

Simulation Environments for Offshore Oil and Gas Emergency Training

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ABSTRACT

Emergency Response and evacuation training for offshore oil and gas workers has traditionally been performed using land-based test facilities and live exercises. Due to risks associated with practicing drills using live exercises, this training has been limited to controlled environments and benign weather conditions. As offshore oil and gas activities move into harsher environments including deeper waters and ice covered waters, operators are required to demonstrate to regulators that personnel are prepared for emergencies in these conditions. Simulation technologies have been specifically created for offshore personnel to practice emergency scenarios in harsh environments using representative equipment and immersive virtual environments. A specific example includes the use of a simulator to practice launching lifeboats in severe sea states and ice. As simulation is adopted by the oil and gas industry as a supplement to existing training or as an alternative to replace specific drills, operators will be required to demonstrate that simulators are effective training tools. Human factors studies have been performed to assess how simulation technologies improve the performance of offshore personnel. These studies assess the value of simulation as a means to reduce time-to-competence. Validation studies are carried out to measure how students become immersed in the simulation environment and how accurately the virtual environment matches the real world. This paper discusses a case study of how a lifeboat simulator was created for the oil and gas industry and how the technology is used to allow oil and gas personnel to practice safely and effectively to increase the competence of offshore personnel. The paper also addresses the design philosophy for developing training technologies to maximize value to the operators, which includes designing simulators to achieve learning objectives which are derived from recognized training standards and regulated courses.

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INTRODUCTION

In the unlikely event of an incident at sea, offshore oil and gas workers must be prepared to deal with the emergency, and, if required, abandon their platform and survive until rescue. Since such instances of distress are rare, offshore workers must rely on training and continual practice (through drills) to ensure that they are prepared should an incident occur. The offshore oil and gas sector recognizes that preparing personnel to manage emergencies through training and exercising is important. There are some internationally recognized guidelines which are used to develop local training programs. Most notable amongst the international guidelines are International Maritime Organization (IMO) resolution A.1079 (28) and the training standards published by the Offshore Petroleum Industry Training Organization (OPITO). The ability to launch survival craft (lifeboats) under a variety of conditions, including high sea states, is one of the competencies required under international standards. There has not been any safe means for offshore workers to demonstrate their competence to launch under adverse conditions using real equipment. In addition, recent accidents have highlighted the dangers of conducting practice launches using real equipment even under calm conditions. Notwithstanding the difficulties in providing practical training for offshore workers to operate lifeboats under adverse conditions, it is part of their duties that they are able to do so. In the worst case, they will be asked to launch under extremely hazardous conditions in which they have never operated and are ill prepared.

BACKGROUND

Survival craft are the primary means of evacuation from platforms and vessels in the event of a rapidly escalating distress scenario. While orderly evacuation using helicopters is the preferred evacuation strategy, helicopter evacuation is not always possible or appropriate in all scenarios. Incidents which are characterized by rapid escalation, poor weather conditions, remote locations or toxic environments require an evacuation strategy which relies upon survival craft carried onboard the platform or vessel. There is a legal requirement to carry survival craft and to have properly trained crews should it become necessary to evacuate under adverse conditions. The need to evacuate a platform or vessel by survival craft is thankfully a rare occurrence. The offshore and maritime industries expend significant efforts to ensure that risks are managed to prevent incidents from occurring in the first place and to mitigate the impacts of an incident so that it does not escalate to the point where evacuation is necessary.

When an incident does occur, evacuation by survival craft has been observed to be a high risk operation. In 2000, the Oil Companies International Marine Forum (OCIMF) observed that there were 75 accidents with the use of survival craft over a one year period. It is not surprising that the study noticed that most accidents occurred during drills and inspections since the vast majority of launches are conducted during practice and not during an incident. The primary risk associated with the use of the survival craft was identified as the launch phase, however the finding cannot be generalized to exclude other risks such as operations in rough weather, since the sample size for that particular type of hazard is very low. Existing training is typically performed using real equipment and is limited to exercises in low sea states or in controlled environments. As a consequence, the first time a trainee will have to launch a lifeboat into a moderate to high sea state will most likely be in a real emergency event.

There is a history of marine accidents and emergencies which illustrate the risks associated with launching survival crafts or lifeboats in weather conditions which are common to offshore operating platforms and vessels. Notwithstanding the rarity of lifeboat evacuation, there have been incidents in which lifeboat evacuation from oil and gas platforms has been necessary. The studies provided below illustrate some of the lessons which have been learned by the offshore industry with respect to the use of survival craft to evacuate structures.

1. Ocean Ranger - On the night of 14th February 1982, a major Atlantic storm passed over the Hibernia Field on the Grand Banks of Newfoundland. During the height of the storm, water entered the ballast control room of the Ocean Ranger and damaged the stability control system. At 0052 hours local time, on February 15, a MAYDAY call was sent out from the Ocean Ranger noting a severe port list to the rig and requesting immediate assistance. The crew abandoned the rig at around 0130 hours using lifeboats. The rig remained afloat for another 90 minutes, sinking between 0307 hours and 0313 hours local time. All 84 crew on board the Ocean Ranger perished in the incident. The Canadian Royal Commission inquiry into the tragedy highlighted the shortcomings in safety and survival training which ultimately resulted in the implementation of enhanced lifeboat coxswain training requirements and the implementation of formal safety cases, which include crew competence, and training as a factor.
2. Rowan Gorilla I - While under tow from Nova Scotia to the North Sea, the jack-up rig Rowan Gorilla I was battered by a North Atlantic storm from December 13 to 15, 1988. Wind and wave action caused the legs of the rig to oscillate transmitting stresses to the supporting structures on the hull. This caused hull fractures to propagate and flood storage tanks in the rig's stern. During the storm, the towline to the Smit London broke, and the tug could only stand by as crew on the rig attempted to control the flooding situation. Around noon of December 15, 1988 a series of waves from 50 to 60 ft high hit the rig, dislodging the remaining loose cargo and causing the stern to hang under the seas. The crew abandoned the rig via the starboard lifeboat. It was noted that the crew was confronted with conditions which required them to use their background experience in seamanship in order to successfully conduct the operation. Due to the state of the seas, the decision was made to leave the crew in the lifeboat until calmer weather arrived. On 16 Dec 1988, the crew was finally ferried via a Zodiac from the lifeboat to the Smit London, which returned to Halifax.
3. Usumacinta - On 23 October, 2007, a cold weather front passed through the Gulf of Mexico bringing storm winds of 130km/hr with waves of 6-8m. The adverse weather conditions caused oscillating movements of Usumacinta and resulted in gas and oil leaks from well 121 in the KAB field. At around 1530 hours on October 23, all 73 personnel on the Usumacinta were ordered to evacuate by lifeboat after a loss of well control. Although both lifeboats were successfully launched, 22 persons were lost in the subsequent survival and rescue phases of the incident. Published analysis of the incident has indicated that training for evacuation in severe weather conditions should be implemented.

Simulation identified as an alternative

From the above, it is clear that the use of a survival craft for an actual evacuation is rare and potentially hazardous. In order to enable lifeboats to operate under a wide variety of evacuation conditions, they have been kept intentionally simple and their successful operation depends upon the skill of the operator. The capabilities of marine evacuation systems have been investigated extensively using systematic series of model experiments in large test facilities. This work aimed to address long-standing knowledge gaps by providing objective, empirical data that can be used by designers, regulators and others in their decisions concerning safety. Results of this research campaign generated research studies focused on evaluating and improving practical emergency preparedness planning and evacuation system design. Observations made during scale model experiments performed with lifeboats in wave tanks inspired the development of simulation training solutions (Veitch et al., 2009). During the experiments, the models were operated by remote control by a technician whose view of the scene was from a video camera mounted in the coxswain's position. The technician viewed in real time the scene from this perspective via a television monitor. During the trial an interesting observation was made. The ability of the technician to launch the lifeboat successfully improved with practice. The fact that the technician's launching and operating skills improved with practice sparked an interest in providing trainee coxswains with an opportunity to acquire similar artificial experience with the difficult and sometimes dangerous launching of lifeboats.

In 2003, Memorial University and the National Research Council of Canada commenced work on a prototype of a lifeboat simulator. Original developments focused on the determining whether it was possible to create a simulator that had the numerical and visual fidelity to achieve the primary goal of being able to practice the launch of a lifeboat into high sea states. Over the past decade, the prototype has matured to an operational training technology that is used by oil and gas personnel to become familiar with the equipment onboard the vessel, the procedures to launch and operate the vessel, and reaction to fault events. The technological advancements utilized best practices for developing simulation technologies based on identified training needs and the methodology continues to be used to expand the capabilities of the simulator.

Needs Analysis

The initial stage focused on determining the gap between learning objectives that could be achieved through conventional programs and identifying the limitations of existing training methods. This required an analysis of the training standards and practices that are in place. Training on the operation of a lifeboat is governed by international training standards contained in Section A-VI/2 of the Standards of Training Certification and Watchkeeping Convention (STCW). Some jurisdictions extend STCW survival craft competence standards, which are intended for seafarers on merchant ships, to the offshore oil and gas industry through the adoption of voluntary training guidelines issued by the International Maritime Organization (IMO). The requirements from STCW Table A-VI/2-1 form the basis of IMO Model Course 1.23 Proficiency in Survival Craft and Rescue Boats (other than Fast Rescue Boats).

The design requirements for the simulator were derived from two challenges which cannot be overcome through existing training programs due to the associated risks and logistics. The first, and most obvious, challenge with existing training methods is the ability to prepare lifeboat coxswains and lifeboat crews for operations in rough weather. It is interesting to take note of the specific STCW Code requirement that coxswains must demonstrate their ability to launch and operate survival craft in rough seas. IMO Model Course 1.23, however, only requires that a candidate explain how to launch into rough seas. The Offshore Lifeboat Coxswain Training Standard published by OPITO has a similar requirement as the IMO Model Course. Moving rough weather operations from the skills section of the training standards to the knowledge section is understandable from a safety point of view. No training institution has been able to safely meet the requirement to have candidates demonstrate their abilities to operate in rough weather using real equipment. The second challenge with existing training methods is the ability to prepare coxswains to launch the particular survival craft which are onboard their platform or vessel. In light of the number of accidents which have occurred during inspections and training drills, IMO has relaxed the requirement that the assigned crew must be onboard the survival craft during the launch phase of the drill. The decision to place the crew onboard the survival craft is now placed with the Master who must consider the risks involved as required under the International Safety Management Code. Most Masters view the new regime as a de facto ban on practice launches with the assigned crew on-board.

Simulator Build and Verification, Validation and Accreditation

The team targeted an experimental design approach where prototypes were built, tested, and new design goals were established as a result of the continuous evaluations performed by subject matter experts and internal engineers. Guidelines on software architecture and hardware design also had to be established to govern how the simulator components would be structured and how project execution would be managed. The end goal was to achieve a simulator with numerical and physical fidelity such that it could be accredited for use in a marine training program.

The development team adopted a modified Verification, Validation and Accreditation (VV&A) framework to outline the interaction between engineers, field experts, and competence assurance personnel who would eventually use the technology for training. The VV&A model is commonly used in Modeling and Simulation (M&S) design and provides processes to ensure that the team is developing features based on identified training needs, the features being developed achieve the degree of fidelity required, and the simulator can be used to achieve training objectives. (MSCO, 2014; Masys et al., 2006). The VV&A process evolved as the technology matured from prototype to commercial technology, as the level of interaction with engineers, end users, and human factors personnel changed as the technology matured from an engineering prototype to a system tested in an operational environment. Initial stages in the VV&A process focused on ensuring numerical, visual, and hardware performance was accurate and system performance was achieved. Later stage testing focused on ensuring the virtual environment immersed the trainee and human factors testing was performed to test whether audio, visual, and motion cues were realistic when evaluated by vessel operators. Through the entire VV&A process, traceability was maintained as design goals were established early by end users, including training personnel, and as features were matured the design goals were continuously evaluated based on alignment to learning objectives. Late stage testing focused on determining if the simulator was suitable for use in training programs with the final stage being acceptance of the simulator by an accreditation committee. Figure 2 summarizes the participants in the VV&A testing throughout the lifecycle of product development.

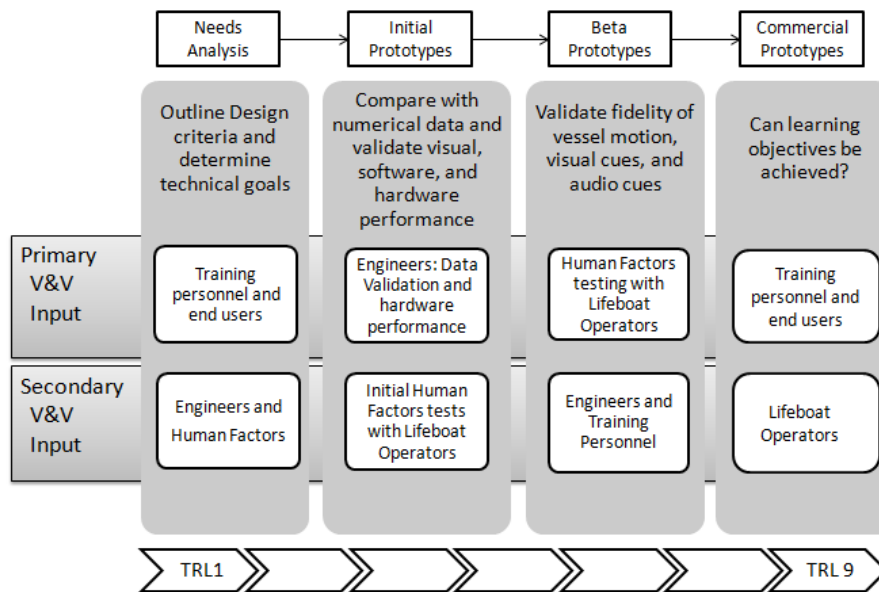


Figure 2: VV&A involvement at stages of development

System architecture was selected based on research into available architecture framework and the alignment with technical goals. Early design requirements determined that the system had to be designed to be modular and scalable and allow for interconnectivity with other marine simulators and allow for multiple types of vessels to be modeled. As the system would comprise of multi-channel visual systems, an instructor station, complex numerical models, and detailed visual environments, the ability to exchange information between simulator components efficiently was critical. The need for distributed simulations and high performance led to the selection of a High Level Architecture (HLA) model with the use of a Run Time Infrastructure (RTI). The HLA-RTI environment is designed to allow for re-use of simulator federates as well and modular development of federate components (Steele, 2000). This facilitated the design methodology as federates such as numerical models and image generation environments would be worked on by independent teams. These federates could then be integrated into a common Federation Object Model (FOM) for testing. Adopting the HLA approach also provided guidelines on how software development would be structured. The engineering team established internal development and testing guidelines around the HLA Federation Development and Execution Process (FEDEP) model. The FEDEP model also links federation design to the VV&A process providing a structured means to evaluate the software throughout the design process based on the continuous evaluations performed by engineers and end users.

Through all stages of development, the technology is continually evaluated against a Technology Readiness Level (TRL) scale to gauge the technical maturity of the simulator as it progressed from an early stage prototype to a system that was tested in an operational setting. As the technology moves from a basic concept (TRL1), to a laboratory tested prototype (TRL5), to a system tested in an operational setting (TRL9), testing can be performed to determine where the technology lands on the scale. The design team is able to evaluate system readiness based on the expected performance of the simulator at different TRLs and the testing methodology changes from internal testing to operator testing as the technology progresses along the scale.

Adoption of training solution

As the simulator progressed to a mature technology, the system was introduced to end users through trial training programs and evaluation studies. Using a simulator for lifeboat coxswain training was a non-conventional training approach which had never been performed. Testing was required to determine how the simulation would be received by instructors and students and to assess how effectively the simulation achieved training outcomes. Tests were performed in operational environments including training institutes using trial course curriculum. Performing studies with end users through trial training programs is considered an integral part of the design methodology as it validates the simulator design outcomes based on goals derived from the initial needs assessment, which is the

ability to achieve learning objectives. An important outcome of this final step is identifying additional learning objectives which can be achieved if new features are added to the simulator. This requires revisiting initial design goals with the ultimate result being a technology that is designed to provide the most training value to the end user.

The verification and validation performed by end users, trainers, and subject matter experts is continuous which makes the adoption of the technology less complicated when as it reaches a stage of maturity where it can be tested in an operational setting. If the technology is successful at achieving learning objectives and is validated through studies in trial training programs, the result is justification that the technology meets the original design purpose. The final goal is accreditation of the simulator for use in lifeboat operator training.

DERIVING TECHNICAL DESIGN REQUIREMENTS

Simulators in the marine industry are normally classified as Full Mission (maximum realism), Multi-Task (procedural trainers), or Part-Task (single-task trainers). The type of simulator which is best suited for a particular application is determined by the degree of presence required to generate a desired learning experience. General performance requirements for simulators used in mandatory training programs are provided by IMO in Section A-I/12 of the STCW Code. The general IMO requirements are transformed into detailed performance requirements by individual administrations. In many cases, administrations accept performance standards articulated by Classification Societies, most notably Det Norske Veritas (DNV), and have devolved responsibility for type approval to the Classification Societies. The approach taken by administrations to approve simulators is not unlike the process in which life-saving appliances are approved. For each major simulator type, e.g.: Propulsion Plant, DNV has defined the minimum performance requirements for Full Mission, Multi-Task and Part-Task variants. Furthermore, DNV has determined the training applications for which each variant of simulator could be used. For new simulator types, DNV can issue a Class S (special) designation indicating that the simulator meets the performance requirements for a particular application. In the case of the lifeboat simulator, the desired outcome was a simulator accredited as Class S based on the ability to achieve learning objectives outlined by IMO model courses and the STCW. Section A-I/12 of the STCW Code requires that simulators must have the following attributes in order to be used in mandatory training programs:

- Be suitable for the training tasks and objectives;
- Simulate the operating capabilities, limitations, and faults (errors) of relevant equipment, to an appropriate level of physical realism;
- Have sufficient behavioral realism to allow a trainee to acquire the target skills;
- Be capable of affording a variety of relevant operating conditions, including emergency and hazardous situations;
- Have a physical interface through which a trainee can interact with the equipment, the simulated environment, and the instructor; and
- Provide a means for an instructor to control, monitor and record the simulated exercises in order to facilitate an effective debriefing with a trainee.

A review of the IMO requirements reveals that they are based upon the key concepts of the learn-by doing process and the process of inducing presence in virtual worlds. From these requirements, performance objectives were identified to evaluate technical outcomes through the VV&A process. The following is summary of the categories of the simulator system which were identified and how suitability was evaluated for each. Figure 3 summarizes the key systems which are continuously evaluated through VV&A testing.

Building effective cueing systems

Determining the physical fidelity of the simulator included evaluating how effectively the simulation environment immersed the trainee in a training scenario through the use of visual, audio, and motion systems. Key events such as recognizing when the lifeboat touched the water using visual and haptic cueing were also critical to achieving learning objectives. Human factors studies were performed to evaluate how effective the simulator was in achieving simulator presence, or the sense of realism, when stimulated by the the cueing systems. Presence is commonly measured by the amount or immersion and involvement a trainee experiences when conducting training exercises (Witmer et al. 2002; Witmer et al, 1998; Wright et al., 2002). Simulation studies have been performed on virtual environments and the researchers applied the approaches to evaluating the cueing systems for the lifeboat simulator. The studies evaluated the performance of the marine equipment, the fidelity of the visual environment, and the

realism of the audio and radio system. The goal was to create an environment that made the trainee feel they were in the cockpit of a lifeboat while making sure that equipment behaved as expected, with realistic limitations, to provide the trainee with the same challenges they would face during a real lifeboat launch. Evaluation of cueing systems was performed with subject matter experts with significant experience in operating lifeboats.

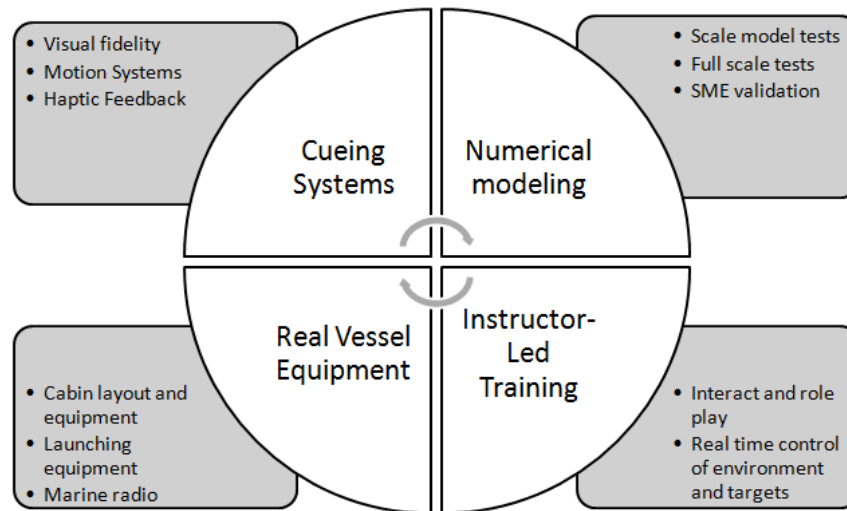


Figure 3: Established Design Criteria

Achieving high fidelity numerical models of small craft behavior in wave environments

Inadequate numerical fidelity would degrade the training environment and not allow for specific learning objectives to be achieved. The modeling of a small vessel in complex wave environments required a specialized modeling technique. Unlike large vessels with higher inertia, the motion of small crafts such as lifeboats is dependent on the position of the vessel on the wave and the instantaneous force on the vessel due to waves, wind and current. Complex 3D wave models were developed to provide localized wave particle velocities and accelerations on a detailed localized mesh to generate accurate visual and numerical representations of the wave environment. Modeling techniques focused on developing high fidelity numerical models to couple the localized motion of the vessel with the 3D wave environment. The numerical fidelity was validated with scale model and full scale tests performed at recognized research facilities such as the National Research Council of Canada's Ocean, Coastal and River Engineering (NRC/OCRE) Center to ensure a high level of accuracy was achieved. Testing was also performed with subject matter experts including coxswains with significant experience in operating lifeboats in launch and recovery exercises to ensure low speed maneuvering behaviors were representative of the real vessel.

Integrating real vessel equipment

To achieve the level of realism to have the simulator accredited for use in training, real vessel equipment was required to be used. The simulator design interfaced real marine equipment including brake release, throttle, steering, air systems and gauges. Components such as the vessel hydrostatic interlock and hook release system had to be accurately modeled to allow for timing of vessel launch and determining how to use override mechanisms if systems failed, which are critical elements of the training program. Radio equipment had to look and behave like marine grade components and allow for interaction with an instructor during training scenarios. Testing focused on determining if the real equipment behaved as expected and triggered events in the simulation appropriately.

Building an intuitive instructor interface

An instructor station Human Machine Interface (HMI) was required to allow for creation of scenarios, control of environmental conditions, introduction of faults and logging of simulator information for trainee evaluation and debriefing. The system had to allow for real time control of events and interaction with the trainee was to be provided through a radio as the instructor role-played as a character in the scenario. The ease of use of the HMI was

continuously evaluated to ensure the instructor could monitor the simulation as needed and easily control conditions and insert faults in real time while not compromising the integrity of the simulation environment.

Accredited Simulation Technologies

In 2007, the lifeboat simulator was accredited by DNV as a Class S technology that could be used for lifeboat operator training based on STCW training requirements. Accreditation was achieved based on the simulator's ability to achieve learning objectives and evaluation of the numerical environment, the visual and audio cueing systems, and the accuracy of the physical controls and layout of the simulator. This outcome, in addition to the acceptance and adoption by end users, validates that the design methodology was able to achieve the desired outcome of building a simulator that could be used to train lifeboat operators.

SIMULATION OUTCOMES TO DATE

Design of simulation technologies for offshore oil and gas training started with the development of a lifeboat simulator concept in 2003. Over the past decade, development has continued on the core technology architecture to create a scalable platform that can be configured to multiple small craft vessel types with variations in visual systems, layouts, and motion systems dependent on the training applications. The modular and scalable backbone has also allowed for expansion to training applications outside of oil and gas, including high speed craft. The design methodology was applied in a similar fashion for each variation, with cueing systems and simulation features designed based on identified training needs and with continuous VV&A performed to ensure the technology outcomes match the design purpose.

Lifeboat Simulators

Through several design iterations a lifeboat simulator was achieved that comprises of an immersive training console equipped with a surround visual system, real vessel equipment, and validated numerical models. The first lifeboat system was deployed at the Marine Institute (MI) Offshore Safety and Survival Centre (OSSC) in St. John's, NL, Canada and is used for lifeboat operator training. Simulator consoles have been developed for davit launch and free-fall launch training. The cueing system has been extended to include a six degree of freedom (6DOF) motion platform to emulate the entry of a free fall lifeboat as it enters the waves and provide a sensation of motion in high sea states. The lifeboat simulator continues to be expanded with technical development focusing on improving cueing systems and adding performance tracking and evaluation toolkits to allow for autonomous training. Environmental models and physics have also been expanded to model the multi-body interaction of ice pieces to create scenarios for evacuations of lifeboats in ice-covered waters, which is an exercise that is required to be rehearsed as oil and gas operations extend to the Arctic (IMO, 2009). Studies performed using the simulator for operations in ice concluded that trainees who ran trials in the simulator prior to performing live exercises outperformed those who used conventional lifeboat training (MacKinnon et al., 2012).



Figure 4: Davit Launch Lifeboat Simulator

Fast Response Craft Simulator

As the lifeboat simulator prototype matured, the development team identified an additional need to train operators of high speed planning craft which are used in offshore oil and gas emergency evacuation and response procedures. These vessels are also used by coast guard and military personnel for search and rescue and patrol operations. The HLA architecture allowed for the replacement of numerical models and physical controls to create an environment that was representative of a Fast Response Craft (FRC) which simulated the motion of a vessel which could achieve speeds up to 40 knots. The scalable HLA backbone was used to add federates for radar simulation and navigational equipment, while utilizing federates that existed in the lifeboat simulator including the visual environment, motion platform, audio system and instructor station. The VV&A process including testing with operators of high speed craft, including coast guards, to validate the fidelity of the motion models and to determine if the simulator could be used for specific training operations including night navigation and performing search and rescue patterns.

Expanding Launch and Recovery Functionality

It is well known that several lifeboat accidents have occurred during recovery exercises where the lifeboat is re-attached to the davit by attaching suspended rings on wires to the lifeboat hooks. Furthermore, the launch and recovery of FRC's for search and rescue and patrol operations has been identified as a high risk training exercise. (HSE, 2006). Using the HLA architecture, the development team has been able to create workstations for hook operators and davit operators to allow for a multi-person simulation with individuals at hook stations, operating davit controls, and maneuvering the vessel. The training environment allows for practice of maneuvering the vessel to a recovery zone, timing of re-attachment of the hooks, and inspection of the equipment prior to recovery. Real hook and ring components are utilized to allow for trainees to operate and inspect the equipment that would be used in a real world situation. The development of launch and recovery simulator add-on is an example of a re-analysis of the original design goals of the simulator, with the new development focusing on building a system that would allow additional learning objectives to be achieved. The design methodology will continue to be used to further enhance the capabilities of the simulators.

SUMMARY AND CONCLUSIONS

The purpose of this effort was to illustrate how proven simulation development techniques can be applied to create novel simulations. The development of a simulator to train offshore oil and gas personnel included adoption of simulator architecture and design methodologies that were commonly used to build military and flight simulators. The application of these technologies and practices to build a small craft simulator integrated domain expertise in harsh environment modeling, small vessel modeling, and survival craft emergency response training to create a simulation-based training solution. As the technology would change the pedagogy of training of lifeboat operators, the development process included an active VV&A to ensure that technical outcomes matched training requirements and the simulator design was shaped based on the ability to complement existing training practices. The authors have identified the following as lessons learned through the development history that has been discussed.

1. A design methodology for simulator development can be found through research of comparable technology development and marine practices. It is suggested the methodology be continuously evaluated when in practice and the process be tailored to the specific application. In the case of building a lifeboat simulator, the determination of design criteria and the level of involvement of field experts and training experts differed in various stages of development.
2. The development of simulator environment for niche applications requires specialized domain expertise to create a high fidelity and highly immersive simulation environment. The specialized numerical models and visual models for the lifeboat simulator required a combination of research expertise in small vessel modeling and validation with users with significant operational experience.
3. Traceability throughout the design process is a project management practice and an engineering design practice that results in outcomes which match identified needs. A detailed needs analysis at the start of the exercise directs technology development, and the effective use of a VV&A process results in a simulator that is built for purpose and which can be adopted by end users.
4. Using modular simulator architecture improves scalability. The adoption of HLA provided a technical backbone that could be re-used and re-shaped and FEDEP models provided a means to structure simulator development.

As a more general analysis, the development of simulation technologies to train offshore oil and gas personnel for emergency simulator shows how simulation can be used to prepare personnel for scenarios which are too dangerous or logistically challenging for live exercises. The methodologies presented and outcomes achieved are evidence of how M&S continues to expand the level of training available to industry.

ACKNOWLEDGEMENTS

Financial support of the research program via the Atlantic Canada Opportunities Agency Atlantic Innovation Fund (AIF), Natural Resources Canada's Program for Energy Research and Development (PERD), the National Research Council Industrial Research Assistance Program (NRC-IRAP), the Government of Newfoundland and Labrador Department of Innovation, Business and Rural Development, and Petroleum Research Newfoundland and Labrador (PRNL) is acknowledged with gratitude. The authors also thank the people at NRC/OCRE who conducted scale model and full scale tests of a variety of small crafts in harsh environment. The authors would also like to thank the staff and graduate students at Memorial University and Virtual Marine Technology who assisted in development.

REFERENCES

- Boosman, Frank, (2007). *Simulation-Based Training: The Evidence Is In*, published on the Website of Chief Learning Officer, Retrieved May 14, 2014.
- Health and Safety Executive (HSE), prepared by MB Mechanical Consultants (2006). *Fast Rescue Craft Recovery by Installation Crane*, Research Report 447, Phase 2 Study.
- The Institute of Electrical and Electronics Engineers, Inc. (2010). *IEEE Standard for Information Technology - Protocols for Distributed Interactive Simulation Applications*, IEEE Std 1516-2010, 345 East 47th Street, New York, NY 10017-2394, USA, 2010.
- International Maritime Organization (IMO), Resolution A .1024(26), (2009). *Guidelines for Ships Operating in Polar Waters*, Adopted December 2009
- International Maritime Organization (IMO), Resolution A.1079(28), (2013). *Recommendations for the Training and Certification of Personnel on Mobile Offshore Units*. Adopted on 4 December 2013, Agenda Item 10.
- Mackinnon, S., Patterson, A., Billard, R., Power, J., Veitch, B., Power-MacDonald, S., Baker, A., Simoes-Re, A. (2012). *Designing Simulators to Maximize Knowledge Transfer*, International Marine Simulator Forum - Marsim 2012.
- Masys, A.J.; van Emmerik, M.L.; Bouc, P. (2006). *Verification, Validation and Accreditation (VV&A) – Leveraging International Initiatives*. In *Transforming Training and Experimentation through Modelling and Simulation* (pp. 10-1 – 10-10). Meeting Proceedings RTO-MP-MSG-045, Paper 10. Neuilly-sur-Seine, France: RTO.
- Modeling and Simulation Coordination Office (MSCO) (2014). *Verification, Validation and Accreditation Recommended Practices Guide*, Retrieved May 14, 2014, http://msco.mil/VVA_RPG.html
- Patterson, A. (2007) *Lifeboat Simulation – The Safe Alternative*. Proceedings of the Company of Master Mariners of Canada.
- Ruddle, R., & Lessels, S. (2006). *Three Levels of Metric for Evaluating Wayfaring*. Presence, Vol. 15, No. 6, 637–654.
- Standards of Training, Certification, and Watchkeeping for Seafarers 2011 Addition, Including 2010 Manila Amendments (2011).
- Steele, J.; (2000). *The Use of DIS and HLA for Real-Time, Virtual Simulation – A Discussion*; RTO NMSG Conference on “The Second NATO Modelling and Simulation Conference”, Shrivenham, UK, 24-26 October 2000, and published in RTO MP-071.
- Veitch, B. Billard, R., and Patterson, A. (2009). *Evacuation training using lifeboat simulators*. By invitation, Sea Technology, April 2009..
- Veitch, B., Billard, R. and Patterson, A. (2008). *Evacuation training using immersive simulators*. Proceedings, International Offshore and Polar Engineering Conference, ISOPE, Vancouver, 1:223-227.
- Witmer, B., Sadowski, W., & Finkelstein, N. (2002). *VE-Based Training Strategies for Acquiring Survey Knowledge*. Presence, Vol. 11, No. 1, 1–18. Presence, Vol. 10, No. 4, (2001), 345–358.
- Witmer, B., & Singer, M. (1998). *Measuring Presence in Virtual Environments: A Presence Questionnaire*. Presence, Vol. 7, No. 3, 225-240.
- Wright, N., & Cohn, A. (2002). *Enhanced Presence in Driving Simulators Using Autonomous Traffic with Virtual Personalities*. Presence, Vol. 11, No. 6, 578–590.