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Defence Research and Development Canada
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Requirements for Periscope Simulation

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Contractor's Document Number: 5135-001 Version 1
Contract Project Manager: Tab Lamoureux, 613-247-0342
PWGSC Contract Number: W7707-098218/002/HAL
CSA: Allan Gillis, Scientific Programmer, 902-426-3100

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2011-091
August 2011

Canada

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Abstract

Defence Research and Development Canada (DRDC) – Atlantic is building a Research and Development (R&D) facility called vVictoria (virtual VICTORIA) to support the VICTORIA Class submarine fleet. As part of this facility, DRDC Atlantic is particularly interested in providing a realistic simulation of the visual scene as observed through the periscope. CAE Professional Services was awarded a contract to determine the requirements of the periscope tasks performed by submariners and their requirements for a simulation, as well as surveying the market for potentially suitable Commercial-Off-The-Shelf (COTS) visual rendering engines. By evaluating the COTS engines against the requirements of the submariners it would be possible to differentiate between the COTS engines and recommend to DRDC Atlantic which application to purchase.

This report describes the methodology by which the objectives were pursued, and the results of the evaluation. Sixteen applications were identified and six were evaluated in detail. Of these six, most engines could, with sufficient effort, present a realistic simulation. However GX2 by GENFX, has already performed much of the development work, and scored the highest in the evaluation. The evaluation also showed that Dangerous Waters, a video game, scored highly and is extremely inexpensive.

Résumé

Recherche et développement pour la défense Canada (RDDC) – Atlantique a ordonné la construction d'une installation de recherche et développement (R & D) nommée vVictoria (virtual VICTORIA) dans le but de soutenir la flotte de sous-marins de classe VICTORIA. Dans le cadre de cette installation, RDDC Atlantique est tout particulièrement intéressé à fournir une simulation réaliste de la scène visuelle, telle qu'observée au moyen d'un périscope. Un contrat a été attribué à CAE Professional Services pour déterminer les exigences des tâches en lien avec le périscope effectuées par les sous-mariniers et la nécessité d'effectuer une simulation, ainsi que pour surveiller le marché afin de vérifier la disponibilité de moteurs de reproduction visuelle possiblement convenables en vente sur le marché. En évaluant les moteurs en vente sur le marché en fonction des exigences des sous-mariniers, il serait possible d'établir la différence entre les divers moteurs en vente sur le marché et de conseiller RDDC Atlantique relativement à l'achat d'une application.

Le présent rapport décrit la méthodologie utilisée pour les objectifs et fournit les résultats de l'évaluation. Un total de 16 applications a été identifié et six d'entres elles ont été évaluées en détail. Parmi ces six applications, la plupart des moteurs seraient en mesure, en fournissant un effort suffisant, de présenter une simulation réaliste, mais l'application GX2 de GENFX a déjà permis d'effectuer une grande partie du travail de mise au point et a obtenu les meilleurs résultats à l'évaluation. L'évaluation a également démontré que l'application Dangerous Waters, un jeu vidéo, a obtenu de très bons résultats et que son prix est très bas.

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Executive summary

Requirements for Periscope Simulation

Tab Lamoureux; Sylvain Pronovost; Alain Dubreuil; DRDC Atlantic
CR 2011-091; Defence R&D Canada – Atlantic; August 2011.

Background: Defence Research and Development Canada (DRDC) – Atlantic is developing a Research and Development (R&D) facility to support the Canadian Forces (CF) VICTORIA Class submarine capability. This facility includes a physical mock-up of the VICTORIA Class control room, representing all positions in the control room. The control room facility will be used for Human In the Loop (HIL) experiments concerned with new decision support systems, team dynamics, and procedures. The research facility is called vVictoria.

As part of vVictoria, DRDC Atlantic are developing a periscope simulation. This periscope simulation must present visual scene rendering of sufficient realism to enable valid generalizations to be made from the results of experiments to actual operations. CAE Professional Services was contracted to establish the requirements of such a periscope simulation, survey the marketplace for suitable Commercial-Off-The-Shelf (COTS) products, carry out a comparative evaluation, and make a recommendation to DRDC Atlantic regarding which product is most appropriate for vVictoria.

Principal results: A brief literature review was performed to understand the periscope task and the particularly critical information elements involved. Subject Matter Expert (SME) interviews and visits to simulator and training facilities were carried out in Halifax. The information collected was collated in a high level task analysis which was then used to develop requirements. Identified products were evaluated against the requirements, scoring points for whether the requirements were met or partially met. Products did not score points for requirements not met. In parallel with this work, the marketplace was surveyed for suitable products. Contact was made with the vendors, and detailed information collected on the products. After the evaluation was completed for all products, some analysis was undertaken, and a recommendation regarding the most suitable product was made.

Sixteen potentially relevant products were identified, and seven of these were subject to a detailed evaluation. The six products and their evaluation scores were: PSim 01 (41%), NAVAIR SPOT (64%), Dangerous Waters (70%), VR Vantage (85%), Delta3D (89%), Vega Prime Marine (91%), and GX2 (98%).

Products evaluated fell into three classes: existing periscope simulations (PSim and SPOT), visual rendering applications (VR Vantage, Delta3D, Vega Prime Marine, and GX2), and video games (Dangerous Waters). As a general observation, with work any of the visual rendering applications could present a high fidelity periscope simulation. GX2 scored highest because much of this work has already been done, whereas the other rendering applications have not been used for submarine simulations. However, VR Vantage have expressed a desire to be involved in the development of the periscope simulator, which makes more difficult any decision about which application to use. Dangerous Waters also scored well, is a fraction of the cost of the rendering applications, was

specifically developed for anti-submarine warfare, and can be used in a networked fashion to represent different operating positions. This may make it another possibility for vVictoria.

The final recommendation is to negotiate with both GENFX (GX2) and VT Mak (VR Vantage) to determine who would provide the best overall service and product for DRDC Atlantic. Regardless, it is recommended that. Dangerous Waters should be purchased and investigated further in order to determine if it can provide an inexpensive vVictoria simulation.

Significance of results: A wide variety of COTS products suitable for periscope simulation are generally available. These range from tool-kits that could be used to build a simulation, to full-fledged stand-alone simulations, to very low cost simulations derived from commercial games. For vVictoria this means it is feasible to start with low cost options and ramp-up to more complicated and expensive simulations as experimental requirements dictate.

For the Canadian Forces (CF) this rich variety of options should result in lower costs when upgrading existing trainers, or creating new ones. Of particular interest is how well the commercial game Dangerous Waters scored. This game is available for approximately $11.00 per seat at the time of writing and may provide a means to place a low cost tactical trainer in the hands of literally every submariner.

Sommaire

Requirements for Periscope Simulation

Tab Lamoureux; Sylvain Pronovost; Alain Dubreuil; DRDC Atlantic
CR 2011-091; R & D pour la défense Canada – Atlantique; Août 2011.

Introduction : Recherche et développement pour la défense Canada (RDDC) – Atlantique travaille à l'élaboration d'une installation de recherche et développement (R&D) dans le but de soutenir la flotte de sous-marins de classe VICTORIA des Forces canadiennes (FC). Cette installation comprend une maquette de la salle de commande de classe VICTORIA, qui représente tous les postes dans la salle de commande. L'installation de salle de commande doit être utilisée pour mener des expériences interactives concernées par les nouveaux systèmes d'aide à la décision, les nouvelles dynamiques d'équipe et les nouvelles procédures. L'installation de recherche se nomme vVictoria.

Dans le cadre de l'installation vVictoria, RDDC Atlantique travaille à la mise au point d'une simulation de périscope. Cette simulation de périscope doit présenter une reproduction visuelle de la scène visuelle suffisamment réaliste pour permettre d'effectuer des généralisations valides à partir des résultats des expériences pour les opérations actuelles. Un contrat a été attribué à CAE Professional Services pour déterminer les exigences d'une telle simulation de périscope, surveiller le marché afin de vérifier la disponibilité de produits convenables en vente sur le marché, effectuer une évaluation comparative et conseiller RDDC Atlantique relativement au produit le plus approprié pour l'installation vVictoria.

Résultats : Un bref examen a été effectué en vue de comprendre les tâches en lien avec le périscope et les éléments d'information particulièrement importants en cause. Des experts en la matière (EM) ont été rencontrés et ont effectué une visite du simulateur et des installations d'entraînement à Halifax. Les renseignements obtenus ont été réunis dans une analyse de haut niveau, qui a ensuite été utilisée pour établir les exigences. Les produits identifiés ont été évalués en fonction des exigences et ont obtenus des points s'ils satisfaisaient entièrement ou en partie aux exigences. Ils n'ont pas obtenu de points pour les exigences non satisfaites. Parallèlement à ce travail, le marché a été surveillé afin de vérifier la disponibilité de produits convenables. On a communiqué avec les fournisseurs et on a obtenu des renseignements détaillés sur les produits. Une fois l'évaluation de tous les produits terminée, certaines analyses ont été entreprises et une recommandation a été émise relativement au produit le plus convenable.

Un total de seize produits possiblement pertinents a été retenu et six de ces produits ont été soumis à une évaluation détaillée. Les six produits et leurs résultats d'évaluation sont les suivants : PSim 01 (41 %), NAVAIR SPOT (64 %), Dangerous Waters (70 %), VR Vantage (85 %), Delta3D (89%), Vega Prime Marine (91 %) et GX2 (98 %).

Les produits évalués se classent dans trois catégories : simulations de périscope existantes (PSim et SPOT), applications de reproduction visuelle (VR Vantage, Delta3D, Vega Prime Marine et GX2) et jeux vidéo (Dangerous Waters). En effectuant un certain travail de mise au point, toutes les applications de reproduction visuelle pourraient présenter une simulation de périscope de haute-fidélité. L'application GX2 a obtenu le pointage le plus élevé puisque la majorité de ce

travail de mise au point a déjà été effectuée, alors que les autres applications n'ont pas été utilisées pour des simulations de sous-marin, mais les responsables de l'application VR Vantage ont exprimé leur souhait d'inclure leur application dans la mise au point du simulateur de périscope, ce qui complique le choix de l'application à utiliser. L'application Dangerous Waters a également obtenu un bon pointage, est bien moins chère que les autres applications, a été spécialement conçue pour la guerre anti-sous-marine et peut être utilisée en réseau afin de représenter divers postes de manœuvre, ce qui en fait une autre application possible pour l'installation vVictoria.

La recommandation finale est de négocier avec GENFX (GX2) et VT Mak (VR Vantage) dans le but de déterminer lequel peut fournir les meilleurs services et le meilleur produit à RDDC Atlantique. Il est tout de même recommandé d'acheter l'application Dangerous Waters et de l'examiner plus en profondeur en vue de déterminer si elle peut fournir une simulation abordable de l'installation vVictoria.

Importance : Bon nombre des produits en vente sur le marché qui sont convenables pour la simulation de périscope sont généralement disponibles. Ils vont de la simple trousse d'outils, qui peut être utilisée pour créer une simulation, aux simulations autonomes au point, en passant par les simulations à prix très bas dérivées de jeux commerciaux. Pour l'installation vVictoria, cela signifie qu'il est possible de commencer avec des options à faible coût et de passer à des simulations plus complexes et plus coûteuses selon les exigences expérimentales.

Pour les Forces canadiennes (FC), cette riche diversité d'options devrait engendrer des coûts moins élevés lors de la mise à jour des simulateurs existants ou de la création de nouveaux simulateurs. Le fait le plus intéressant est le pointage élevé du jeu commercial Dangerous Waters. Ce jeu se vendait environ 11 $ par siège au moment d'écrire le présent rapport et pourrait permettre de fournir un simulateur tactique abordable à littéralement tous les sous-mariniers.

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Acknowledgements

CAE Professional Services would like to acknowledge the assistance of the Canadian Forces Naval Operators School – Submarine School for their access to facilities, documents, and subject matter experts. Particular thanks go to LCdr Pete Bryan for sharing his expertise. We also wish to express our appreciation to Lt (N) Jimmy Lau for sparing the time to escort us around the school, answer our questions, and provide the documentation and multi-media resources we needed.

1 Introduction

1.1 Overview

Canadian Forces (CF) purchased four conventional diesel-electric UPHOLDER Class submarines from the Royal Navy in 1998 to replace the decommissioned OBERON Class of submarines. The new submarines were renamed VICTORIA Class and were delivered to Canada from December 2000 onwards (see Figure 1).

Figure 1: HMCS Windsor Leaving Faslane, Scotland.

As with all military platforms, the expected operational life of the VICTORIA Class is long (in the region of 30 years or longer). This operational life can only be achieved through a diligently followed program of preventative and corrective maintenance. However, to maintain the submarine's operational effectiveness, a midlife upgrade of sensor, weapons, and propulsion systems can be expected. In anticipation of this midlife upgrade, Defence Research and Development Canada (DRDC) – Atlantic has responsibility to perform Research and Development (R&D) on the Command and Control (C2) systems in the submarine.

R&D on C2 is often focused on the digital information displays and controls provided to operators. This is important work because, with the advent of more capable and flexible sensor and weapons systems, there is more information that must be represented to the operator. It is becoming desirable to present this information in integrated, composite representations that combine different data in ways that mimic an expert's internal mental model to support situation awareness, problem solving, and decision making.

This approach to information display reduces the mental workload, minimizes the chances of human error, and alleviates the display management activities that an operator must perform.

Since many of the sensor and weapons systems aboard any vessel come from a variety of vendors, such integrated, composite displays are rarely provided. Rather, a systems integrator must build displays that integrate the different sources of data and present them coherently. Unfortunately, there are no rules concerning how this should be done. Therefore, R&D is necessary to support this systems integration effort when the midlife upgrades are performed.

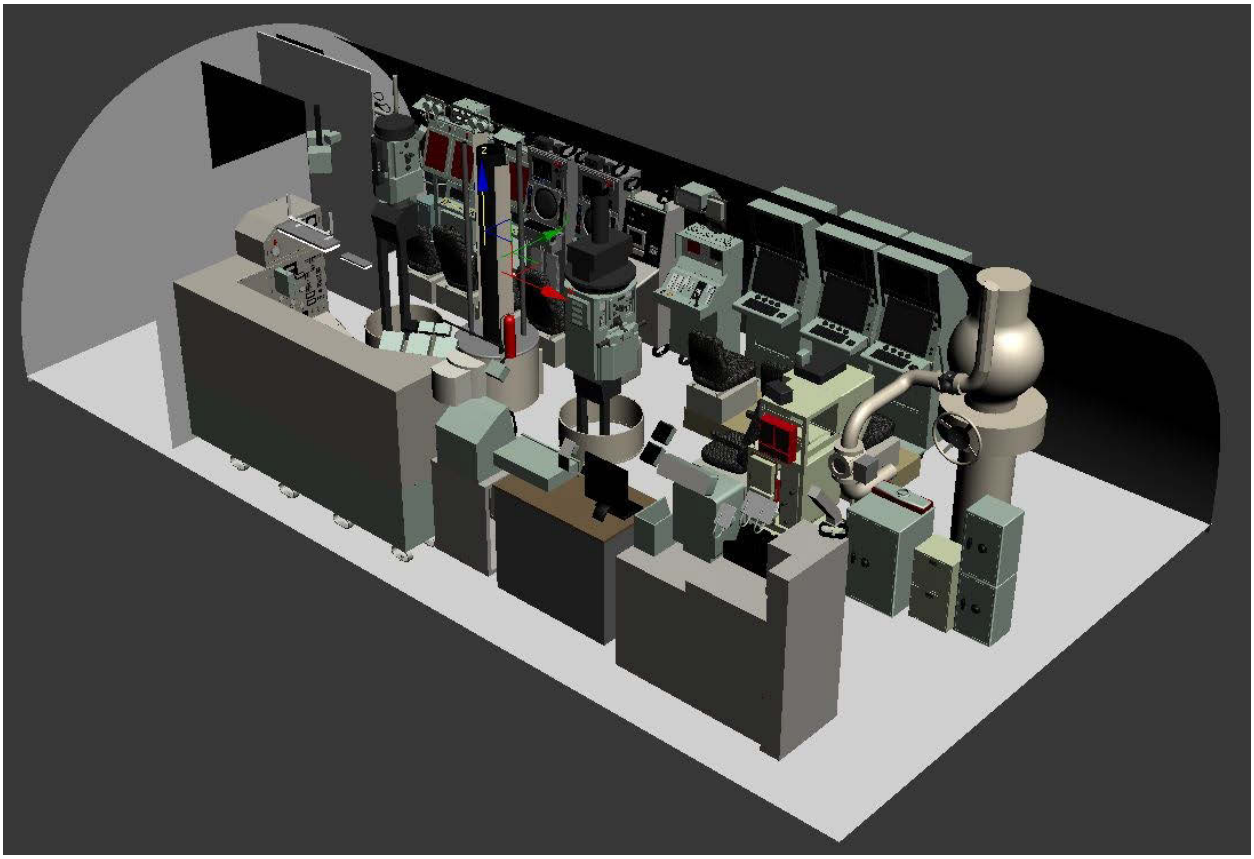

Figure 2: Three Dimensional Model of VICTORIA Class Control Room.

Introduction of new systems also changes the dynamics of the work aboard a submarine. For instance, integrated systems may change the manning/skills requirement, new equipment may affect the sightlines and communication, and operator tasks may evolve. To study new concepts in C2 systems, and understand the impact this may have on the team in a submarine control room, DRDC Atlantic is engaged in a number of efforts, including three-dimensional modelling of the control room (see Figure 2) and constructing a life-size simulation of the control room. This simulation facility will faithfully replicate the systems, equipment, manning, and volume of space in the submarine control room, allowing DRDC Atlantic to effectively support the CF in extending the effective operational life of the VICTORIA Class submarine. The simulation facility is called Virtual Victoria (vVictoria).

DRDC Atlantic is interested in developing the simulation for the periscopes in the VICTORIA Class such that they are suitably realistic to allow generalizable results to be derived. The VICTORIA Class has two periscopes: an attack periscope and a search periscope. The attack periscope has optical, image intensification and thermal capabilities. The body of the attack periscope is narrower than the search periscope, but must be raised higher (exposing a thicker body) to use thermal systems. The attack periscope is aft of the two, directly in front of the Officer Of the Watch's (OOW) seat. The search periscope is forward (roughly adjacent to the Submarine Control Console [SCC] '1' position) and also has a Global Positioning System (GPS) antenna, Electronic Warfare (EW) equipment, and an Automatic Identification System (AIS) antenna. Both periscopes have limited magnification capabilities and are limited in the degree to which they exchange data with other shipboard systems. Anecdotally, the search periscope is preferred because it has a better optical path (i.e. the path by which the image is delivered to the observer has fewer changes in direction and is larger, allowing a more detailed image to be viewed).

1.2 Objectives of this Work

DRDC Atlantic contracted CAE Professional Services (CAE PS) to assist in the development of periscope requirements for vVictoria. The stated objectives of this work are as follows:

1. Develop the software requirements for periscope visuals;
2. Review potential Commercial-Off-The-Shelf (COTS) products against the requirements; and,
3. Develop the requirements for a simplified periscope that will use the software.

Elaborating on these requirements, this work aimed to describe the elements of the visual scene viewed by the submariner through the periscope that allows him to draw data from the environment. These elements would become the requirements that any simulation software would have to replicate. If the periscope performed any technological function, this would also form a requirement that must be supported by simulation software. Finally, the requirements for a simplified periscope corresponded to the physical dimensions, buttons, displays, etc. that would be required to build a physical facsimile of the periscope in vVictoria.

1.3 This Document

This document is comprised of the following sections:

- Section 2 Method: this section describes the method adopted to generate the requirements and evaluate potential COTS applications against them to recommend a platform on which to base the periscope simulation.
- Section 3 Task Analysis and Requirements: this section describes the task analysis and the requirements generated. Requirements are split into four sections corresponding to the search periscope, the attack periscope, synthetic environment (i.e. the 'parent' simulation), and physical requirements.
- Section 4 Commercial Off The Shelf Applications: this section provides brief descriptions and the evaluation of each of the applications proposed as suitable platforms on which to base the periscope simulation.
- Section 5 Discussion and recommendations: discusses the findings and makes recommendations for the purchase of a suitable COTS application on which to base the periscope simulation.

2 Method

In order to ensure that requirements for a periscope simulator were comprehensive, a systematic and deliberate approach was taken to their generation. As an overview, six steps were followed: data collection; task analysis; COTS product identification; development of the evaluation method; evaluation; and analysis. Each of these steps is discussed in detail below.

2.1 Data Collection

There were three primary methods of data collection in this project: online research, document review, and interviews with Subject Matter Experts (SMEs). Online research was primarily used for general background on the VICTORIA Class submarine and its periscope, and to identify documents for further review. Online research was also used to identify potential COTS applications for periscope simulation for later evaluation, although this method was secondary to the CAE PS Modelling and Simulation (M&S) expert's own knowledge and experience.

Based on the online research and material provided by the contract Technical Authority (TA), a number of documents were obtained. These included Human Factors (HF) reports and promotional material. A complete list of references is provided at the end of this document. These documents were supplemented by training presentations and manuals provided by the Naval Operators School during the data collection visit.

A visit to Halifax was made on the 9th and 10th of November, 2010. During this time, the Submarine Command Team Trainer (SCTT) was visited and an exercise observed. The simulator was running and the periscope was investigated to understand its functions and provide context to later information provided in interviews and documentation. The periscope maintenance trainer was also visited in the Tactical Weapons System (TWS) room. Interviews were held with a submariner with limited experience on the periscope, and the Commanding Officer (CO) of the Submarine School.

The objective of the interviews and documentation review was to understand what elements, both in terms of information and functionality, of the periscope are crucial for the submariner to do their job. Thus, the interviews and reviews focused on three main areas: what tasks are performed using the periscope; what information do you take from the periscope; and what functionality does the periscope provide. In practice, the answers to these questions were related, and led to many further questions, for example "how do you determine range?", "what cues do you use to determine the orientation of a ship?", and "what makes a task difficult?"

To further narrow down the objective of the interviews and documentation review, the analysts were only concerned with that information that affected what a simulator must do. Thus, the review was not concerned with (for example) how to calculate the range to a target, but was concerned with the information the operator would draw from the periscope to make that calculation.

2.2 Task Analysis

A high level task analysis was performed to ensure systematic coverage of the requirements associated with periscope tasks. The hierarchical view of the task analysis is shown in Figure 3.

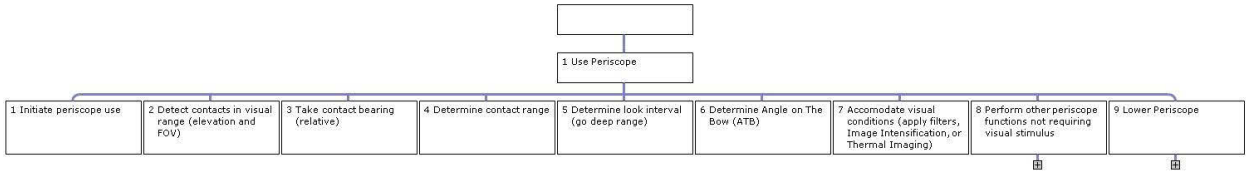

Figure 3: Hierarchical Task Analysis (HTA) of Periscope Use.

In general, the first and last tasks (initiating periscope use and lowering the periscope) are concerned with physical requirements. Tasks 2 to 7 are where the bulk of the periscope requirements are to be found, being concerned predominantly with the skilled use of the periscope to make sense of the world around the submarine.

For each task in the task analysis, the support offered by the periscope was considered. In some cases it might have been a simple physical property such as folding and unfolding the handles, or raising and lowering the periscope. In other cases, for example a detection task, the requirement might have been to present a realistic entity in the viewfinder. Each requirement was then considered for whether it could be further broken down. For example, to determine Angle on the Bow (ATB) (which assumes the entity is detected in the first place) it is necessary to judge the orientation of the contact. There are a number of visual cues that might contribute to this judgement, including the perception of navigation lights, ship's wake, bioluminescence, ship's bow, ship's stern, hangar doors, and bow wave.

The requirements, mapped to the different tasks and the different requirement areas (i.e. search periscope, attack periscope, synthetic environment, and physical requirements), were documented in a spreadsheet that also includes the evaluation scheme. The task analysis and the requirements generated are discussed in more detail in Section 3.

2.3 COTS Product Identification

In parallel with the task analysis and requirements definition, the M&S expert surveyed the marketplace to identify COTS products that might be suitable for rendering the periscope visualizations in a simulation of the submarine control room. Two approaches were taken to address this task: actual periscope simulators were identified and the manufacturers contacted; and simulation rendering engines were identified and technical material reviewed.

The task was rendered more difficult by forcing a separation between the periscope (i.e. the focus of this work) and the synthetic environment. In essence, the periscope is an 'outstation' of the synthetic environment that offers a limited window for the submariner into the 'reality' of the synthetic environment[1]. As such, the periscope simulation will subscribe to data published by the synthetic

[1] This assumes a certain software/simulation architecture. The periscope could be an 'outstation' whereby it is its own application reconstructing the synthetic environment based on the data provided by the simulation. Or the periscope could actually be an entity within the simulation/synthetic environment.

environment and will build it as a visual representation for consumption by the submariner using the periscope. To the user, there would be very little, if any, input from the periscope back to the synthetic environment[2]. The M&S expert attempted to maintain separation of the two simulation functions. Nevertheless, if an application, or suite of applications, supports the periscope simulation and the synthetic environment, this was noted in the analysis.

The other consideration the M&S expert needed to make was whether or not the COTS product supported the introduction of new information and decision support tools. This would be a primary use of the vVictoria and could be accomplished via a number of ways, including building the prototype system within the periscope simulation, or building the prototype system on its own, and overlaying its display with the periscope display.

2.4 Development of Evaluation Method

Having generated the requirements, it was desirable to find a way to use them to evaluate potential COTS simulation products. Since there seems to be very little research that distinguishes the relative importance of elements of a periscope visual simulation (although the work by Kirschenbaum, 1999, provides some direction), it was decided not to attempt to weight any of the requirements. Instead, it was decided that each potential COTS solution would be considered against each requirement, and rated as:

- 'yes' (the solution satisfies the requirement), score 1;
- 'partially' (the solution partially satisfies the requirement), score ½; or
- 'no' (the solution does not satisfy the requirement), score 0.

The total 'yes' and 'partially' scores would be summed and divided by the total possible score to give a percentage. This would provide an immediate sense of the relative adequacy of the different COTS solutions. Where necessary, the evaluated solutions would be supplemented with notes.

Two other considerations were included in the evaluation: cost of the COTS application, and resource effort required to build the periscope simulation. The cost was given as an estimated total final price and also a 'price per point'; that is, the total final price was divided by the points scored by the COTS application, giving a cost per point. This approach weights requirements equal to cost, so is only provided as additional information for decision-making purposes. The resource effort required to build the periscope simulation was also estimated in terms of person months (e.g. six people for one month, one person for six months, etc.). This was not combined with other data and was provided as another key item of information to be fed into the decision-making process.

All the evaluation data (i.e. compliance with requirements, cost, effort) were recorded in a spreadsheet that automatically tabulates the results. This spreadsheet also lists all the requirements, mapped to the requirement type and the task.

[2] However, at a system level, the synthetic environment would need to know how high the periscope was above the surface of the water, since this affects detection by other ships, visually and electromagnetically. The submariner can also publish a 'bearing cut' which is fed into the Fire Control System (FCS). This input would likely pass back to the synthetic environment before being fed to the FCS.

2.5 Evaluation

For each COTS solution, a new worksheet was created in a single spreadsheet file. The spreadsheet file also contained a summary worksheet to provide a summary of the results. Each COTS solutions identified was considered against all of the requirements, with compliance being rated as ‘yes’, ‘partially’, ‘no’ or ‘unknown’. When necessary, supplemental notes were made. Evaluations were undertaken by two analysts, and verified by another analyst to support consistency in the results.

2.6 Analysis

Once the evaluations were completed, the patterns of results were considered across all COTS solutions and conclusions were drawn about what the market offers as standard, and what would require some effort on the part of DRDC Atlantic to create. Given the observed patterns, and comparing the individual products to the patterns, the overall score, the cost per point, and the resource effort required had greater meaning in context and recommendations were made concerning which product represented the best value for money for DRDC Atlantic’s vVictoria facility.

3 Task Analysis and Requirements

As introduced above, a high level task analysis was performed to organise the requirements. A total of nine tasks were described at the highest level (see Figure 3). For each task, requirements were generated falling into four categories:

- Search periscope;
- Attack periscope;
- Synthetic environment; and
- Physical requirements.

In practice, some requirements fell into more than one category. A total of 75 unique requirements were identified. These were divided between the requirements categories and tasks as depicted in Table 1. Note that some requirements map to more than one category. In this case the cell has two numbers, separated by an oblique, the first number being the unique requirements and the second number being those requirements shared between categories.

Table 1: Requirements Mapped to Tasks and Requirement Categories.

	Search Periscope	**Attack Periscope**	**Synthetic Environment**	**Physical Requirements**	**Totals**
Initiate periscope use			2	4	6
Detect contacts	3 and 5 shared with attack periscope	8 and 5 shared with search periscope	11	7	34
Determine bearing	4, all shared with attack periscope	4, all shared with search periscope	1	2	7
Determine range	3, all shared with attack periscope	3, all shared with search periscope	1		4
Determine look interval			1		1
Determine ATB			3		3
Accommodate difficult conditions		2	8	1	11
Do other periscope tasks					
Lower periscope					
<<no task>>	1 shared with attack periscope and 4 shared with synthetic environment	1 shared with search periscope and 4 shared with synthetic environment	1 unique and 4 shared with search and attack periscopes	3	9
Totals	19	26	32	17	**94/75**

There are some apparent imbalances between requirement categories, specifically that the synthetic environment has the most requirements, followed by the attack periscope, then the search periscope, and finally the physical requirements. This is primarily because this work has assumed that much of the visual information will be generated by models that are resident in the synthetic environment, rather than in the periscope simulation. The periscope simulation is assumed to be more of a repetition of the synthetic environment than a simulation itself. The attack periscope has more requirements than the search periscope because it has more functionality (specifically thermal and image intensification views). The physical requirements are fewest because many requirements are covered under one, which is the requirement that any physical periscope be built with the dimensions and features described in the three dimensional model.

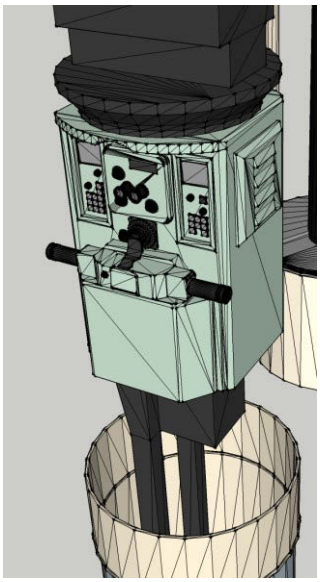

Figure 4: Attack Periscope (from VICTORIA Class 3D Model).

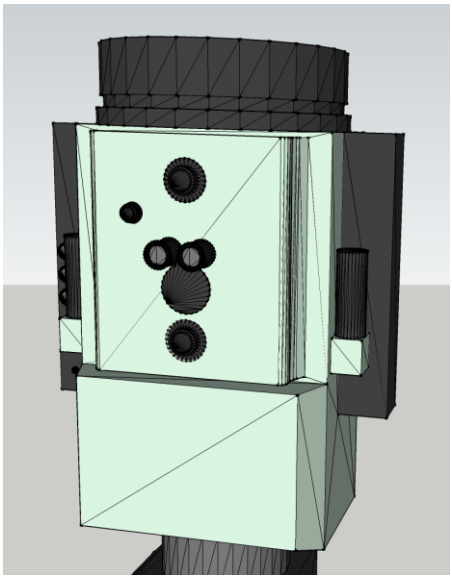

Figure 5: Search Periscope (from VICTORIA Class 3D Model).

There are also some apparent imbalances between the tasks. This is primarily because the requirements are focused on the periscope simulation. Thus, the task "Perform other periscope tasks not requiring visual stimulus", almost by definition, does not beget any periscope simulation requirements. Other tasks do not lead to requirements because they have already been listed under an earlier task. This is particularly apparent for "Detect contacts in visual range" which has 44 requirements mapped to it. This is because it is the first thing the submariner is going to do with the periscope, so all the visualization requirements are derived from it. Determining the look interval, range, or ATB all build on requirements that have been met in order to permit the submariner to detect a contact in the first place.

The complete list of requirements is presented below (Table 2). It will quickly become apparent that several requirements demand that an entity be "...modelled sufficiently realistically...". This is a shortcoming of the approach in that there is no way to determine compliance with this requirement without surveying qualified and experienced submariners. However, there are some requirements that provide a performance metric (e.g. discriminate a 15 metre difference on the main beam at 6 nautical miles (nm); discriminate significant differences at 1.84 nm; read hull lettering at 0.28 nm). Nevertheless, it will be the judgement of the analysts in the first instance, rather than the qualified opinion of experienced submariners.

Table 2: VICTORIA Class Periscope Simulation Requirements.

Requirement Type	Subcategory	Derived from Task Type	Requirement Description
Physical Model	Hardware - Structural	Initiate periscope use	physical periscope must have folding handles
Physical Model	Hardware - Perceptual	Detect contacts in visual range (elevation and FOV)	simulation viewer should be conventional LCD mounted within periscope tube
Physical Model	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen resolution must be 1280x1024 or higher
Physical Model	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image update rate of 30 Hz or higher
Physical Model	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image refresh rate of 60 Hz or higher
Physical Model	Periscope/Ownship - Behaviors	Take contact bearing (relative)	operator must be able to rotate periscope
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6 nm (proxy for the assessment of ship type) using the regular optical periscope (vice

Requirement Type	Subcategory	Derived from Task Type	Requirement Description
			image intensification or thermal)
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28nm (517m) based on hull lettering heights of 1.85m
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.
Simulation World	Environment - Visuals	Accommodate difficult conditions	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)
Simulation World	Periscope/Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display
Simulation World	Environment - Behaviors	Accommodate difficult conditions	simulation must impose pitch, roll, heave, etc. on submarine entity
Simulation World	Environment - Visuals	Accommodate difficult conditions	simulation must present sea states
Simulation World	Environment - Visuals	Accommodate difficult conditions	simulation must present time of day
Simulation World	Environment - Visuals	Accommodate difficult conditions	simulation must present sun, moon, stars accurately based on time of day and weather
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)
Simulation World	Environment - Visuals	Accommodate difficult conditions	simulation must show shine, glare, reflection, etc.
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence
Simulation World	Environment - Visuals	Accommodate difficult conditions	simulation must present washover (due to speed of sub, sea state, height of periscope)

Requirement Type	Subcategory	Derived from Task Type	Requirement Description
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation
Simulation World	Periscope/Ownship - Visuals	Accommodate difficult conditions	must feature other masts that occlude LOS (blind arcs)
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope
Visualisation - Attack & Search Periscopes	Periscope/Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting
Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder
Visualisation - Attack & Search Periscopes	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder

Requirement Type	Subcategory	Derived from Task Type	Requirement Description
Visualisation - Attack & Search Periscopes	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Accommodate difficult conditions	screen must present thermal image if selected by operator
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Accommodate difficult conditions	screen must present image intensification if selected by operator
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator
Visualisation - Attack & Search Periscopes	Periscope/Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 7 to 22 degrees on high power (6x), 4.2 degrees FOV
Visualisation - Attack Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging
Simulation World, Attack & Search Periscope	Periscope/Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine

Requirement Type	Subcategory	Derived from Task Type	Requirement Description
Visualisation - Attack & Search Periscopes	Periscope/Ownship - Behaviors	Determine contact range	must be able to split image vertically
Visualisation - Attack & Search Periscopes	Periscope/Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees
Visualisation - Search Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)
Visualisation - Search Periscope	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)
Physical Model	Hardware - Perceptual	Initiate periscope use	must have two independently focusable eyepieces
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have servo rotation control on right periscope handle
Physical Model	Hardware - Controls	Accommodate difficult conditions	Must have filter knob (four positions)
Physical Model	Hardware - Structural	Detect contacts in visual range (elevation and FOV)	Must have left and right panniers
Physical Model	Hardware - Controls	Interoperability	Periscopes must have all controls that attack and/or search periscopes have currently (refer to diagram)
Physical Model	Hardware - Perceptual	Detect contacts in visual range (elevation and FOV)	Monitor in periscope must be mounted as far back as possible to allow eyes to focus on infinity
Physical Model	Hardware - Structural	Initiate periscope use	must be built to the dimensions dictated by 3D model
Physical Model	Hardware - Structural	Initiate periscope use	must have foldable periscope handles
Physical Model	Hardware - Perceptual	Interoperability	Periscopes must have all displays that attack and/or search periscopes have currently (refer to diagram)
Physical Model	Hardware - Perceptual	Take contact bearing (relative)	Periscopes must have relative bearing indicator above main body
Physical Model	Hardware - Perceptual	Interoperability	Periscope should be painted military grey

4 Commercial Off The Shelf Applications

A total of seventeen COTS applications have been considered for inclusion in this report, of which seven prospective simulation solutions have been reviewed in further detail. A summary of the reasons for discarding the other simulation applications is provided below in Section 4.1.

The top seven candidate platforms for periscope simulation (in no particular order) are:

- PSim 01 by Subdivision AB (Sweden);
- Sonalysts Combat Simulations – Dangerous Waters by Sonalysts, Inc.;
- the Submarine Periscope Observation and Tracking (SPOT) by US NAVAIR (Naval Air Systems Command);
- Vega Prime Marine (an extension of Vega Prime, by Presagis);
- VR-Vantage by VT Mäk (a VT Systems Inc. company);
- Delta3D; and
- GX2 Rendering Engine by GENFX.

The features used to evaluate the simulation platforms were derived from the requirements listed in Section 3 (see Table 2 above). The results are presented below in Table 7 to Table 11, by platform, in alphabetical order. The "degree of success" for each platform was benchmarked against the requirements using the following calculations:

- Each simulation platform scored one point for each requirement successfully met;
- Each simulation platform scored ½ point for each requirement partially met, and an explanation was provided;
- Each simulation platform scored no points for each requirement not met;
- Each simulation platform scored no points if it was unknown whether or not it satisfied a requirement;
- Each simulation platform scored ½ point if the evaluators decided it 'probably' met the requirement, because while it is not explicitly stated in the documentation or primary sources of information, it was nevertheless observed or inferred from pictures, videos, other promotional material, product reviews, etc.;
- Each simulation platform received a final score for the degree of success it would provide as the technical solution to periscope visualization, translated into a percentage value, using the following equation:

$$\textit{Percentage score} = \textit{((sum of requirements met) + (sum of requirements partially met)/2 + (sum of requirements probably met)/2) / (total number of requirements)}$$

The following criteria (in Table 3 below) have not been evaluated for the simulation platforms, because they are only relevant to a final, physical implementation in a facility, and are not properties of the simulation platforms themselves.

Table 3: Periscope Simulation Requirements not Used in the Evaluation.

Requirement Type	Subcategory	Derived from Task Type	Requirement Description
Physical Model	Hardware - Perceptual	Initiate periscope use	Must have two independently focusable eyepieces
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have servo rotation control on right periscope handle
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have filter knob (four positions)
Physical Model	Hardware - Structural	Detect contacts in visual range (elevation and FOV)	Must have left and right panniers
Physical Model	Hardware - Controls	Interoperability	Periscopes must have all controls and displays that attack and/or search periscopes have currently (refer to diagram)
Physical Model	Hardware - Structural	Initiate periscope use	physical periscope must have folding handles
Physical Model	Hardware - Perceptual	Detect contacts in visual range (elevation and FOV)	simulation viewer should be conventional LCD mounted within periscope tube
Physical Model	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen resolution must be 1280x1024 or higher
Physical Model	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image update rate of 30 Hz or higher
Physical Model	Periscope/Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image refresh rate of 60 Hz or higher
Physical Model	Periscope/Ownship - Behaviors	Take contact bearing (relative)	operator must be able to rotate periscope

4.1 COTS Visualization Products Not Subject to Detailed Review

Other products were considered and discarded for various reasons. They are listed below with a short description as well as a summary of the reasons why they were dismissed.

- VBS2 (Virtual Battlespace 2) by Bohemia Interactive was developed in close cooperation with the US Marine Corps and the Australian Defence Force. It offers realistic battlefield simulations and the ability to operate land, sea, and air vehicles, although the emphasis has been on land-based warfare. VBS2 has been used by the Royal Navy for orientation and limited training of sailors, and is well-regarded in this capacity. VBS2 has not been reviewed in detail for this project because it has a hard-coded restriction on the size of objects that can be built and can be controlled. VBS2 has the capacity to represent ships (for instance, the Rigid-Hulled Inflatable Boat (RHIB) simulation at DRDC Atlantic is based on VBS2 and represents large ships) but there are some issues associated with the rendering and control of large entities.
- VBS2Fusion is an Application Programming Interface (API) that allows developers to extend the capabilities of VBS2. The VBS2Fusion API is based on the C++ language so developers no longer have to learn the VBS2 scripting language. Although VBS2Fusion provides significant immediate improvements to the VBS2 platform (without additional development effort), it does not overcome some of the issues associated with rendering and controlling large entities, so it was not considered in detail for this contract.
- ScubaSim by Breakaway (US) was considered because of the way it rendered subsurface, surface, and transitions between the two. However, very little information is available about the simulation and it is most likely an application developed specifically for a customer (probably the US Navy).
- 24 Blue by Breakaway (US) is another example of a maritime simulation, specifically aircraft carrier operations. However, the emphasis is on carrier deck operations and it also seems that the simulation is developed specifically for the US Navy. Breakaway does, however, market a development environment called mōsbē. However, there is no evidence that they have modelled different sea states or the transition that occurs between air and water environments.
- MetaVR is primarily a terrain visualization and has not been used to visualize the ocean at sea-level. Most of their visualizations are based on existing Geographical Information Service (GIS) data. The lack of any previous ocean modelling, or the modelling and control of ships, precluded this application from further consideration.
- Virtual Reality Scene Generator (VRSG) by MetaVR, Inc. is an ‘out-of-the-box’ simulation presenting depictions of terrain for Ft Campbell, Ft Benning, Ft Irwin, Ft Lewis, Greater Baghdad and an Afghan village in Kabul province. VRSG also provides 3D content libraries. Based on the available information, this visualization has not been used to model marine environments and would involve a great deal of effort to do so.
- Nautis (formerly Ship Simulator Professional) by VStep (Netherlands) is a very cost-effective solution for surface operations and has realistic views of the water from above. It has also a submarine model available. Although distributed simulation is claimed in a promotional video, it is not clear what mechanism is used to network distant simulations.
- X-Plane by Laminar Research offers nearly photo-realistic flying simulations, the ability to network simulations, and is customizable. However, it has never been applied to the simulation of naval vessels, nor has it been used to model the ocean except when viewed from above. The lack of a body of knowledge about using X-Plane for maritime applications precluded this application from further consideration.
- Periscope simulation by Noya Software was developed specifically for the Israeli Navy. The military discontinued funding for the project but Noya Software retains the rights to the product and could leverage the experience to provide periscope visuals. The application is built using Lingo,

Shockwave, Director, 3D studio and C++ so is unlikely to integrate easily with a simulation without significant effort.

- OGRE (Object-oriented Graphics Rendering Engine) is a scene-oriented, flexible 3D engine written in C++ designed to make it easier and more intuitive for developers to produce applications utilising hardware-accelerated 3D graphics. OGRE is open-source and seems to have an extensive community of developers, but that community is largely focused on creating fantasy fighting games. Without a body of knowledge about OGRE for maritime applications, OGRE was removed from further consideration.

4.2 PSim 01 by Subdivision AB (Sweden)

The PSim periscope simulation platform (see Figure 6 and Figure 7) is part of the Royal Swedish Navy submarine training facility. A description taken directly from the website (http://www.subvision.se/simulators.html) follows:

> *"PSim 01 is a periscope simulator ideal for integration in submarine training platforms. It is built with the purpose to look and feel like a real periscope with all external controls available and easily handled. PSim 01 is used together with a computer to simulate the function of a real periscope. Sensors in PSim 01 detect the operator's actions and this information is sent to the computer. The computer generates an image based upon sensor information. This image is presented on a screen in PSim 01 and is viewed by the operator through the optics."*

Table 4 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 6: PSim 01 Periscope.

Figure 7: PSim 01 Periscope Simulation View.

Table 4: Results for PSim 01 by Subdivision AB (Sweden).

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	unknown	Split is implemented, but I don't have that detail
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	unknown	Sim is not connected to HLA. Takes input via RS232.
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	unknown	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	probably	Other similar requirements are met
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28 nm (517 m) based on hull lettering heights of 1.85 m	probably	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	partially	Only fog is implemented, and that is static images (it doesn't move or dissipate)
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	unknown	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	no	Water is static, so ownship does not move
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	partially	Water surface and sky is visualized statically with a background image. Different background images representing different sea states may be loaded. Hence, water surface is not dynamic!
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	no	Celestial bodies not accurately placed
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	no	Celestial bodies not accurately placed
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	partially	Position and attitude data has to be input to the simulation from an external source.
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	no	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	no	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	no	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	no	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	no	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present washover (due to speed of sub, sea state, height of periscope)	no	Static images used, so no washover
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	no	
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	yes	
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	Through serial port
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	yes	
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	probably	
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	no	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun	no	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	no	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	probably	
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools	unknown	
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	no	
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance	no	
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	unknown	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	unknown	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)	unknown	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	unknown	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator	no	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	1.5x, 6.0x and 12.0x implemented
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	no	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	partially	Can do -10 to +60 degrees
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	partially	Can do -10 to +60 degrees

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	no	
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	unknown	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	probably	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	partially	Can do -10 to +60 degrees
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)	partially	3.0x not implemented
			Number of Requirements Met	18	(value of 1)
			Number of Requirements Partially Met	7	(value of 1/2)
			Number of Requirements Not Met	18	(value of 0)
			Number of "unknown"	10	(value of 0)
			Number of "probably"	5	(value of 1/2)
			Degree of Success of Technological Solution	**41%**	

4.3 Sonalysts Combat Simulations – Dangerous Waters by Sonalysts, Inc.

Dangerous Waters is an anti-submarine warfare game (see Figure 8 and Figure 9), developed with high-fidelity simulation capabilities in mind, from sensors to target motion analysis, to ship model physics and navigation capabilities and constraints. A description taken directly from Sonalysts, Inc. website (http://www.sonalystscombatsims.com/dangerous_waters) follows:

> *"S.C.S. – Dangerous Waters … (is) … the first title of its kind, allowing you total control over multiple air, surface, and submarine platforms in a modern-day naval environment! The game allows you to focus your attention and to take direct control of individual crew stations and also plan and execute combined arms naval strategies from a top-down 'Commander's Eye' perspective."*

Table 5 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 8: Kilo Class Submarine – Periscope View.

Figure 9: 688(I) Class Submarine – Stadimeter View.

Table 5: Results for S.C.S. – Dangerous Waters by Sonalysts, Inc.

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	yes	
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	yes	
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	probably	given the documentation on class/range determination from periscope and stadimeter
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	probably	given the documentation on class/range determination from periscope and stadimeter
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28nm (517m) based on hull lettering heights of 1.85m	probably	given the documentation on class/range determination from periscope and stadimeter
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	partially	according to reviewers, the weather does not change within a "mission", so if it rains, it rains all over the geographical area and for the duration of the mission

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	yes	
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	yes	read in a review
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	yes	from documentation and promotional material, there are at least clouds, weather, sun, stars, and time of day
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	partially	according to reviewers, sea states and wind do not match 100% the accurate impact of such environmental conditions on manoeuvering capabilities. Similar comments were made with regards to maneuvres when the platform is damaged or collides with another platform
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present washover (due to speed of sub, sea state, height of periscope)	yes	read in a review
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	yes	
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	unknown	
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	yes	
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	yes	
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun		
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	yes	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	yes	
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools	unknown	but does support HLA for distributed simulation systems. May be sufficient for data collection via an RTI
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	yes	Data Base Editor: According to the Development Capabilities link on the SCS Webpage: The non-commercial version of the S.C.S. Simulation Engine includes a database editor, replay viewer, batch processing mode, and HLA/DIS capability. The database editor allows the end-user to add and remove platforms as well as modify a vast array of parameters for existing platforms. The replay viewer gives the end-user the

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
					ability to save sessions and review them in their entirety at a later time. Batch processing mode is useful when large numbers of unattended, tightly controlled runs are required. The HLA/DIS capability provides for real-time connectivity to other simulations. The S.C.S. Simulation Engine's robust and extensible architecture allows it to be an effective solution for a number of diverse modeling tasks.
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance	yes	
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	partially	most of the periscope models have a stadimeter capability merged with the periscope station
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	unknown	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)	unknown	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator		
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	unknown	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	unknown	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV	unknown	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)	unknown	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	unknown	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	unknown	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	unknown	
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	yes	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	unknown	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)	unknown	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)	unknown	
			Number of Requirements Met	36	(value of 1)
			Number of Requirements Partially Met	3	(value of 1/2)
			Number of Requirements Not Met	0	(value of 0)
			Number of "unknown"	14	(value of 0)
			Number of "probably"	3	(value of 1/2)
			Degree of Success of Technological Solution	**70%**	

4.4 Submarine Periscope Observation and Tracking (SPOT) by the US NAVAIR (Naval Air Systems Command)

The SPOT (see Figure 10 and Figure 11) is part of a full-fledged submarine piloting and navigation training system developed by the US NAVAIR. A description taken directly from the website (http://nawctsd.navair.navy.mil/Programs/TrainerDescriptions/UnderseaPrograms/MiniSubPilot.cfm) follows:

> *"The Mini-Submarine Piloting and Navigation Training System (Mini-SPAN) provides Interactive Courseware (ICW) training on a variety of submarine systems. It can be configured to provide training at the operator or team level in piloting and navigation operations. All of these procedures can be taught prior to commencing hands-on performance with actual SSN 688 and Trident class Submarine equipment. The trainer supports prerequisite, pipeline, and refresher courses of instruction for SSN 688 and Trident Class Submarine Students. One instructor is required to support student activities on the Mini-SPAN.*
>
> *The Mini-SPAN Trainer uses SubSkillsNet Software to provide individual and team procedural and operator training for: (1)* ***Submarine Periscope Observation and Tracking (SPOT)****, (2) On-Board Radar Collision Avoidance (ORCA), (3) Officer-Of-the-Deck (OOD) training which consists of: Surface Collision Avoidance (SurfCAT), On-Board Radar Collision Avoidance (ORCA), and Global Positioning System (GPS) operations, (4) Sonar Collision Avoidance Training (SCAT) and Surface Submarine Navigation and Piloting (SSNAP) operations. Each student station is also capable of operating independently to allow students to progress at their own pace. The Mini SPAN trainer is capable of utilizing additional training course ICW materials without modification to the trainer hardware.*
>
> *The Mini-SPAN consists of SubSkillsNet Software and Commercial-Off-The-Shelf (COTS) delivery system. It consists of one Instructor/Operator Station, two dual speed hubs, and several student stations. The major components of the Instructor/Operator Station are the computer, the monitors, the Uninterruptable Power Supply (UPS) and the Hubs. The major Student Station components include the computer, the monitors, and the UPS."*

Table 6 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 10: NAVAIR SPOT Training Room.

Figure 11: NAVAIR SPOT Training Room Control Station.

Table 6: Results for the Submarine Periscope Observation and Tracking (SPOT) by the US NAVAIR (Naval Air Systems Command).

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	no	
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	unknown	Didn't ask, but most likely does
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	unknown	Didn't ask
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6 nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	unknown	Didn't ask, but most likely does
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28 nm (517 m) based on hull lettering heights of 1.85 m	unknown	Didn't ask, but most likely does
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	partially	Rain and Fog only
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	yes	
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	unknown	Didn't ask, but most likely does

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	partially	Sea states 0 to 6
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	yes	Planets are not included
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	partially	Heel over only in response to sea state
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	unknown	Didn't ask, but most likely does
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	no	
Simulation World	Environment - Visuals	Detect contacts in visual range	simulation must present washover (due to speed of sub, sea state, height of	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
		(elevation and FOV)	periscope)		
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	yes	
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	yes	
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	unknown	Didn't ask
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	yes	
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	yes	
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun	partially	Only on ship models
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	partially	Only in response to sea state

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	yes	
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools	unknown	Didn't ask
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	yes	
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance	yes	
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	unknown	Didn't ask
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	unknown	Didn't ask
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)	unknown	Didn't ask
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV		Awaiting answer
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)		Awaiting answer
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	unknown	Didn't ask

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	unknown	Didn't ask
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	no	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	no	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)		Awaiting answer
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)		Awaiting answer
			Number of Requirements Met	32	(value of 1)
			Number of Requirements Partially Met	5	(value of 1/2)
			Number of Requirements Not Met	4	(value of 0)
			Number of "unknown"	13	(value of 0)
			Number of "probably"	0	(value of 1/2)
			Degree of Success of Technological Solution	**64%**	

4.5 Vega Prime Marine (an extension of Vega Prime, by Presagis)

Vega Prime is a cross-platform, scalable 3D environment creation toolset designed for visual simulations (see Figure 12). It has numerous extensions and options, of which Vega Prime Marine was reviewed for this evaluation. A description taken directly from the website (http://www.presagis.com/products_services/products/options/vega_prime_marine) follows:

> *"Vega Prime Marine solves the problem of creating water surfaces for realistic oceans, lakes, or coastlines in real-time 3D simulation applications. This Vega Prime option allows you to easily add realistic dynamic water surfaces to any Vega Prime application. Combining the realism of an accurately synthesized dynamic ocean surface with the performance required for interactive real-time 3D simulation and training, Vega Prime Marine provides the necessary effects for realistically simulating ocean surfaces and the vessels that interact with them. This optional module provides a high performance native wave model that allows you to control the state of the sea, including the distributions of direction, height, wavelength, and alignment with the wind.*
>
> *Developers can define parameters as well as vessel characteristics that control the appearance of bow, stern, and hull wakes. The size and shape of the waves correspond to the size, shape, and speed of the vessel, and these waves also interact with the ambient water waves that the vessel encounters. These can serve as a visual aid in determining the speed, maneuvering, and turning of the vessel in the simulation environment."*

Table 7 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 12: Vega Prime Marine's Dynamic Water Surface Environment.

Table 7: Results for Vega Prime Marine (an extension of Vega Prime, by Presagis).

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	yes	
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	yes	
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6 nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	partially	This is dependent on the CFG.
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	partially	This is dependent on the CFG and on the hardware
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28 nm (517 m) based on hull lettering heights of 1.85 m	partially	This is dependent on the CFG and on the hardware
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	Obtain entity models from DND (PMO Aurora or other). This is dependent on CFG, but normally not a problem.
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	yes	Vega Prime Marine supports refraction, but it is not specified if it supports *atmospheric* refraction. No specific mention of haze, but this is normally supported

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	yes	Easily supported by CFG and synthetic environment
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	yes	Supports all 13 sea states of the Beaufort scale
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	probably	This is mostly dependent on the CFG. Heel over may be a little harder to get.
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	yes	Responds to pitch, roll, heave
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	probably	Not specifically mentioned, but features suggests that it is supported
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	unknown	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present washover (due to speed of sub, sea state, height of periscope)	unknown	Difficulty is probably high
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	yes	As long as you connect a terrain database to it
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	yes	
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	yes	
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	yes	This is a function of the entity model
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	yes	This is a function of the entity model
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	partially	The ship interacts with the waves (adjustment of heave, pitch and roll). Not clear how the effects of a turn are managed.
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	yes	This is a function of the entity model
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools	yes	Can be done using an overlay
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	yes	
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance	yes	
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	probably	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)	yes	Also, horizon not visible when no celestial body is above the horizon
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	yes	
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	yes	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)	yes	
			Number of Requirements Met	49	(value of 1)
			Number of Requirements Partially Met	4	(value of 1/2)
			Number of Requirements Not Met	0	(value of 0)
			Number of "unknown"	2	(value of 0)
			Number of "probably"	3	(value of 1/2)
			Degree of Success of Technological Solution	**91%**	

4.6 VR-Vantage by VT Mäk (a VT Systems Inc. company)

VR-Vantage is a COTS visualization toolset for distributed simulations in visual environments (see Figure 13). Add-ons by Antycip Simulation such as MyOcean3D (http://www.antycipsimulation.com/resources), a real time simulation of ocean water, and JRM Technologies' SensorFX packages for sensor simulations (http://www.jrmtech.com/ProductsForMSDevelopershtm.html) are third-party extensions of high interest, but outside the scope of the current review, and should be investigated in future literature reviews.

A description taken directly from the website (http://www.mak.com/products/vr-vantage.php) follows:

> *"VR-Vantage [...] includes 3 powerful components.* ***MÄK Stealth****: MÄK's 3D information station. Whether you need it for situational awareness, simulation debugging, or after action review, the MÄK Stealth provides the most data about your networked virtual world, and presents it in a clear and accessible way.* ***Vantage IG****: For those who need an out-the-window (OTW) scene or a view from a remote camera, VR-Vantage includes Vantage IG — the configurable desktop image generator. Vantage IG is designed for easy integration into desktop trainers and war gaming simulations.* ***VR-Vantage Toolkit****: Developers will enjoy the VR-Vantage Toolkit — a platform for 3D innovation. The toolkit comes with all the software you need to completely rebuild the visual applications like the MÄK Stealth or the Vantage IG, but it also allows you to customize and extend these applications to fit your unique requirements. It gives you the power to embed any of the MÄK Stealth or Vantage IG capabilities directly into your simulation applications. And because the VR-Vantage Toolkit is based on Open Scene Graph, you can leverage value-added plug-ins built by the OSG community and MÄK partners."*

Table 8 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 13: VR-Vantage Image Generator.

Table 8: Results for VR-Vantage by VT Mäk (a VT Systems Inc. company).

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	yes	
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	yes	
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6 nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	partially	This is dependent on the CFG.
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	partially	This is dependent on the CFG and on the hardware
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28 nm (517 m) based on hull lettering heights of 1.85 m	partially	This is dependent on the CFG and on the hardware
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	Obtain entity models from DND (PMO Aurora or other). This is dependent on CFG, but normally not a problem.

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	partially	Not certain about snow. Atmospheric refraction is more than likely not supported easily.
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	yes	Easily supported by CFG and synthetic environment
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	partially	We tell the visuals the amplitude and period. Whether it is realistic or not is an open question.
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	probably	Most tools do this now
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	probably	This is mostly dependent on the CFG. Heel over may be a little harder to get.
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	yes	Reflections may look more or less realistic
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	unknown	Might be possible to attach such an effect to the ship

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	unknown	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	unknown	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present washover (due to speed of sub, sea state, height of periscope)	unknown	Difficulty is probably high if it is feasible
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	yes	As long as you connect a terrain database to it
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	yes	
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	yes	This is a function of the entity model
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	yes	This is a function of the entity model
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun	yes	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	unknown	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	yes	This is a function of the entity model
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools	yes	
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	yes	VR Vantage is compliant; used with VR Link
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance	yes	
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	yes	Can do it with second output of video card
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 1 2nm (24 k yards)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator	yes	This is an add-on that must be purchased
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	yes	As long as this is not for a polarized image (just a colour filter is OK)
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	yes	
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	yes	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
			Number of Requirements Met	46	(value of 1)
			Number of Requirements Partially Met	5	(value of 1/2)
			Number of Requirements Not Met	0	(value of 0)
			Number of "unknown"	5	(value of 0)
			Number of "probably"	2	(value of 1/2)
			Degree of Success of Technological Solution	**85%**	

4.7 Delta3D

Delta3D is an open source game and simulation engine. It has a wide user base and has been applied to a number of different applications, including military applications. Delta3D is appropriate for a wide variety of uses including training, education, visualization, and entertainment. In particular, Delta3D is relevant to the modeling and simulation and Defence communities because it includes support for High Level Architecture (HLA), After Action Review (AAR), large-scale terrain support, and SCORM Learning Management System (LMS) integration. Delta3D is developed and tested on Windows XP and Linux. More details about Delta3D can be found at http://www.delta3d.org/index.php.

Delta3D has been used for naval applications in the past. In addition to simulations of damage control and firefighting aboard ships, of particular interest are the projects 'SurfTacs' (for junior surface warfare officers). SurfTacs is described as an adjunct to traditional forms of Navy training and focuses on shiphandling of an Arleigh Burke Class Guided Missile Destroyer in multi-ship tactical manoeuvring situations (see Figure 14 and Figure 15).

Table 9 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 14: Image from SurfTacs.

Figure 15: Overview Image from SurfTacs.

Table 9: Results for Delta3D.

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	yes	
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	yes	
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6 nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28 nm (517 m) based on hull lettering heights of 1.85 m		
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	yes	
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	partially	build own physics
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	partially	Can render an open ocean, but no direct sea state mapping. You do have control over the size and direction of waves. See "osgOcean" for details.
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	yes	osgEphemeris project
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	no	Would require programming your own physics (provided)
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	partially	build own physics
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	partially	build own physics
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	no	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	no	but could use glowing texture
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present washover (due to speed of sub, sea state, height of periscope)	yes	But would take some artistic talent
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	yes	
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	yes	
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	yes	
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	yes	
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	yes	
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	no	build own physics
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	yes	
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools.		
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	yes	
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance		
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	partially	depends upon resolution of display
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator	no	Very complicated process, suggests a commercial sensor package
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	yes	Nothing built in, but with realtime graphics you can render however you like
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	yes	
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	yes	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)	yes	
Physical Model	Hardware - Perceptual	Initiate periscope use	must have two independently focusable eyepieces	yes	
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have servo rotation control on right periscope handle	yes	
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have filter knob (four positions)	yes	
Physical Model	Hardware - Structural	Detect contacts in visual range (elevation and FOV)	Must have left and right panniers	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Physical Model	Hardware - Controls	Interoperability	Periscopes must have all controls and displays that attack and/or search periscopes have currently (refer to diagram)	yes	
Physical Model	Hardware - Structural	Initiate periscope use	physical periscope must have folding handles	yes	
Physical Model	Hardware - Perceptual	Detect contacts in visual range (elevation and FOV)	simulation viewer should be conventional LCD mounted within periscope tube	yes	
Physical Model	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen resolution must be 1280x1024 or higher	yes	
Physical Model	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image update rate of 30Hz or higher	yes	
Physical Model	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image refresh rate of 60Hz or higher	yes	
Physical Model	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to rotate periscope	yes	
			Number of Requirements Met	56	(value of 1)
			Number of Requirements Partially Met	5	(value of 1/2)
			Number of Requirements Not Met	5	(value of 0)
			Number of "unknown"	0	(value of 0)
			Number of "probably"	0	(value of 1/2)
			Degree of Success of Technological Solution A	**89%**	

4.8 GX2

GENFX GX2 Render Engine is a custom rendering engine that renders high fidelity ocean and littoral scenes, at over a billion triangles per second at 60 HZ. This render engine is equivalent to Lyra which is offered by Presagis as the natural partner to Vega Prime. Using a custom host interface and GENFX NSI networking software GX2 can communicate with a host simulation. GX2's predecessor (psim) has been integrated into submarine bridge simulations for the US Navy and the Royal Australian Navy. GENFX GX2 supports Red Green Blue (RGB, i.e. colour), InfraRed, and Black and White periscope view for 688, SSGN and Collins class submarines. In addition GX2 supports BridgeView, a 360 degree open air simulation for up to 5 crew members training for the 688 and SSGN class.

Gx2 has an impressive video on Youtube showing a periscope view from under the water, transitioning to above the water, complete with washover effects, diffraction, etc. This video can be found at: http://www.youtube.com/watch?v=Zxge0Ve4h14. Screenshots are also provided below (Figure 16 to Figure 18).

The network interface supports multiple channels (or viewpoints) which can be linked together to act as one viewing surface to create 360 degree displays for a more immersive experience in the virtual world. Using this same technology the network interface can link together many different physical locations possibly linking a surface vessel, classroom and instructor into the virtual world with the submarine trainer. GX2 was built to run standalone or as an add-on to other game/simulation engines.

GENFX provides visual databases: The software comes with Digital Terrain Elevation Data (DTED II) data that spans the globe to give you a starting point, GENFX can then integrate customer data sources, DTED, satellite imagery and models using the GX2 Culture Editor to create high fidelity scenes with specific required cultural content for training in the littoral waters along the Canadian coastline and elsewhere.

GENFX can provide custom development to support training requirements not available in the current version of GX2. GENFX consultants have more than 19 years of consulting experience developing computer graphics special effects and virtual worlds. Custom device drivers can be created to link periscope control interfaces and custom IO interfaces. GENFX can provide copies of the simulation engine and sample data for evaluation by the customer. All integration and customization has been done by GENFX Employee's to date.

Pricing of GX2 is dependent on the project. GX2 is typically sold per site with integration and support. For periscope simulation GX2 is a fairly complete solution it is currently being used by two of the world's Navies.

Table 10 below presents the detailed evaluation and the overall score. The outcome is discussed in more detail in Section 5.

Figure 16: GX2 'Above the Water' View.

Figure 17: GX2 Night Vision View.

Figure 18: GX2 Thermal View.

Table 10: Results for GX2 by GENFX.

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Hardware - Controls	Determine contact range	size of split must be published to readout beside periscope in minutes of arc	yes	
Simulation World	Systems	Initiate periscope use	simulation must take a feed to know which direction the periscope is pointing	yes	
Simulation World	Systems	Initiate periscope use	simulation must persist and continue to run while periscope is 'off/down'	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to differentiate between two entities of 15 m difference on the main beam at 6 nm (proxy for the assessment of ship type) using the regular optical periscope (vice image intensification or thermal)	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to identify the class (i.e. detail, mast shape, main gun, etc.) at 1.84 nm	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to read hull lettering at a range of 0.28 nm (517m) based on hull lettering heights of 1.85 m	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must be sufficiently realistic in terms of silhouette, size, colour, mast, gun, hangar, bow shape, stern shape, funnel, bridge, etc.	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present weather (i.e. clear, hazy, cloudy, mist, rain, snow, atmospheric refraction)	yes	low effort to implement sleet and atmospheric refraction
Simulation World	Periscope/ Ownship - Behaviors	Interoperability	simulation must send all entity behaviour to periscope visual display	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Behaviors	Interoperability	simulation must impose pitch, roll, heave, etc. on submarine entity	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sea states	yes	Pierson-Moskowitz 0-9
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present time of day	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present sun, moon, stars accurately based on time of day and weather	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must move realistically (e.g. heel over in the turn, show a radius to the turn vice instantaneous)	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show shine, glare, reflection, etc.	yes	
Simulation World	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must change appearance based on viewing angle	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic bow wave which changes in size according to speed	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation entities must show realistic second wave which changes in size and relative location alongside of ship according to speed	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show realistic wake and 'rooster tail'	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must show bioluminescence	partially	not implemented but wakes are implemented. Medium effort to implement
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	simulation must present washover (due to speed of sub, sea state, height of periscope)	yes	
Simulation World	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	land topography must be modelled in order to allow visual fixing for navigation	yes	GX2 is used as a navigational trainer by the USN
Simulation World	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	must feature other masts that occlude LOS (blind arcs)	yes	Overcomes Z-fighting and occlusions due to waves and earth's curvature
Simulation World	Systems	Take contact bearing (relative)	simulation must make available bearing data from periscope to other simulation entities (specific case of sending contact and contact bearing to FCS)	yes	
Visualisation - Attack & Search Periscopes	Systems	Take contact bearing (relative)	bearing data must be published in response to the operator pressing a button on the periscope	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Take contact bearing (relative)	simulation must keep track of periscope's bearing relative to submarine's head (i.e. 0 degrees)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Take contact bearing (relative)	simulation must allow bearing resolutions of 1 degree to be obtained	yes	
Simulation World	Entities - Visuals	Determine contact range	dimensions/heights of identification features of vessels must be accurately modelled in simulation	yes	
Simulation World	Environment - Behaviors	Determine look interval (go deep range)	speed of simulation entities must be modeled accurately	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Simulation World	Environment - Visuals	Determine Angle on The Bow (ATB)	shadows must fall accurately on simulation entities according to position of the sun	yes	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	simulation entities must heel over accurately in the turn	yes	
Simulation World	Entities - Visuals	Determine Angle on The Bow (ATB)	entity characteristics must be sufficiently realistic to allow viewer to determine entity orientation assuming ship is large enough in FOV to show detail and environmental conditions permitting	yes	
Visualisation - Attack & Search Periscopes	Systems	Interoperability	must support the calculation and presentation of experimental decision support tools	yes	
Simulation World, Attack & Search Periscope	Systems	Interoperability	HLA compliance	yes	
Simulation World, Attack & Search Periscope	Systems	Interoperability	TCP/IP compliance	yes	
Simulation World, Attack & Search Periscope	Hardware - Perceptual	Interoperability	must allow a Tactical Television Console to present an image slaved to that in the periscope viewfinder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs in view finder	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	cross hairs must be centered on FOV and elevation, corresponding to the bearing	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	must be able to view a point source of light at 12 nm	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	horizon shall be at 12 nm (24 k yards)	yes	
Visualisation - Attack & Search Periscopes	Environment - Visuals	Detect contacts in visual range (elevation and FOV)	scene must correspond to periscope height	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present thermal image if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present image intensification if selected by operator	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen must present colour filter if selected by operator	no	easily implemented
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to position cross hairs on target	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope elevation = -15 to 30 degrees	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope low power magnification = 1.5x = 32 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope high power magnification 6x (8 degrees FOV)	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation - 15 to 30 degrees on low power (1.85x), 13.7 degrees FOV	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope thermal imaging elevation -7 to 22 degrees on high power (6x), 4.2 degrees FOV	yes	
Visualisation - Attack Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	attack periscope must be raised to use thermal imaging	yes	
Simulation World, Attack & Search Periscope	Periscope/ Ownship - Behaviors	Interoperability	simulation must accurately provide 'size' of periscope target to main simulation engine	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to split image vertically	yes	
Visualisation - Attack & Search Periscopes	Periscope/ Ownship - Behaviors	Determine contact range	must be able to exercise fine control over magnitude of split (to ~1' of a degree)	yes	
Visualisation - Search Periscope	Entities - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope elevation = -15 to 60 degrees	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope low power magnification = 1.5x = 24 degrees field of view (FOV hereafter)	yes	
Visualisation - Search Periscope	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	search periscope high power magnification 3x, 6x, 12 x (down to 3 degrees FOV)	yes	
Physical Model	Hardware - Perceptual	Initiate periscope use	must have two independently focusable eyepieces	yes	
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have servo rotation control on right periscope handle	yes	
Physical Model	Hardware - Controls	Detect contacts in visual range (elevation and FOV)	Must have filter knob (four positions)	yes	

Requirement Type	Subcategory	Derived from Task Type	Requirement Description	Requirement Met by Tech Solution	If partially met, explain why here
Physical Model	Hardware - Structural	Detect contacts in visual range (elevation and FOV)	Must have left and right panniers	yes	
Physical Model	Hardware - Controls	Interoperability	Periscopes must have all controls and displays that attack and/or search periscopes have currently (refer to diagram)	yes	
Physical Model	Hardware - Structural	Initiate periscope use	physical periscope must have folding handles	yes	
Physical Model	Hardware - Perceptual	Detect contacts in visual range (elevation and FOV)	simulation viewer should be conventional LCD mounted within periscope tube	yes	
Physical Model	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	screen resolution must be 1280x1024 or higher	yes	
Physical Model	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image update rate of 30Hz or higher	yes	
Physical Model	Periscope/ Ownship - Visuals	Detect contacts in visual range (elevation and FOV)	image refresh rate of 60Hz or higher	yes	
Physical Model	Periscope/ Ownship - Behaviors	Take contact bearing (relative)	operator must be able to rotate periscope	yes	
			Number of Requirements Met	67	
			Number of Requirements Partially Met	1	
			Number of Requirements Not Met	1	
			Number of "unknown"	0	
			Number of "probably"	0	
			Degree of Success of Technological Solution	**98%**	

5 Discussion and recommendations

The review of the marketplace identified a number of excellent candidate COTS applications for providing the visual rendering for a periscope simulation. For the most part, these applications scored very well on the evaluation. This, of course, made it very difficult to make an unequivocal recommendation regarding a preferred application. Instead, a variety of additional, intangible factors should be considered alongside the evaluation scores. The technical scores are tabulated in Table 11 with estimates of cost to get the simulation running, and amount of labour required.

Table 11: Results of Evaluation of COTS Applications.

COTS Application	Score	Cost	Labour
GX2	98%	Medium-High	Low-Medium
Vega Prime Marine	91%	Medium-High	Medium
Delta3D	89%	Low	High
VR Vantage	85%	Medium[3]	High
Dangerous Waters	70%	Low	Medium
SPOT	64%	High	High
PSim 01	41%	High	High

GX2 scored highest with 98%, followed by Vega Prime Marine, Delta3D and VR Vantage. However, GX2 and Vega Prime Marine have existing products that are close to the vVictoria requirement; both VR Vantage and Delta3D would incur greater effort to set up and use. For instance, many of the features that Delta3D can support are not necessarily supported "out of the box" and would require a programmer to spend time coding in C++ using the provided API in order to create a submarine visualization. The Delta3D representative stated that "It is *not* an out-of-the-box submarine simulator. Delta3D requires C++ programming to accomplish your requirements." The same is true, to a lesser extent, with VR Vantage, since, compared to Vega Prime Marine, it is less developed with respect to support for marine effects. The Swedish PSim 01 does not present the visuals required to match the capability offered by the other simulations (it is also likely to be relatively expensive).

An important point to make is that Mak have expressed significant interest in creating a submarine simulation and in creating such a simulation for DRDC Atlantic. GENFX have also expressed an interest, but not so keenly as Mak. Notwithstanding any issues surrounding Intellectual Property (IP), this may be a very effective way for DRDC Atlantic to obtain a high fidelity simulation at a competitive price through receiving discounted rates from the vendor on the product and development labour. VR Vantage also presents the advantage that DRDC Atlantic already has a license for its use, whereas GENFX and Vega Prime Marine would need to be purchased (Delta3D is open-source and therefore free).

[3] Based on existing license and anticipated investment in project by VT Mak.

In the case of GENFX, Vega Prime Marine, VR Vantage and Delta3D, the effort required to set it up will not only cost money, but it will also take time. Thus, the application that provides the best product "out of the box" should require the least amount of time and money before it can be used in vVictoria.

Following this line of thought, another option would be to use the NAVAIR SPOT simulation; the advantage is that it is already built, so the effort to implement missing features is much reduced. However, it is unknown how much it would cost to obtain SPOT, and how much it would cost to get NAVAIR to implement the missing features. NAVAIR may provide DRDC Atlantic access to the code to bring any desired modifications in the future but whether NAVAIR would want to 'authorize' such changes, or whether DRDC Atlantic would want to undertake the development, is uncertain. Purchasing SPOT is likely a faster route, but it is not known at this moment the cost compared to developing the implementation from scratch using either Vega Prime Marine or VR Vantage. To obtain costs, enquiries would have to be made through DND and DoD. The consideration of SPOT is probably not worth further consideration, however, since GX2 is already being used by the USN for submarine training. Acquisition costs for GX2 are therefore likely to be lower as will be the time required to modify the product to meet DRDC's needs.

Another issue of interest is the access to the code underlying the simulation and rendering engine. Note that the code to which we are referring is the application that is developed with the use of a toolkit (like Vega Prime); i.e. not the toolkit's code itself. In the cases of GX2, Vega Prime, and VR Vantage, because they are commercial 'for profit' applications the size and maturity of the developer community is smaller. The Delta3D community is larger because it is open source. Accessibility to code for future development or modifications is normally dependent on the contract that the customer has with the developer. The CF traditionally contract industry to develop an application, but IP rights remain with the Crown (the contract with the contractor normally has a clause permitting the contractor's reuse of the code for other projects, but the contractor delivers the code and an executable along with documentation). This is unlikely to be the case with GX2 or SPOT, who will want to retain their IP. Other companies (for instance Mak and Presagis) offer Developer's Licenses that allow a developer to augment/change the capabilities of a toolkit. The costs of these types of licenses were not investigated within the scope of this contract.

The final viable course of action with regard to purchasing a periscope visualization is to use Dangerous Waters. What this game lacks in terms of fidelity is vastly outweighed by its cost. Note also that it scored 70% in the evaluation. The game could be used for all elements of the vVictoria and it provides an API to develop new interfaces and capabilities. There is a mature and extensive community of users and developers online (although they may have moved onto new projects) and the company (Sonalysts) performs contracts for the US DoD. It may be desirable to use Dangerous Waters as a low-cost fall-back position.

Considered as a whole, any of the applications reviewed here could, with sufficient effort, be used to create a high-fidelity visualization for a periscope simulation. The element least likely to have been addressed in some form previously is the transition from below water to above water. A submariner will bring the boat to periscope depth and raise the periscope, and will look through the periscope before the periscope breaks the surface of the water. Additionally, the submariner wants to make the periscope as minimally-observable as possible. This means that the periscope visualization should include 'washover'; that is, water breaking over the periscope. Experimentally, this is important because it makes it more difficult for the submariner to detect targets and estimate range. The only rendering engine to have built and demonstrated this element is GX2.

Another issue that needs to be addressed is the architecture of the vVictoria simulation facility. A specific games engine (e.g. Dangerous Waters) that provides all components of the simulation (e.g. entities, missions, environment, visuals) is the simplest way of moving forward. However, any more elaborate solution will require a combination of elements. This contract has evaluated several products that variously address the entire periscope simulation or elements of the rendering/visualization phases of a simulation. Thus a significant question becomes "What best integrates with the back-end of the simulation?". This question cannot be answered under this contract.

On the basis of the evaluation performed here, the clear leader in terms of a fully-realistic periscope visual simulation is GENFX GX2. This product scored nearly perfect in the evaluation. Without concrete discussions between GENFX and DRDC Atlantic concerning the specifics of the purchase, costs are hard to estimate, but it is expected that they are competitive with Vega Prime/Presagis and VR Vantage/Mak. Therefore, on the basis of this evaluation, CAE PS make three recommendations:

1. It is recommended that DRDC Atlantic pursue GENFX GX2 as the solution for its periscope rendering engine;
2. DRDC Atlantic should also enquire of Mak to understand what avenues for collaboration may exist for their mutual benefit; and
3. Additionally, because it is inexpensive by any measure, can be used over a network, and can be run as an individual operator position (as opposed to an entire manoeuvring unit), DRDC Atlantic should purchase Dangerous Waters (if it does not already own a copy) and engage students to develop the game for use as the simulation and visual rendering engine of vVictoria. As part of this purchase, DRDC Atlantic should purchase the user guide for Dangerous Waters. There is a knowledgeable community of Dangerous Waters users and developers, and specialist development support could be sought from Sonalysts, who are still engaged in R&D for the US Navy and open to contracting opportunities.

6 References

Bacon, D.K. (1995). Integration of a submarine into NPSNET. Unpublished MSc thesis. Monterey, CA: Naval Postgraduate School.

Canadian Forces Naval Operations School. CH85 Attack Periscope. Training document EO 404.1.

Canadian Forces Naval Operations School. Operate Contact Evaluation Plot (CEP). Training document EO 002.1.

Canadian Forces Naval Operations School. Periscope Safety. Training document.

Department of National Defence. Excerpt from Victoria Class Submarine Command Team Trainer Statement of Work.

Description of Bottom Gun (US Navy training game). http://www.dodgamecommunity.com/modules.php?op=modload&name=...

Description of Incredible Sims Toolkit model of Royal Navy Trafalgar Class submarine. http://incrediblesims.com/News/royal-navy-subsafe-3d-simulator.

Dominquez, C., Long, W.G., Miller, T.E., and Wiggins, S.L. (2006). Design Directions for Support of Submarine CO Decision Making. Presentation to the Undersea Human Systems Integration Symposium, Mystic, CT.

Dominquez, C., Long, W.G., Miller, T.E., and Wiggins, S.L. (2007). Design Directions for Support of Submarine Commanding Officer Decision Making. Proceedings of the 2nd Annual Workshop on Meta-Information Portrayal, 21 – 23 August, Washington, DC.

Dry, M., Lee, M., Vickers, D., and Huf, S. (2005). Psychological implications for submarine display design. Defence Science and Technology Organisation Technical Report 1766.

HMCS Windsor. Periscope Watchkeeping. Training document.

Kirschenbaum, S.S. (1999). What makes decision tasks difficult? Presented at the 4th Command and Control Research Technology Symposium, 29 June–1 July, Newport, RI.

Laxar, K.V. (1998). US Navy color vision standards revisited. Naval Submarine Medical Research Laboratory memo report 98-01.

Magee, L.E. and Sweeney, D.M.C. (1991). Submarine periscope simulator fidelity. Defence and Civil Institute of Environmental Medicine Report number 91-01.

Ministry of Defence (1987). Upholder Class Submarine Search Periscope: Detailed Description Equipment Overhaul Manual. Document Number B$8409 (3D, 5D) Vol 1.

Ministry of Defence (1988). Upholder Class Submarine Periscope Maintenance Information. Document Number BR8409 (5 ABC).

Paulson, H.M. (1966). The performance of the Farnsworth Lantern at the submarine medical research laboratory and in the field from 1955 to 1965. Naval Submarine Medical Center report number 466.

Prensky, M. (2001). “Simulations”: Are they games? In Digital Game Based Learning. McGraw-Hill.

Prensky, M. (2001). True believers: Digital game-based learning in the military. In Digital Game Based Learning. McGraw-Hill.

Sperling, H.G. and Farnsworth, D. (1950). Periscope acuity at night: Central and paracentral acuity as a function of contrast and adaptation. Medical Research Laboratory report number 157.

Thales. Promotional material for CK038 Search and CH088 Attack Electronic Periscopes.

Thomas, S., Schott, G., and Kambouri, M. (2004). Designing for learning or designing for fun? Setting usability guidelines for mobile educational games. In J. Attewell and C. Savill-Smith (Eds.) Learning with mobile devices: Research and development. London, Learning and Skills Development Agency.

Xiao, J.B., Hu, D.B., Hu, J.H, and Xia, J. (2009). Study on the periscope training simulation system based on VR technology. In the Proceedings of the International Forum on Computer Science – Technology and Applications.

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Defence Research and Development Canada (DRDC) – Atlantic is building a Research and Development (R&D) facility called vVictoria (virtual VICTORIA) to support the VICTORIA Class submarine fleet. As part of this facility, DRDC Atlantic is particularly interested in providing a realistic simulation of the visual scene as observed through the periscope. CAE Professional Services was awarded a contract to determine the requirements of the periscope tasks performed by submariners and their requirements for a simulation, as well as surveying the market for potentially suitable Commercial-Off-The-Shelf (COTS) visual rendering engines. By evaluating the COTS engines against the requirements of the submariners it would be possible to differentiate between the COTS engines and recommend to DRDC Atlantic which application to purchase.

This report describes the methodology by which the objectives were pursued, and the results of the evaluation. Sixteen applications were identified and six were evaluated in detail. Of these six, most engines could, with sufficient effort, present a realistic simulation. However GX2 by GENFX, has already performed much of the development work, and scored the highest in the evaluation. The evaluation also showed that Dangerous Waters, a video game, scored highly and is extremely inexpensive.

Recherche et développement pour la défense Canada (RDDC) – Atlantique a ordonné la construction d'une installation de recherche et développement (R & D) nommée vVictoria (virtual VICTORIA) dans le but de soutenir la flotte de sous-marins de classe VICTORIA. Dans le cadre de cette installation, RDDC Atlantique est tout particulièrement intéressé à fournir une simulation réaliste de la scène visuelle, telle qu'observée au moyen d'un périscope. Un contrat a été attribué à CAE Professional Services pour déterminer les exigences des tâches en lien avec le périscope effectuées par les sous-mariniers et la nécessité d'effectuer une simulation, ainsi que pour surveiller le marché afin de vérifier la disponibilité de moteurs de reproduction visuelle possiblement convenables en vente sur le marché. En évaluant les moteurs en vente sur le marché en fonction des exigences des sous-mariniers, il serait possible d'établir la différence entre les divers moteurs en vente sur le marché et de conseiller RDDC Atlantique relativement à l'achat d'une application.

Le présent rapport décrit la méthodologie utilisée pour les objectifs et fournit les résultats de l'évaluation. Un total de 16 applications a été identifié et six d'entres elles ont été évaluées en détail. Parmi ces six applications, la plupart des moteurs seraient en mesure, en fournissant un effort suffisant, de présenter une simulation réaliste, mais l'application GX2 de GENFX a déjà permis d'effectuer une grande partie du travail de mise au point et a obtenu les meilleurs résultats à l'évaluation. L'évaluation a également démontré que l'application Dangerous Waters, un jeu vidéo, a obtenu de très bons résultats et que son prix est très bas.

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Periscope; simulation; visualization; platform; VICTORIA Class

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