|---|
| **MOE: Percentage of contacts correctly localised.**<br><br>**Baseline Case**<br>- Single platform<br>- Each Nation to collect MOPs using national Platform<br>**NCW Case**<br>- Two NCW capable platforms<br>- Each Nation to collect MOPs using national Platform integrated with TTCP Blue Surface Ship<br>- TTCP Blue ship Combat System Serves<br>  - OS Location<br>  - Sensor reports (sensor signal follower)<br>  - Contact report<br>- No centralised fusion | MOE(Percentage of contacts correctly localised) = fn(MOP1, MOP2, MOP3, MOP4) |

In decomposing the MOEs into observable and measurable entities, a number of Measures of Performance (MOPs) have also been established. Where the MOEs used in this program measure outcomes or effects of NCW operations, MOPs measure specific physical quantity related to a distinct and readily measured event. That is, a metric that characterizes the performance of combat systems or subsystems that support warfighting and contribute to a successful outcome (e.g., detection range, time elapsed from detection to classification)

The following table of MOPs represent an initial set of measures collected.

| | |
|---|---|
| **MOP l: Track association errors**<br>Influencing Parameters<br>- Contact density:<br>  1. Varied during the scenario (increasing)<br>  2. Contact initialisation times programmed (\ increasing contact density)<br>  3. Moderate speed of contacts<br>- Track quality<br>  1. Tracker quality (try to keep constant through some models) | Measurement Options:<br>1.A-Scan (time vs number of errors)<br>2.Time to correct error<br><br>–Type I error: missed association<br>–Type II error: incorrect associations |
| **MOP 2: Tracks Continuity**<br>•Influencing Parameters<br>- Contact density => seduction<br>- Sensor overlap => organic<br>- Sensor overlap => OTH | Measurement Options:<br>1.Time track continually held<br>2.Number of times track lost/dropped/miss-associated per track |
| **MOP 3: Robustness (number of reports supporting track)**<br>Influencing Parameters<br>- Sensor overlap – organic<br>- Sensor overlap – OTH | Measurement Options:<br>1.Number of reports supporting track<br>- Organic sensor reports supporting contact report<br>- OTH sensor reports supporting contact report |
| **MOP 4: Localization error**<br>Influencing Parameters<br>- Type II errors<br>- Track quality<br>  Tracker quality (try to keep constant through some models) | Measurement Options:<br>1. A-Scan (time vs errors)<br>- Positional error (Lat – Long)<br>- Course error<br>- Speed error<br>- AOU<br>2. Sum total errors |

| | |
|---|---|
| **<u>MOP 5: Time to Classify</u>**<br>Influencing Parameters<br>- Number of reports supporting track<br>- Accuracy of individual report classification<br>- Diversity of sensor types (ESM, Sonar, Radar, IRST, …)<br>- Confidence in report source | Measurement Options:<br>- time to make correct classification |
| **<u>MOP 6: Time from detection to engagement</u>**<br>Influencing Parameters<br>- Number of reports supporting track<br>- Accuracy of individual report (MOP4 and MOP5)<br>- Confidence in Classification | Measurement Options:<br>- time from initial detection to weapon firing |
| **<u>MOP 7: Time to associate NCW Tracks</u>**<br>Influencing Parameters<br>- Number of reports supporting track<br>- Accuracy of individual report (MOP4 and MOP5) | Measurement Options:<br>- time |

## Headmark

The RAN has adopted a modernisation methodology that is strategy, effects and concepts based. The implementation of this methodology is the Navy Innovation Strategy. The Headmark experimentation program is the program by which experiments are conducted on concepts within a Joint and Combined environment to guide the development of capability requirements. As shown in figure 2, the Navy Innovation Strategy will focus on the period 2015-2030 for maximum pay-off and will inform Enhanced Fleet capability development decisions and scope the Future Fleet requirements.

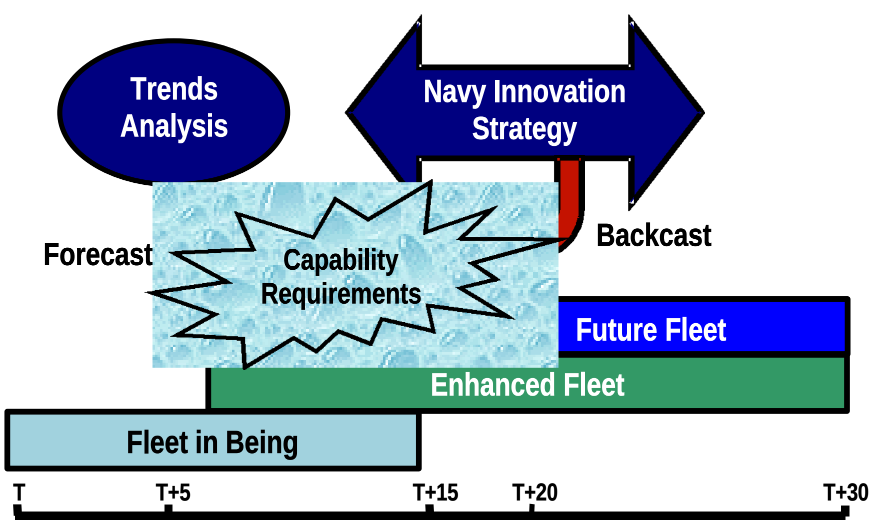


**Figure 2: Navy Planning Process**

The Navy Innovation Strategy and the role of Headmark experimentation is summarised in figure 3. First step, as in any innovation strategy, is to identify the effects and concepts to be investigated. For the RAN this is primarily a Navy activity with support from DSTO on the types of concepts that might be valid in the time frames addressed by the innovation strategy. These effects and concepts are then captured in the Future Maritime Operational Concepts (FMOC). The FMOC describe the way in which forces operate and will be supported in maritime aspects of joint and combined operations. At this time, the RAN has developed two FMOC papers, FMOC 2010 and FMOC 2020. FMOC 2010 is aimed at exploring how we (the ADF) will use the equipment currently available and being acquired by 2010. FMOC 2020 considers the fleet at 2020 and permits exploration of alternative Naval force structures at that time.

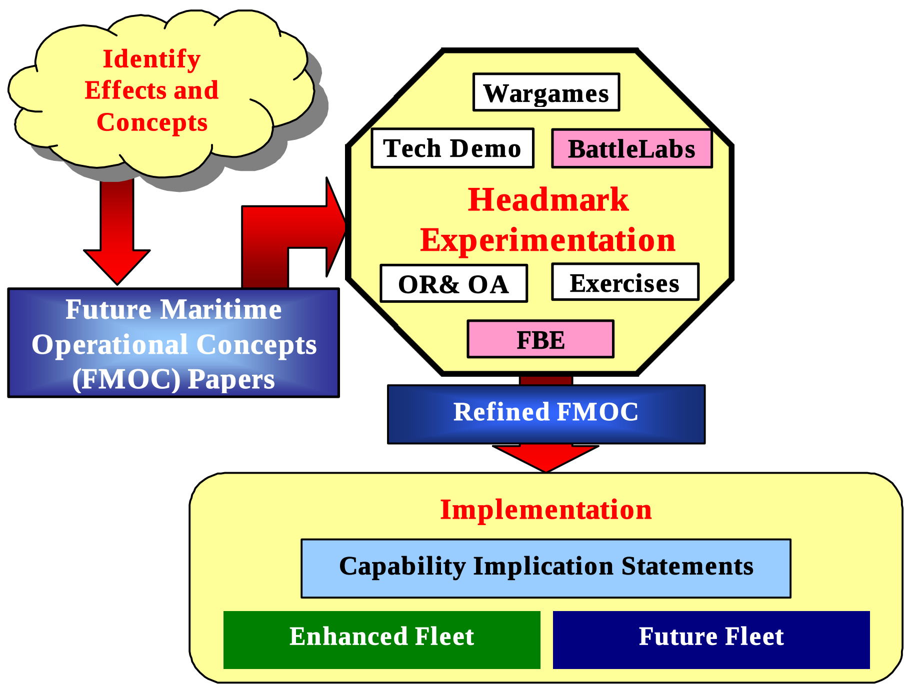


**Figure 3: Navy Innovation Strategy**

Command and Control figures prominently in both FMOC 2010 and 2020. At 2010, one of the postulated operational enablers for the fleet is C4ISR. Three aspects of C4ISR require experimentation for 2010, these are Network Centric Warfare, Interoperability, and Intelligence, Surveillance and Intelligence. Importantly, it is recognised that the enhanced fleet will only be partially networked by 2010 and the objective of the Headmark experimentation program will be to develop a body of evidence to support introducing NCW concepts into enhanced fleet operations. Note here that the wargames and traditional OR that is the starting point of Headmark experimentation will only start to explore NCW issues for 2010, instead the detailed body of evidence for NCW at 2010 will need to come from the involvement in FBE and use of Battlelabs as described in this paper.

In the 2020 timeframe, the NIS has postulated that Knowledge, Command and Control (KC2) will be a key enabler to maritime operations. Here, KC2 is defined as the combination of superior knowledge of the operational art, battlespace awareness and command and control facilities to that of an adversary. In this timeframe it is more difficult for technology experiments such as FBE, battlelabs and the TTCP activities to demonstrate what technology will be achievable in 2020. However, the more technical experiments will provide advice on the potential NCW concepts in 2020, and these concepts can be included in the wargames and traditional OR that will assist in developing force options for the future fleet.

The Headmark experimentation program, whilst a new activity for the RAN, has been formulated along similar lines to experimentation programs in other countries, especially the USN [2]. Co-operation with the USN is occurring at many levels, as the issues to be addressed for the future fleet are similar for all Navies. The FBE and TTC activities in this paper are just two examples of the cooperation that is occurring.

## Virtual Submarine & BattleLabs

A virtual environment (VE) is a synthetic computer generated environment (both platform and natural surroundings), which closely represents real or proposed future military platforms. The operations, technologies or algorithms under assessment typically determine the fidelity of this representation. As an example, DSTO's Maritime Operations Division (MOD) has developed a virtual submarine [3,4] to facilitate investigations into a wide range of submarine combat system functions. The DSTO Virtual Submarine includes the following functionality:

- tactical command and control system;
- sensor processing technologies (both acoustic and non-acoustic);
- representation of the acoustic environment;
- weapons systems;
- platform motion control; and,
- computer networks and an open system architecture.

DSTO's virtual naval platforms, like the virtual submarine, are being used to provide DSTO, the RAN and industry with facilities that support research & development, acquisition, training and operations research. The virtual submarine in particular provides a facility where existing combat system problems can be identified and resolved, and new combat system functions can be trialled under realistic conditions.

Virtual environments are created from a combination of simulated systems, emulated components and real systems. The DSTO virtual submarine, for example, employs simulated sonar processing and emulated engagement functions, coupled to the real tactical command and control software running on commercially available hardware. This basic configuration can be combined with other simulated systems to represent many different submarine equipment fits, and the fidelity of the representation can be tailored to meet the requirements of the experiment.

Essentially, virtual environments/platforms are an amalgamation of simulations, real systems, stimulators and emulators linked together to provide a credible platform situated in its operating environment. The difference from previous simulation concepts is one of scope. The ability to network together disparate and distributed components, coupled with the increased availability of high performance off-the-shelf equipment means that the same architecture can support multiple roles (training, experimentation, development, research, and fault reconstruction). The main technology drivers toward this evolution in simulation concepts come from the complexity of modern systems, in particular:

- The increasing recognition of the difficulty in modelling single and group decision making issues that maybe critical to overall system effectiveness;
- Difficulties in modelling the cognitive aspects of individual component Human-Machine Interface interactions and understanding their implications for the entire system;
- Requirements to investigate experimental/developmental systems that can not easily be deployed into operational settings;

- Requirements to conduct data flow, tracking and parameter/process variation investigations (outside the tightly configuration controlled environments of production systems); and,

- Requirements to explore software, network and systems engineering issues (e.g., fault reconstruction in combat systems), which are not explored in this paper.

Incorporating the effect of individual human-machine interaction has traditionally been a problem for simulation based studies. Here the problem is how to model what a human does when interfacing with a computer or machine over long periods or in periods of high work-load. One solution is to put a human in front of a system that can be reconfigured to allow the investigation of the cognitive impact of changes. It is often preferable to conduct these experiments in the simulators and emulators that constitute a Virtual Environment, rather than the real military systems with their costly and time-consuming processes for reconfiguration. An associated question is the issue of how a team of operators work together; of how a group of naval platforms work together; of how platforms from different services work together; or how a new system might integrate with older/in-place systems. Providing the military domain to study these types of topics is essentially equivalent to staging major exercises. Virtual environments may provide an alternative by connecting the components/people together using a wide-area-network, and thereby removing some of the logistical problems.

Another area where VEs make a significant contribution is in the provision of a flexible experimentation testbed that can be configured to accurately represent a number of existing or future/proposed military platforms. This allows the exploration of system performance issues such as fault reconstruction and rectification, as well as the evaluation of alternative systems and algorithms prior to incorporation into operational platforms. As the VE is detached from real safety critical systems (such as weapons) and the real environment, the software systems can be reconfigured without the rigorous testing required of a real platform.

### *The DSTO Undersea BattleLab*

DSTO's Maritime Operations Division (MOD) has developed two Undersea BattleLabs to facilitate a wide range of submarine combat systems research and development activities. An Undersea BattleLab is a situated virtual submarine bringing together real and simulated combat system components to provide an environment to immerse warfighters, scientists, engineers, defence acquisition and industry representatives. The first of these labs has been established at HMAS STIRLING, Western Australia, and is used to better understand the operational performance of in - service systems as well as provide an environment to trial incremental combat system improvements. The Undersea BattleLab in DSTO Salisbury, South Australia is focused on supporting the research, development and analysis of next generation combat system concepts. Both these BattleLabs incorporate various configurations of Virtual Conventional Submarines (including a Virtual Collins, Virtual Augmented Collins, and Future submarine combat system applications).

The DSTO forward looking research programs are using these Undersea BattleLabs to explore the value of network enable Australias' Submarines and the combat system technology required to achieve this. This includes research and development into the impact of Network Centric Warfare (NCW) on (1) command team picture compilation, (2) target localisation and solution generation, (3) track management, (4) contact classification, (5) weapons engagement, (6) submarine communications, (7) submarine navigation, and (8) combat system architectures. In addition to exploring technology issues, the BattleLabs may be used to investigate changes to submarine operational concepts in a NCW environment.

DSTO's Undersea BattleLabs facilitates a wide range of submarine combat systems research and development activities. Already, it has been used to support the introduction of a number of components being procured under the COLLINS-class Submarine Combat System Augmentation program – including technical input on Target Motion Analysis & Track Management Applications, X-Terminal based open systems consoles, and the Control Room internal communications system.

As well as providing the facilities with which to undertake problem identification and acquisition support for programs, the Undersea BattleLabs will also provide DSTO with the ability to rapidly respond to emergent issues related to the new systems as they are introduced into RAN service.

Establishing an experimentation framework:

With the Undersea BattleLabs, DSTO has developed the ability replicate the actual data protocols that are used to communicate between the various Combat Systems components. This allows real or simulated, and existing or proposed systems to be mixed transparently to support a wide variety of experimentation opportunities. As discussed above, it is possible for the Undersea BattleLabs to support high fidelity and rigourous testing of specific Combat System Components, through to the emulation of an entire Control Room of a Conventional submarine to address operator work-flow and command & control investigations.

Given the flexibility of approach chosen as the basis of the Undersea BattleLabs, DSTO can conduct lab-based experimentation of combat system components up to total submarine performance. This flexibility extends to the instrumentation of the BattleLab submarine to collect required MOPs. Either present or future submarine options can be achieved by reconfiguring (or separate submarine instantiations) of the Undersea BattleLab to match the required experimentation profile. Reference [4] presents an example where the Undersea BattleLabs have been used to support an operations research task.

One particular instantiation of our Undersea BattleLab is the vCOLLINS as used for the FBE-Juliet and discussed in more detail below. This installation has been designed to collect specific MOP, but also demonstrates how the Undersea BattleLab design philosophy supports rapid assembly of experimental systems that do not require any substantial infrastructure and can be deployed at some distance from the DSTO labs.

## TTCP-MAR TP-1: Maritime Command, Control and Information Management

The Technical Cooperation Panel, Maritime Group, has established a Technical Panel (TTCP MAR TP-1) responsible for collaboratively on areas related to maritime command, control and information management. A major activity within this technical panel is a collaborative experimentation program into the application and impact of NCW concepts on maritime coalition operations. To support this program the technical panel has established a joint synthetic environment (called the TTCP Virtual Environment) to support coalition-based NCW experimentation. This TTCP Virtual Environment is based on the same environment used within the DSTO Undersea BattleLabs (described above) and includes a virtual platform that can be configured to represent a coalition surface ship or submarine.

TTCP member countries (Australia, Canada, New Zealand, United Kingdom and the USA) are currently integrating their own virtual national platforms with the TTCP Virtual Environment and conducting an initial NCW surface surveillance experiment. These experiments will collect preliminary MOE and MOP data as described in the above MOP table.

The longer-term focus for this experimentation program is to expand the range of questions being addressed to include anti-submarine warfare, rapidly deployable systems, unmanned autonomous vehicles, and eventually anti-air warfare and sea-based land attack.

DSTO's Submarine Combat Systems Group are integrating the DSTO Virtual Submarine with the TTCP Virtual Environment in order to research the network enabling of Australian submarines in a coalition setting.

## Fleet Battle Experiments

Fleet Battle Experiments are managed by the Maritime Battle Center (MBC) of the Naval Warfare Development Command (NWDC) in Newport, RI. Within these experiments, NWDC operationally examine and evaluates innovative warfighting capabilities for future development and rapid transition to the fleet.

The MBC state the following as goals their FBE Goals (from Reference 4):

1. *Improve how we fight: OPLANS, Doctrine, TTP, CONOPS for the current Navy*
2. *Validate requirements and define capability disconnects*
3. *Explore technological, doctrinal and organizational desired operational capabilities for the future*
4. *Foster innovation--an agent for change*

These FBEs are a vehicle for concepts-based experimentation and usually involve a mixture of live forces, models & simulations, surrogates and emulations. These experiments have been conducted on a regular basis for a number of years (now scheduled annually) and provide, amongst other things, a venue for prototype development. Contributers to the FBEs include the defence, commercial and academic world. A major theme or operational concept is associated with each FBE and recent experiments have incorporated the emergent threats of fast, lightweight attack craft, and a number of different Assured Access and Joint Strike and Interoperability experiments.

The Institute for Joint Warfare Analysis (IJWA) in Monterey, CA is responsible for developing the experiment analysis plan and providing analyses of the results for each FBE.

### *A Virtual Collins in FBE-J*

Operating in parallel to Joint Forces Command Experiment Millennium Challenge'02, FBE-Juliet will be conducted in July/August 2002, with the Coalition component of the experiment being focused on improving C2 for Joint/Combined operations. This effort will be focus on the Anti-Submarine Warfare (ASW) mission area, with coalition partners functioning in support of maritime superiority and sea control, to enable access and maneuver for follow-on expeditionary forces.

Australia (AUS), Canada (CAN), and the United Kingdom (UK) naval forces comprise the multi-national component working with U.S. naval forces, with the U.S. functioning in the Lead Nation role. Operational Control (OPCON) and Tactical Control (TACON) of the assets will be with the JFMCC (Joint Force Maritime Component Commander). The live and virtual forces Order of Battle participating in this initiative include:

- USS BENFOLD (DDG-65), operating live in the FBE Operating Areas (OPAREAs), with an HSL DET (SH-60B) providing an Air ASW helicopter.

- HMAS COLLINS (S-73), DSTO and the RAN will operate a virtual submarine from the Naval Undersea Warfare Center (NUWC) laboratory facility in Newport RI.

- HMS ARGYLL (F-231), operating as a virtual ship from the NC3SI laboratory facility in Portsdown West UK, with support from the Defence Science & Technology Laboratory [Dstl].

- HMCS HALIFAX (FFH-330), operating as virtual ship from the Defence Research Establishment Atlantic (DREA) laboratory facility in Halifax Nova Scotia CAN.

The major objective is to integrate and establish a shared information environment for effective command and control multi-national operations in a network-centric operational framework. Three major elements of this initiative are to investigate:

- Coalition C2 interoperability (to include shared battlespace situational awareness),

- Dynamic network reconfigurability (for improved network connectivity and communications reliability), and

- Secure information sharing (policy-based domain management and information assurance).

Under this overarching set of objectives, DSTO has instantiated the vCOLLINS for FBE-J to provide sufficient fidelity with the following additional DSTO objectives;

1. Learn to Experiment
2. Establish Connectivity between Real and Virtual Platforms
3. Work coalition into NCW
4. Examine reduced manning from automation
5. Examine Capability and limitations of current technology in NCW
6. Examine Rapidly Deployable Sensors (RDS)

Australian participation in Fleet Battle Experiment Juliet (FBE-J) will consist of a virtual submarine (vCOLLINS) emulating a subset of COLLINS submarine capabilities. The virtual submarine will be implemented in hardware located at NUWC, Newport RI, and will communicate via network links with other virtual coalition entities located in Canada and the UK, as well as with US virtual and live platforms. Live platforms will be operating within the SOAR range, which will provide geographic and ground truth information to the simulator to allow incorporation of virtual entities. A representation of the DSTO participation in FBE-J can be seen in Figure 4.

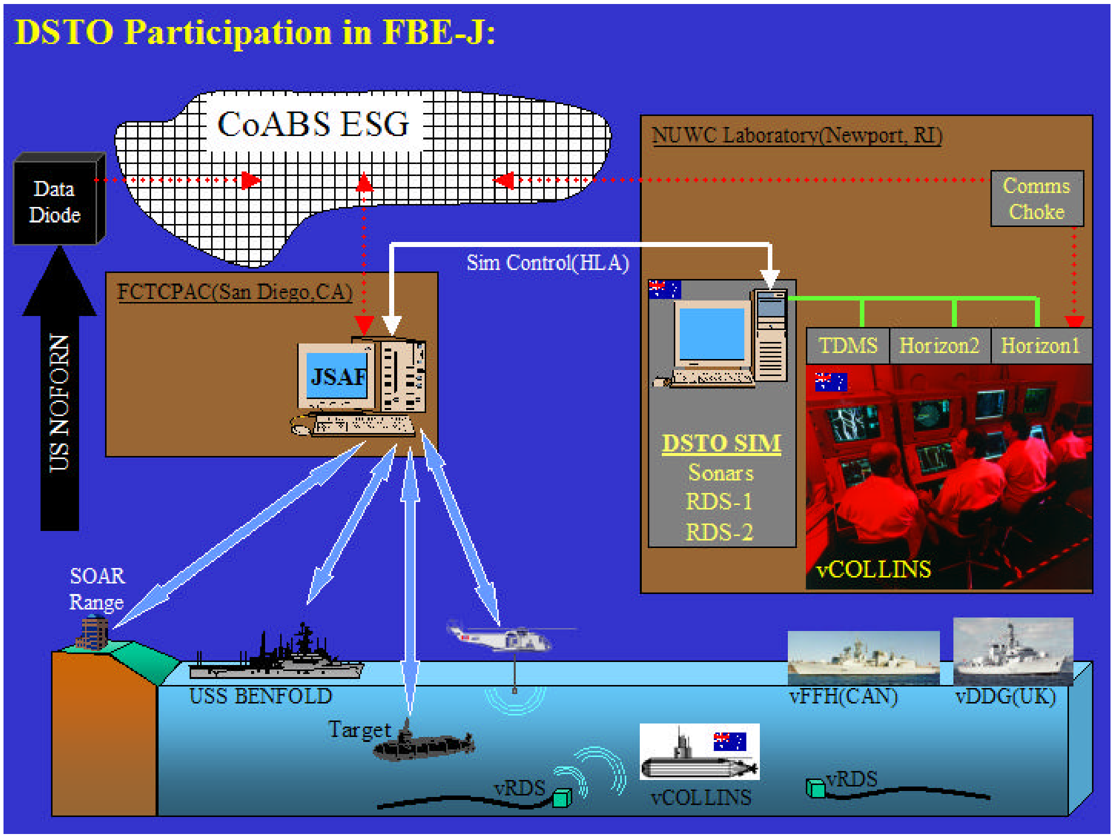


**Figure 4: Representation of DSTO Participation in FBE-J**

The vCOLLINS will participate in the experiment via the US controlled Joint Semi-Automated Fleet simulator (JSAF) within an FBE coalition Wide-Area Network (cWAN). The vCOLLINS will receive scenario and environmental information from this simulator, and will provide its position to the JSAF simulator. Internal simulations within the vCOLLINS will handle its own dynamics, sensor capabilities and communications. Sensor information from vCOLLINS will be provided to other coalition players using CoABS grid technology (Control of Agent Based Systems, a DARPA project to allow information sharing, including from legacy systems).

The vCOLLINS sensors will form part of the coalition Expeditionary Sensor Grid (ESG). A major aim of the experiment is to examine the benefits and drawbacks of submarine participation in such a network-centric environment.

vCOLLINS simulated sensors will include a flank array, a towed array, and two deployed sea-bed arrays designated RDS (Rapidly Deployable Sensors).

vCOLLINS organic processing will include standard sonar track management processing functions (ie. TDMS). COLLINS processing will also include two implementations of the HORIZON track and contact fusion processor. The HORIZON-1 module performs fusion of tracks and contacts received from the coalition platforms. This reduces the volume of tracks supplied to the 'All-source' fusion module (HORIZON-2). HORIZON-1 also implements a CoABS agent that finds coalition track/contact information from the ESG and filters solutions provided back to the ESG.

A communications "choke" between the vCOLLINS and Coalition WAN will limit communications to period when the submarine is at 'Communications Depth'. Such operations also allow testing of CoABS automated registration and update regimes settings and will support investigations into the effects of non-continuous communications on the effectiveness of proposed NCW concepts. The choke will be implemented by DSTO, and will have user-variable bandwidth.

It should be noted that this vCOLLINS instantiation shows how systems of various maturity can be melded together into the one experimental system. That is, for FBE-J, the vCOLLINS incorporates examples of in-service systems (eg. TDMS), R&D systems (HORIZON) and advanced operational concept systems such as the vRDS systems (which are intended to replicate a possible future sensor system for the RAN).

## Summary

This paper has given an overview of the research and experimentation program that has been established to investigate network enabling of the RAN Collins Class submarines. The program contains some specific technical experiments using the DSTO Battlelab but is mostly exploiting opportunities to explore Network Centric Warfare within wider experimentation programs such as the RAN Headmark program (especially wargames) and Fleet Battle Experiments. The challenge is now to set the relevant MOE, start collecting data, and then performing the analysis required to answer the questions of what capability does network enabling the Collins bring to the RAN and what are the technical issues and risk associated with networking the submarine.

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