National Defence Défense nationale

Canadian Forces College

Collège des Forces Canadiennes

VIRTUAL REALITY SIMULATORS FOR ENHANCING RCN TRAINING

Lieutenant-Commander Phillip Durand

JCSP 45

Service Paper

Disclaimer

PCEMI 45

Étude militaire

Avertissement

Canada

CANADIAN FORCES COLLEGE/COLLÈGE DES FORCES CANADIENNES
JCSP 45/PCEMI 45
14 Oct 18

DS545 COMPONENT CAPABILITIES

VIRTUAL REALITY SIMULATORS FOR ENHANCING RCN TRAINING

By Lieutenant Commander Phillip Durand
For Commodore A. Topshee, CCFP/RCN Training Coordinator

VIRTUAL REALITY SIMULATORS FOR ENHANCING RCN TRAINING

AIM

1. This service paper aims to recommend new strategies for training development and delivery within the Royal Canadian Navy (RCN) based on the current advances in Virtual Reality and Virtual Environments simulators.

INTRODUCTION

2. Virtual Reality (VR) or Virtual Environment (VE) simulators (henceforth referred to as simulators) have been popular in visual entertainment since the advent of touchscreens and VR goggles. The use of simulator technology in a training environment is not a new phenomenon; the RCN has capitalized on the effectiveness of VR in its navigation simulators for over a decade. The use of simulators for navigational training has been extremely effective; core navigational and shiphandling skills are taught and expanded upon within the safety of a computer program executed on a mock bridge, offering a high fidelity (realistic) experience. Of course, no computer program can fully prepare Navigating Officers and Commanding Officers for operating a ship in pilotage waters or during shiphandling manoeuvers, but it allows the basic principles of force, effects of weather and the proper use of verbal commands to become automatic, allowing the officer to focus on the complexities of the specific situation instead.

3. This service paper will outline how the RCN can capitalize on the successes of the navigational simulators by expanding it into the domains of damage control and ship familiarization, mechanical and combat systems engineering training, emergency medical response and first aid training, and deck evolutions such as replenishment at sea (RAS) and flight operations training. It will suggest a new training paradigm for both the Fleet schools and Sea Training Group training programs, and the associated policy required to implement it. Finally, it will spotlight a simulator program used by the US Navy as an example of simulator technology for the RCN to explore further.

DISCUSSION

4. Using simulator technology for training provides a wide range of benefits. First and foremost, it cuts costs associated with putting ships to sea for training, both in fuel and in wear of equipment.[1] Complex or catastrophic casualty drills that cannot be simulated with equipment under operation, or drills that carry risk to ship equipment, personnel or navigation (propulsion drills or emergency breakaways) can be conducted safely in a controlled environment.[2] [3] [4]Simulators are not subjected to mechanical problems, weather conditions or other command taskings, nor do they require the time and personnel overhead of large safety teams, transits to

---

[1] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.
[2] ibid
[3]Fabrizia Mantovani, Gianluca Castelnuovo, Andrea Gaggioli, and Giuseppe Riva. 2003. "Virtual Reality Training for Health-Care Professionals." CyberPsychology & Behavior 6 (4)
[4] Franck Ganier, Charlotte Hoareau, and Jacques Tisseau. 2014. "Evaluation of Procedural Learning Transfer from a Virtual Environment to a Real Situation: A Case Study on Tank Maintenance Training." Ergonomics 57 (6)

and from operation areas and coordination with the ship's daily operations.[5] Students can interact with models, components, or respond as if it were reality; it encourages active engagement which enhances the retention of new material.[6] Drills on simulators can range from basic to advanced concepts, and they can be quickly reset and frequently repeated to allow for rapid skill acquisition.[7] Drills can be paused for instructor input, or recorded responses replayed for enhanced debriefs.[8] Ultimately, if used in a progressive program that includes both simulator and underway training, simulators significantly increases the efficiency of underway training by allowing at sea trainers to focus on advanced whole unit training instead of spending valuable time on operator basics.[9] [10]

5. However, there must be caution on over-relying on simulators in training; time in simulators must be balanced with actual time underway. Simulators require a high fidelity in operations to be effective; simulators that vaguely resemble operations or conditions onboard ship may even hinder training by training irrelevant or "simulator" responses in students.[11] It is challenging to train full teams in simulators – such as engineering watch teams, RAS teams and multiple damage control teams, and therefore simulators are limited in the ability to prepare students on how to incorporate or respond to other team members.[12] Simulators cannot simulate the normal sensations of a ship underway, such as sights, sounds, movement or flow of daily routine that is part of the authentic underway experience[13], nor can it simulate the stress of potentially catastrophic or fatal consequences of poor decisions or misjudgements of the situation.[14] In the end, simulation can develop the baseline cognitive reactions and knowledge needed to do the job at sea, but to be effective, trainees need the multisensory experience of live action exercises to internalize the skillset fully. These restrictions highlight the need for a properly integrated training program of simulator-based and underway training[15] [16]

---

[5] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.

[6] Fabrizia Mantovani, Gianluca Castelnuovo, Andrea Gaggioli, and Giuseppe Riva. 2003. "Virtual Reality Training for Health-Care Professionals." CyberPsychology & Behavior 6 (4)

[7] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.

[8] ibid

[9] ibid

[10] Franck Ganier, Charlotte Hoareau, and Jacques Tisseau. 2014. "Evaluation of Procedural Learning Transfer from a Virtual Environment to a Real Situation: A Case Study on Tank Maintenance Training." Ergonomics 57 (6)

[11] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.

[12] ibid

[13] Roland J. Yardley, Harry J. Thie, Christopher Paul, Jerry M. Sollinger, and Alisa Rhee. 2008. An Examination of Options to Reduce Underway Training Days through the use of Simulation. Vol. MG-765. Santa Monica, CA: Rand Corp.

[14] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.

[15] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.

[16] Fabrizia Mantovani, Gianluca Castelnuovo, Andrea Gaggioli, and Giuseppe Riva. 2003. "Virtual Reality Training for Health-Care Professionals." CyberPsychology & Behavior 6 (4)

6. Table 5.1 from a RAND research paper represents a succinct overview of the factors associated with simulator training.[17] It summarizes training benefits between underway, alongside and in shore-based simulator so well that it was felt imperative that it be included in Annex A. Table 5.1 details factors associated with training, and uses a stoplight visual representation based on variables such as cost, training constraints and cohesiveness to highlight which types of training are most useful for the various factors associated with training. In their conclusion, RAND found that simulators are best used to sustain readiness, enhance capabilities, save resources and reduce risk, but must be augmented with training underway.[18] Table 5.1 should be used in conjunction with the development of any training program that incorporates simulator technology as a way to guide which training requirements are best suited for training underway, alongside or at a simulator training facility.

7. The following are ways to incorporate simulator technology into training:

a. Damage Control. The effectiveness of simulators in damage control training was proven in an experiment on US Shadwell, a US Navy Damage Control testing platform, in which two crews were tested on spatial navigation and firefighting, with one team receiving simulator training before the test. The test found the team that received simulator training took only one wrong turn and were more timely and effective in fighting the fire.[19] Simulators were able to train the damage control crews in the two factors found to impact the effectiveness of crews the most: compartment familiarization and operating in low visibility[20]. The results of this experiment show that basic ship familiarization, traditionally done with Know Your Ship Booklets, can be done with simulators before sailors arrive at their first unit. One of the benefits of the realism of the Multipurpose Reconfigurable Training System (spotlighted in paragraph 9) was the ability for new sailors to familiarize themselves with the layout of the Virginia-class submarines.[21] Sailors can virtually explore each compartment, familiarize themselves with the hazards and damage control tools of each space, and be tested within the program to find relevant tools, practice firefighter procedures or solve damage control problems in conditions of low visibility.[22] Simulators free up senior personnel typically involved in giving damage control tours and are not impacted by regular ship maintenance programs. Although there are already two live fire damage control trainers that allow personnel to experience fighting floods, fire and gas in the most realistic conditions possible, the trainers are limited in the number of personnel they can train.

---

[17] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.
[18] ibid
[19] D. L. Tate, L. Sibert, and T. King. 1997. "Virtual Environments for Shipboard Firefighting Training." Naval Research Laboratory.
[20] ibid
[21] Cardona, Caroline. 2018. "Central Florida Acts as Hub for Special Technology Training for Navy, Military." Sep 11.
[22] D. L. Tate, L. Sibert, and T. King. 1997. "Virtual Environments for Shipboard Firefighting Training." Naval Research Laboratory.

Similar to underway training, these live fire trainers are most effective if students are already trained to a level suitable for advanced damage control scenarios[23];

b. Mechanical and Combat Systems Engineering. Both engineering trades have much to benefit from simulator training, including basic skill introduction and enhancement, mechanical equipment knowledge, and casualty exercises. There are two types of engineering requirements to train for: routine plant operations, including the starting, stopping, operations and maintenance of required equipment, and responses to engineering casualties, including emergency responses and at sea emergency repairs.[24] Paragraph 4 has already highlighted the benefits of using simulators to train casualty responses and routine operations of equipment. However, as an addition, research from civil engineering showed the benefits of using a 4D simulator – a 3D model of an object constructed or deconstructed over time – to allow students to observe components from the most suitable camera and zoom position, and grasp how the parts interacted together to form the whole. By interacting with the simulated object, the learners can reach an understanding not possible through regular interaction with the component.[25] These 4D simulators can be used to train engineers in dismantling, troubleshooting and reconstruction on most, if not all, critical mechanical and combat systems onboard ship;

c. First Aid. The use of simulator technology within the civilian world has been shown to improve retention in medical training.[26] Additionally, many part trainer simulators have been developed to focus on the individual skill sets in dealing with scenarios that are limited in resources and contain medical emergencies that are not commonly seen in hospitals; scenarios that are well suited for ships at sea. The high fidelity allows trainees to experience realistic reactions of virtual patients to the trauma and the treatment methods chosen with no risk, training sailors on subtle signals to watch for and proper application of first aid methods.[27] Simulators allow abstract and unperceivable concepts, such as biological functions, to be visualized and interacted with by students.[28] Trainers can assess individual skill levels and knowledge gaps, and provide training as required.[29] As such, both medical responders and individual sailors would benefit immensely through the use of simulator training; and

d. Deck Evolutions. Little research or available technology was available on the use of simulators with deck evolutions, such as replenishments at sea (RAS), towing evolutions and small boat or helicopter operations, as there were few examples in the

---

[23] Franck Ganier, Charlotte Hoareau, and Jacques Tisseau. 2014. "Evaluation of Procedural Learning Transfer from a Virtual Environment to a Real Situation: A Case Study on Tank Maintenance Training." Ergonomics 57 (6)
[24] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.
[25] Fabrizia Mantovani, Gianluca Castelnuovo, Andrea Gaggioli, and Giuseppe Riva. 2003. "Virtual Reality Training for Health-Care Professionals." CyberPsychology & Behavior 6 (4)
[26] Dale S.Vincent, Andrei Sherstyuk, Lawrence Burgess, and Kathleen K. Connolly. 2008. "Teaching Mass Casualty Triage Skills using Immersive Three-Dimensional Virtual Reality." Academic Emergency Medicine 15 (11)
[27] Fabrizia Mantovani, Gianluca Castelnuovo, Andrea Gaggioli, and Giuseppe Riva. 2003. "Virtual Reality Training for Health-Care Professionals." CyberPsychology & Behavior 6 (4)
[28] ibid
[29] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.

commercial sector of simulator programs that trained such evolutions. However, based on the examples provided in damage control, firefighting, engineering casualty and routine operations, and first aid, programs custom made for deck evolutions would carry similar benefits for operators; research has shown that simulator training is well suited for the transfer of both procedural and sensorimotor skills.[30] RAS operators can work the different operating procedures of equipment used for Liquid, Heavy and Light Jackstay replenishment, as well as emergency responses and safety infractions. Similarly, programs can be created to simulate helicopter operations in Ship without Air Department (SWOAD), small boat operations and anchor or tow operations, and emergency procedures for each of those evolutions as well. Here, VR goggles would prove to be beneficial as it would situate sailors on a RAS or boat deck to expose them to situations that generally carry much risk, or allow sailors to repeat drills multiple times to ensure that they are well memorized and internalized.

8. The inclusion of simulator training will require changes to policy and training programs. Personnel should be required to meet certain proficiency standards on simulators before being allowed to proceed to sea to ensure that they exhibit a level of training ready for advanced underway training scenarios.[31] Ships should be provided desktop trainers, and be mandated to use both desktop and full simulator training to maintain perishable skills.[32] The use of simulation should satisfy most of the criteria listed in On-the-Job packages, allowing for accelerated qualifications of operators. A progressive training program for each of the four areas of training considered here should be developed to allow for a consistent building of skills from desktop trainers, full-scale simulators or VR goggles, and underway unit level training; Sea Training Group and Fleet School would require extensive cooperation to develop such a program effectively. Table 5.1 in Annex A[33] should be used to determine which elements of training should be done underway, alongside or within a simulator training facility. Finally, training scenarios should be enhanced and inspired by real-life accidents and infractions; publications such as ProNotes, Significant Incident Reports and Boards of Inquiry from both the Canadian and International Navies should be consulted when developing these scenarios.

9. There are many commercial simulators already available for purchase. As an example, Naval Air Warfare Center Training Systems Division (NAWCTSD) in Orlando is using 3D simulators called the Multipurpose Reconfigurable Training System (MRTS) to train sailors of a Virginia Class submarine in ship and engineering familiarization.[34] The MRTS includes a virtual reality goggle attachment. Trainees can explore a realistic replica of their ship, including where essential damage control equipment, tools and manuals are located. They can take engine parts, dismantle them to understand the components of the part, then problem solve malfunctions of the engine itself. Trainees found that the simulators prepared them for their jobs at sea and that their

[30] Franck Ganier, Charlotte Hoareau, and Jacques Tisseau. 2014. "Evaluation of Procedural Learning Transfer from a Virtual Environment to a Real Situation: A Case Study on Tank Maintenance Training." Ergonomics 57 (6)
[31] Roland J Yardley, James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.
[32] ibid
[33] Roland J Yardley, James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp
[34] Cardona, Caroline. 2018. "Central Florida Acts as Hub for Special Technology Training for Navy, Military." Sep 11.

skill retention was much higher. Multiple participants were able to take apart and put back together different pieces of vital equipment at the same time, instead of requiring either multiples of the same part or the same part being deconstructed and repaired multiple times. Students are able to be trained and certified to do basic skills such as load a torpedo.[35] The MRTS 3D system allows individual training without the requirement for multiple systems or massive infrastructure. It will enable students to interact with the simulation using shipborne procedures, and instructors can introduce different casualties into the system for the students to problem solve. A system such as the MRTS 3D, or a similar commercial design would be beneficial for the RCN in the four areas of training discussed.

CONCLUSION

10. Although the RCN has already invested in simulator technology for navigation, seamanship and combat operations, there is potential for further inclusion of simulator training in the areas of damage control, deck evolutions, marine and combat systems engineering and first aid. The benefits of simulator training are numerous, including less cost associated with days underway, better quality individual training, minimal associated risk, especially in casualty and emergency drills, and shorter required training times. However, the RCN must be prudent not to rely too heavily on simulator training; the most effective training program is one that maximizes the graduated process from individual and part-team skills-based training in simulators to unit and fleet-based training at sea. The simulator technology, ranging from desktop programs to full VR goggles, presents a wide variety of options for the RCN to purchase and implement to improve the quality of training for the sailors and officers at sea.

RECOMMENDATION

11. This paper recommends that the RCN establish a team in charge of procuring simulator technology in the form of desktop programs, full team trainers and VR goggles, along with associated programs for training in damage control, mechanical and combat systems engineering, deck evolutions and first aid. It is further recommended that the nominated team develop a progressive training plan in the four areas explored in this paper that combines the effectiveness of simulator training with underway training to optimize both time in simulator and time at sea. Finally, resources should be made available so that units can take advantage of time alongside for teams to maintain and enhance their skills on a continuous basis.

Annex: A. Table 5.1: Factors to Consider in Using Shore-Based Simulators or Shipboard Equipment for Training

[35] ibid

BIBLIOGRAPHY

All Hands Update: MERTS. Directed by US Navy. 2017.

Cardona, Caroline. 2018. "Central Florida Acts as Hub for Special Technology Training for Navy, Military." Sep 11. https://www.clickorlando.com/news/central-florida-acts-as-hub-for-special-technology-training-for-navy-military.

CUBIC. "Training Engineers of Tomorrow using Virtual Environments." https://www.cubic.com/innovation/success-stories/training-engineers-tomorrow-using-virtual-environments., accessed 14 Oct, 18.

Farra, Sharon L., Elaine T. Miller, and Eric Hodgson. 2015. "Virtual Reality Disaster Training: Translation to Practice." *Nurse Education in Practice*15 (1): 53-57. https://www.sciencedirect.com/science/article/pii/S1471595313001765.

Ganier, Franck, Charlotte Hoareau, and Jacques Tisseau. 2014. "Evaluation of Procedural Learning Transfer from a Virtual Environment to a Real Situation: A Case Study on Tank Maintenance Training." *Ergonomics* 57 (6): 828-843. https://www.ncbi.nlm.nih.gov/pubmed/24678862.

Mantovani, Fabrizia, Gianluca Castelnuovo, Andrea Gaggioli, and Giuseppe Riva. 2003. "Virtual Reality Training for Health-Care Professionals." *CyberPsychology & Behavior* 6 (4): 389-395. http://www.liebertonline.com/doi/abs/10.1089/109493103322278772.

MRTS 3D®; YouTube. NSA Orlando 2017.

Naval Air Warfare Center Training Systems Division. 2016. *Multipurpose Reconfigurable Training System (MRTS) 3D®.*

Sampaio, A. Z. 2007. "The use of Virtual Reality Models in Civil Engineering Training." *International Journal of Simulation Modelling* 6 (2): 124-134.

Schank, F. John, Thie, J. Harry, Graf, M. Clifford, II, et al. 2002. *Finding the Right Balance: Simulator and Live Training for Navy Units*. Santa Monica, CA: Rand Corp.

Tate, D. L., L. Sibert, and T. King. 1997. "Virtual Environments for Shipboard Firefighting Training." *Naval Research Laboratory.*

Tichon, J. G., Hall, R. and Higlers, M. G. "Education and Training in Virtual Environments for Disaster Management." Association for the Advancement of Computing and Education, http://espace.library.uq.edu.au/view/UQ:99847.

Vincent, Dale S., Andrei Sherstyuk, Lawrence Burgess, and Kathleen K. Connolly. 2008. "Teaching Mass Casualty Triage Skills using Immersive Three-Dimensional Virtual Reality." *Academic Emergency Medicine* 15 (11): 1160-1165. http://www.ingentaconnect.com/content/bpl/aem/2008/00000015/00000011/art00025.

Wang, Peng, Peng Wu, Jun Wang, Hung-Lin Chi, and Xiangyu Wang. 2018. "A Critical Review of the use of Virtual Reality in Construction Engineering Education and

Training." *International Journal of Environmental Research and Public Health* 15 (6): 1204. https://search.proquest.com/docview/2108409321.

Watters, Andrea and Mikel Lauren Proulx. 2017. *Producing Ready, Relevant Learning for Sailors*. Vol. 99. Washington: Superintendent of Documents.

Yardley, Roland J., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. *DDG-51 Engineering Training: How Simulators can Help*. Santa Monica, CA: Rand Corp.

Yardley, Roland J., Harry J. Thie, Christopher Paul, Jerry M. Sollinger, and Alisa Rhee. 2008. *An Examination of Options to Reduce Underway Training Days through the use of Simulation*. Vol. MG-765. Santa Monica, CA: Rand Corp.

Annex A: Table 5.1: Factors to Consider in Using Shore-Based Simulators or Shipboard Equipment for Training

Table S.1
Factors to Consider in Using Shore-Based Simulators or Shipboard Equipment for Training

Factor/Location of Training	At Sea	Pierside	Shore-Based Simulator
Cost	High fuel costs plus wear and tear	Lower cost, but wear and tear	Lower cost, no wear and tear
Operate own ship's equipment	All engineering equipment can be operated	Some can be operated, but not all	Ship's equipment not operated
Cueing of watchstanders	Some cueing by training team on drill imposition	Some cueing by training teams on drill imposition	No cueing
Number of ECC drills than can be done	All 40	32 of 40	35 of 40
Time available by crew for training	Dedicated crew underway, but underway time is decreasing	Maintenance demands in port are high. CCS is hub of activity in port—conflicts will arise	No conflicts, but competes with other unit's training needs
Training constraints	ECC drills normally done underway on a not-to-interfere basis with other training needs and/or impact bridge operations or ship's ability to navigate	Some conflicts with in-port maintenance demands and other ship events	Trainees must leave ship for training. Must trade off what they would be doing if they stayed on board, and what doesn't get done
Who gets trained	2 of 3 Engineering Watch Teams composed of CCS and in-space watchstanders	2 of 3 Engineering Watch Teams composed of CCS and in-space watchstanders	3 of 3 CCS watchstanders but not in-space watchstanders
Personnel involved in training	ETT and all watchstanders	ETT and all watchstanders	CCS personnel
Impact on nonengineering watchstanders	Electrical load limitations for combat systems, navigation and bridge equipment	Small impact	None
Usefulness to utilize for varying skill levels	Good for experienced and inexperienced personnel, but expensive and potentially hazardous if incorrect actions taken	Good for experienced and inexperienced personnel and less expensive; potentially hazardous if incorrect actions taken	Good for experienced and inexperienced personnel and least expensive over time; good for continuation training
Impact of watchstander errors	CCS personnel and in-space watchstanders – potential for being costly and dangerous	CCS personnel and in-space watchstanders—potential for being costly and dangerous	Trains CCS personnel only— no hazard to personnel or equipment

Table S.1—Continued

Factor/Location of Training	At Sea	Pierside	Shore-Based Simulator
Feedback mechanism to trainees	In-space watchstanders stopped for safety violations. CCS watchstanders will perform immediate and controlling actions—graded as effective or ineffective based on observation and written comments about their actions	In-space watchstanders stopped for safety violations. CCS watchstanders will perform immediate and controlling actions—graded as effective or ineffective based on observation and written comments about their actions	Program can be "frozen" to provide instruction to watchstanders. Printout of time and sequence of actions offer ability to trace actions and timeline and provide objective feedback
Time it takes to conduct training	Longer. Must be approved by commanding officer and deconflicted with other training events onboard	Long. Deconfliction is required with ongoing maintenance and other shipside training	Short. Provides list of drills and runs training events. Events may be repeated to ensure proficiency
Maintenance of Engineering Training Team (ETT) Casualty Control Proficiency	Proficiency of ETT is unknown and untested	Proficiency of ETT is unknown and untested	Good. ETT members receive proficiency training as well as 1st and 2nd watch teams; ECC drill proficiency can be maintained in a shore-based simulator
Engineering watchstander's cohesion	Good. All are trained and communicate together	Good. All are trained and communicate together	Good for CCS watchstanders only
Physiological—heat, sound, sight, smell, ship movement, stresses	The real thing	Fewer stresses in port	Simulated environment
Realism of drill imposition	Some impositions different from an actual casualty, e.g., grease pencil used to indicate a high tank level	Simulations and deviations exist	Casualties alarm and occur to CCS watchstanders as they would underway
Effectiveness standard	Underway demonstration standard is 50%	Onboard demonstration standard is 50%	Can be trained to a higher effectiveness standard
Energy savings/carbon footprint	High energy use	Reduced energy use	Little energy use
Safety	Proficiency gained on operating equipment	Proficiency gained on operating equipment	Safe. Can train and gain proficiency before getting underway

[36] Roland J Yardley., James G. Kallimani, Laurence Smallman, and Clifford A. Grammich. 2009. DDG-51 Engineering Training: How Simulators can Help. Santa Monica, CA: Rand Corp.