Lifeboat Launching and Clearing in Pack Ice Conditions

PRAC Project No: C8-08

Final Project Report

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Summary

Improving the state of knowledge of lifeboat launching and clearing in pack ice conditions was one of the priority research needs identified over two years ago by industry stakeholders during the offshore safety Community of Interest facilitated by PRAC. This reflected the interest in the operability limitations of existing lifeboats in pack ice, as well as the recognition that while such ice conditions do not occur frequently in the vicinity of current projects offshore Canada, their occasional occurrence can have significant impact on operations.

The project proceeded largely in accordance with the original two-year plan. Five co-op engineering students and one graduate student have worked on the project. These personnel resources were complemented by project engineers from the Principal Investigator’s AIF project team and project engineers from the industry partner (VMT).

Objectives and outcomes

The main goal of this project was to develop best practices in launching and operating lifeboats in pack ice. The original goal did not change during the two years of the project. Achieving the goal required two steps: establishing performance limitations and corresponding best operating practices, and incorporating the best practices in a training simulator to facilitate knowledge transfer to industry personnel.

Measurable outcomes included:
(1) Mapping the performance limits of lifeboats during launching into pack ice and clearing the installation. This includes limits imposed by environmental conditions and structural integrity.
(2) Identifying the faults that can occur during the launching and clearing process in ice.
(3) Developing procedures that constitute best practices for launching lifeboats into pack ice and clearing an installation.
(4) Incorporating the performance limits, faults, and best practices in a desktop and immersive simulation environment to facilitate knowledge transfer and training.
Progress

YEAR 1:

Activity:
(1) Map the performance limits.

(1.1) Environmental conditions impose limits on the lifeboats’ ability to launch and to make way. The limits imposed by pack ice in various concentrations, thicknesses, and floe sizes were investigated using model tests in an ice tank. The results of this and related performance evaluation work provided the basis for mapping environmental performance limits. Note that this work included launching model lifeboats in pack ice and then driving the lifeboat through pack ice while making a variety of measurements.

Outcome:
Map of operability performance limits imposed by ice and other environmental conditions.

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Map of operability performance limits imposed by ice and other environmental conditions.

The report “Performance Limits” (reference 1) documents the outcomes of this task.

Anticipated Start Date: Month 1
Anticipated End Date: Month 2
Progress: Completed (by co-op student Matthew Snow). Documented.

YEAR 1:

Activity:
(1) Map the performance limits.

(1.2) Structural integrity is another limiting factor on lifeboat performance. Structural integrity may be compromised in several conditions, such as in pack ice fields under compression, where the concentration is high and the loads transmitted through the field are high, or when the boat is launched onto an ice floe. Another condition is when the lifeboat is operating at speed and collides with an ice floe. This will be evaluated based on structural design considerations and complemented by existing measurements made during model tests, and measurements made during full-scale trials in the Winter 2007 and 2008/9. The structural integrity assessment will help us establish design and performance criteria for pack ice operations, taking into account the risk of loss of structural integrity.

Outcome:
Map of operability performance limits imposed by structural integrity.

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Map of operability performance limits imposed by structural integrity.

The reports “Tensile Tests” (reference 2), “Hydraulic Ram Tests” (reference 3), “Pendulum Tests” (reference 4), “Lifeboat Field Trials” (reference 5), and “Mathematical Model: Lifeboat-ice Impact” (reference 6) document the outcomes of this task. Note that this work was documented too late in the project to be incorporated in the simulation environment.

Anticipated Start Date: Month 3
Anticipated End Date: Month 12
Progress: Completed (by graduate student Allison Kennedy)
Month 20
Month 24
Documented.

YEAR 1:

Activity:
(1) Map the performance limits.

(1.3) Evacuation is initiated only in response to an emerging hazard, usually a major hazard such as fire and explosion arising from a process accident, or loss of structural or watertight integrity due to a collision or a consequence of an escalating fire/explosion. The immediate consequences of the emerging hazard can include smoke and toxic gas releases, radiant heat and overpressure, for example. While it was not proposed to study any of these under this proposal, it was considered important to frame the evacuation process in terms of credible scenarios so that the context is realistic.

Outcome:
Identification of major hazard scenarios under which evacuation in ice might be required.

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Identification of major hazard scenarios under which evacuation in ice might be required.

The report “Hazard Scenarios and Failures” (reference 7) documents the outcomes of this task.

Anticipated Start Date: Month 1
Anticipated End Date: Month 3
Progress: Completed (by co-op student Matthew Snow). Documented.
YEAR 1:
Activity:
(2) Identify the faults: failure analysis.
As described above, evacuation is initiated in response to an emergency so it is useful to consider launching and clearing an installation in the context of credible hazard scenarios. This task involved identifying the failure scenarios during the launching and clearing phases of the evacuation process. It was deemed important to identify these failure scenarios. This helped identify the higher risk elements in the evacuation process in ice, and thereby focused efforts on strengthening these aspects through changes to design, equipment, procedures, and training.
Outcome:
Identification of launch and clearing faults.
The report “Hazard Scenarios and Failures” (reference 7) documents the outcomes of this task.
Anticipated Start Date: Month 4
Anticipated End Date: Month 12
Completed (by co-op student Matthew Snow). Documented.

YEAR 1:
Activity:
(3) Develop the procedures.
Coxswains on offshore installations are typically not exposed to a wide range of operating environments so do not build up a repertoire of experience-based expertise, such as tactics to use to maneuver through pack ice, or how to launch in pack ice in white-out conditions during a blizzard, or how slow to go through pack if one is to avoid puncturing one’s hull. This expertise was gathered using the project team’s knowledge of performance of lifeboats in pack ice and complemented by dedicated full-scale trials during the Winter 2008/9. An important source of operational knowledge was the small craft operators at OSSC who have experience with lifeboats in pack ice. Interviews with these instructors were very helpful. This task resulted in a catalog of safe operating procedures for credible evacuation scenarios in pack ice conditions.
Outcome:
Safe operating procedures for credible evacuation scenarios in pack ice.
The report “Launch Procedures” (reference 8) documents the outcomes of this task.
Anticipated Start Date: Month 1
Anticipated End Date: Month 12
Completed (by co-op student Matthew Snow). Documented.

YEAR 1:
Activity:
(3) Develop the procedures.
Likewise, operating procedures for dealing with faults will be described, focusing on the pack ice conditions.
Outcome:
Safe operating procedures for dealing with faults particular to operations in ice.
The report “Launch Procedures” (reference 8) documents the outcomes of this task.
Anticipated Start Date: Month 1
Anticipated End Date: Month 12
Completed (by co-op student Matthew Snow). Documented.
YEAR 2:
Activity:
(4) Incorporate the operations knowledge in a training simulator.
(4.1) The first task is to build the core elements into the simulation environment: characterize pack ice conditions (size, shape, distribution, relevant physical parameters); build a graphical model of pack ice floes; develop a mathematical model of floating pack ice and pack ice in waves, suitable for real-time simulation; develop a mathematical model of pack ice floe interaction with lifeboat and other floes, suitable for real-time simulation; implement these elements in a desk top simulation environment.
Outcome:
Model of lifeboat operations in ice in simulation environment.
Summary: A brief summary of the outcomes is presented below to complement the three reports that document this development (references 9A, 9B, 9C). The project team was able to successfully create a desktop simulation environment that simulated a lifeboat maneuvering and interacting with ice floe objects. The desktop simulator resides with VMT. The development team utilized a physics engine (PhysX by NVIDIA) to model an ice field in which ice-ice collisions and vessel-ice collisions could be detected and resultant forces calculated. The physics engine allows for placement of ice targets, association of material attributes (mass, material, friction coefficients), application of forces, and calculation of resultant ice and vessel movements.
The final desktop prototype includes the following functionality:
(i) An independent physics model of ice to ice interaction in 2D, with a field size of approximately 20 m x 20 m;
(ii) 3D visualization of the simulation with the Lifeboat Simulator’s Visual System using the Vega Prime Image Generation engine;
(iii) Incorporation of ice field modeling tools into the Lifeboat Simulator Instructor Station, allowing the instructor to generate an ice field based on size of ice targets and required ice field concentration;
(iv) Simulation of a lifeboat in a 3D environment using desktop controls for driving and maneuvering;
(v) Development of ice target visual models.
The proof of concept prototype provides an excellent platform for simulated ice modeling and small craft interaction. The real time performance of the simulation was achieved in the 3D environment using the physics engine. Bringing the proof of concept to a commercial prototype will focus on incorporating the physics models into the simulation math engine, extending the dimensions of the ice field and number of ice objects, and modeling motion in 6DOF.
Anticipated Start Date: Month 13
Anticipated End Date: Month 24
Completed (by joint VMT-PRAC project development team led by VMT). The outcome is a desktop simulator.

YEAR (2):
Activity:
(4) Incorporate the operations knowledge in a training simulator.
(4.2) The second task is to incorporate the knowledge from parts (1), (2), and (3) into the simulation environment to facilitate knowledge transfer. This includes credible hazard scenarios, critical faults and operating procedures.
Outcome:
Simulator training for lifeboat operations in ice.
Summary: A brief summary of the outcomes is presented below to complement the three reports that document this development (references 9A, 9B, 9C). The hazard scenarios and fault lists generated in the project will be utilized in the development of curriculum for simulation-based training for lifeboat operations in ice-covered waters. The project has reinforced the issues associated with lifeboat evacuation in ice including the ability to launch the vessel in ice-covered waters, maneuvering through pack ice, avoidance of danger, possible prolonged rescue times and possible damage to the vessel with
high speed. A trial training program (described more fully under the heading “Next steps” below) is being developed through a project funded by Transport Canada to assess trainee performance in ice. This trial program is utilizing outcomes of the Lifeboat Launching and Clearing in Pack Ice Conditions project. The study will compare test groups that will use the live boat and the simulation for similar training. Measurements will include the following:

- Path length to ‘safety zone’
- Time to ‘safety zone’
- Number of boat/ice collisions
- Mean and peak contact speeds at collision
- Location on boat/ice collisions

As the ice modeling is brought into VMT’s Survival Quest Product line, curriculum will be developed for a simulation-based training program for ice operations. The ice floe models, faults, and events specific to ice fields will be added to the instructor tools to allow for creation of the hazard scenarios identified in this study.

Anticipated Start Date: Month 13
Anticipated End Date: Month 24

The continued development of the ice environment in a simulator training environment, as well as the accreditation of the training, is the subject of a new project that was catalyzed by the subject PRAC project.

Next steps:

VMT has identified significant interest from industry to support adding ice interaction models to the Survival Quest Lifeboat Simulator Product line. Oil and gas and shipping operations are quickly being extended to the Arctic. With increased activity in these environments, the need for emergency preparedness and safety training will also increase. VMT is currently seeking industry support to bring ice models into the simulator. The proof of concept development of the ice modeling tools and vessel-ice interactions provide a valuable starting point. Building a simulation-based training program for operation in ice-covered waters will require the following:

- Incorporating the multi-body ice interaction models into the full mission simulator architecture;
- Extending the models of vessel-to-ice and ice-to-ice interactions to 3D mathematical models;
- Developing visual models of pack ice fields of varying levels of ice cover, allowing for variation in ice density, ice thickness, and hardness;
- Extending modeling of vessel interaction with bodies of ice and resultant damage to the vessel based on varying speed and ice conditions.

In addition to refining the technology, effort will be placed on development of training curriculum for training of evacuations in ice-covered waters. Curriculum will focus on developing representative training scenarios to practice route planning and decision-making, and to provide awareness of the impact of speed on maneuvering and vessel damage with ice interaction.
Dissemination and technology transfer and publication
As described above, task 4 is the main means of knowledge mobilization. Rather than publishing the results of this work, the knowledge will be disseminated via a training mechanism.

Funding
1. Graduate student Allison Kennedy was supported in part through this PRAC project. More than 50% of her financial support was derived from other sources. Allison was also awarded a graduate studies scholarship.
2. This PRAC project was embedded in a large project team that included the PI’s AIF project and a major research program based at IOT under the direction of Antonio Simoes Re. The overall leverage for the PRAC project was very large. There was considerable depth in this group for co-op and graduate student mentorship, as well as for project management, and this proved to be useful. The project was driven by ‘market’ needs via the interaction of the project group with VMT. VMT was involved with the project from its inception. The plan was that VMT would take on a more substantial role in the second year of the project, particularly in the knowledge mobilization elements associated with training simulators.
3. Since this PRAC project started, the main project leaders (Veitch, Simoes Re) helped to catalyze a related JIP, which is also organized and managed by PRAC, which has as its ultimate goal the development of evacuation craft that can operate in a range of ice conditions. This new JIP complements PRAC’s very first JIP, which was in partnership with VMT and focused on the development of a lifeboat launch simulator. This original JIP completed successfully at the end of 2009. There is potential for the outcomes of these two JIPs to be combined to reinforce each other in future work.
### Employment summary:

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<th>contributions</th>
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| Allison Kennedy | Graduate student (Master of Engg.) May-present | Material Tests  
Purpose: To determine the tensile strength of lifeboat fibreglass and how it is affected by the following factors: material lay up, temperature, heat treatment and pre-stress.  
Approach: Conducted tensile tests on a set of fibreglass specimens. Some specimens were pre-treated while others were not. Results were analyzed using a half-fraction factorial design method.  
Hydraulic Ram Panel Tests  
Purpose: To determine the limits of lifeboat fibreglass in terms of maximum force, impact energy and pressure prior to failure and how the limits vary with panel size.  
Approach: Tested different sized fibreglass panels until failure. Recorded force and panel displacement during impact. Computed impact energy for each panel size.  
Pendulum Impact Tests  
Purpose: To determine controlled ice impact force values. To ensure the full scale lifeboat’s physical and electronic state was adequate for field testing.  
Approach: Conducted laboratory impact tests on the full-scale lifeboat in which ice pieces were impacted into an instrumented impact panel installed in an instrumented lifeboat from various angles. Load cells recorded impact force while LVDT’s measured both the global and local displacement of the lifeboat.  
Full Scale Field Trials  
Purpose: To determine realistic ice impact force values in both thin level ice and broken heavier pack ice conditions. To test operational capability of remote control system used to maneuver the lifeboat.  
Approach: Field tested instrumented (full-scale) lifeboat in level and broken pack ice conditions. Lifeboat was driven at half and full throttle into both ice types. Impact force, local deflection as well as global and local accelerations were measured for each impact.  
Mathematical Model  
Purpose: To develop a mathematical model to predict impact forces between a conventional lifeboat and ice.  
Approach: The model is based on a simple energy balance between the lifeboat and ice. It assumes a relationship exists between ice pressure and contact area. The model was used to predict forces resulting from
impact speeds tested in field trials and compared to recorded values. This model can be modified to predict impact forces at various hull locations as well as various ice conditions (strengths).

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| Matt Snow        | Co-op (engineer) student      | Jan-Apr, 2008   | (1) Researched and documented the likely hazards and faults that lifeboats would encounter during launching and operating;  
(2) Summarized IOT/MUN experimental research on the performance of lifeboat operational limits in pack ice;  
(3) Consulted with experienced lifeboat operators at MI/OSSC to develop recommendations for additions/changes to current launching and clearing procedures to accommodate pack ice conditions. |
| Chelsea Davis    | Co-op (engineer) student      | May-Aug, 2008   | (1) Worked with David Murrin (academic advisor on structural engineering issues) and Allison Kennedy (graduate student) on destructive experimental testing of fiberglass lifeboat panels;  
(2) Used hydraulic ram to test fiberglass to failure and determine load limits. Note that technical problems were encountered with lab equipment that truncated the test program. |
| Matthew Mine-Goldring | Co-op (engineer) student | Jan-April 2009  | (1) First iteration of incorporating the ice into a stand-alone desktop simulation of lifeboat operations. Target characteristics based on previous experimental work (see performance limits in ice referenced above). This work was continued by Jason Forbes. |
| Jason Forbes     | Co-op (engineer) student      | May-Aug, 2009,  | (1) Co-located at VMT to advance first iteration ice simulation (see above) and embed it into VMT's lifeboat simulator. This included integrating ice simulation framework, pack ice defined in both the physics engine and graphics engine, random ice placement, synchronizing the physics and graphics, and realistic collision interaction in a 2D environment.  
(2) Created a simulation with the graphics engine and a physics engine (PhysX). This work was continued by Donovan Benoit. |
| Donovan Benoit   | Co-op (engineer) student      | Sep-Dec, 2009   | (1) Integrated simulation work done by Jason Forbes into the Portico RTI code base (FRC simulator). Involved replicating the physics engine development into the actual simulator, and integrating the ice simulation with the instructor station. This co-op student was assigned to the PRAC project, but was financed from another source. |

**Additional human resources summary:**

Matt Kennedy & Nuno Pereira  
Digital graphic artists (AIF)  
Matt Kennedy and Nuno Pereira are digital graphics artists employed on the PI’s AIF project. Their...
Recommendations: Next steps

As the PRAC Lifeboat Launching and Clearing in Pack Ice Conditions project reached the midway point last year, we decided to engage Transport Canada on the regulatory front. Note that engaging Transport Canada (the Canadian regulatory body with authority over the matter of marine safety) was something we were advised to do at the outset of the PRAC JIP (Lifeboat Virtual Trainer) project by industry representatives (and in particular by David Day of HMDC).

This next step is being undertaken under the leadership of Antonio Simões Ré (IOT) with Brian Veitch (MUN), Jonathon Power (IOT) and Tony Patterson (VMT) as co-applicants. We have secured $110,000 of funding from Transport Canada for 1 year. The project is entitled “Validation and Accreditation of Small Craft Simulator Training (VAST)” and it aims to examine the utility of the lifeboat simulator in light of the national and international maritime standards that are being changed to accommodate simulation training if it can be demonstrated to be effective.

This is an important initiative and the PRAC Lifeboat Launching and Clearing in Pack Ice Conditions project and the PRAC Virtual Trainer project have been important catalysts. That is, PRAC’s investment in the early stages have been very important enablers. In order to validate and subsequently accredit lifeboat simulation technology and training outcomes, a suitable training curriculum is required. This has been undertaken by VMT using outcomes from this PRAC project (Lifeboat Launching and Clearing in Pack Ice Conditions) as the basis of the curriculum. The simulator technology that serves as the platform for the knowledge mobilization has likewise been developed through the PRAC JIP (Lifeboat Virtual Trainer) and the
corresponding AIF project led by Brian Veitch.

This parallel project sponsored by Transport Canada is in progress and is due to complete at March 31 2010. It will essentially involve comparative trials between a group of trainees who receive simulator training and a group of trainees who receive conventional training and then both groups will operate an actual lifeboat in ice field. Briefly, the status of this project is that the experiments have been designed and the ethics case has been approved. VMT is working with support from the PI’s AIF project team on developing the simulation environment to a level that will enable the comparative exercise to be executed. The project team has submitted a proposal to Transport Canada to continue with a second phase of this project in the new fiscal year.

List of referenced project reports

1. Performance Limits, Matt Snow.
2. Tensile Tests, Allison Kennedy.
5. Lifeboats Field Trials, Allison Kennedy.
8. Launch Procedures, Matt Snow.
9A. Computational Simulation of Lifeboat Interaction with Pack Ice, Matthew Mine-Goldring.
9B. Simulation of Lifeboat Interaction with Pack Ice I, Jason Forbes.
9C. Simulation of Lifeboats in Ice, Donovan Benoit.