Virtual Battle Experiment – Echo (VBE-E):
SWARM Attack Command and Control (C2) Issues

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ABSTRACT

In 2002 a multinational study group on Netcentric operations used operations research techniques to examine force defence effectiveness for a small coalition force facing a surface swarm attack. The study group recommended a number of C2 related "netcentric" applications that improved effectiveness. In October 2006, Virtual Battle Experiment Echo (VBE-E) will use the Combined Federated Battle Laboratories Network (CFBLNet) to link together command teams in each of four nations to conduct an hypothesis testing experiment to investigate two of the recommendations. A total of 18 sets of two simulation runs will be conducted over a ten day period examining the force defence of a small convoy protected by two generic coalition frigates. The emphasis of the experiment will be to examine coalition C2 issues with the addition of UAV sensors to extend range, and third party targeting to allow increased weapon availability. Secondary objectives for the experiment include demonstrating the use of distributed simulation to conduct rigorous experimentation, and the development of tools to explore situational awareness and command team workload.

1.0   INTRODUCTION

In 2002 a multinational study group on Netcentric operations, TTCP[1] Maritime Systems Group (MAR) - Action Group One (AG-1) used operations research techniques to examine force defence effectiveness for a small coalition force facing a surface swarm attack. AG-1 recommended a number of C2 related "netcentric" applications that improved effectiveness. Following on the operations research work an associated group, TTCP MAR Technical Panel One (TP-1), with a focus on Maritime Command and Control issues has taken on the task of examining some of the C2 recommendations in a coalition context. Between 2-14 October 2006, Virtual Battle Experiment Echo (VBE-E) will use the Combined Federated Battle Laboratories Network (CFBLNet)[1] to link command teams in each of five nations together to conduct an hypothesis testing experiment to investigate two of the recommendations. One of the original scenarios, a Maritime Force Defence scenario, will be used to examine the force defence of a small convoy protected by two generic coalition frigates. The emphasis of the experiment will be to examine coalition C2 issues with the addition of Unmanned Aerial Vehicle (UAV) sensors to extend range, and third party targeting to allow increased weapon availability. Secondary objectives include demonstrating the use of distributed simulation to conduct rigorous

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[1] TTCP – The Technical Cooperation Program, a five country (Australia, Canada, New Zealand, United Kingdom and United States) agreement to carry out collaborative research in non-atomic defence applications.

experimentation, and the development of human performance assessment tools to explore situational awareness, workload, and shared awareness and decision-making of the coalition command team. A total of 18 sets of two treatment runs will be conducted over a ten day period.

TP-1 has, over the past decade, built a distributed simulation infrastructure for use in multinational experimentation. This infrastructure is based upon the Virtual Maritime Systems Architecture (VMSA)[2] developed by Defence Science and Technology Organisation (DSTO) in Australia. VMSA is an instantiation of High Level Architecture (HLA) [3] distributed simulation standard that is tailored for maritime command and control applications. TP-1 have been building an experimentation capability around VMSA through three previous international experiments, and a number of national experiments. Each national member of the panel contributes elements of the overall infrastructure in order to develop a larger capability.

The main objective of this paper is to introduce the symposium participants to the capability for scientific or military experimentation at the tactical operations level that can be realized using distributed simulation. Coalition Warrior Interoperability Demonstration (CWID) (formerly Joint Warrior Interoperability Demonstrations (JWID)) and Multi-National Experiments (MNE) have used distributed simulation for coalition experimentation over the past few years, but the majority of the investigations have been in specific communications and collaboration tools at the planning or higher operations level. Distributed simulation is just as valid at the tactical level, which is where the majority of force protection issues exist.

2.0   VBE-E EXPERIMENT DESIGN

Virtual Battle Experiment –Echo (VBE-E) is the fourth in a series of experiments that TP-1 has conducted to look at maritime command and control in a coalition context. These experiments have had two general objectives: firstly to conduct discovery experimentation in a variety of tactical scenarios, and secondly to develop experimentation infrastructure and procedures. VBE-E continues this process of adding capability and expanding the types of maritime operations examined. Previous experiments have developed a distributed simulation for building maritime virtual environments and allowed member nations to stimulate a variety of national tools for track fusion. Experiments have been conducted looking at anti-submarine warfare, surface warfare, and combined submarine task-group operations. Following a Concept Development and Experimentation (CD&E) spiral development of concepts approach TP-1 now extends the operations research work of AG-1 on coalition force defence against swarm attacks by adding a human in the loop (HIL) simulation analysis. This will be the first hypothesis testing VBE conducted by the panel.

In VBE-E, coalition command crews will be given UAV and third-party targeting capabilities proposed in the AG-1 recommendation and will operate in a similar force protection scenario. Eighteen scenario runs will be conducted in an effort to determine the validity of the action group's recommendations. Each run will consist of two national command crews operating virtual frigates and facing a swarm attack. Command crews will consist of a Commanding Officer (CO), Operations Room Officer (ORO), Force Protection Officer (FPO), and Surface Weapons Controller (SWC), or national equivalents. Each set of runs will consist of a baseline frigate trial and a trial with the addition of a UAV. National crews will be paired for experimental runs with each other nation to form coalition teams. In doing so the experimentation more realistically represents coalition conditions while minimizing the cost of participation to each nation. Each nation will provide two separate command crews, thus providing 7 *chose* 2 = 21 different combinations. The experiment will be able to exercise 18 of these in the available time frame, making a total of 36 simulation runs over 10 days.

In order to obtain sets of coalition crews, VBE-E will be distributed between four of the five nations using a secure network, the fifth nation is providing a collaborative planning tool. This allows each nation to site their

virtual frigate close to a naval base and use serving officers in the experimentation. An important part of this experimentation is the interaction of coalition crews with differing military cultures and national Rules of Engagement (ROE).

Development of the experiment began in April 2005 with agreement by the nations on the basic framework and objectives. Further experimental design was conducted during project team meetings in October 2005 and April 2006. DRDC Atlantic has taken the lead for Canada for this particular experiment, and is developing the plan and core simulation based upon the TP-1 infrastructure. DRDC Human Research Ethics Committee has reviewed and approved the experiment protocol and a pilot study of the experimental framework was conducted 14-18 August 2006. A final project team meeting was held at DRDC Atlantic 21-25 August to familiarize the other nations with the infrastructure, and to test analysis procedures. Training of the military personnel who will participate in VBE-E in October 2006 took place 18-22 September using the full networked simulation.

2.1 Objectives

Two primary objectives of VBE-E are:

- To use the TP-1 virtual battle experiment (VBE) to conduct a rigorous coalition-based experiment

- To validate AG-1 combat system assumptions and conclusions; specifically from the fast inshore attack craft (FIAC) swarm analysis

The hypothesis that will be examined is:

- **If** UAV based EO/IR sensors are available **then** the number of FIAC which get within attack range of their target (defined as a leaker) will be reduced

Due to the requirement for multiple runs in order to evaluate the hypothesis only this one of the AG-1 hypotheses will be rigourously tested. A second hypothesis postulates a technological capability for third party targeting that is close to being realized in many navies. The use of third party targeting has more to do with the extant Rules of Engagement (ROE) and Commander's appreciation of the situation, than if the ship is technologically able to fire its main gun using a track from another platform. Thus, the capability for third party targeting of the main gun has been given as part of the frigate's base capability, and usage of the capability will be tracked during all runs.

The secondary objectives for the experiment are:

- To use the scenario as a discovery exercise to investigate appropriate methods for assessing situational awareness and workload of a command team during a maritime force defence operation.

- To examine individual and team decision-making in a coalition engagement decision-making task.

2.2 Scenario

The scenario to be used follows the basic scenario used by AG-1, that is, a convoy of two high-value vessels (HVUs) is being escorted through a constrained waters strait by two coalition frigates. This is a Force Defence operation, where all ship systems are active and the force protection team is closed up with sentries and machine guns manned. Intelligence reports indicate that there is a possible threat from terrorists against either the freighters or ships. One warship will lead the convoy and the other will bring up the stern. The two HVUs follow the lead ship to form a column as shown in Figure 1. The area is busy with numerous fishing

vessels and pleasure craft. As the convoy transits the strait a swarm of small attack craft will form up and attack one of the HVUs.

The base scenario will consist of solely the convoy and the attack craft. The second scenario will involve a UAV which will be allowed to patrol ahead of the lead ship or as requested by the Officer in Tactical Command (OTC). While there will be typical coalition rules of engagement (ROE) and procedures provided to the OTC, each nation will operate under normal national constraints and ROE. Each command team will be briefed on the mission prior to a scenario and will be informed of the possibility of attack during the exercise.
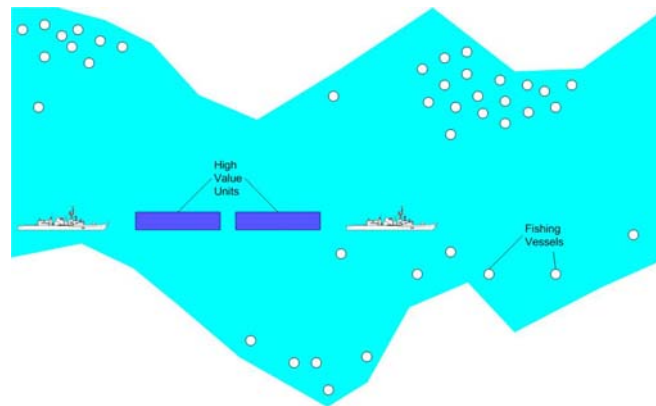

Figure 1 Scenario Description

The actual geographic area to be used in the experiment will be the Northumberland Strait, 46˚N 63˚W, between the Canadian provinces of Prince Edward Island (PEI), New Brunswick (NB) and Nova Scotia (NS). Figure 2 shows the navigational charts for the area. Three dimensional (3D) terrain will be generated to provide background for visual and electro-optic sensors on the UAV. Visual sighting reports will be generated for the command team by experimentation personnel using 2D displays.

- The weather conditions will be sunny and clear, with no noticeable sea state.

- There will be navigational tracks for the ships to follow.

- There will be some neutral merchant traffic, fishing and pleasure craft.

- There will be a number of situations in the scenario that feign the possibility of an attack and which may induce false alarms. These include:

  - Pleasure craft off a resort

  - Fishing fleets

  - Cross strait traffic

- Although the same basic scenario will be used throughout the experiment the onset of attack will take place at different times to minimize participants' familiarity with the scenario.
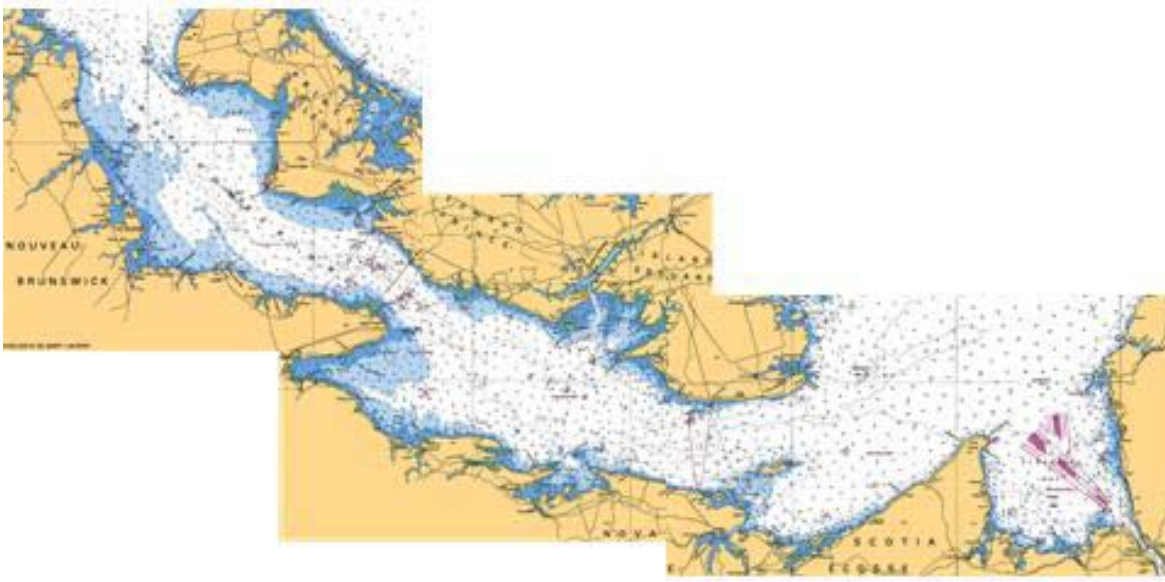
Figure 2: VBE-E Scenario Location – Nautical chart of Northumberland Strait

In the scenario, attackers and small neutral craft will be indistinguishable prior to initiation of attack. Upon attack initiation, attack craft behaviour will change to converge at high speed on one of the HVUs, and graphical representation in the UAV simulation will change from civilian personnel to personnel carrying guns or rocket propelled grenades.

Neutral craft closing on the convoy can be warned off by gun fire, flares or radio comms traffic. Attackers will only be deterred by physical damage.

2.3   Analysis

The UAV hypothesis will be tested using the following measures of effectiveness:

- Response time (i) - Time from initial detection to classification as hostile.

- Response time (ii) - Time from attack initiation to initial detection.

- Response lag – Difference in time from when information used to classify as hostile available to actual classification.

- Open fire range - Mminimum range of attackers to target at time of first shot for each ship.

- The number of leakers, which is defined as the number of attack craft which make it to within attack range of the target. (This is the MOE used in the original action group report).

- Attack duration – time from start of attack to time last attacker is destroyed or reaches attack range.

- Number of neutral vessels damaged.

Analysis of the third party targeting will depend mostly on observer event records to correlate commander decisions with actual gun usage. The simplified combat system being used also records actions such as the assignment of tracks to weapons.

A major part of the analysis effort is focussed on the utility and correlation of a wide variety of psychological/ human factors test instruments and team behaviour monitoring. Since this is a discovery exercise, specific technological collaboration capabilities are less of interest than obtaining an understanding of how coalition command teams work.

In the experimentation the following test instruments will be used:

- Audio and video recording of operations room

- Observer recording of team interactions (within frigate and between frigates) using PDA (personal data assistant) electronic recording

- Instantaneous personal workload assessments – prompted for input from participants by observers, and noted by observers

- Behavioural Observations (noted by observers)

- NASA TLX [4] workload measurement - post-scenario using computer based survey software

- Pre-scenario questionnaires

  - Participant background questionnaire

  - Observer background questionnaire

- Post-scenario questionnaires for participant

  - General information on completed mission

  - Situational Awareness Rating Technique (SART) [5]

  - Team shared Awareness questionnaire

- Post-scenario questionnaire for observer

  - Observer comments on team behaviour and assessment tools

Data collected will initially be reviewed and analyzed for trends in performance measures. The data will then be categorized and analyzed in more depth for dependencies on scenario.

3.0 INFRASTRUCTURE

The general experimentation infrastructure has been developed over the past eight years by the members of TP-1 and tested in a series of international and national experiments. In each experiment the panel has some technical objectives to expand the capabilities of the infrastructure. In this particular experiment the panel is moving from single site experimentation to multi-site experiments, and from strictly discovery experimentation to a combination of hypothesis testing and discovery. While the VMSA infrastructure is built upon an instantiation of the HLA distributed simulation standard (IEEE 1516) it is based around combat system and sensor capabilities rather than platforms since the focus of the panel's work is composing combat systems. Thus, instead of a component federate (simulator) for each platform in the overall Federation (simulation), VMSA has a single federate for each platform capability (sensor or weapon system) that models that capability for all platforms. VMSA also allows the integration of other standalone simulations using gateway technologies. For example, VBE-E will use the Joint Semi-Automated Forces (JSAF) program to generate some of the neutral shipping and attackers.

Other parts of the infrastructure include experimental plan formats and the testing of networks.

3.1 Virtual Frigate

The main parts of the synthetic environment for the experiment are the two virtual frigates, within which the command teams will play the scenarios, and the generation of neutral and red forces. Figure 3 gives a human based view of the simulation. The virtual frigates are composed of simulation elements for the frigate sensor and weapon systems, and combat system consoles for each member of the command team. Each platform has a command team consisting of:

- Commanding officer (may also be Officer in Tactical Command (OTC) for the convoy);

- Operations Room Officer (ORO) (in charge of coordination of information for the CO);

- Surface Warfare Coordinator (SWC) – in charge of radar, ESM and main gun;

- Force Protection Officer (FPO) – in charge of the sentries and machine gun mounts.
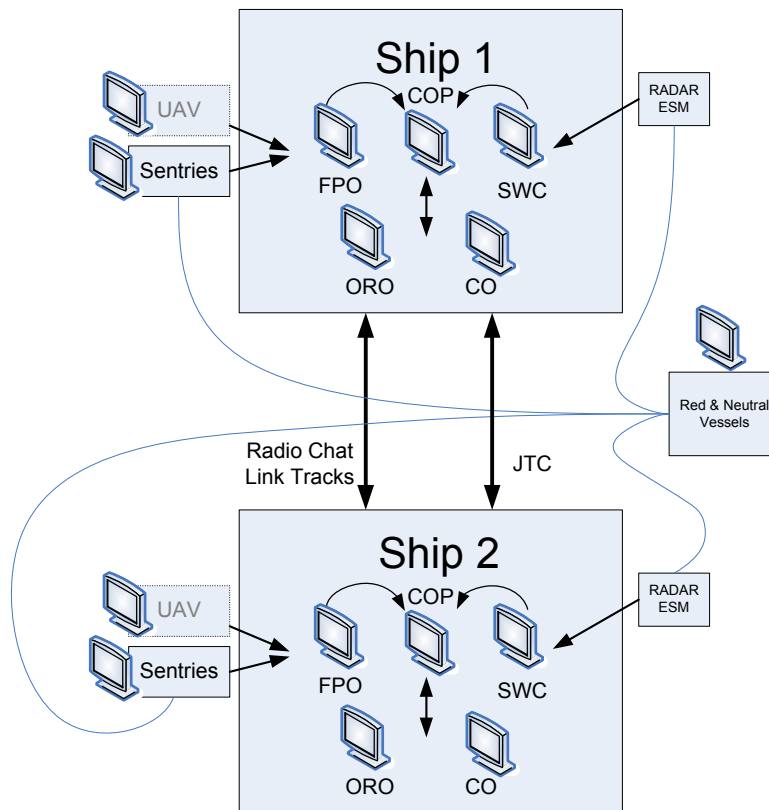

Figure 2: Human in the Loop Diagram – screens represent individual machines, blue lines show influence on sensors, black arrows show communication between machines. The UAV is only available during specific experimental runs and on a single platform at a time.

Game staff will play the part of ship sensor and weapon operators, and sentries. Game staff will also control neutral shipping and the swarm attackers. Synthetic radio channels are provided from the FPO to the sentries

and for the CO/ORO between ships using a program called TeamSpeak™ developed for online gaming. Chat lines are also available between ships, and an operations planning tool (JTC) is provided to the COs to coordinate operations.

The principal combat system element is a C2 research testbed called Horizon, jointly developed by Innovation Sciences and DSTO. The Horizon testbed features a plugin architecture making it relatively easy to add functionality and has been used in previous VBEs. New for this experiment is an updated interface to VMSA, and a gun control plugin. Using Horizon operators can manage and fuse tracks from radar and ESM, enter visual sighting reports and use them to target gun systems. In VBE-E both the main gun and machine guns will be managed from the Horizon interface.

Weaponry available to the ships are based upon a generic frigate and are limited to a main 76mm gun with surface burst shells, six 50cal heavy machine guns, and 5.56mm handheld semi-automatic rifles operated by sentries. The ships have surface search radar based upon the SPS-49 and optical sighting by sentries. In the hypothesis treatment a single lightweight UAV with endurance greater than the 2 hour scenario duration and a top speed of 120 knots is available. The UAV sensor is a medium fidelity electro-optic device, modelled by Microsoft Flight Simulator.

3.2   Distributed Simulation

Figure 4 gives a federate-based view of the synthetic environment. The federation is essentially a VMSA based HLA federation with a gateway to the JSAF program to provide a variety of neutral and red forces. The federation is using the MaK Technologies run-time-infrastructure (RTI) [6] and will run on the Combined Federated Battle Lab Network (CFBLNet). The CFBLNet is a secure experimentation network that links the participant nations. TP-1 has previously run some federation tests using the network. The majority of federates will be run from one particular nation (either Australia or Canada) with only the ones required for the participants and interactors being deployed to the other nations. This architecture gives the experiment a generic combat system functionality which is not native to any particular nation. Thus, differences in performance should come from differences in command decisions and national Rules of Engagement, not differences in technical capability.
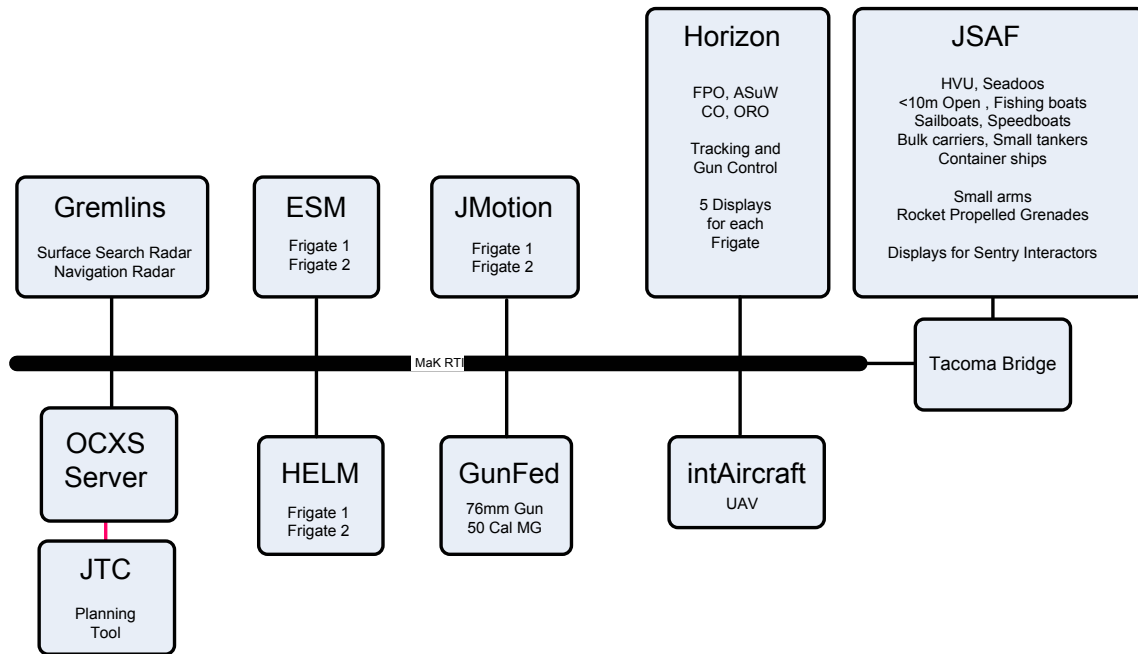
Figure 4: Federate-based Architectural Federation

The synthetic environment provides the following stimulus to the virtual frigates:

- Terrain elevation and feature data for the Northumberland Strait including navigational features such as buoys and shoreline features such as resorts, fishing ports and commercial ports.

- Coalition communications using TeamSpeak ™.

- Motion, 3D model, independent motion, navigation radar emissions and radar returns of:

  - Local fishing traffic

  - Local pleasure craft (sailboats and personal watercraft)

  - Local shipping and crossing Strait traffic

  - Neutral merchant shipping

  - Red swarm motion, behaviour, 3D representation (weapons hidden and weapons loose), weapon fire events and damage from coalition weaponry.

- Coalition platform sensor inputs (radar and ESM), helm responses, damage from Red force and some limited audio feedback (e.g., gun firing).

Threat (red) capability will be 8-10 small craft with rocket propelled grenades (RPG) and 7.62mm automatic weapons. The small craft will be similar to the pleasure and small commercial craft found in the area. Thus, personal water craft (seadoos), small open boats or fishing craft may be used by the red forces. Red forces will attack the coalition frigates if the frigates come closer to the attacker than the actual target. Weaponry from the red forces will damage the frigates only if models can be implemented in time. Red force will however take damage from blue force systems using the damage models built into the Joint Semi Automated Forces (JSAF) program.

3.3 Networking

The distributed simulation will use the Combined Federated Battle Laboratory Network (CFBLNet). A secure enclave has been established using TacLane encryption between the four national sites. As with the experiment, Canada has led this CFBLNet initiative, including the issuing of keymat to the other nations. This has been an important step in the expansion of networking capabilities, since this is the first time Canada has led a complete initiative.

Primary network services are being provided by the United Kingdom for Domain Name Service, File Transfer and Voice Over Internet Protocal (VOIP). Additional, resources are being provided by the other nations as required. The HLA Run-Time Infrastructure is licensed from Canada. In addition, Australia and Canada will share the responsibility for hosting the main simulation elements for each particular run. Since there is significant time latency between northern and southern hemispheres, Australia will handle primarily southern hemisphere experimental runs, while Canada handles the mainly northern hemisphere ones. This also allows a better split in personnel so that runs can be made around the clock.

4.0 CONCLUSIONS

Simulation has long provided a means to examine complex problems in a structured and controlled environment. However, in many cases the size and complexity of the required simulations have precluded these studies. By breaking the simulation down into components and making use of high fidelity component simulators the complexity required can be achieved but only if the component simulators can be linked together. Since the component simulators have seldom been co-located in the past, opportunities for study have been limited. The use of distributed simulation technology is overcoming these obstacles. For the past decade distributed simulation has provided opportunities for limited (often national) discovery experimentation.

With the advent of high bandwidth networking nationally and internationally, the opportunities for linking previously stand-alone simulation capabilities is expanding rapidly. The CFBLNet is one such network. This has in turn enabled driving local simulators from synthetic environments that are geographically distant. Thus, rather than bringing subjects to the simulator, the simulator can be taken to the subjects.

The opportunities these capabilities provide for concept development, and the study of subjects like military and team decision-making are large and growing. While many technological capabilities can be modelled constructively, the most important input in the art of war is human, and human reactions are not well modelled as yet. Therefore Human-in-the-loop (HIL) simulations are required for command and control studies. Distributed simulation gives the opportunity to construct experiments that can study human command and control issues – like team shared awareness and decision making. These issues are even more important in complex environments such as littoral waters, and confused tactical situations like SWARM attacks.

Virtual Battle Experiment Echo has extended TTCP Maritime Systems Group Technical Panel One's ability to study command and control issues. The data obtained from the experiment will provide the basis for designing future studies, and progress the study of coalition force defence issues.

5.0 REFERENCES

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