19th ICCRTS

Development of a Naval C2 Capability Evaluation Facility

Primary: Topic 4: Experimentation, Metrics, and Analysis

Secondary: Topic 5: Modelling and Simulation

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At the tactical level, Command and Control (C2) Agility implies that command staff has a range of well-developed, and understood, concepts of operation that they can choose from for their organizations. The development of alternative operational concepts, even to adjust an operations centre to the inclusion of new or changed capabilities can be problematic at the unit level. For a naval platform, changes to the physical environment are generally both difficult and expensive. In order to support naval concept development and experimentation, Defence R&D Canada has developed the concept of a Maritime Capability Evaluation Facility. This concept would provide the reconfigurable physical infrastructure to conduct operator in the loop experimentation on C2 concepts, thus enabling the investigation of concepts of operation early in the naval capability development cycle. A prototype facility to support submarine C2 research has been developed and used to investigate a wide range of technologies that could be used in the development of a full Navy capability. This paper describes the prototype and a number of the technologies investigated.

1.0 INTRODUCTION

Command and Control (C2) Agility and the NATO C2 Agility Model [1] are built upon the concept that C2 organizations can switch organizational structures and processes to best match the C2 situation facing them; in some cases using multiple C2 processes simultaneously for different collaborations or situations. At the tactical level time scales are often more compressed and therefore it is essential that command staff have well-developed and understood options available. The C2 Agility Model reinforces the importance of concept development and experimentation that were heavily promoted over the past decade in order to provide that understanding. However, experimentation at the tactical level can be problematic due to the necessity to modify equipment or platforms, particularly those which directly interact with or are part of weapon systems. On naval platforms this is especially true since even small changes may invalidate weapon certification.

As navies move to save costs by crew reduction, the concept of specialized mission crewing options and cross training of crew members looks attractive. Concepts such as these that are investigated in isolation can miss the complex interactions currently in-place between primary and secondary duties, at-sea training, quality of life etc. Recognition that the tactical C2 is a complex system is important and leads to a requirement for holistic experimentation in order to understand likely and unintended consequences of changes in one warfare area on another area or process [2]. This requirement is extant whether the new concept is one of new equipment, tasks, organization or critical space layout. Offsetting this requirement for in depth understanding is the fact that technology is changing much faster than current programs can conduct acquisition, let alone concept development and then acquisition. There is, therefore, an urgent need for processes and infrastructure to reduce the cost and timescale of experimentation in order to better tailor acquisition, or process change, to the concepts that provide realistic and practical gains.

Defence R&D Canada (DRDC) has identified a requirement for the capability to provide evaluation support to the ongoing evolution of shipboard command and control [3]. This evolution can come in a wide variety of forms ranging from changes in doctrine or personnel to major changes in weaponry. DRDC believes that this requirement is applicable across the Department of National Defence (DND).

System engineering experience [4] indicates that early full system evaluation of designs is required in highly complex systems since sub-system evaluation may not be predictive of the overall system effect. It has been shown by both allies and industry that there are significant savings to trialing changes to systems before implementation in operational units. However, the cost of full system evaluation has often been deemed prohibitive for all but the largest of projects.

While capability maintenance packages are often discussed in terms of new technology, it is well understood that often the actual systems are a complex socio-technological systems of systems in which the commander and human operators are critical parts. In particular, the command and control process supported by the combat control system (CCS) is such a system. Thus, any changes to the equipment, personnel, training, tactics, procedures, sensors, algorithms need to be assessed from a systems perspective.

DRDC has developed a concept called the Maritime Capability Evaluation Laboratory (MCEL)[3] to provide a cost-effective long-term infrastructure for naval C2 concept evaluation. The basic idea is to instantiate an infrastructure model that minimizes the cost of entry for naval concept development (or acquisition) projects to conduct evaluation experimentation as part of the systems engineering prior to major implementation engineering and equipment acquisition. This requires the construction of physical emulations of naval critical spaces that are readily available for use and have associated baseline warfighting performance measures. Despite advances in virtual worlds, C2 remains an inherently human exercise that requires a level of human interaction that is not currently available except by putting the team into an emulation of its physical environment.

The laboratory is expected to support the full-scale implementation of the ship's C2 systems and critical spaces; while utilizing modelling and simulation to implement sensors and weapon effects. The level of environmental fidelity will depend upon the requirements of the capability being tested, but it is expected that MCEL will make use of Royal Canadian Navy (RCN) standard models whenever possible. System components fidelity will also depend upon requirements. The laboratory must also include control, monitoring and data collection instrumentation to evaluate the effectiveness of human operators, and networking capabilities to allow it to be linked with other simulation and training facilities, including ships alongside. Integral to this concept is the ability to baseline current capability so that the effects of new concepts and processes can be fully evaluated.

DRDC's mandate within DND is to investigate new concepts and technology. Thus, in 2008, DRDC initiated a project with two objectives, firstly to investigate new operations room concepts for the VICTORIA Class submarine [5,6] and secondly to develop a prototype MCEL infrastructure within which to conduct performance experimentation on developed concepts and investigate enabling technologies. This paper addresses some of the lessons learned from the VICTORIA Capability Evaluation Laboratory (VCEL) which resulted from the second objective.

2.0 VICTORIA CAPABILITY EVALUATION LABORATORY (VCEL)

The VICTORIA Capability Evaluation Laboratory (VCEL) is a prototype command and control concept evaluation experimentation laboratory. Originally named the virtual VICTORIA or vVICTORIA it has evolved from work conducted by allies such as the Australian virtual Collins.

The general concept is to provide a flexible and adaptable emulation of the VICTORIA class submarine operations centre within which investigators can cost effectively modify the environment to expose operational personnel to new command and control concepts. The level of experimentation to be conducted in the VCEL is at the point where a full war-fighting team is required. That is to say that while individual usability assessments could use VCEL, it is really aimed at enabling the evaluation of concepts that impact a significant portion the whole command or operating centre team.

This human-in-the-loop level of experimentation imposes a number of constraints:

1. the physical limitations of the space must be realistically represented;

2. all inter-personal communications modalities need to be represented;

3. all expected sensor/information stimuli must have realistic levels of availability; and,

4. all individual and team behaviours, communications and interactions must be recordable.

From the start of the project the design concept was for a full scale physical mock-up of the VICTORIA class submarine operations centre. This is in contrast to many training systems which can incorporate 30% or more extra space to accommodate trainers and observers. In the case of VCEL it was felt that an important part of operational procedures were the constraints imposed by the physical space. The physical mock-up would be populated with enough of the physical equipment to enable the experimentation requirements of the concept evaluations being developed by the concept development team. A system design that allowed a variable fidelity in equipment emulation, alongside experimentation data collection, was therefore required. Figure 1 provides a concept diagram for the implemented software system. A key part of the final system was the use of a version of the commercial naval game Dangerous Waters produced by Sonalysts[7] to provide background computer generated forces, scenario implementation, and initial operating capability for internal systems.

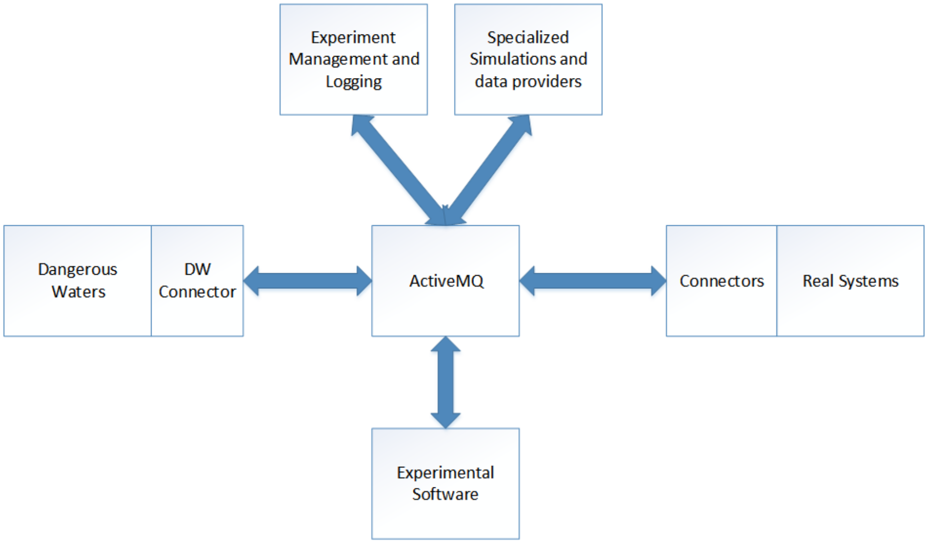


Figure 1: VCEL software system diagram.

At the centre of the system is free and open source server for implementing messaging between software components, ActiveMQ[8]. Using this technology allowed the integration of a wide variety of systems, ranging from actual boat systems to in-house developed emulated systems.

At the top of the diagram are the system management, monitoring, and logging applications. In VCEL, these were all written in-house to meet our specific needs. There is also a box for specialized simulations and data providers; two examples in VCEL are a data provider that reads sound-speed profiles and responds to queries, and a very basic Automatic Information System (AIS) network simulation that creates AIS reports for other software to consume.

Figure 2: The ECPINS system [OSI].

To the right are real systems that are integrated with VCEL. Currently we only support the ECPINS-W commercial off-the-shelf (COTS) electronic charting and navigation system. In principle, anything could be connected, though an adaptor would be required to interface with ActiveMQ. Figure 2 shows the ECPINS station in VCEL.

At the bottom of Figure 1 is a box representing experimental software. In the VCEL context, this means prototype interfaces or entire systems meant for operators to use directly. We have been very successful using Adobe Flash and Apache Flex as rapid application development (RAD) tools for creating new operator interfaces and systems, and for emulating real systems where it is impractical to use them directly. The Flash based operator interfaces were constructed as web applications and connected to ActiveMQ via an open source remoting and messaging technology known as BlazeDS[9]. The only architectural exception was for mapping in which the open source MapServer[10] platform was used to drive map based display elements directly. Figure 3 shows the architecture for activating the Flash interfaces from the simulation.

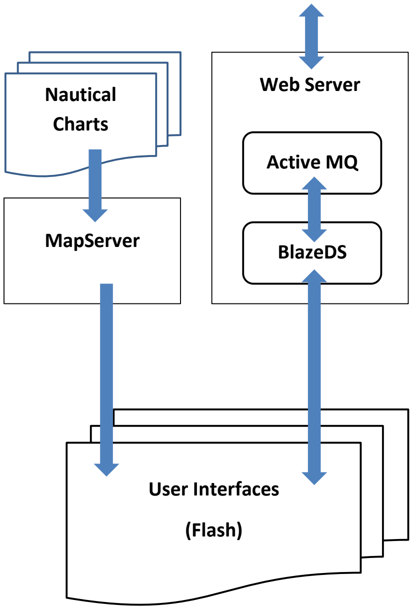


Figure 3: Interface Activation Architecture.

Finally, on the left of Figure 1 is a modified version of Sonalysts' "Dangerous Waters[1]" modern naval combat game. This software provides all operator interfaces, periscope, sonar, radar, electronic countermeasures (ECM), weapons and effects, ship motion simulation, as well as an extensive scenario editor. While it does not directly simulate a VICTORIA class submarine, it does provide representative stations where real naval operators can do their jobs.

Communications systems use their own client-server software, and as do some of the independent data collection systems.

Following the system design, all experimental control, data collection and observation is conducted outside the shell of the physical space emulation. Thus, the experiment participants are isolated from interference from observers and other exercise control activities.

3.0 VCEL TECHNOLOGIES

During the implementation of the VCEL the team investigated a wide range of technologies and gathered ideas from collaborators in several allied nations. For example, the team had several opportunities to discuss ideas with the technical team at DSTO's Maritime Experimentation Laboratory (MEL) and ANZAC Combat System Integration Laboratory (ACSIL). Much of the advice and ideas gleaned were anecdotal and do not appear to have been reported in the open literature. In the spirit of that exchange, we do not claim any special insight, but rather wish to pass on to others some of our technical experiences.

3.1 Theatre Set Design Technologies

Early in the project definition process the VCEL team recognized that there was a great deal of similarity between theatrical and television set usage and the proposed usage of VCEL. Thus, one of the main areas of expected technology leverage was from the entertainment industry.

VCEL Shell Emulation

In many cases operations centre mock-ups are developed within facilities that have been designed as "computer" facilities. In general these facilities have been built (whether security shielded or not) with standard 8 foot ceilings and minimally raised floors. Portable dividers are sometimes used to mimic bulkheads when the facility is much larger than the required space. A number of issues with this type of facility have been reported anecdotally.

i. while the idea of the raised floors is to keep network wiring and electrical power distribution out of the way, often the floors are only minimally raised in order to retain as much headroom as possible. This has been found to impede the ease of rewiring as multiple floor panels must be removed each time.

ii. the removal of floor panels to access wiring and centre floor power distribution tends to be problematic as there is almost always a console or other piece of furniture that must be moved in order for the floor panel to be removed.

iii. when permanent walls exist, the peripheral power and networking is often permanently installed in them which then causes problems with maintenance as consoles have to be moved in order to access the walls. Note: this is an actual issue for maintenance in many operations centres as well, but is compounded in a facility that is meant to be flexible and adaptable.

Following discussions with colleagues at DSTO, the team contracted a television set designer to assist in developing a modular and flexible design which was then implemented under a second contract [11]. The resulting design (See Figure 4) incorporates a number of features to address issues mentioned above.

a. All around access to the operations room mock-up's shell. By using the television stage concept of building the set within a larger space it is possible to provide access from all directions.
    i. Using theatrical stage design the set is raised to a level where it is feasible to access the floor from outside (not inside). In VCEL's case the floor is raised 18 in (25cm) off the floor which gives sufficient room for technicians to use a mechanics crawler to move about underneath.
    ii. The floor is supported on 3in (7.5cm) diameter aluminum pipes set into a 2x8 frame. In terms of design the pipes could easily be replaced with longer or shorter lengths to fit a space.
    iii. The walls all have removable panels to enable access to the backs of consoles.

    iv. The ceiling has cut-outs in the framing modules to allow ease of wiring.
    v. The overall ceiling of the structure was re-enforced to support personnel and has access panels.

b. Major construction is with ¾ inch (75mm) good-both-sides plywood. This provides an easily workable and replaceable material – if a hole is required it is easy to make and/or repair.
    i. The floor is a double layer of plywood on top of the 2x8 timber framework, providing a very stable and quiet platform.
    ii. Wall frames were placed to emulate approximate location of hull framing with curved sections cut from ¾ in plywood. Exterior walls and removable panels were also of ¾ inch plywood.
    iii. Interior walls are ¾ in plywood, which while thicker than the metal walls of a naval platform are much closer in dimensions than residential construction methods.

c. Use of foam panels or thin plywood for curved and/or complicated surfaces. In the case of VCEL ¼ plywood was used to emulate the curved surface of the pressure hull. Using metal guide channels (standard home siding accessories) the plywood can easily be slid in or out through the openings on the sides of the facility. (See Figure 4)

Figure 4: The VCEL experimental space.

Overall the design was both easy to construct in modules and went together extremely quickly [4]. It remains to be determined how easily it will come apart. The VCEL shell was not constructed with the intention of frequent changes to wall positions. Some experimentation will be required to determine how the basic set/stage technology would best be used if multiple ship classes or ship compartments were to be supported from the same set/stage. Certainly the floor structure would provide a good stable foundation upon which modular walls could be installed.

Another issue of importance is the integration of the shell with the building infrastructure. The VCEL differs from a television set in its life span. Many television sets have a limited lifespan, while navies tend to keep ships for decades, thus there were a number of elements of the original design that had to be adapted to longer term usage and government fire regulations:

1. While the design called for the plywood to be sealed with paint there was a concern about the overall amount of combustible material and a fire-retardant paint was required for all surfaces (inside, outside, underneath etc.),
2. The original concept was for all power and network distribution to come from outside (i.e., extension cords). However, the fire marshal mandated that power be provided permanently within the structure. In a future instantiation with movable walls this would necessitate installation of power within the raised floor structure.
3. In usage of the facility the team has also determined that more permanent networking within the shell structure connected to a patch panel would simplify maintenance and adherence to security protocols.
4. While the overall building that contains VCEL has environmental controls it was recognized early on that with a large number of personnel and electrical equipment in an enclosed space that the shell would need environmental control as well. Thus, an early addition to the interior was the inclusion of air ducting to match that of the real VICTORIA class boats which was tied into the building's systems.
5. Another issue that came up a number of times was the need for an internal grid system on the floor to assist in the placement of consoles and other equipment and the calibration of video data collection systems. Essentially the team had to retroactively mark out a grid on the floor of the shell after construction which would have been much easier to have done during construction; marked and then sealed with a clear finish so the marks are not worn off with use.

Console Emulation

As with the Shell, theatre construction techniques were used to create mock-ups of the major console components within the operations centre [12]. A combination of plywood, plastic sheeting and fibreglass was used to create consoles that dimensionally match actual equipment. All consoles were mounted on lockable wheels so that they can easily be rearranged. The downside of this mobility is the need of the floor grid positioning system mentioned above.

The construction philosophy was to build the general physical form of consoles out of good two side plywood (finished to the correct colour scheme) leaving the console display surfaces open. The display surfaces were then covered with ¼ inch (6.5 mm) plastic panels. The plastic panels were easier to mount and remove than plywood while retaining the ease of shaping to fit to control features and displays (see Figures 2 and 5 for examples).

In line with the general project philosophy to only model to the level required for the planned experimentation, only console controls expected to be required were instantiated. This was motivated both by the amount/complexity of controls in the operations room and the mandate to explore 'cost effective" technologies. Early on in the project the console construction team investigated obtaining the actual multi-function switches used in one of the consoles with the intention of connecting them to a simple controller that could be activated by software later. The cost of the switches alone was more than the cost of the entire shell. Following this discovery it was decided to be extremely careful in picking which switches to emulate, and wherever possible to emulate them in software on touch panels.

An exception to this policy was some of the rotary control switches on one of the standard control consoles; there was a desire to provide the actual physical control mechanism but the actual switches were prohibitively expensive, the solution came from a similar control device used for arcade games which were obtained at a fraction of the cost. The use of gaming technology in general is discussed in more detail below.

In the cases where the controls or displays were determined not to be required as stimulus for the project's experiment it was decided to use full scale pictures of the controls attached to the control surfaces instead of implementing them. This preserves the appearance and environment.

An issue that has arisen with the mobile plywood construction is that in some cases the consoles have had stability issues due to heavy displays in the upper parts without the corresponding heavy hardware in the lower casing. When coupled with the consoles being on wheels rather than firmly attached to the floor or bulkhead, this has required some mobility compromises.

3.2 Centralized Simulation/Emulation technologies

Based on the VCEL team's experience with distributed simulation experiments, one of the technology areas of particular interest was that of simplifying experimentation setup and system configuration. Simply put, human-in-the-loop experimentation with teams generally requires a large number of relatively independent systems that must be networked together. This implies the requirement to coordinate the configuration of all those systems. For example, the start-up of the VCELsystem requires accessing a large number of tools, services, applications and other software on a variety of physical and virtual computers, often in a specific order which can take a significant amount of time. Automation of these processes to save time and reduce the number of human errors was of high importance.

The initial technology investigated was the use of server based virtual machines and thin clients. The concept was for all console displays and controls to be on thin-clients driven from a central server thus reducing (or eliminating) the requirement for significant computer hardware in consoles within the shell. Further, if the drivers were run within virtual machines on the server than the configuration of the system might be saved as a set. While this does not markedly reduce the initial setup and configuration, bringing a previous experimental setup back up on the system could be much easier. Unfortunately, as the system design developed a number of issues arose:

1. elements of the system required access to graphics hardware that the virtual machines would not emulate;
2. the lag on user interface interactions was too long;
3. there was difficulty running multiple applications on the same thin client;
4. the thin clients turned out be more fragile than expected; and,
5. the move to touch screens to emulate controls meant that the number of displays where the thin clients could be used was minimal.

In the final system design virtual machines are used extensively to host appropriate elements but local computers were required for all consoles. However, an alternate open source scripting technology (StAFF/STAX[13]) has been used successfully to reduce the start-up/shut-down time. In addition, the use of a common simulation system, Dangerous Waters, reduced the overall configuration problem.

3.3 Gaming Technologies

The VCEL team has been investigating the use of commercial gaming technology and serious games for experimentation for a number of years [14]. In our experience the technology has a number of attributes that make it useful:

1. First and most obvious is the low cost. Compared to traditional simulation systems, serious game technology is extremely economical (by orders of magnitude in many cases). Even in cases where a commercial game cannot be used off-the-shelf but requires modification, the cost is still much lower than that of traditional simulation systems;
2. Another attribute of game technology is how accessible it is to end-users. Not only do trainees (or in our case experiment participants) find it easy to pick up and use, so do scenario developers, instructors, and system administrators. This accessibility comes from the simple fact that games must be easy to use out-of-the-box, without instruction, or else they have no market; and,
3. A third attraction of games is that we can often find a game that does most or all of what we require from a simulation system.

Of course, game technology does have some drawbacks. The fidelity of the simulation itself is often not to the standard of traditional simulators as the need to run on consumer hardware is of paramount importance, and gameplay is more important than fidelity. Game technology is often built on a closed architecture, and this can make it very difficult to take a commercial off-the-shelf (COTS) game and interface with existing simulation systems. For example, in the training or simulation context it is easy to imagine a need to interface with a Distributed Interactive Simulation (DIS) or High Level Architecture (HLA) simulation, and there are very few COTS games that can do this out of the box.

Dangerous Waters by Sonalysts

While the original simulation system concept was an HLA based distributed simulation using a set of in-house simulation federates, licenses for a naval serious game (Dangerous Waters by Sonolysts) became available early in the project timeline. The Dangerous Waters game had been investigated by the team previously and another DRDC project had worked with Sonolysts to develop a version, known as DW-MSEAS, with a several significant enhancements compared to the commercial version (including HLA compatibility).

Dangerous Waters (DW) is a commercial game that was first released in 2006 and is still available at a cost of approximately $15 per seat. There are many features of DW that make it particularly attractive in the maritime context:

1. First, it includes simulations of many platforms: maritime patrol aircraft, maritime helicopters, surface ships, and submarines;
2. It includes a comprehensive scenario generation tool;
3. While not providing all of the consoles or capabilities of any naval platform, DW does provide each type of console. Thus, while DW provides only a single sonar console, that console has multiple screens that provide access to the breadth of submarine sonar capabilities at a reasonable level of fidelity;
4. Additionally, DW provides a unique multiplayer mode where each crew station (Figure 5) on the controllable platforms can be run by a separate player. This was critical to our

experimentation because we needed to have a complete command crew doing their jobs within the control centre of the submarine; and,

5. DW comes with an after action replay system that records reconstruction level data.

While the HLA interoperability with the Real Time Reference (RPR) Federation Object Model (FOM) solved some of the design issues there were other requirements that required access to internal model data that are not covered by the RPR FOM and thus Sonalysts was contracted to create an interface that allows access to a wider variety of internal simulation state data.

DW essentially provided all of the core functionality required to simulate the operation of a submarine. DW includes an overall tactical picture, electronic warfare, radar, radios, ship control, periscope, narrow and broadband passive sonar, active sonar, as well as target motion analysis and fire control. When the submarine is operating on the surface, there is also a sail-bridge position available. Under-the-hood DW includes an underwater acoustics model, environmental modelling of currents, time-of-day, sea state, wind, rain and cloud levels, and everything else needed for a simulation of the physical environment.

From a content perspective, DW also provided us with enough to get started. While the VICTORIA class submarine is not a controllable platform within DW, there are several controllable submarine platforms that can stand in for the VICTORIA class. In our current experiment, we are making use of the LOS ANGELES class controllable submarine within DW to simulate the VICTORIA class workstations. DW also comes with a complete terrain database for the world between 85° north and 75° south latitude (this latitude range is larger than is typical of many COTS games).

Figure 4: The target motion analysis and fire control stations inside VCEL.

As the system came together and experimentation support activities were begun, other benefits to using DW have come to light. In particular,

1. The scenario generation system is quite easy to use particularly compared that in a number of legacy training systems;
2. The DW periscope simulation was determined to provide as good performance as the majority of third party or standalone simulators[15]; and,
3. Sonalysts have been very responsive in providing extensions to the interface to provide access to additional internal state variables.

It should be pointed out that DW has not been a panacea as, for example, it does not have a semi-automated forces capability. Platforms are either controllable, needing human control, or scripted. However, it has provided a great deal of capability out-of-the-box which enabled the team to move onto other issues that otherwise would not have gotten addressed.

3.4 Consumer hardware used in VCEL

All of the computer equipment used in VCEL is COTS, and most of that is consumer class hardware that can be purchased at any computer retailer. Exceptions to this are the network switches, which are enterprise-grade, and the rack-mount equipment which, while still COTS, is lower-end enterprise grade. In the past we have found that the types of network switches sold for household use often cannot handle the kind of throughput required by simulation systems.

The team also tried ultra-low-cost mini-systems for inside the consoles. In spite of pre-testing, component quality is an issue. The team has found that the savings in initial cost is not worth the maintenance issues that arise from lower quality hardware. For example, it can take a long time and effort to track down issues with intermittent faults in things like network cards. While these issues are not generally a problem in a home system, complex distributed simulations can be quite sensitive to network and hardware issues.

3.5 Data Collection Systems

Since the purpose of the VCEL is to conduct experimentation, data collection systems are a major element of the overall system. In many experimentation and training facilities extra space is built into the facility to allow for observation of participant behaviour. However, from the outset the intent of VCEL was to enable the inclusion of ergonomic issue experimentation which meant that the mock-up could have no extra space. Thus, the data collection system had to enable remote observation and data collection from outside the shell, and do so in the low-light conditions often found in an operations centre.

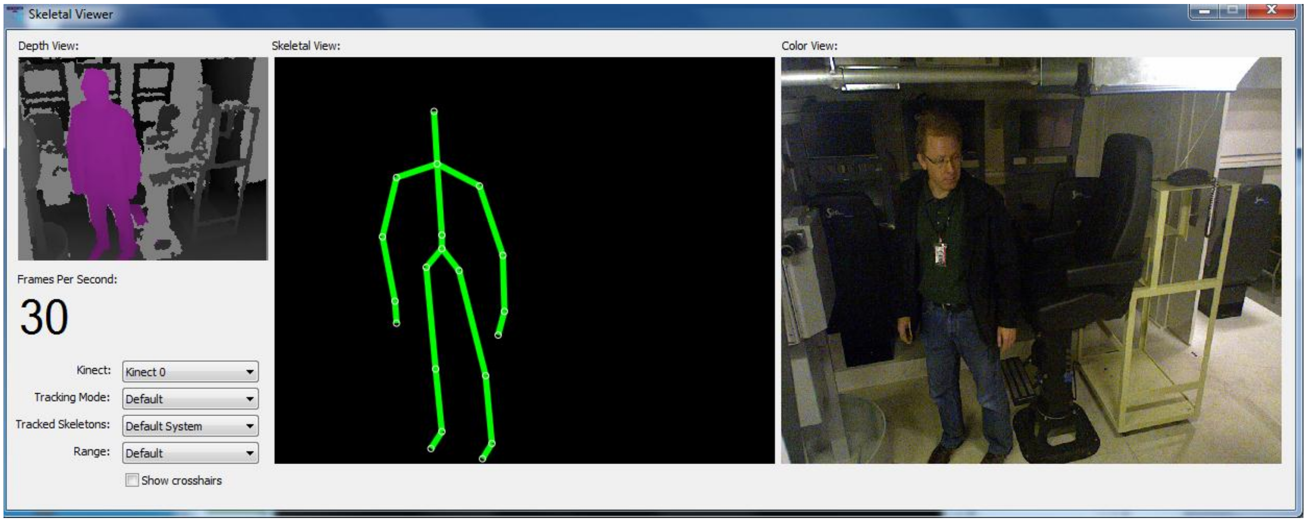
The initial solution was the inclusion of multiple low-light surveillance quality camera systems with both recording and display on large screen displays for observers. In addition, an open source screen capture system, Taksi [14] has been attached to all consoles. The downside of Taksi is that it is not start-up automatable. These systems provide generalized observation and recording functionality.

On the audio side the system uses a radio system simulator developed by the Canadian Army (SimSpeak) to provide the internal communications network. SimSpeak uses its own client-server software and includes a recording function. All participants are fitted with individual MP3 format recording devices to provide individual non-communications audio records. The MP3 players are cheap, durable, and eliminate the security issues with wireless devices. Figure 6 shows one of the commercial MP3 players used in VCEL.

Figure 5: Commercial MP3 player used for voice recording.

These systems provide good coverage of console operators and communications. However, as the concept development team developed their experimentation requirements it was realized that a system was required to track the location of the watch officer, where they were looking, and if looking at a particular display, what part of the display. The team had available stationary eye tracking systems that had been used for previous experiments but the combination of a non-stationary participant and no wireless led to a need to look at mobile eye tracking solutions. Following a competitive bid process a set of SMi eye tracking glasses were obtained to provide the in-display tracking. This system consists of a pair of light weight glasses with an eye tracking sensor, field of view camera and audio recording. All data are recorded on a portable recording unit that can be attached to the participant's belt. Up to three hours of data can be recorded in a session. Unfortunately the system does not allow for real-time monitoring of the data.

In order to digitally track participant location and movement the team turned again to gaming technology; in this case the Microsoft Kinect system. Using in-house software developed for VCEL and a set of four Kinect sensors, the system can automatically track the position, posture and orientation of the mobile participants. Figure 6 is a screen capture of the Kinect data as it is collected in real-time.



Frames Per Second: 30

Kinect: Kinect 0

Tracking Mode: Default

Tracked Skeletons: Default System

Range: Default

☐ Show crosshairs

Figure 6: Screen-shot of the Kinect based data acquisition system in action.

3.6 Rapid Prototyping

While Dangerous Waters provided the initial operating capability for console displays in VCEL, the design was always to incrementally replace the game emulations with either actual software or in-house emulations to instantiate all the consoles in the operations centre. In addition, it was recognized that many concepts of interest would require new screen concepts and designs. Thus, the team has investigated a couple of rapid prototyping systems.

The system requirements included not only the ability to rapidly develop new screen designs but to be able to activate them from the underlying simulation system.

The team has found that the combination of Adobe Flash with BlazeDS for client-server communication is quite effective. Initially there was some hope that the abundance of online Flash graphics libraries would provide an efficiency advantage. However, military systems have been found to use a lot of custom interfaces and there were fewer pre-built gauges, widgets, and other UI components than initially hoped. This was also compounded by the fact the UI components had to exactly match the concept designs. Indeed, legacy military interfaces are often quite compact, unique and combine a large amount of functionality from a small number of controls. This has resulted in the activation of some displays (especially the touch screen replacements for physical switches) being more complex than originally expected.

On the other hand the mapping client in Flash, OpenScales, was found to be quite useful, and, once the hurdle of understanding geographic data formats was overcome, integration of maps into tactical displays has gone well. MapServer makes extensive use of lengthy configuration files (.MAP) to explicitly define all aspects of the map including chart data sources, size/extent, layers, points, boundaries and how each object is to be rendered. Generating, editing, and troubleshooting these xml files proved very time consuming.

More recently the team has been investigating HTML5 which has some promise, but as yet associated tool chains are not as mature as with Flash.

3.7 Free and Open-Source Software (FOSS)

Another early design decision was to use as much free and open-source software (FOSS) as was practical. While the actual advantage from online Flash graphics libraries was less than expected, implementation of the overall software architecture was facilitated greatly by FOSS.

The following FOSS software have been used:

1. “MapServer is an Open Source platform for publishing spatial data and interactive mapping applications to the web. Originally developed in the mid-1990’s at the University of Minnesota, MapServer is released under an *MIT-style license*, and runs on all major platforms (*Windows*, *Linux*, *Mac OS X*). MapServer is not a full-featured GIS system, nor does it aspire to be. [10]” VCEL uses Mapserver to generate maps for tactical overlays etc. in its in-house emulations;
2. ”BlazeDS is the server-based Java remoting and web messaging technology that enables developers to easily connect to back-end distributed data and push data in real-time to Adobe® Flex® and Adobe AIR™ applications for more responsive rich Internet application (RIA)

experiences. [9]" This is a key piece in linking activated Flash interfaces to the simulation data network;

3. STAF/STAX Software Testing Automation Framework and STAF Execution Engine are used in VCEL to automate the start-up/shut-down processes and have cut those times by close to 50%.

   "The Software Testing Automation Framework (STAF) is an open source, multi-platform, multi-language framework designed around the idea of reusable components, called services (such as process invocation, resource management, logging, and monitoring). STAF removes the tedium of building an automation infrastructure, thus enabling you to focus on building your automation solution. The STAF framework provides the foundation upon which to build higher level solutions, and provides a pluggable approach supported across a large variety of platforms and languages.[13]"

   "STAX is an execution engine which can help you thoroughly automate the distribution, execution, and results analysis of your test cases. STAX builds on top of three existing technologies, STAF, XML, and Python, to place great automation power in the hands of testers.[13]"

4. Apache Active MQ[8] is the message server heart of the software design which links the wide variety of information providers and consumers together (See Figure 1).
5. Taksi [16]is a video capture/screen capture tool for recording 3D graphics applications (such as games).
6. OpenScales is an open source (LGPL) mapping framework written in ActionScript 3 and Flex that enables developers to build Rich Internet Mapping Applications.
7. Apache Tomcat is an open source software implementation of the Java Servlet and JavaServer Pages technologies.

3.0 CONCLUSIONS

There exists, in some communities, the feeling that creating an operations room level experimentation capability is a very expensive proposition. What DRDC has shown in this project is that with the judicious use of commercial and FOSS products that a fully activated mock-up of a naval command space can be developed relatively cheaply. Total research funding for the VCEL project was under a million dollars Canadian with an in-house team of about four technical personnel who were also working on a variety of other projects.

The main cost (money and time) savers that enabled the project were:

1. The use of entertainment industry set design technologies and best practices;
2. The use of modified commercial gaming technology to provide baseline capabilities with high usability;
3. The use of COTS and consumer grade hardware;
4. The use of FOSS software for architecture and simulation infrastructure; and,
5. The use of well-established mature interface development tools.

None of the above technologies were a perfect match to our problem and all have capability gaps that had to be supplemented with in-house development and solutions. However, the base of available simulation technology (both hardware and software) is substantial and growing. By focussing custom development on the gaps it is possible to develop cost-effective experimentation capabilities for complex systems.

The final caveat is that maintenance of complex systems will always be a problem and picking quality parts and quality software modules is likely to save substantial costs in the long-term. Note, quality does not necessarily mean expensive.

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