SARex2

Surviving a maritime incident in cold climate conditions

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1 EXECUTIVE SUMMARY

To comply with the IMO Polar Code requirement regarding survival in a rescue craft until rescue or for a minimum of five days has proved to be a hard and complicated endeavor. Multiple mechanisms are at play and interact. As a result, survival is not only about providing the correct equipment with the right functionality, it is also about physical and mental robustness and the ability to conduct the right tasks for the duration of the stay.

The SARex exercise proved that the margins determining survival are very small and there is no room for error. Strong leadership is essential, and the rescue craft captain's knowledge and experience are critical factors for success. This is currently not addressed in the standard maritime training regime.

Maintaining an adequate body temperature is essential to mitigate the effects of hypothermia. This can be achieved by reducing heat loss. Maintaining a sustainable heat loss is a result of both the habitable environment provided by the rescue craft and the insulation provided by the personal protective equipment. As a result, there are strong dependencies between the functionality provided by the rescue craft and the functionality provided by the personal protective equipment.

Today's requirements with regard to water and rations do not seem to be adequate for a five-day survival scenario. All exercise participants lost about 2 kg of body mass during the first 24 hours in the rescue craft. This was mostly due to small water rations. The effect of dehydration will result in reduced blood circulation, causing freezing of extremities and loss of motivation and cognitive abilities.

Prevention of the development of fatigue and maintaining cognitive abilities are key elements to success, as survival for an extended period (e.g. five days) is not a 'waiting game'. It is essential to continuously perform all the small tasks required for survival. Preventing the development of fatigue and maintaining cognitive abilities are closely linked to other mechanisms at play, e.g. seasickness, dehydration, hypothermia, energy level and pain level. A minimum degree of comfort on board the rescue craft will be required to survive for a prolonged period of time in that environment.

One element of the SARex was the evacuation of a lifeboat by helicopter. Evacuating a large number of personnel by helicopter proved not to be efficient. For larger incidents involving many casualties, marine SAR resources are essential for an efficient rescue.

The exercise also tested Emergency Position Indicator Radio Beacons (EPRIBs). It is evident that the functional range of the 121.5 MHz beacon is limited to a few nautical miles. Based on the tests carried out by SARex, a reduced duty cycle on the EPERB does not interfere with the direction-finding abilities on the rescue vessel.

It is, however, clear that, with today's technology, only transmitting a carrier with no information coded into the signal is not very efficient. Utilizing technology where the RF signal (radio frequency signal) also contains information, e.g. an automatic identification system (AIS signal), is more efficient. Technology like that described above will not only increase the battery time or transmission power. It will also enable the SAR organization to obtain the position of the lifeboat/life raft, either through the information coded into the signal or by homing in on the signal.

It should be noted that the authors of the main part of this report are responsible for the analysis and the statements made in the report. The report may not reflect the opinion of the sponsors and the participants involved in the exercise.

2 PREFACE

Following a successful search and rescue exercise (SARex 1) north of Spitzbergen in April 2016, the Norwegian Coast Guard, the Norwegian Maritime Authority (NMA and University of Stavanger decided, in late 2016, to conduct a SARex 2 exercise to investigate whether improved rescue equipment would substantially increase the probability of 'long-term survival' in a lifeboat or a life raft employed in Arctic waters.

The scenario of concern is as for the 2016 SARex 1 exercise: A mass evacuation from a cruise vessel in distress in Arctic waters. Bearing in mind the potential catastrophic outcome of such an event, it is of general interest to study and train on how survival can be ensured over a time period that is sufficient for rescue vessels (for example Coast Guard vessels) to arrive with assistance.

The rationale behind their interest is that the NMA represents Norway in the International Maritime Organization (IMO), the International Organization in charge of the law of the sea. Representatives of the NMA have been instrumental in preparing the Polar Code (The International Code for Ships Operating in Polar Waters). As the Polar Code came into force on 1st January 2017, it is of key importance to see how the functional requirements of the code can be fulfilled. The 2016 exercise (SARex 1) documented that standard rescue means would not satisfy the requirements of the Polar Code and that improvements in equipment would be necessary.

The concern raised after the SARex1 exercise has been central in the ongoing discussions in IMO and the Norwegian Coast Guard wanted to continue to work with the academic institution in charge of SARex 1 (i.e. the University of Stavanger) to identify whether a scientific follow-up exercise could be arranged. It is the opinion of the Coast Guard that SARex 1 was particularly successful and that an exercise conducted jointly with the same academic institution would be seen as independent and the results trustworthy to be reported to industry and in academic papers. The conclusions would also be strengthened if this institution could independently ensure that the results from the exercises could be compared and reported in a format similar to that for SARex 1.

The concern raised after the SARex 1 exercise has initiated work in the IMO and among equipment manufacturers and, due to these efforts, there was considerable interest from academic organizations and industry participants in contributing to SARex 2.

The initiative taken by The Norwegian Maritime Authority and the willingness of a large group of relevant organizations to participate are much appreciated. The exercise gave the officers and the young cadets onboard KV Svalbard the possibility to train on the ultimate rescue operation: an operation we hope will never materialize. In particular, the Coast Guard appreciate the good relationship with the University of Stavanger. It is hoped that the results of the exercises will provide input to realistic guidelines for the implementation of the Polar Code.

KV Svalbard, 20th May 2017

Endre Barane, Commanding Officer

3 CONTENTS

4 SAREX 2

4.1 General

More marine activity is taking place in cold climate regions than ever before. Much of this activity is linked to passenger/cruise activities. A large number of vessels, ranging from large cruise vessels carrying thousands of passengers to smaller open boats taking tourists to local tourist destinations, are part of this development. For the Svalbard area, this activity is expected to increase in the coming years (Brunvoll, 2015). There is, however, limited understanding of the risks imposed by this activity and the requirements this activity imposes on the SAR suppliers.

The marine industry has traditionally functioned in a retrospective way, and regulations have been developed after large-scale accidents. These accidents can be regarded by many as black swans, as they have not been predicted or foreseen (Taleb, 2007). An example of this is the sinking of the 'unsinkable' vessel, RMS Titanic. The development of the IMO Polar Code International Maritime Organization, 2016) is an example of the contradiction, as it tries to mitigate an accident in the Arctic/Antarctic region before it has happened. Identifying and mitigating the effects of concern is a challenging endeavor.

The aim of this report is to discuss the data, findings and experiences from SARex 2 in relation to the requirements specified in the Polar Code regarding the equipment, staffing and training of personnel that may face the need to evacuate a ship in polar areas. The findings are based on gathered data material, workshops with the exercise participants and discussions with the captain and crew on board KV Svalbard.

SARex 2 is built upon the findings developed in SARex 1 (Solberg et al., 2016). The methodology utilized in both the planning and the execution phases of SARex 2, was developed in SARex 1. Most of the participating organizations/project partners have been involved in both SARex 1 and SARex 2.

4.1.1 Exercise organization

The exercise was organized by Knut Espen Solberg (GMC/DNV GL), in close cooperation with Ove Tobias Gudmestad (University of Stavanger) and Endre Barane (Norwegian Coast Guard).

Eivinn Skjærseth (Norsk Luftambulanse) was in charge of the development and execution of the medical tests/observations and documentation of the medical results.

The equipment manufacturers were given the freedom to modify their equipment to comply with the functional requirements defined in the IMO Polar Code and, at the same time, to be commercially competitive.

In addition to in-kind contributions from the project partners, the project obtained economic support from The Norwegian Maritime Authority (NMA), SARiNOR (Maritimt Forum Nord) and the University of Stavanger.

4.1.2 Exercise execution

The captain and crew on board KV Svalbard conducted the overall management of the exercise's execution, in close cooperation with Knut Espen Solberg. Professor Ove Tobias Gudmestad, University of Stavanger, was responsible for the scientific documentation during the exercise and the communication of the result to scientific institutions/academia.

4.1.3 Exercise location

The SARex 2 took place on 3rd to 4th May 2017 in Krossfjorden, a 28-km-long fjord (inshore) on the west coast of Spitzbergen on Svalbard, just north of Ny Aalesund. The SARex 2 was part of a one-week expedition on board KV Svalbard for the testing of equipment related to emergency evacuation of ships in polar waters.

4.1.4 Exercise objectives:

- Investigate the functional requirements as defined in the International Code for Ships Operating in Polar Waters (IMO Polar Code)
- Study the adequacy of modified lifeboats, life rafts and Personal Protective Equipment (PPE) for use in cold climate conditions
- Assess helicopter evacuation in a cold climate environment
- Assess the reliability of EPIRBs and Personal Location Beacons (PLBs) in a cold climate environment
- Train Norwegian Coast Guard personnel on emergency procedures in cold climate conditions, with particular reference to evacuation and rescue from cruise ships

4.2 Exercise participants

	Contributor	Institution
Organizers:	Knut Espen Solberg	GMC & University of Stavanger
	Ove Tobias Gudmestad	University of Stavanger
	Bjørn Ivar Kruke	University of Stavanger
Academia:	Eivinn Skjærseth	St. Olavs hospital HF, Trondheim
	Bjørn Carlsen	Rescue man, air ambulance
	Milan Cermack	Medical doctor, Newfoundland
	Konstantinos Trantzas	MSc student, University of Stavanger
	Daniel Kristoffer Johnsen Swart	MSc student, University of Tromsø
	Fred Schanke Hansen	UNIS Svalbard
	Robert Brown	Marine Institute, Memorial University, St Johns, Newfoundland
	Magne Petter Sollid	University of Tromsø
	Brian Murray	PhD student, University of Tromsø
Equipment manufacturers:	Andreas T. Laursen	Viking-Life
	Jørgen Dyholm	Viking-Life
	Jan Jaap Boot	Nor-Safe
	Lars Ove Seglem	Nor-Safe
Regulators:	Jan Erik Jensen	Petroleum Safety Authority
	Erik Johann Landa	Norwegian Maritime Authority
	Turid Stemre	Norwegian Maritime Authority
	Kristian Torkildsen	Norwegian Maritime Authority
	Rune Magne Nilsen	Norwegian Maritime Authority
	Jan Reinert Vestvik	Norwegian Maritime Authority
	Johan Iseskjær	DNV GL
Persons of interest:	Andreas Kjøl	Viking Ice Consultancy/Viking Supply Ships
	Marit Brandal	Innovasjon Norge
	Lars Vollen	SARiNOR/Maritimt Forum Nord
	Jahn Viggo Rønningen	Rederiforbundet (/SARiNOR)
	Jorodd Asphjell	Member of Parliament (AP)
	Lars Gunnar Dahle	Media/Journalist

4.3 International code for ships operating in polar waters (IMO Polar Code)

The IMO Polar Code is a set of functionally based rules to mitigate the additional challenges associated with operation in the Arctic/Antarctic region (International Maritime Organization, 2016).

4.3.1 Sources of hazards (Chapter 3)

The Polar Code considers hazards, which may lead to elevated levels of risk due to increased probability of occurrence, more severe consequences, or a combination of both:

- Ice, as it may affect hull structure, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks and malfunction of safety equipment and systems;
- low temperature, as it affects working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems;
- extended periods of darkness or daylight as they may affect navigation and human performance;
- high latitude, as it affects navigation systems, communication systems and the quality of ice imagery information;
- Lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks, with increased potential for groundings;
- Remoteness, causing limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response;
- potential lack of experience in polar operations among the ship's crew, with potential for human error;
- potential lack of suitable emergency response equipment, with the potential for limiting the effectiveness of mitigation measures;
- rapidly changing and severe weather conditions, with the potential for escalation of incidents;
- Fragile environment with respect to sensitivity to harmful substances and other environmental impacts, and its need for longer restoration.

4.3.2 Polar Service Temperature (para 1.4.3)

For ships operating in low air temperature, survival systems and equipment shall be fully operational at the polar service temperature (PST) during the maximum expected rescue time. The PST refers to a temperature, specified for a ship intending to operate in low air temperature, which shall be set at least 10 degrees centigrades colder than the lowest Mean Daily Low Temperature (MDLT) for the intended area and season of operation in polar waters.

4.3.3 Manning and training (Chapter 12)

Ships operating in polar waters are appropriately manned by adequately qualified, trained and experienced personnel. The Polar Code does not specifically address the qualification, training or experience required to conduct a stay of a minimum of five days in a survival craft.

4.3.4 Expected time of rescue (para 1.2.7)

The maximum expected time of rescue is specified as "the time adopted for the design of equipment and system that provide survival support. It shall never be less than 5 days". In other words, this is the standard which the equipment and rescue resources must meet. This is also the dimensioning requirement for individuals' own survival after an abandon-ship incident, that is to say the period in which survival is down to the activities of the survivors themselves, prior to the arrival of rescue organizations.

4.3.5 Polar Code - Summing up

The particular hazards in polar waters are dimensioning factors for survival equipment and preparedness activities for organizations operating in these regions. Cold climate, lack of onshore infrastructure, huge distances, shifting weather conditions, less available rescue resources, limited rescue capacities, and communication challenges are issues making preparedness and rescue operations particularly important and challenging. The expected time until rescue of a minimum of five days is a dimensioning factor not only for lifesaving equipment but also for the training of ships' crews.

4.4 Polar Code – our interpretation

The term 'survival' is frequently used in the code but not defined. Based on discussions with project partners, including medical personnel, it has become clear that survival is only possible if the casualty is able to maintain adequate functionality to safeguard individual safety when exposed to the environment for a prolonged period. During SARex 1 (2016), the project chose to define the following as the overarching goal for Chapter 8:

*The equipment required by the Polar Code is to provide functionality that enables the casualty to **safeguard individual safety**, which means to maintain **cognitive abilities, body control** and **fine motor skills** for the maximum expected time of rescue.*

It is assumed by many that the stay in the rescue craft is a passive 'waiting game', in which the survivors wait for the SAR parties to arrive. We believe, however, that surviving in a rescue craft for five days will require active participation by the survivors. Active participation means to conduct basic tasks like:

- Alerting SAR units
- Coordinating the different rescue craft
- Managing onboard resources
- Keeping lookout
- Rationing food/water supplies
- Conserving body heat (preventing condensation)
- Ensuring blood circulation (moving limbs regularly)
- Relieving oneself (going to the 'bathroom')
- Caring for sick/injured personnel
- Actively participating in the evacuation from the rescue craft to the rescue vessel

Conducting the above tasks will require cognitive abilities, body control and fine motor skills.

In addition to the above-mentioned abilities, maintaining the motivation to conduct the required tasks is also of great importance. Maintaining motivation requires preventing the development of both peripheral fatigue and central fatigue. Fatigue is defined as *extreme tiredness resulting from mental or physical exertion or illness*. Quantifying motivation or fatigue is difficult.

It is clear that reduced functionality within the physical domain will, in many cases, also result in the development of fatigue and a reduced motivation to continue the fight. Based on discussions with doctors and physiologists, a hypothermic state will, in most cases, represent the *start of the end* in a cold climate survival scenario lasting for a minimum of five days. This is not only because regaining heat is difficult but also because the development of fatigue accelerates when the survivor is in a mild hypothermic state. It is of great importance that the survivors never reach even a mild hypothermic state, as recovery will be difficult.

There are variations within a population concerning ability to handle cold, physical abilities in relation to body core temperature and metabolism. When interpreting the Polar Code, it is beneficial to avoid criteria based on body temperature readings, due to large individual variations and diurnal variations. Body functionality is the preferred parameter that defines the potential survivability of personnel.

Survival is dependent on carrying out the right actions at the right time (safeguarding individual safety). The following functionality parameters have been identified as critical for carrying out the activities essential for survival (ability to safeguard individual safety):

4.4.1 Cognitive abilities

All actions essential for survival are initiated through cognitive processes. Being able to comprehend the situation and to carry out relevant actions requires cognitive abilities. Staying mentally fit is also important for the ability to generate the motivation, and prevent the development of fatigue, required for survival.

There is a strong relationship between loss of cognitive abilities and reduction of body core temperature.

4.4.2 Body control

When the body’s core temperature falls below about 35.5 degrees C., the large muscle groups start a process of rapid contraction, resulting in shivering. Through the muscle contractions, the body produces heat, trying to increase the body’s core temperature. These contractions are not controllable, and the person is unable to attend to his/her own needs or carry out the actions required to ensure survival.

Seen from a five-day perspective, the contractions can only endure for so long before the muscles are exhausted. The duration is dependent on individual health, age and fitness. If the person is not brought into a warm space, a further decrease in body core temperature is experienced when the shivering stops.

4.4.3 Fine motor skills – extremities

Survival is dependent on carrying out actions (see above). Many of these actions require fine motor skills and are carried out by the use of hands, i.e. pushing the PTT (Push-To-Talk) button on a VHF radio, opening water rations and opening/closing zippers for venting.

4.4.4 Prevention of development of fatigue

Survival in a rescue craft will require the participants to maintain the motivation to carry out the tasks required for survival. If a state of fatigue develops, the ability to carry out the required tasks is reduced. Quantifying fatigue/motivation is a difficult endeavor, and the causes behind development of fatigue can be both complex and interrelated. It is, however, clear that development of fatigue is affected by the following parameters:

- Physical pain – The pain can typically result from injuries, static non-ergonomic sitting positions, lack of ability to move and frostbite.
- Mental stress – Survival is dependent on maintaining motivation and focusing on survival. Mental stress will reduce these abilities. Mental stress can, for example, originate from the uncertainty associated with not being in control in a new environment or being separated from family members during the evacuation phase.
- Energy level – Consuming a higher level of energy and water than is being introduced to the body will reduce the energy level.
- Sleep deprivation – Not having the ability to sleep reduces the ability to maintain a high level of motivation.
- Lack of cognitive abilities – Maintaining a high level of motivation will require rational decision making, which again is linked to cognitive abilities.

Due to the above arguments, it is evident that a certain amount of **basic comfort** is needed to prevent the development of fatigue over a prolonged period of time. There are great individual variations, which are linked not only to individual physical abilities but also to individual mental robustness.

4.4.5 Revised expression

Based on the findings from SARex 2, a revised expression has been developed:

*The equipment required by the Polar Code is to provide functionality that enables the casualty to maintain the **motivation to survive** and the ability to **safeguard individual safety**, which means to maintain **cognitive abilities, body control** and **fine motor skills**, in addition to **preventing the development of fatigue** for the maximum expected time until rescue.*

4.5 Equipment utilized

4.5.1 Lifeboat

A Webasto fuel operated heater has been installed in the lifeboat. During SARex 2, the temperature in the lifeboat was relatively good. This meant that some passengers took off their survival suit while in the lifeboat. A toilet was installed at one end of the lifeboat. Passengers therefore did not have to leave the lifeboat to go to the toilet.

The seating benches in the lifeboat were fitted with padding, to make seating arrangements more comfortable.

4.5.1.1 Lifeboat description

Prior to SARex-1, the lifeboat manufacturer, Norsafe, was aware of the limitations of a standard (SOLAS design basis); however, by using such a product in these initial tests, valuable data and experience were gained.

Norsafe and NMA agreed that the most interesting approach for SARex2 would be to modify the standard SOLAS* lifeboat (utilized in SARex 1) with technical adaptions, in order to mitigate the findings from SARex 1. A selection was made based on available resources, and a modified lifeboat was shipped to Spitzbergen in April 2017.

During SARex 1, the following issues were identified:

- Low temperature when engine was not running
- Bad air quality when engine was not running
- High air humidity resulted in condensation and ice building up on cold surfaces and poor visibility.

The lifeboat utilized in SARex 1 was a standard SOLAS design basis conventional (Davit launched) totally enclosed lifeboat, with the design name Miriam: an 8.5-meter, 55-person lifeboat.

This specific lifeboat was available from stock; it is a 2013-model boat, which was originally delivered with serial number “16849. GA” can be seen in Figure 1 below.

*SOLAS = Safety of Life at Sea, a convention under IMO

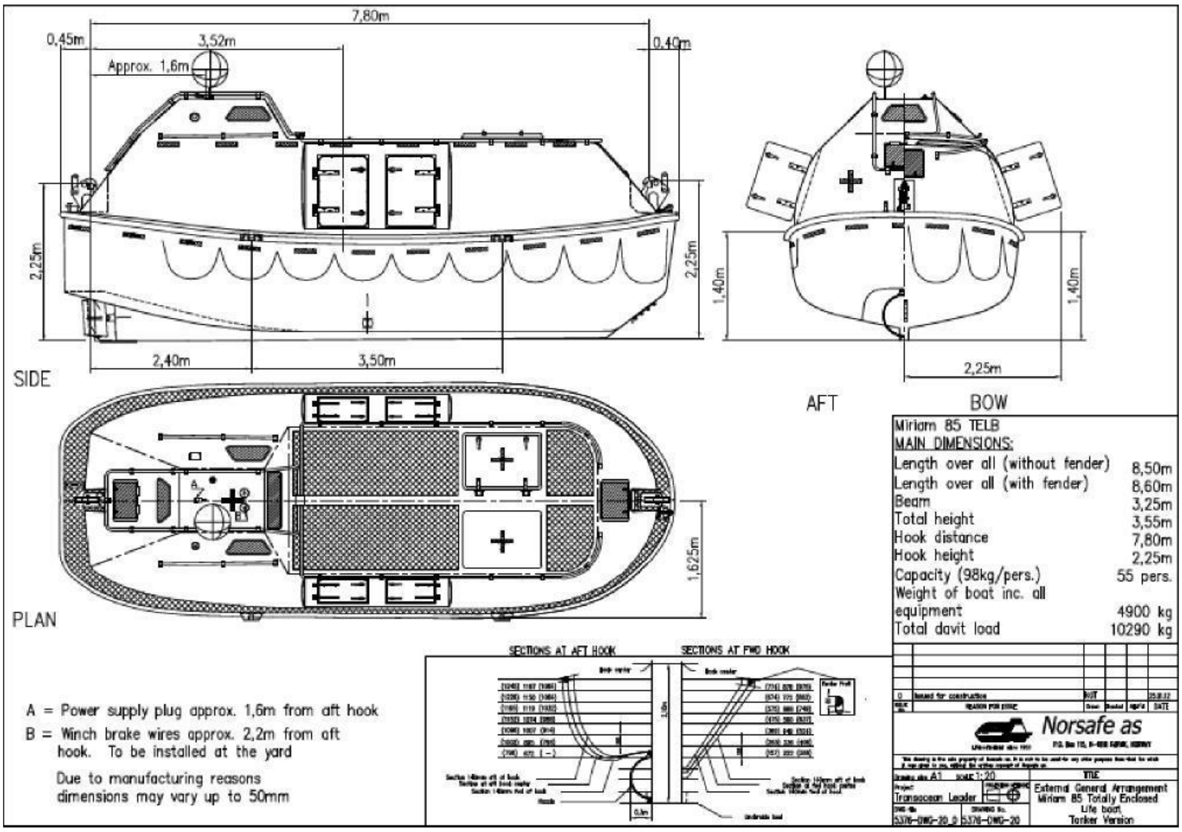


Figure 1. Details of lifeboat used in the exercise

4.5.1.2 Modifications to lifeboat

The following modifications were made to the lifeboat to meet the needs in a cold climate survival situation:

Heating system

- Standby heating system 400 W (0.55-liter diesel/hrs. @max speed)
- Heating system consisting of Eberspächer heater (4 kW) and heat exchanger
- Fuel tank (diesel) for heating system (53-liter capacity)
- Electrical cabin heater (1200 W) - standby
- Engine heater - standby

Ventilation system

- Two separate fans
- Adjustable from 400 m3/h to zero
- Volume of lifeboat is 30 m3 (volume of 24 people is 2.16 m3 – gives a total exchange rate of 14.3 exchanges per hour)
- Cold air is sucked in from the cockpit roof and transported via a duct down to the heat exchanger. After heating, the warm air is distributed to the flooring of the craft (4 outlets)
- When internal temperature allows, cold air is sucked from the stern of the lifeboat and distributed without preheating to the lifeboat cabin.
- The combination of the two fans gives a balanced ventilation and heating system, with the task of maintaining air freshness and temperature setting.
- Separate consumption battery for electric system (12.8 V lithium ion phosphate 90 Ah)

- Primarily for ventilation system
- Special generator fitted to engine with upgraded capacity (90 Ah)
- Special charger electronics for power management
- Temperature control system for battery

Other:

- Insulated seats (26)
  - Based on best existing backrest positions
- Toilet (compact carry-on design)
  - Toilet curtain for privacy
- Sleeping bench (capacity 3 persons, including sleeping bags and sleeping mats)
- Activity pack
  - Cards, games, books, reading material
- LED lighting inside craft
- Reinforcements to hull and keel
- Protections against ice to nozzle, cooling lines, etc.
- Protections against ice buildup on critical openings such as bilge relief valves in bulk heads, etc.

4.5.2 Life raft

The life raft utilized in the exercise was supplied by Viking Life and had an inflatable floor and the following specifications:

- 25 DKSN, 25-person self-righting life raft with inflatable floor
- Serial no.: 12121911
- In addition to standard equipment, extra-long paddles and United States Coast Guard (USCG) approved Thermal Protective Aids (TPAs) were included

Most common SOLAS-approved life rafts have only a thin layer of plastic separating the floor from the water, however, this life raft had the floor suspended about 40 cm above the sea surface. Between the floor and the sea surface was an open chamber. The life raft canopy was also elevated, providing greater headroom, enabling the participants to stand more or less upright inside the life raft.

4.5.3 Personal protective equipment (PPE)

A variety of PPE was utilized during the exercise. All had in common that they were fully functional immersion suits with integrated boots. The following equipment was utilized:

- 1 x Helly Hansen E-307 immersion suit.
- 12 x VIKING PS5002 standard immersion suits
- 2 x VIKING PS5002 immersion suits with extra insulation at the lumbar area
- 2 x VIKING PS5002 immersion suits with extra insulation at the lumbar area and outer fabric made in GORE-TEX™
- 4 X Viking PS4170 anti-exposure, work and immersion suits in GORE-TEX™ fabric
- 6 x Asivik self-inflatable sitting mats
- Nordkapp suit (supplied by the Coast Guard)

5 AIR QUALITY AND VENTILATION TEST

5.1 Test goal

The goal of the test was to assess the need for ventilation on board a survival craft.

5.2 Test setup

With the lifeboat stored on the deck of KV Svalbard, the exercise participants entered the vessel, and the hatches were closed. During the test, the amounts of O_2, CO and Co_2 were logged. The test was split into two:

Test 1:

- The participants had normal pulse,
- Standby heating was disconnected,
- Hatches were closed, excepting the two side hatches,
- Lifeboat was embarked by 49 persons,
- Hatches were closed,
- After 45 min., ventilation was started,
- After 63 min., test was aborted.

Test 2:

- Lifeboat was ventilated with all hatches open (after first test),
- Hatches were closed, excepting the two side hatches,
- All participants did physical exercise prior to entering the vessel to increase heart rate. During the test, physical activity was encouraged (within the limited space available) to maintain a high heart rate during the whole test period.
- Lifeboat was embarked by 49 persons,
- Hatches were closed,
- All participants exercised in the lifeboat for one minute with a stop of 5 minutes between exercise sessions,
- After 30 min., ventilation was started,
- After 61 min., test was aborted.

Boarding of lifeboat for O2/CO2 tests.

5.3 Results

During the test, CO_2 and O_2, temperature and humidity were measured, monitored and recorded. Results can be found in Figures 2a and 2b below.

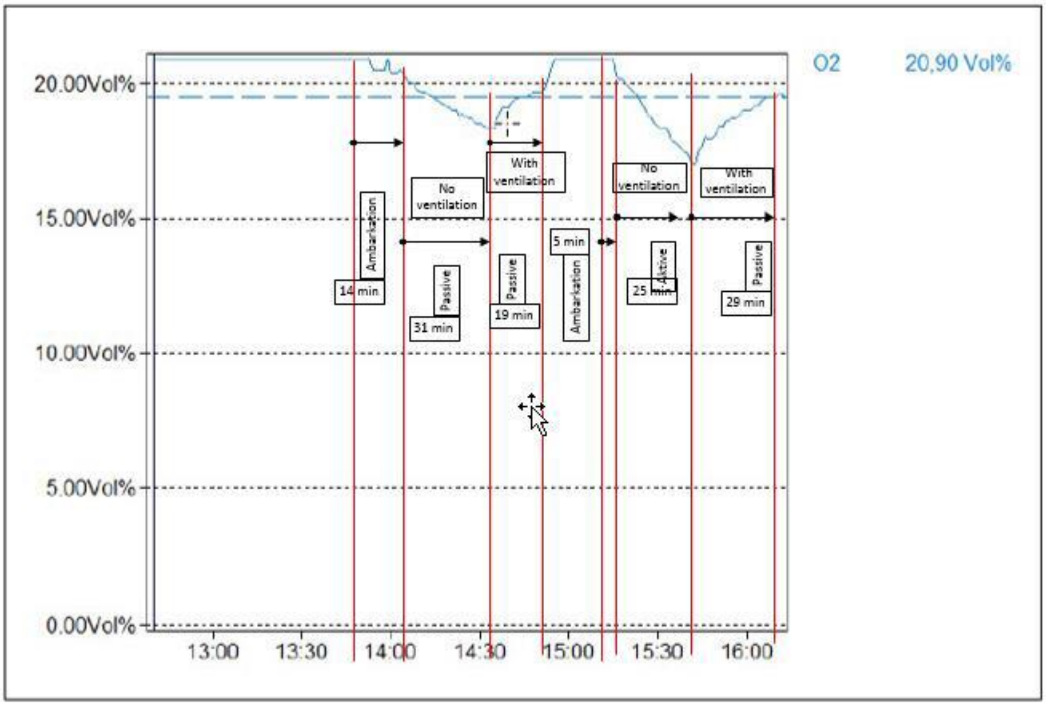


Figure 2a. Volume of O_2 in the lifeboat as function of time with 49 persons onboard.

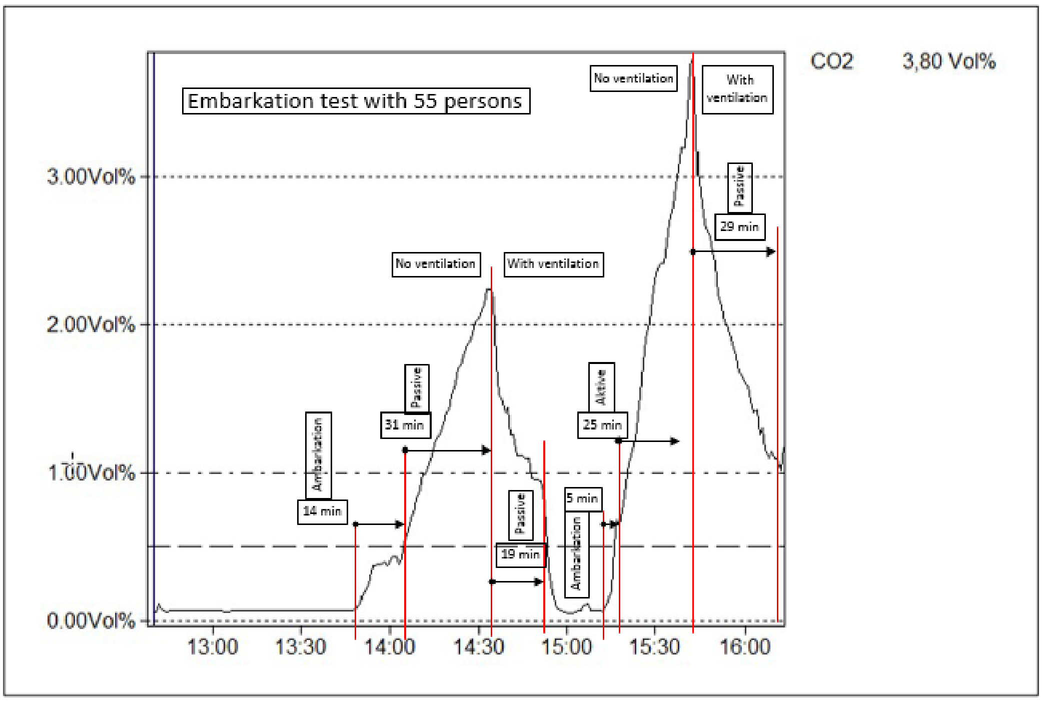


Figure 2b. Volume of CO_2 in the lifeboat as function of time with 49 persons onboard.

Inside lifeboat during O2/CO2 measurements.

5.4 Discussion

5.4.1 Oxygen levels

The O_2 levels decrease linearly down to about 18% in trial no 1 and down to about 17% in trial no 2. Based on the rate of change, it is evident from the graph (Figure 2a) that increased physical activity was taking place during trial no 2.

The Occupational Safety and Health Administration, OSHA (Light & Coleshaw, 1992), states that the optimal O_2 level is between 19.5% and 23.5%. When conducting physical activity at oxygen concentrations of 16% to 19.5%, the cells fail to receive the necessary oxygen to function properly. At levels from 10% to 14%, mental functions become impaired and respiration intermittent.

Participant blood oxygen levels were measured during test for safety reasons.

During the test, critical levels were not reached. However, each trial only lasted about 30 minutes. If the trials had lasted for another 30 minutes and the O_2 depletion had progressed at the same speed, critical levels would have been reached (Malesky, 2017).

5.4.2 CO_2 levels

The buildup of CO2 increased rapidly during embarkation and reached a level of around 5,200-5,700ppm before the hatches were closed. When the participants were relaxing, the CO_2 levels reached about 23,000 ppm after about 31 minutes, and the exercise was aborted (Figure 2b).

In trial 2, the participants had high pulse rates and were conducting exercise within the space available to simulate the oxygen consumption/CO_2 production present when people are experiencing the uncontrollable shivering associated with a reduced body core temperature. During trial 2, the CO_2 concentration rose to 38,000 ppm during the 25-minute trial.

Findings from the study, “Survivability of occupants of totally enclosed motor propelled craft” (Light & Coleshaw, 1992), indicate that levels of CO_2 reach 35,000 ppm to 36,000 ppm after about 40 minutes when filling a 42-person lifeboat with 42 persons during summer conditions (air temperature of 17 degrees). This study harmonized well with our results.

5.5 Conclusion: Air quality and ventilation test

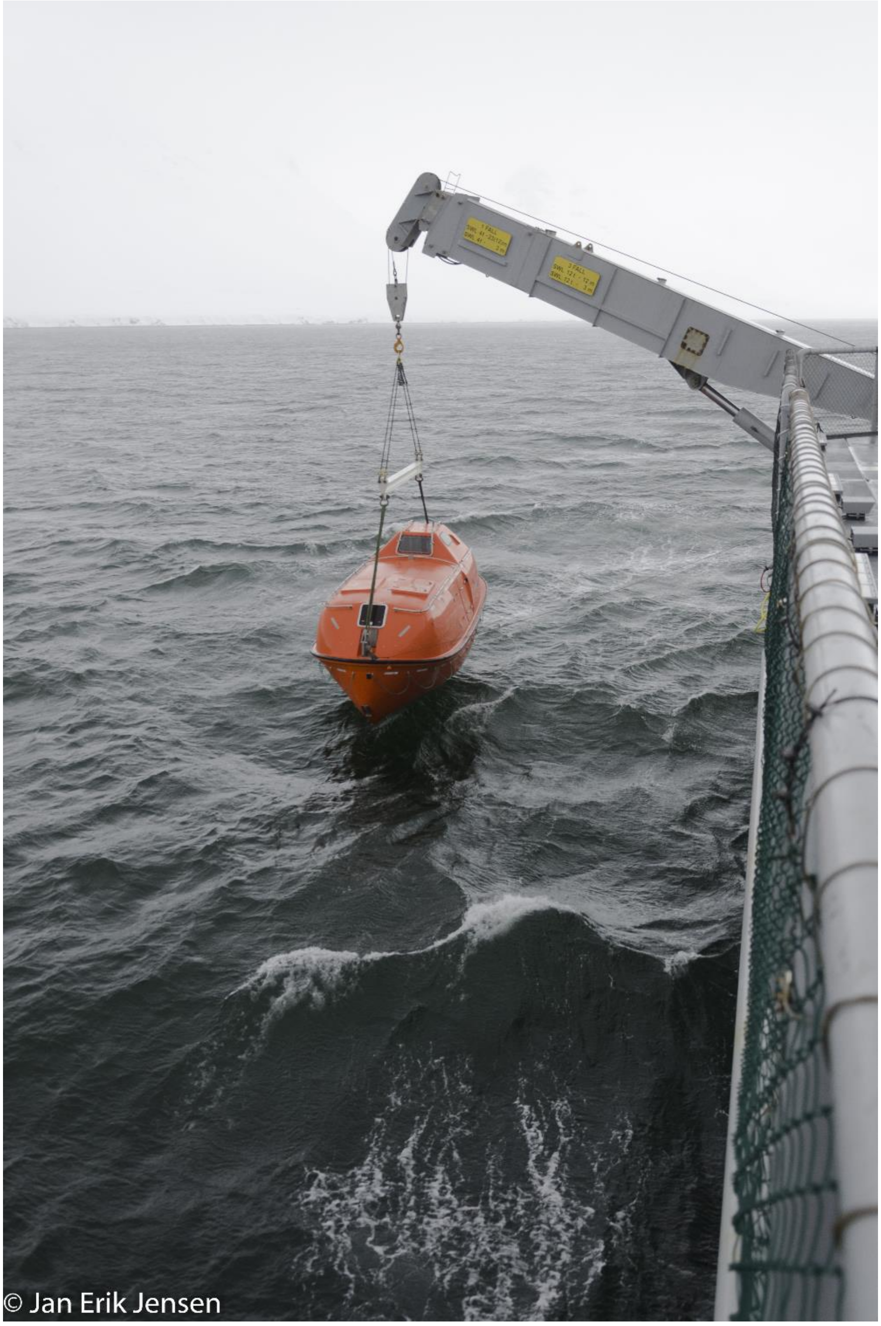
There are currently no specific acceptance criteria for the level of O_2 or CO_2 at which ventilation shall be initiated in a rescue craft. High levels of exposure to O_2, CO and CO_2 for a prolonged period of time (minimum five days) can cause irreversible damage to the human body.

Utilizing threshold values from The Occupational Safety and Health Administration, OSHA, in a survival setting could be regarded as a conservative approach. It seems reasonable to compare air quality limits for a rescue vessel in a survival setting to those of a submarine environment. In a submarine (peace time) the limits are typically set at 10,000ppm before commencing measures to reduce CO_2 (chalk filters), with maximum levels at 20,000ppm. For O_2, minimum levels are set to 17%.

6 SURVIVAL TEST

6.1 Test goals

The goal of the test was to assess the impact caused by modified and improved SOLAS equipment on the functionality of survivors in a real-case survival setting.



Launching of lifeboat.

6.2 Exercise participants

Officers from KV Svalbard served as captains on board the lifeboat and the life raft. Civilians and crew members from KV Svalbard formed the rest of the personnel to man the rescue craft.

6.3 Medical team

A team of medical doctors was in place to assess the condition of the participants at regular intervals during the exercise. They conducted cognitive and physical tests, in addition to measuring vital body parameters. They were given the authority to abort the exercise for participants showing signs of hypothermia or loss of functionality.

When leaving the exercise, exercise participants underwent medical tests, both initially in the hangar on board KV Svalbard and then in the infirmary on board KV Svalbard. They then underwent the same cognitive and physical tests they had been exposed to during the exercise.

6.4 Exercise scenario

One lifeboat and one life raft were launched by KV Svalbard in the Krossfjorden area. The boat and raft were then filled/manned by the civilian exercise staff and crew from KV Svalbard.

6.5 Exercise conditions

Exercise start 3rd May 2017:

- Air temperature: 0 degrees C
- Wind: variable
- Sea state: less than 0.5 meter

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Exercise end 4th May 2017:

- Air temperature: - 9 degrees C
- Wind: 35 knots steady, gusting up to 55 knots
- Sea state: less than 1-2 meters

Survival test site.

6.6 Onboard observations from rescue craft

Different activities were carried out in the lifeboat and in the life raft. Despite the differences, there were several similarities between the activities in the rescue craft.

6.6.1 Prior to entering the survival craft

The exercise started with dressing in the hangar. Participants supplied their own 'personal protective equipment':

- Two layers of underwear (preferably woollen)
- Some brought hats/caps
- Some brought gloves or mittens

The participants were then provided with a variation of suits. After being dressed, the Man Overboard Boats (MOB boats) transported the participants to the lifeboat and the life raft.

6.6.2 Organization of activities

The captain of the rescue craft, an officer from KV Svalbard, chose a second in command among the passengers. This initial arrangement was followed by organizing some core activities on board:

- The buddy system: two persons were paired by the captain as buddies. The 'buddies' were tasked to look after and take care of each other. The buddy system was in place throughout the exercise, especially in the life raft.
- Duty roster: duty officers were organized with shifts of three people in the life raft and one person in the lifeboat on duty at all times. The duty station was at a particular position next to the main canvas opening on the life raft and at the helm in the lifeboat. The duty officers' tasks were related to:
    - Looking out for ice, polar bears, walrus, rescue vessels/helicopters, other life rafts/-boats, etc.
    - Controlling the ventilation and thereby the temperature level and the CO_2 concentration
    - Radio communication
    - In the lifeboat, the duty officer was also responsible for charging the batteries.

The crew on board the rescue craft did not always fully respect, and operate according to the instructions of, the rescue craft captain. In a real situation, an operational duty system, and a crew adhering to the system, is of the utmost importance in order to maintain good living conditions and increase the probability of survival.

- Medical responsibility. One first-aid-trained crew member from KV Svalbard was given the responsibility for medical issues on board. He distributed seasickness tablets every 12 hours. He also distributed paracetamol if required. The captain logged all medication that was distributed (the time and person receiving the medication).
- Food and water responsibility. The captain maintained control of water and food distribution. Usually, it is recommended not to eat or drink for the first 24 hours in a survival situation. In SARex 2, this recommendation was not followed, and the participants consumed standard rations during the exercise.

- An important aspect of maintaining morale in a rescue craft is a tidy craft. In the life raft, one exercise participant was chosen to be responsible for garbage collection (garbage from food rations and water rations etc.). Much garbage was collected but not all. There is a collective responsibility to ensure that all garbage is collected and the living conditions inside the raft are the best possible.

6.6.3 Getting familiar with the equipment

In the lifeboat, most of the survival equipment, food and water are stored in lockers. The life raft comes with two big sacks filled with standard equipment, food and water. The captain of the life raft distributed the equipment to the passengers on board, gave them a few minutes to become familiar with it and then asked everyone to present the item to the rest of the crew. This included why the item is used and instructions on how to use it. That gave everybody an opportunity to familiarize themselves with all the equipment on board. This later proved very valuable, since much of the equipment was needed for various activities on board.

Visits by the safety crew and medical personnel forced the natural activities on board the rescue crafts to be halted for periods of time.

6.6.4 Getting familiar with fellow passengers

A final part of the initial organization was the process of becoming familiar with everyone on board.

Everyone was asked to present himself/herself and include knowledge they thought could be relevant for the situation. A second presentation of first names was conducted later in the exercise. During this presentation, the passengers were asked to mention an animal with the same first letter as their name. This formed a lighter mood among the passengers and made it easier to remember the names.

The captain later engaged the crew in various discussions and quizzes. This was a very good initiative and broke the monotony. Some of the exercise participants withdrew from the discussions and from their duty team. It is important to get all participants involved in the activities, even if they are reluctant to do so.

6.6.5 Why organizing and familiarization are important activities

Utilizing the knowledge, expertise and capabilities among the passengers is very important for survival. Drinking and eating the rations may be crucial for the passengers' cognitive and physical ability, which is needed to conduct the various activities on board the rescue craft. Taking part in the various activities on board may also contribute to maintaining the cognitive and physical capacity required for survival over a longer period of time.

One important reason for becoming familiar with who is on board is to gather knowledge of the skills available in the group. Passengers could possess important skills, e.g. related to medical expertise, diet, language knowledge, physical training, etc.

It is also important that significant information is communicated to the rescue craft captain, e.g. if passengers are injured or dependent on medication.

Communication was sometimes challenging on board the rescue craft. In the lifeboat, the engine restricted conversation and communication across the boat, while in the raft the wind, waves and flapping of the canopy restricted conversation.

Communication on board the rescue crafts was difficult with increasing winds.

6.6.6 Endex

The abortion of the exercise was determined by the captain and crew on board KV Svalbard. The plan for aborting the exercise was adjusted several times, due to changes in the weather conditions. In the final stages of the exercise, both of KV Svalbard's MOB boats were involved in maintaining control of the rescue craft, while exercise participants were transferred back on board KV Svalbard.

Boarding the MOB boat from the rescue craft upon endex turned out to be challenging, because of the waves and strong wind. It took the MOB boat several attempts to come alongside the rescue craft successfully, despite the considerable experience of the MOB boat drivers. Moving between small vessels in high wind and waves proved to be very difficult. The cold climate conditions, with slippery handholds and surfaces due to freezing sea spray, added an additional challenge.

A successful transfer from life raft to MOB boat is therefore dependent on both experienced MOB boat crew, and the passenger being in a physical condition to make such a move possible. If the passengers were ill, unconscious or lying on a stretcher, such a transfer would not have been possible without a high risk of causing further injuries.

Transfer of personnel from rescue craft to mob-boat was difficult and involved a substantial risk with increasing wind and waves.

6.7 Medical observations during survival test

6.7.1 Medical challenges

A survival situation in polar waters will pose many challenges to the survivors:

Temperature: The low ambient air and seawater temperatures in the Arctic environment, in combination with unpredictable, rapidly changing weather conditions, predispose subjects to hypothermia and frost-related injuries. Loss of function appears rapidly in cold air, and this will negatively affect the ability to perform the tasks necessary for survival.

Air quality: In an enclosed space containing people, there will be a buildup of CO_2 and consumption of O_2. The amounts of produced CO_2 and consumed O_2 will depend on the metabolic rate of the individuals present. In a cold climate survival situation, hypothermia can develop, and this may elicit shivering, known to increase normal metabolism up to fivefold, for as long as energy reserves are sufficient. A buildup of CO_2 will rapidly affect clarity of mind and attitude to sustain survival skills. It must be noted that air quality and inside temperature is connected. When doing manual/mechanical ventilation, cool air will flow into the rescue craft.

Water: Weight and space considerations will cause limited water availability when boarding a rescue vessel. Water is a crucial resource for maintaining vital functions over time.

Seasickness: High seas and lack of view predisposes one to severe seasickness, which often causes nausea and vomiting, electrolyte disturbances and dehydration. Seasickness also increases the development of hypothermia and dehydration.

Mobility: Lack of space will cause limb and back stiffness, reduced functionality and pain. The sleep cycle will be affected, and the resulting fatigue will increase the risk of error and faulty decision-making.

Hunger: The lack of food will affect the survivor but will not be critical in the first five days for most people.

Elimination: Establishing a routine and system for the disposal of urine and feces on board a rescue vessel is a necessity in a real situation. Protective suits are not ideal for elimination and often necessitate partial or complete doffing, causing exposure to cold. Due to individual privacy needs, this may induce an effort to retain both urine and feces, affecting hypothermia development and causing discomfort.

In sum, all challenges will affect the survivors at different stages, but the impact will increase and accumulate with time.

6.7.2 Medical tests

To assess the condition of the participants, medical tests and measurements were conducted throughout the exercise.

The overarching limitation to the tests was the absolute safety of the participants, causing the extraction from the exercise of any individuals showing significant objective affection by any of the named challenges above and, specifically, the affection of fine motor skills, the presence of uncontrolled shivering and reduced cognitive skills.

6.7.2.1 Skill tests

Throughout the survival exercise, the participants were tested using three different skill tests.

1. Penny transfer test. This is a fine motor skills test extracted from the "Bruininks-Oseretsky Test of Motor Proficiency, Second Edition". The task was to move a penny from a board with one hand and transfer it into the other hand before dropping it into a cup. The participants were given 20 coins and 20 seconds to complete the task.
2. Grip strength. This test evaluated gross motor skills, by using a Baseline hydraulic hand dynamometer, with three attempts on each hand, recording the best result on each hand in kg.
3. Subtraction test. This was performed to evaluate cognitive skills by subtracting sevens from one hundred to zero, with no time limit. The outcome was either complete or incomplete.

The hypothesis was that cold temperature, lack of sleep, water and food would impair the participants' functional level with regard to fine -, gross motor, as well as cognitive skills. The skill test results were interpreted by estimating a linear trend of the data from each skill test. Thus, a negative value (a=$\frac{\Delta y}{\Delta x}$) of the collected data from each participant and test (y) versus time (x) would be characterized as a negative trend.

6.7.2.2 Subjective reporting

The participants also reported subjective scores on seven different factors believed to impact on the ability to survive. The scores were reported on a numerical rating scale, with scores ranging from 1 to 10, where at 10 the participant was most affected by the factor and least affected at 1. The factors assessed were cold sensation, fatigue, hunger, thirst, discomfort, positivity and nausea.

6.7.2.3 Vital parameters

The participants´ vital parameters were mapped, monitoring epitympanic temperature, oxygen saturation (SpO_2) and heart rate before the exercise, every six hours during the exercise and after the exercise. Blood pressure was only measured before and after the exercise. The participants´ bodyweight, wearing one layer of wool underwear, was documented before and after the exercise.

Visits to the rescue crafts were done at regular intervals to ensure safety and conduct medical assessments.

6.8 Results

6.8.1 Skill tests

Skill tests were performed as planned throughout the exercise. The results show that the skill tests generally were performed with improvement throughout the exercise. There was little difference between participants in the two vessels, both in average and range. There was a general positive trend of average for both vessels. We observe that more than one third of the participants trended negatively in one or more of the skill tests during the survival exercise. See Figure 3a below for more details.

We note that, despite ideal conditions, already after one day, more than one third of the participants showed a negative trend in their performance in skill tests affecting motor functionality. The results from the subtraction test showed a positive trend in both vessels.

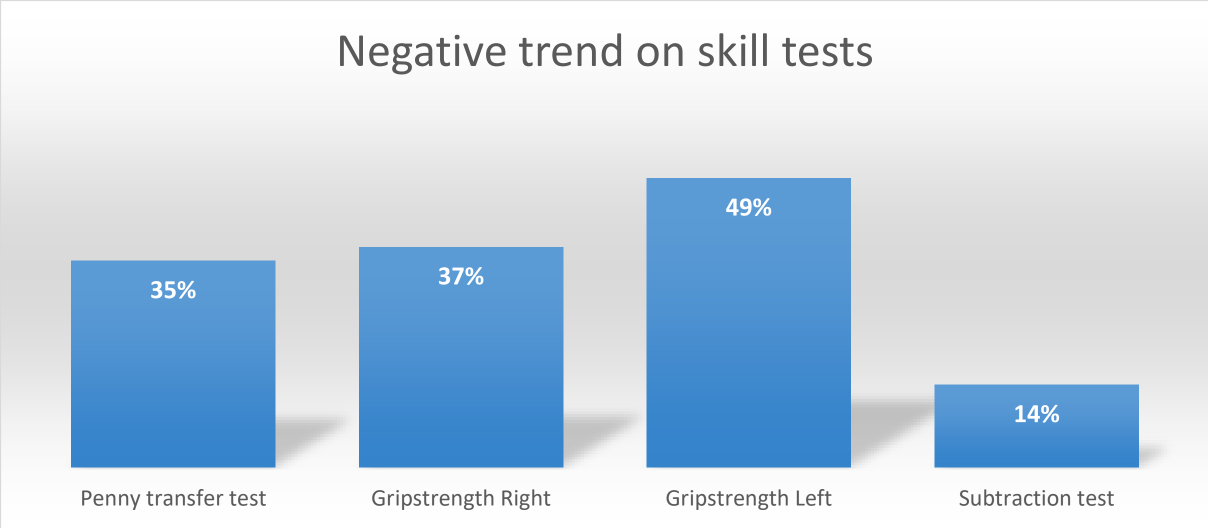

Figure 3a. Bar chart showing percentage of participants with negative trend in skill tests throughout the exercise

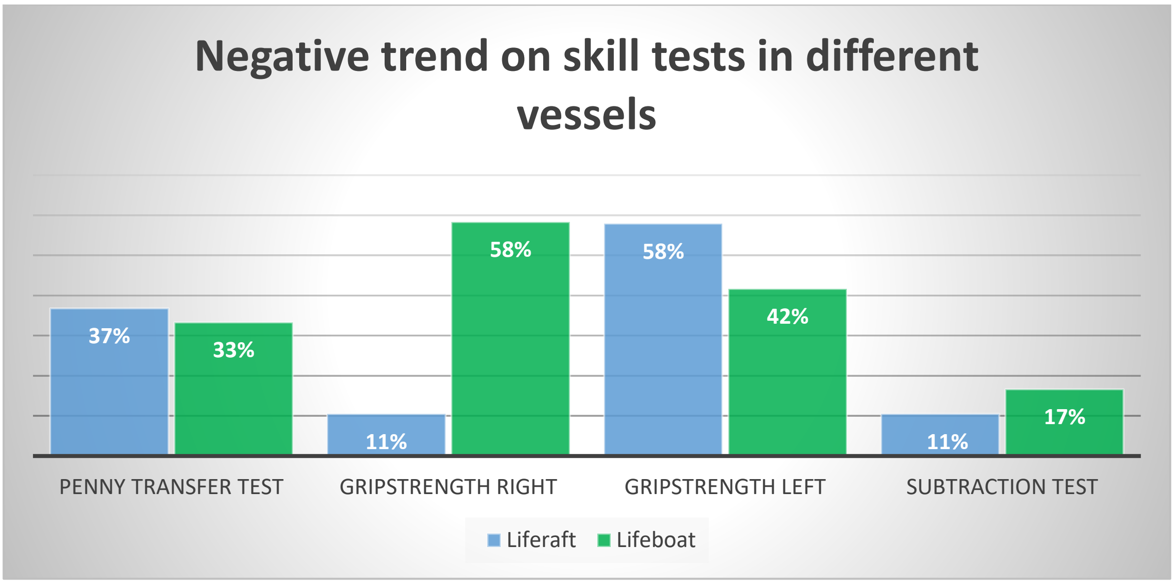

Figure 3b Bar chart showing percentage of participants in each vessel, with negative trend in skill tests throughout the exercise.

6.8.2 Subjective scoring on numerical rating scale

Subjective scoring on seven factors affecting survival ability was performed. A higher percentage of negative trends was observed in the life raft, compared to the lifeboat. The findings (Figure 4) are illustrative of many important differences between the two vessels.

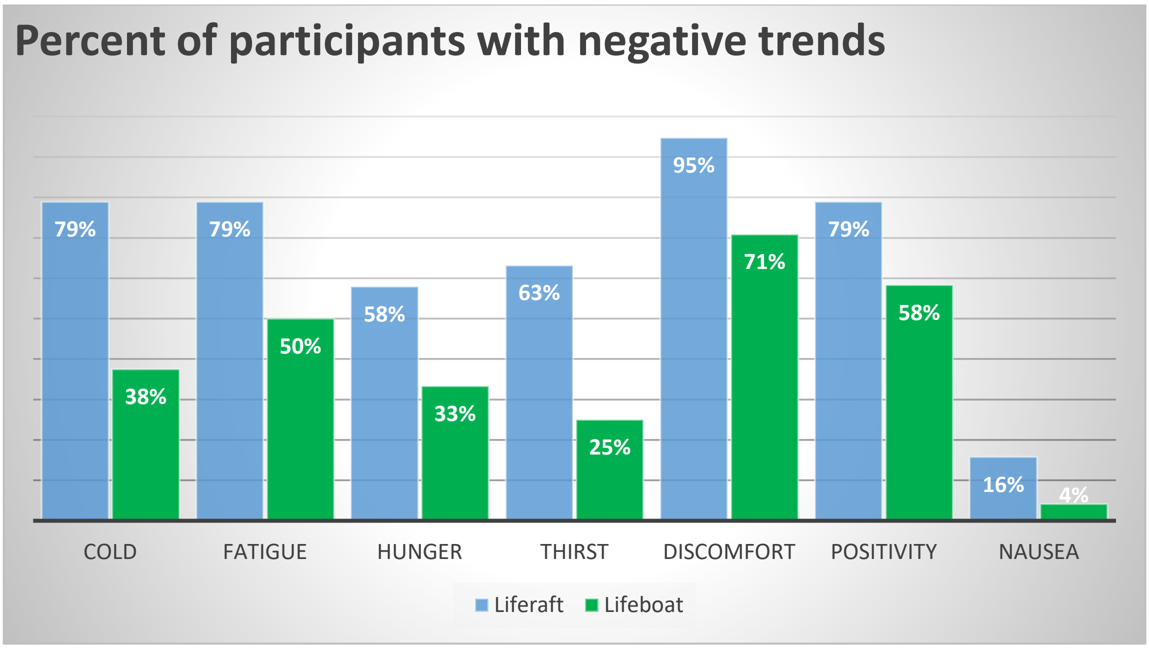

Figure 4 Percentage of participants in each vessel with negative trend in self-reporting NRS form scoring seven factors influencing survival throughout the exercise. Life raft participants trending more negatively than lifeboat participants on all factors.

6.8.2.1 Fatigue

All life raft participants started off scoring mild fatigue, and there is a clear shift towards the right in the following hours. See Figure 5 below.

In the lifeboat, the participants started off with more fatigue from the offset. On baseline scores, eight (33%) of the participants report moderate fatigue, and the distribution keeps shifting to the right throughout the exercise. When analyzing the eight participants scoring moderate fatigue at baseline, only three of them display a negative trend for fatigue throughout the exercise.

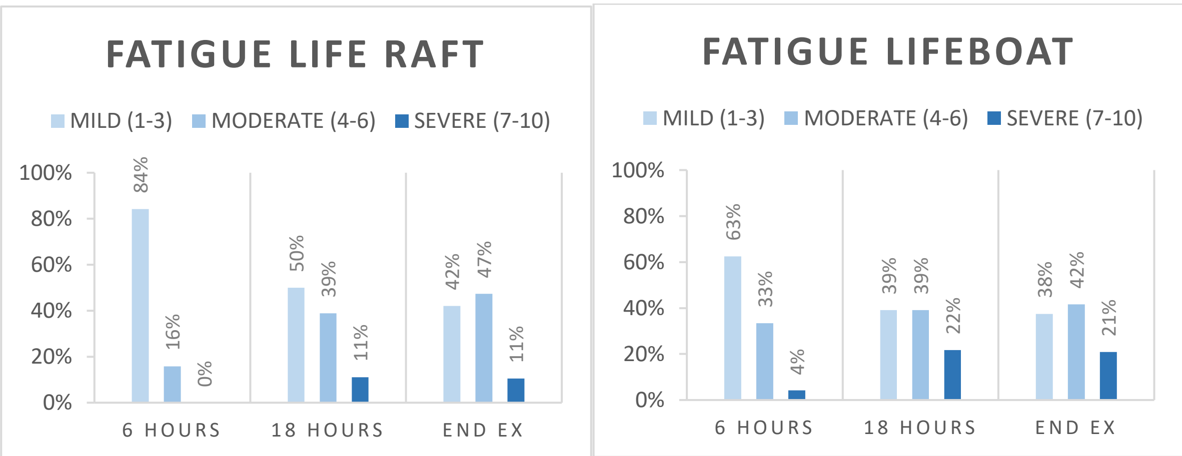

Figure 5 Percentage of participants in each vessel scoring mild (1-3), moderate (4-6) or severe (7-10) fatigue throughout the exercise. The bar chart shows redistribution of fatigue intensity throughout the exercise.

6.8.2.2 Thirst and hunger

Thirst and hunger were also perceived differently in the two vessels, with an earlier right shift of scores in the life raft. See Figure 6 below. The distribution of thirst intensity in the raft is very gradual.

The distribution pattern is more irregular in the lifeboat, but the results at the end of the exercise are similar. Also note the average thirst scores in Figure 7 below, where the average in the life raft is increasing more than in the lifeboat.

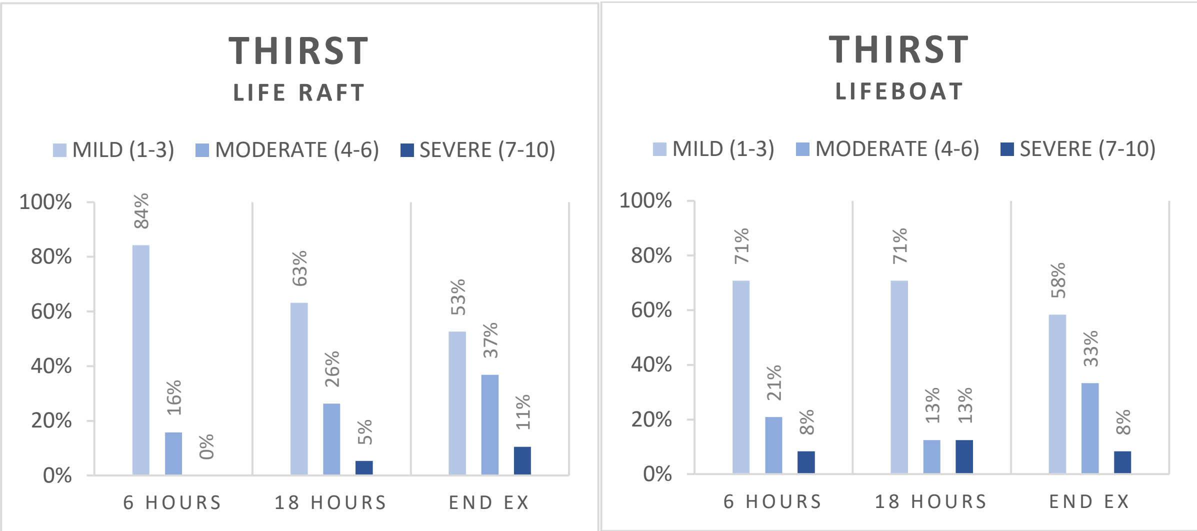

Figure 6 Percentage of participants in each vessel scoring mild (1-3), moderate (4-6) or severe (7-10) thirst throughout the exercise. Observe an earlier redistribution in the life raft, before both groups get a similar distribution at the end of the exercise (endex).

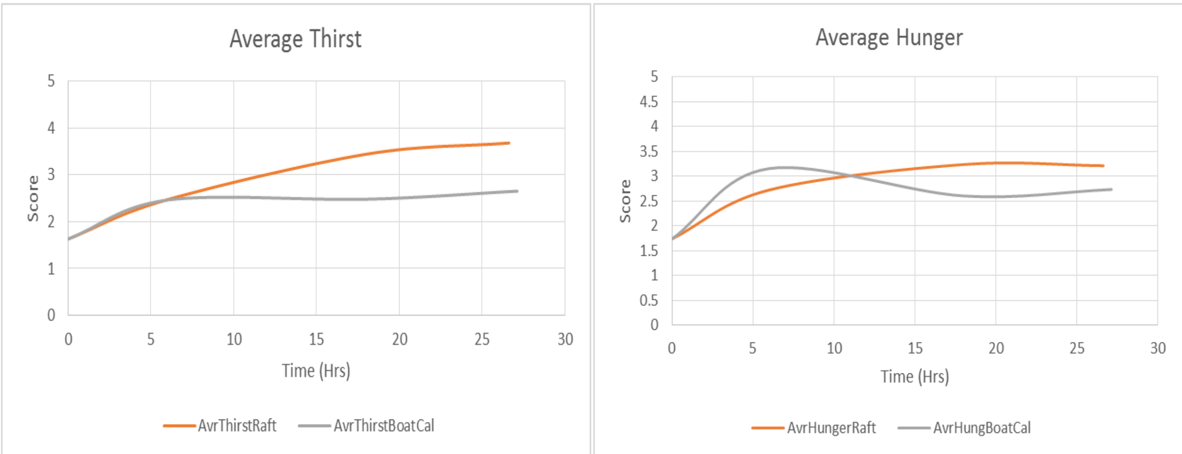

Figure 7 Averaged NRS scores on hunger and thirst, comparing participants' scores in the two vessels.

6.8.2.3 Discomfort

It might seem odd to evaluate discomfort in a survival setting. We believe that discomfort will be ignored in the initial phases of a real survival situation, but it is evident that discomfort will become an issue negatively influencing the ability to survive and adding negative stress; see Figure 8 below. It is evident that discomfort was an issue in both vessels. More life raft participants show a negative trend, butcomparing the numbers, the lifeboat participants experience more discomfort.

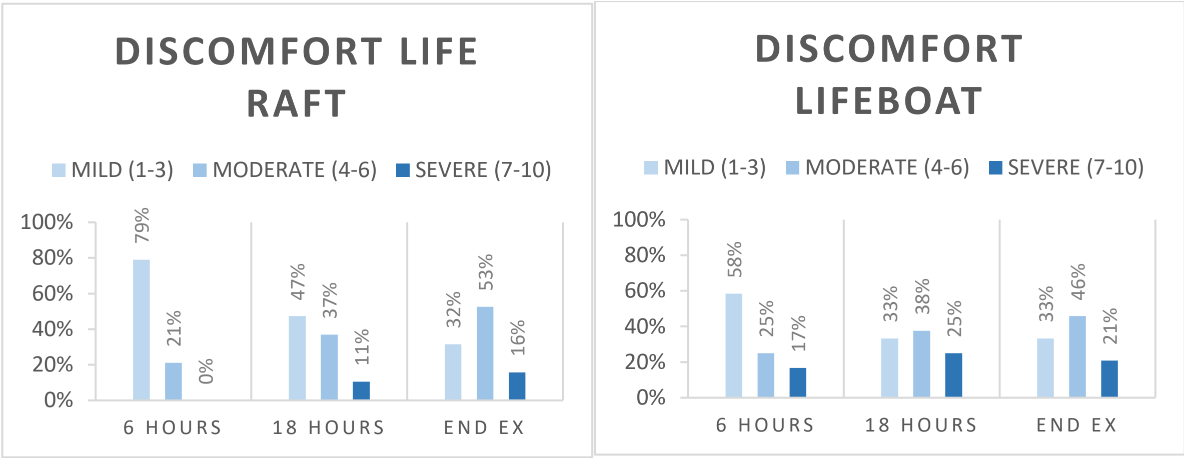

Figure 8 Percentage of participants in each vessel scoring mild (1-3), moderate (4-6) or severe (7-10) discomfort throughout the exercise

6.8.2.4 Physiological parameters

When looking at the physiological parameters measured (Figure 9 below), the results indicate minor difference between the two vessels. Both groups seem to experience a rise in heart rate after commencing the exercise. This response is far less than would be expected to be observed in a real-life event, but every participant expects some degree of discomfort during this exercise, and the increased heart rate may illustrate this. The next heart rate measurements reflect the activity level in the two vessels. There are more tasks and planned activities in the lifeboat, whereas in the life raft the activity level reflects attempts to conserve energy. During the night, it seems as if the life raft participants were more able to relax, reflected in a marked collective lowering of the heart rate. The following morning, they experienced increased cold sensation and discomfort on waking.

Ear temperature in the life-rafters is markedly lower than in the life-boaters at the end of the exercise. This supports the subjective reports on numeric rating scale on cold sensation, where the life raft participants score markedly higher on cold sensation than their lifeboat counterparts. There is also a slight decrease in ear temperature in the lifeboat participants.

Blood pressure was measured before and after the survival exercise, and again there is a difference between vessels; the systolic blood pressure seems higher and more spread in the lifeboat participants at the end of the exercise, compared to baseline values.

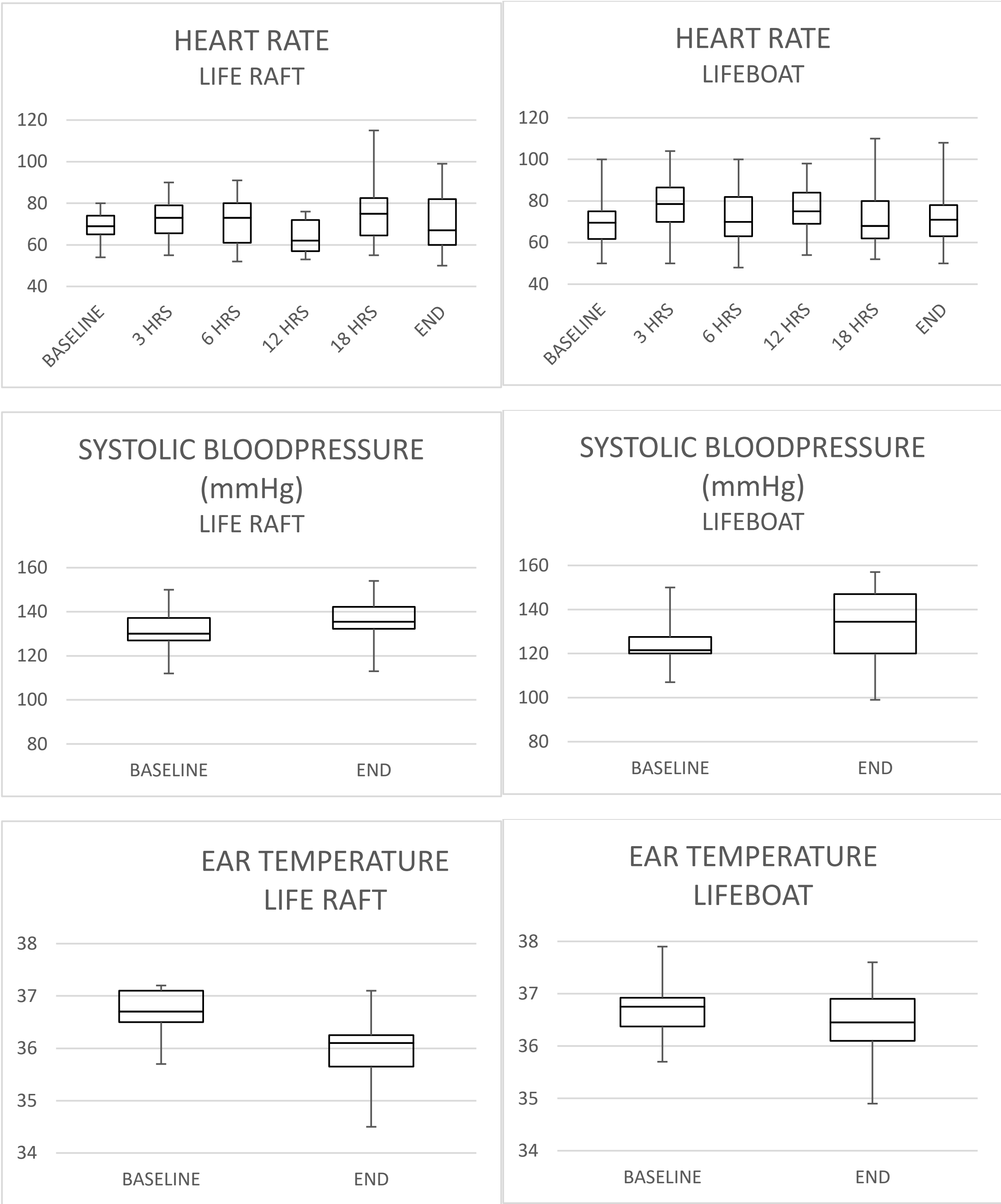

Figure 9 Box plots showing quartile distribution of vital parameters throughout the exercise, comparing participants in the two vessels.

6.8.2.5 Weight loss

The participants weighed in just before donning the survival suits, wearing one layer of clothes. They were again weighed when returning to KV Svalbard, wearing the same one layer. The mean weight loss for the life-rafters was 1.8 kg, ranging from 3.6 to 0.2 kg, as opposed to 2.0 kg, ranging from 3.5 to 0.7 kg, for the life-boaters (Figure 10). Factors affecting weight loss are intake of food and water, elimination, sweating and other insensible water losses. This is to be regarded as a serious weight loss in such a short time.

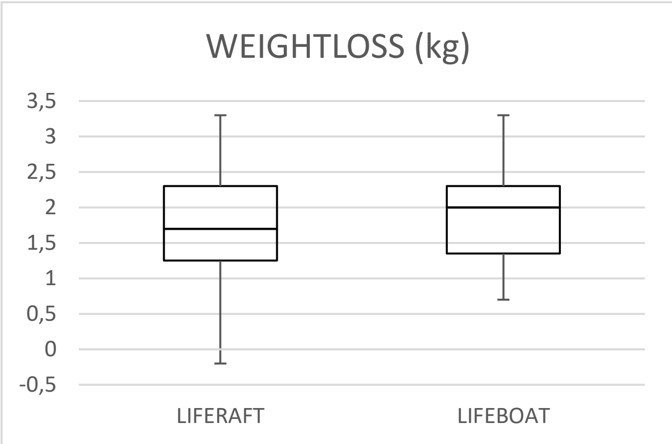

Figure 10 Box plots showing the quartile distribution of all participants' weight loss throughout the exercise. Comparison between the participants in both vessels.

6.9 Discussion of medical aspects

Survival in cold climate areas poses substantial challenges to humans. Knowledge on factors influencing survival under these circumstances is important. There was no point in creating a worst-case scenario; rather, the object was to test a close-to-ideal scenario, and to evaluate whether survival for the extent of five days would be possible. The participants had no current health problems and a mean age far below that of the average cruise passenger.

We introduced three skill tests that could demonstrate loss of function during the survival exercise, but, at the same time, we stated that, due to participant safety and the remote location of the exercise, we would not allow participants to be clinically affected by the elements. This introduces the difficulty of achieving convincing results in the tests performed over the time span of the exercise. However, a negative development throughout the exercise would indicate a tendency of decreased functionality. We observed a negative trend in more than a third of the participants, in both vessels. This finding is a mere indication of the start of a development towards reduced functionality, which in turn will affect the ability to survive.

The employed skill tests did not show an apparent loss of functionality during the observation period. We expected that real hypothermia development would affect the test results, and, in the absence of such a hypothermic condition, it might be stated that the results confirm that the participants were kept in a physiologically safe range.

The numerical rating scale scores on factors influencing survival are descriptive of the development in the two vessels and demonstrate clear differences between the two environments.

The development of increasing cold sensation aboard the life raft was expected, as the temperature in the raft was lower. There was a constant need to ventilate CO_2, reducing the temperature. The only heat source was the participants themselves, and this became more evident as the number of participants was reduced throughout the exercise. The lifeboat also experienced increased cold sensation. This was surprising, as the lifeboat was equipped with a heater and controlled ventilation. The participants were instructed to sit strapped in their seats, but we observed that this was not the case, as they were not able to sit in the same position for many consecutive hours.

It is likely that the differences in environment in the two vessels explain the differences in thirst. The ambient temperature in the life raft was constantly lower than in the lifeboat. The air in the lifeboat was dryer. Five participants on the lifeboat had moderate thirst at baseline score. These factors are believed to influence the thirst scores, but it is surprising that the difference already appears on the first day. When investigating further, it became clear that the commanders of each vessel distributed the rations in different ways. The life-rafters received 500ml/24 hours, the life-boaters 1000ml/24 hours. Thus, the raft participants received less water and food than the participants in the lifeboat, and this could explain the earlier feeling of thirst in the life raft. The lifeboat participants received all their rations at the beginning of the exercise, but there were differences as to when they consumed them. This was done in a more controlled way and at regular intervals in the life raft. The difference in distribution and consumption could explain the more gradual change among the life raft participants and the irregular change in the lifeboat. At the end of the exercise, both groups have a very similar distribution pattern, indicating that they would need more generous water rations, to increase their chance of survival over a minimum period of five days.

Findings on discomfort were also unexpected. We would expect the life raft to be the less comfortable vessel, but the participants in the lifeboat scored more intense discomfort through the exercise. During the debrief it was made clear that multiple factors contributed to discomfort in each vessel. In the lifeboat, the hard seating and lack of spaces to lie down were problematic for most participants. This caused back pain and unease. The only relief was to stand up every now and then. Most participants in the lifeboat experienced headaches and un-wellness after the exercise, for unknown reasons. In the life raft, the main factors causing discomfort were low ambient temperature, humid air, wet floor, waves and lack of space to move.

With regard to fatigue, the two groups had a different outset. Eight of the lifeboat participants already scored moderate fatigue on the baseline report. Of the lifeboat participants, 15 were conscripted privates serving on KV Svalbard; being part of a duty schedule on the ship may have affected the outset fatigue levels. Discomfort also influences fatigue and may explain the higher scores in the lifeboat group. The reason behind fewer participants on board the lifeboat experiencing a negative trend in fatigue may be the relaxation duty roster, created in the lifeboat soon after the exercise started. This structured rotation allowed three participants to sleep for three hours at a time. There was no similar duty structure on board the life raft, where most participants were relaxing most of the time, and the duty schedule only covered tasks to be covered by the crew. It is also probable that the inflated structures on the life raft allowed more comfortable relaxation than the harder seating areas in the lifeboat.

Despite not being visible in the self-reporting scheme, two people were removed from the exercise due to a combination of both mental and physical deterioration. They were in a state of no longer acting proactively. This includes symptoms such as lack of communication, lack of awareness and lack of actions preventing the development of hypothermia, e.g. opening the survival suit to dry out moisture or instigating physical activity to prevent the development of hypothermia. The deterioration came as a result of both mental and physical stress and can be regarded as development of fatigue beyond acceptable limits. It is important to note that there was no single cause for development of the fatigue but a combination of events/stresses that were beyond the individuals' mental and physical robustness levels. If the individuals had not been removed from the exercise, a severe hypothermic state would have developed within a short time.

All participants were given tablets containing 25 mg meclozin (Postafen™) to prevent seasickness. This is standard equipment (supposed to last for 48 hours) in rescue kits for sea survival. The pills were given one hour before the exercise started and administered every 12 hours on board the vessels. This preventive measure, as well as quite calm sea conditions, made nausea an negligible factor in our exercise. There are reasons to believe that nausea will be an important factor affecting survival in rougher sea conditions.

6.9.1 Indications of survivability margins

One individual had noticeably worse subjective report parameters throughout the survival exercise. Cold reached a score of 9, fatigue 7, thirst and discomfort 8, at the end of the exercise. In addition, his fine motor skills were negatively affected. We found that this person had been unlucky and damaged his survival suit. This subject matched the scheme with the highest scores on the numerical rating scale (NRS) self-report schemes (see Figure 11 below), as well as a very negative trend in the penny transfer test, assessing his fine motor skills. The defect/damage in his protective equipment allowed water to enter the suit, and, due to the high risk of hypothermia, we extracted him from the exercise 23 hours after boarding the life raft. The damaged suit negatively affected several aspects of his survivability and serves as a reminder of how small are the margins, which severely decrease the probability of survival for a longer period under the conditions experienced.

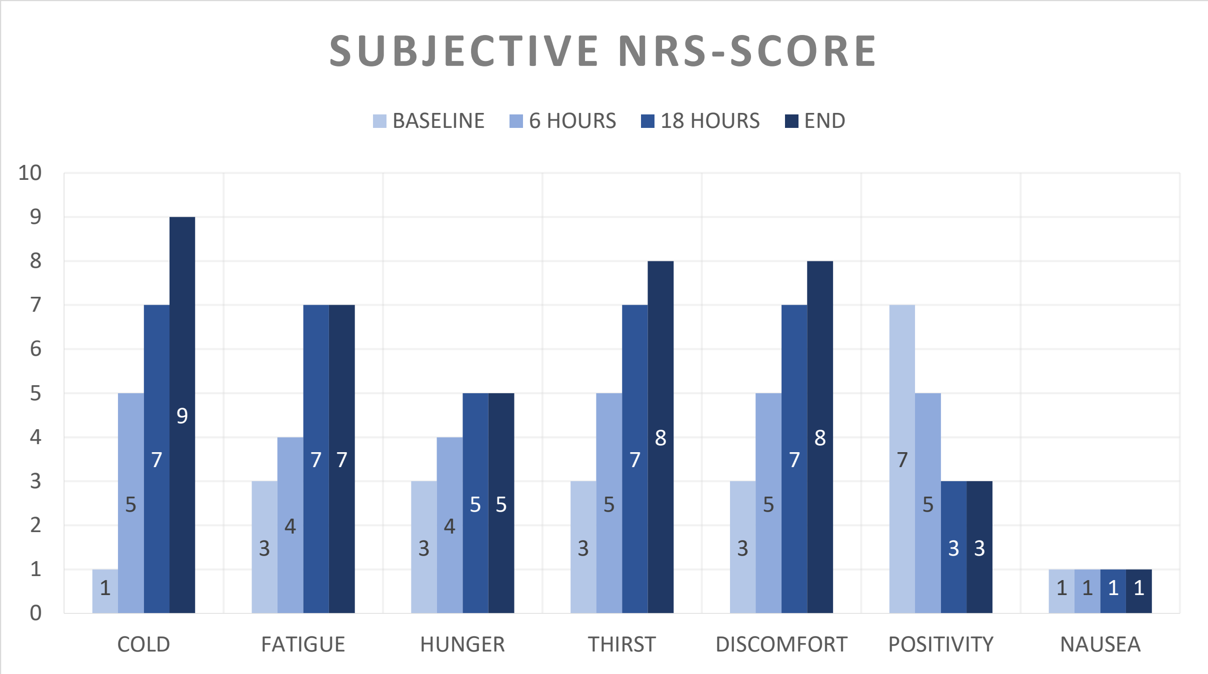

Figure 11 The NRS scores from participant no. 26 with a defect in his rescue suit, causing water intrusion and cooling. The extra effort necessary to stay on top of things caused increased fatigue, thirst and discomfort. The insight into possible consequences of the defective suit also severely affects the participant's positivity.

6.10 Conclusions on medical aspects

Survival in a cold climate environment is a very challenging endeavor, influenced by many factors. SARex have made observations in the very environment, in which the rules of the Polar Code apply. Already, after one day in a survival craft, the participants showed symptoms and signs caused by exposure to the elements. The survival exercise was ended after 27–30 hours. It seems very unlikely that all participants would have been able to survive for an additional four days inside the survival craft, with the personal protective equipment and rations provided, despite our exercise having been performed with healthy, relatively young individuals under quite optimal conditions. It should be noted, however, that the conditions for those who were onboard the lifeboat were far better than for those who had stayed in the life raft.

This leaves little doubt that survival for five days in a cold climate environment would be an extremely challenging endeavor when utilizing the equipment provided in this exercise.

It seems vital to provide increased insulation of vessels/personal protective equipment, heating capability and controlled ventilation. In addition, providing more generous water supplies in the rations and more space for moving around, by reducing the certified capacity in each rescue vessel, would contribute to a reduction in the likelihood of developing fatigue and to an increase in the probability of survival.

6.11 Discussion of survival test

6.11.1 The adequacy of modified survival craft for use in cold climate conditions

Both the rescue craft were modified to mitigate the challenges associated with cold climate operation. The modifications were modest, not involving high costs, to ensure commercial attractiveness for industry. They would, however, be priced more highly than standard SOLAS equipment.

6.11.1.1 Life raft

The life raft in SARex 2 was of a different type than that used in SARex 1 in 2016. However, some changes were made, based on experiences from SARex 1. In SARex 1, the passengers on board the life raft sat directly on the floor, with only a thin layer between themselves and the cold seawater. In SARex 2, the life raft was equipped with an inflatable floor. The exercise participants used pumps to inflate the floor. The passengers sat on a layer of air and were not directly exposed to the heat loss generated by the cold sea surface.

The life raft in 2017 also had sidewalls it was possible to sit on. In 2016, the passengers could only sit directly on the floor. In 2017, the structure of the raft made it possible to vary between sitting on the floor and on the sidewalls. This change in seating arrangements turned out to be good for changing seating position and for the possibility of carrying out some physical exercise to increase body temperature.

Some points worth mentioning:

- The raft came with two waterproof bags for the equipment.
- The raft did not have pockets for storing equipment. Since most of the survival suits also did not have pockets, storage of equipment proved to be difficult. Equipment could not be laid on the floor as people were lying on it; free space was not available.
- A small water leak made the floor wet at all times. The only option for keeping things dry was to put equipment inside the survival suits. That equipment could be difficult to find late. The raft came with a valve to collect condensed water and rainwater. There was no secure connection between the hose and the valve.
- The tent of the raft was held up by solid beams filled with air. Some handles fastened to the beams would have made it much easier to move around in the raft.

6.11.1.1.1 Heat loss: life raft

The heat loss from a unit is proportional to the difference in temperature (delta T). The only heat source inside the raft was the exercise participants. An individual's metabolism controls their body and tries to maintain a body temperature of about 37 degrees C. During periods of increased cooling, the body will adjust the metabolism to compensate for the heat loss and maintain a body temperature of 37 degrees C.

From the figure below, it is evident that the internal temperature of the raft was between 10 and 15 degrees C. for the first 20 hours of the test. Variations seen in the figure are a result of venting activities and visits by the medical crew. The heat loss did, however, increase as the ambient temperature decreased and the wind increased. Furthermore, additional heat was produced by the participants.

In a perfectly insulated container, the heat loss caused by the wind would be marginal, as the outside surface of the container would maintain the same temperature as the ambient temperature. In Figure 12 below, it is evident that the heat loss is increasing at a great rate as the wind speed increases.

The temperature inside the raft is fairly constant from about 12 to 18 hours into the exercise. From 18 hours onward, the internal temperature gradually decreases. This is due to the fact that the exercise participants are not able to compensate for the heat lost to the environment.

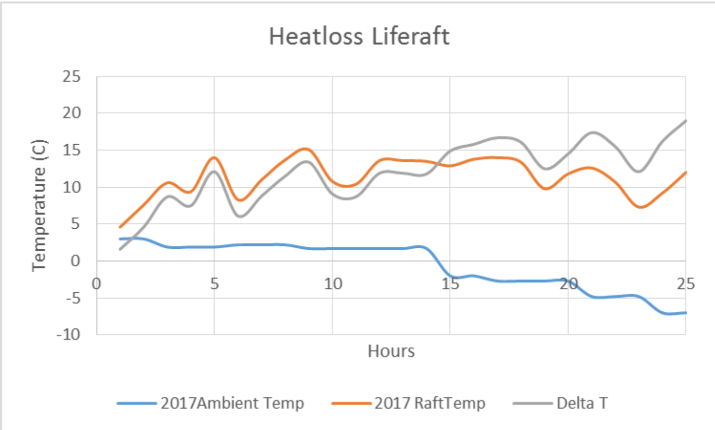

Figure 12 Heat loss in life raft

Comparing the delta T (the difference between the internal life raft and ambient air temperatures) between 2016 and 2017 is difficult and should be done with caution, as parameters like PPE, ambient air temperature and wind speed differ. However, if we look at periods when the conditions were the most similar (the same number of people and a difference in ambient air temperature of 1.5 degrees), the heat loss (delta T) is about 12 degrees for the life raft utilized in 2017, while delta T for the life raft utilized in 2016 was about 25 degrees. This indicates that the life raft in 2017 had significant improved functionality, as the heat loss experienced from this was about half that of the standard SOLAS-approved life raft utilized in 2016.

Studies conducted by Defence R&D Canada (DuCharme, 2007) show that the effect of an inflated/elevated floor is to significantly reduce heat loss from the raft, which harmonizes with our results.

6.11.1.2 Lifeboat

The lifeboat used in SARex 2017 was the same as that used in 2016. It was, however, upgraded with toilet facilities, seating insulation, heater and facilities for three people to lie down.

The additional facilities were beyond what can be expected in most lifeboats. Based on the medical observations, it came as a surprise that negative trends were observed for the lifeboat participants. This is assumed to be the result of a combination of several different mechanisms at play (see chapter *Medical Observations during Survival Test* for more information).

Several of the participants on board the lifeboat complained about moisture. Moisture generation is a result of a combination of factors, including:

- Moisture generated from participants' breath
- Condensation on cold surfaces
- Heat introduced to the system
- Air circulation

Based on the figure below, it is evident that the lifeboat environment contained about 80% humidity for a majority of the time. This is about the same humidity as experienced in the life raft. To be able to decrease the humidity, increased air circulation in combination with a higher degree of insulation of the cold surfaces would have improved the situation.

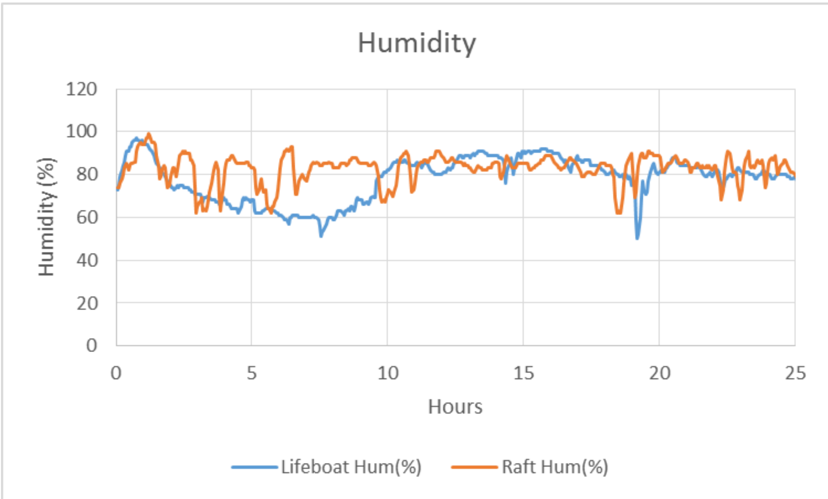

Figure 13 Humidity in rescue craft

6.11.1.2.1 Heat loss: lifeboat

A diesel heater had been mounted in the lifeboat. Both the airflow and temperature were adjustable. In addition, the engine emitted heat when warm. As the engine was utilized to recharge the batteries at regular intervals, it was warm at all times throughout the exercise.

From Figure 14 below, it is evident that there are no correlations between the ambient air temperature and the internal temperature of the lifeboat. This proves that the heat introduced to the system (heater and engine) compensated for all heat loss.

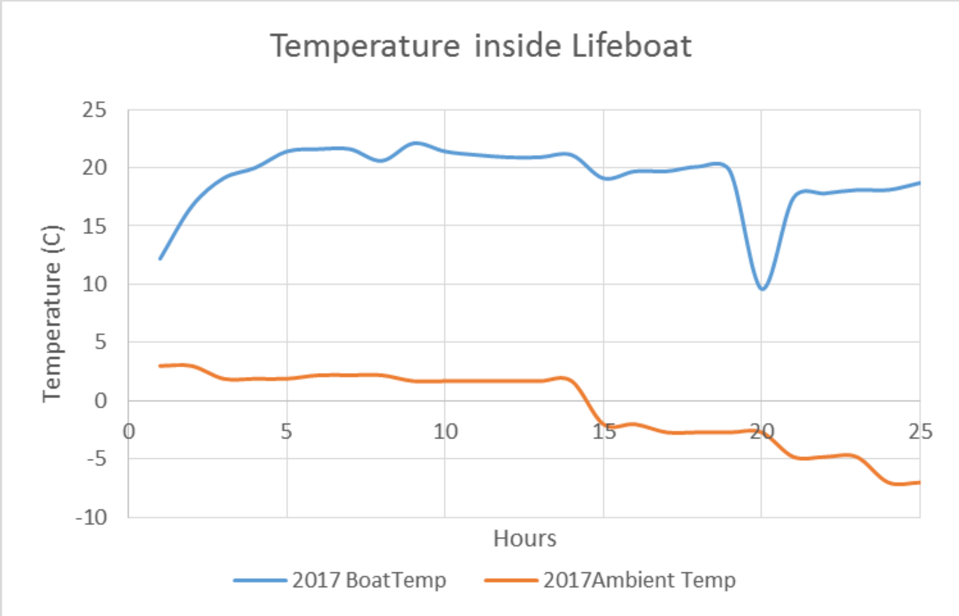

Figure 14 Temperature inside lifeboat

6.11.2 The adequacy of PPE for use in cold climate conditions

Every exercise participant was asked to bring his/her own underwear, socks, cap/hat, and gloves or mittens. The result was a variety of types, standards and quality. The effect of this reduces to some extent the validity of the exercise, however, it will represent a realistic case where passengers have to go to the survival crafts:

- There was no registration of type of underwear. We therefore do not know the extent to which the exercise participants wore decent quality woolen underwear.
- Some exercise participants brought gloves, others brought mittens, and some brought neither gloves nor mittens. We did not register the quality of gloves or mittens. Some brought woolen gloves or mittens; others brought gloves or mittens made of leather or Gore-Tex.
- The exercise participants were asked to bring two pairs of high quality woolen socks. Some participants, however, brought only one pair of socks, or socks of inferior quality, such as cotton socks.
- Some exercise participants brought their own headwear; others did not. We did not register the quality of headwear. Some brought woolen headwear; others brought headwear made of cotton or Gore-Tex.

It is difficult to conclude on the impact of wearing personal protective equipment on the exercise participants' well-being during the exercise or their ability to remain in the rescue craft. Bearing in mind the harsh climate conditions during the exercise and that one important factor for being pulled out of the exercise by the medical doctors was low body temperature, it is likely that inadequate personal protective equipment would result in being removed earlier. It is also fair to expect that wearing high quality underwear, socks, mittens and hats would give an exercise participant a very good foundation for being able to stay in the rescue craft over a longer period of time. It was also observed that all exercise participants remaining in the life raft until endex (6 exercise participants out of 19) wore decent headgear.

Another issue is the combination of insulation layers (typically wool) and survival suit. It is important to see the insulation layer in relation to the type of survival suit utilized. Some survival suits came with padding in the seat, to protect against the cold of the seawater; others had integrated gloves, making it very difficult to use hands without taking off the suit. The survival suits were fitted with hoods. Some exercise participants, especially those who had been handed a survival suit that did not fit them, observed that they could not wear the hood due to the strain on their neck muscles.

Many of the survival suits came without pockets. In a life raft, with water on the floor, it is of the utmost importance to keep all clothes and equipment dry. Without pockets, the only place to store gloves, headgear, food, etc., is to put items inside the suit. Some items quickly ended up at the bottom of the suit. Retrieving the items proved to be difficult and involved either stripping down the suit or asking a good friend to search down your suit.

Some life raft participants utilized seat pads. They gave protection against not only the cold bottom but also the wet floor of the life raft. Many participants commented that these seat pads made a huge difference to the ability to survive.

The use of technical equipment often requires skills. This applies to radio equipment, medical equipment, pyrotechnics, the actual life raft itself, etc. Technical skills and knowledge are, however, also important for the proper use of survival suits. It was observed that, during a 30-hour stay in a survival suit in a cold climate environment, there are some important issues that require attention:

- When staying in a suit for a longer period of time, condensation tends to accumulate on the inside. This condensation must be ventilated at regular intervals for the person to stay dry and warm.
- Many survival suits are made for static positions. They are not made for physical activity. There is typically one belt on each leg, just above the ankles, for tightening the suit to make it possible to walk relatively easily. These belts must be loosened when sitting in the raft to allow air to move around inside the suit. If the belts are not loosened, you may end up with freezing feet because warm air is not moving freely inside the suit.
- Many survival suits come with neoprene gloves. These gloves, which are waterproof, are constructed to keep you warm in cold weather conditions. The gloves are not breathable, so condensation accumulates. The condensation is warmed to body temperature right away and helps keep the hands warm. This is good if you keep the hands in the gloves at all times.
- If your hands are cold, and you struggle to regain the heat, then the buddy system could be a good option: to warm your hands on the stomach of your buddy, or to borrow a pair of woollen gloves.

There are many issues to pay attention to regarding the use of the survival suits. Some instructions on these issues should be communicated or should accompany the suit.

6.11.3 The adequacy of water and rations

The water and food supplied to the participants were standard SOLAS-approved rations and were not purposely designed for a cold climate survival scenario.

A majority of the participants lost between 1.4 and 2.2 kg during the exercise. There were slight differences between the life raft and the lifeboat. Most of this weight loss was the result of fluid (water) loss. If this loss continued, most of the exercise participants would be in a dehydrated state. The symptoms of dehydration will vary with the amount of total body water loss.

- 5% to 8% loss of total body water content can cause fatigue and dizziness
- 8% to 15% loss of total body water content can cause physical and mental deterioration
- 15% to 25% loss of total body water content can cause death

Based on our observations, it is evident that many of the exercise participants would enter a state where fatigue and deterioration would highly affect their functionality within a five-day survival scenario. This would render them in a condition, in which they would no longer be able to safeguard their individual safety.

The food rations provided did not compensate for the energy consumed by the heat loss. Studies on military personnel exposed to high physical stress show that they develop a reduced body core temperature when not supplied with sufficient rations. A study conducted by Norwegian defence research Establishment (Teien, 2014) showed a core temperature difference of 0.4 C between participants receiving sufficient rations and those not receiving sufficient rations. It can be expected that insufficient rations will contribute to a higher probability of developing hypothermia.

6.11.4 Space requirements

Most participants addressed the importance of the ability to move about. When the exercise participants were strapped to their seats, almost everyone complained of back pain after just a few hours. The movement of the raft in the waves made participants naturally shift positions regularly, as long as the space to move was available.

In the life raft, shifting of weight (which requires movement) was necessary to keep the raft in a stable condition, especially at increasing wave height.

The space available for movement is correlated with the utilized capacity of the rescue craft (the capacity of the rescue craft/the number of persons on board the rescue craft). The capacity calculations are based on the standard IMO definition of a standard maximum linear width of 430 mm and a body weight of 75 kg. A study of offshore workers conducted in Canada (Kozeya et al., 2008/2009) indicates that 85% of the studied population were heavier than the IMO definition of 75 kg and that 98% of the workers had a shoulder breadth greater than the 430 mm defined in the IMO requirements.

If a rescue craft is filled to 100% of its capacity, the desired space for movement will not be available. This will increase the probability of blood clots and contribute to the development of fatigue.

6.11.5 Exercise participants – differences from a real scenario

There are expected to be differences between this exercise and a real-case scenario. The key elements that made the results from this exercise different than those expected in a real-case scenario are the following:

- All exercise participants knew in advance that they would be participating in this exercise. They therefore had the opportunity to prepare themselves mentally and physically, and to bring personal protective equipment of a good standard.
- The concentration of cold climate experience and naval experience was high among the exercise participants. It is less likely that this level of experience would be available to the same degree among cruise passengers.

- The exercise participants' physical condition was fairly good and the average age relatively low. It is likely that cruise passengers would be older and in less robust physical condition.
- The level of motivation among the exercise participants was high. They looked forward to taking part in the exercise, albeit some with more cautious enthusiasm.
- The morale of the exercise participants may have been influenced by the presence of KV Svalbard. This is positive, regarding the willingness to play along in the exercise, but it may also have had a negative impact.
- The exercise participants came from the crew on board KV Svalbard and the scientific staff. It is fair to assume that management of the KV Svalbard crew may prove easier for the officers in charge of the lifeboat and life raft, than management of a loosely composed collection of people such as a group of tourists on board a cruise vessel.
- Although SARex 2 is an international exercise, most of the participants were Norwegian. A more international and multicultural setting may have resulted in challenges that were not faced in this exercise.

6.11.6 Exercise artificialities

There will always be some artificialities in exercises. These will influence the external validity of the exercise findings, i.e. the extent to which the findings from the exercise are transferable to other settings. The question is how relevant the findings from the exercise will be, compared to the situation faced by people (tourists on board cruise vessels and others) after a real shipwreck in Arctic cold climate conditions.

The exercise participants boarded the life raft from one of KV Svalbard's MOB boats. They were able to execute a dry boarding, i.e. none of the exercise participants was wet following a rescue via the sea. It is likely in an abandon-ship scenario that some people will board the lifeboats and life rafts from the sea. In cold climate conditions, this could significantly affect survivability.

One major artificiality is that KV Svalbard was in close proximity to the lifeboat and life raft. It is relevant to assume that the presence of the region's most well equipped and experienced SAR ship and crew will have an impact on the morale of the exercise participants. When needing to go to the toilet, the exercise participants in the life raft were allowed to either use the MOB boat or to board KV Svalbard, this did, however, represent a mayor cooldown activity that should not be disregarded when evaluation the exercise. In a real scenario, survivors would be required to make the best of the facilities on board the rescue craft.

Another possible impact of the presence of KV Svalbard on the exercise was that the existence of a safe haven could mean that the option to abort the exercise was close at hand. The exercise participants were of course volunteers and could abort the exercise whenever they felt the need to do so. This option of an early retreat to KV Svalbard may have had a cognitive impact on the will to engage in life-maintaining activities on board the rescue craft.

Aborting the exercise involved being transferred from the rescue craft to KV Svalbard with the mob-boat.

In SARex 2, medical doctors visited the life raft at regular intervals to test the cognitive and physical status of the participants. They were also supposed to measure the exercise participants' body temperature. Unfortunately, the measurement of body temperatures proved to be difficult for technical reasons, resulting in the participants' body temperature not being measured in the last part of the exercise. Although the visits by the medical doctors were always a welcome change to the routine in the raft, they were also an artificiality, creating some disturbance. The visits also meant opening one of the entrances, resulting in cooling down the temperature inside the raft.

6.12 Survival craft recommendations

6.12.1 Compliance with the Polar Code

Resolution MSC 385(94), the Polar Code, states that survival for five days is to be achieved. To increase the probability of survival for five days in a survival craft, the following recommendations have been identified.

6.12.1.1 Recommendations: lifeboat

Based on discussions with the participants and the medical team, the following improvements to life boats are recommended:

- Increase sitting comfort – considerable discomfort was experienced due to non-ergonomic seats. This resulted in back pain and inability to move.

- Ample space for the persons on board to move to maintain sufficient blood circulation has to be ensured when determining the capacity of the survival craft – limited space to move restricted blood circulation and eventually made the participants unable to function properly. Inability to move also increases the probability of blood clots, especially after 24 hours of inactivity.
- Ensure sufficient ventilation/heating/insulation to minimize condensation as condensation generates poor visibility through the windows, in addition to making the personnel on board wet (which reduces the effectiveness of their insulation layers).
- Install CO_2 or O_2 alarm systems to keep ventilation to a minimum.
- Increase water rations, as the current water rations will lead to dehydration, which will influence the ability to survive, with regard to prevention of the development of fatigue, preservation of cognitive abilities and resistance to hypothermia.
- Increase food rations to prevent the development of hypothermia.

6.12.1.2 Additional recommendations: lifeboat

Additional recommendations that might increase the probability of survival are:

- Consider removing from the “Immediate Precautions” manual the ‘24-hour rule’ before using the food rations. The medics monitoring the participants during the test were unable to explain the 24-hour rule.
- Consider inside handles to make it safer to move around and to stand or sit in the door openings. The possibility to move around and stretch one’s legs is important, especially for a prolonged stay.
- Consider handles on the roof for use when being lifted off by helicopter.
- Consider heater to be supplied with dry air from outside, also distributing warm air to cockpit windows. Non return air outlets should be used to let the moist air out.
- Consider an easily available system for storage of equipment and survival suits during the survival period.
- Consider toilet facilities that flush straight out to sea, reducing the probability of spills and odor and improving the hygiene level.

6.12.1.3 Recommendations: life raft

Based on discussions with the participants and the medical team, the following improvements to life rafts are recommended:

- During a five-day stay, it is important to have the possibility to exercise. Due to the shape of the canopy, the self-righting life rafts provide the possibility to stand up and move around. On self-righting life rafts, the upper side of the buoyancy modules can be used as extra accommodation/seating area.
- Ample space for the persons on board to move to maintain sufficient blood circulation has to be ensured when determining the capacity of the survival craft, note the need to provide space for both personal survival equipment and for exercising.
- Self-righting technology is recommended for ease of entering the life raft, hence reducing the time spent in the water.

- The use of an inflatable floor or similar is strongly recommended to reduce the heat loss through the bottom.
- The use of seating mats or similar is recommended, as they reduce heat loss through the floor and elevate the survivors out of potential water puddles on the floor. Seating mats should be part of the personal survival kit. Participants using the seating mats were satisfied with their performance. Seating mats should be supplied for everyone.
- CO_2 or O_2 alarm systems should be installed to keep ventilation to a minimum.
- Water should be increased, as the current water rations will lead to dehydration, which will influence the ability to survive, with regard to motivation, cognitive abilities and resistance to hypothermia.
- Food rations should be increased to prevent the development of hypothermia.
- Instructions should be improved, as the small letters in the "Immediate Precautions" manual are difficult to read. Some people are unable to read the instructions without glasses.

6.12.1.4 Additional recommendations: life raft

Additional recommendations that might increase the probability of survival are:

- Consider protecting the zipper against icing, which might complicate closing the door.
- It was difficult for the towing boat to catch the towing bridle. Consider a towing bridle in every corner, which would make it possible to catch one, no matter how the life raft turns toward to the wind. The crowfoot can also be used as a guy line, if the life raft is used as a tent on the ice.
- Consider handles on arc tubes to make it safer to move around and to stand or sit in the door openings. The possibility to move around and stretch one's legs is important, especially for a prolonged stay.
- The hand pump can build up pressure to boost the inflatable floor. Over-pressure valves should be considered.
- Joint points in the inflatable floor are not insulated. Joining points are of single-layer fabric and, here, the evacuees are sitting closer to the cold water. Although the floor is placed between the buoyancy tubes, it is still below water level.
- Two viewing ports are preferred, since viewing in the opposite direction must otherwise take place through the open door.
- It was difficult to close the viewing port with gloves. A different system that can be operated with gloves should be considered.
- The inner and outer canopy sticks together due to condensed water. Something to maintain distance between the two is needed.
- The zipper is difficult to operate at high wind velocities. Improved closing facilities should be considered.
- Consider removing from the "Immediate Precautions" manual the '24-hour rule' before using the food rations. The medics monitoring the participants during the test were unable to explain the 24-hour rule.
- Consider toilet facilities inside the life raft, using the anti-vacuum tubes or similar.

- Many appliances such as pyrotechnics, first aid kit, torch, on-scene communication, etc. are lying around on the floor. A mesh or pockets in the arc tube should be considered.
- Consider replacing the viewing port with a window.
- Consider improving instructions, as the small letters in the "Immediate Precautions" manual are difficult to read. Some people are unable to read the instructions without glasses.
- A sponge of good quality and size is essential for keeping the floor dry.
- The canopy catches a significant amount of condensed water due to humidity. The water can be collected, as in the rainwater collector.
- Consider improving the opening, in order to reduce the water (rain) entering the life raft.

6.13 Evacuation by helicopter: test

The utilization of helicopters in the evacuation of survivors is an integral part of most countries' SAR capacities. A helicopter is a great tool, as it has the capability to travel at high speed and cover large distances in a short time. Lifting individuals from the vessel, rescue craft or from the water is, in many cases, the preferred method of transferring personnel.

However, there are limitations, with regard to several factors affecting a rescue operation:

- Flight time due to fuel capacity
- Fight time due to crew resting hours
- Flight time due to technical problems
- Lifting weight/capacity (fuel and number of persons)
- Weather restrictions
- Range
- Visibility

In a remote Arctic environment, many of the above limitations will affect a SAR operation.

To be able to efficiently utilize a helicopter in a SAR operation, it is important to understand the limitations associated with helicopter operation.

On Sunday 7th May 2017, a helicopter evacuation was carried out. The objectives of this exercise element were to:

- Identify challenges and the time needed for the evacuation of personnel from a lifeboat by helicopter.
- Ensure learning for rescue helicopter staff and Coast Guard staff.

The weather was good, with a slight breeze and good visibility. KV Svalbard was located mid-Isfjorden outside of Longyearbyen; 27 persons (including 10 privates from KV Svalbard) were onboard an enclosed lifeboat, 6 nm away from KV Svalbard. All persons were fit and dressed in survival suits. The helicopter was made available from Longyearbyen Airport and was equipped with rescue equipment and with a rescue man.

6.14 Execution of the helicopter evacuation from the lifeboat

Rescue directly from the lifeboat was considered to be difficult and risky, due to the motions of the lifeboat and the narrow hatch opening on the side of the lifeboat. Most personnel were transferred to the roof of the lifeboat and lifted on to the helicopter.

Due to high movements, no handholds and an icy and slippery surface, some evacuees were asked by the rescue man to jump into the water. They were lifted directly from the water.

One group of people was flown back to KV Svalbard, while the second group had to return to Longyearbyen with the helicopter, due to technical problems onboard the helicopter.

6.15 Exercise validity

The exercise was carried out in ideal conditions, and it can be assumed to be a 'best case', compared with a real scenario. The following parameters were present during the exercise:

- Visibility – good
- Temperature – -2°C
- Waves – 0.1 meter
- Icing on lifeboat – marginal
- Participants – well rested and well fed; no disabilities or injuries
- Helicopter crew – well rested and well fed
- Distance traveled before pick-up of participants – about 2 nautical miles
- Distance traveled with evacuated participants – about 6 nautical miles

6.16 Assessment of the exercise

The exercise revealed several issues of interest.

- The personnel being hoisted from the water were wearing survival suits and an inflatable life vest. To be able to attach the people to the hoisting sling, all inflatable life vests had to be punctured by the rescue man's knife. In a large-scale event, this would consume valuable time.
- From when the helicopter arrived on the scene, it took considerable time to prepare the rescue lifting operation.
- The lifeboat roof was slippery and small. In addition, a slight swell caused it to slightly roll. Due to the above-mentioned factors, only two persons (in addition to the rescue man) could go onto the roof at a time. The exercise participant could not go onto the roof until the rescue man was ready to put on their slings, to minimize the risk of falling off the roof. This consumed valuable time.
- The evacuation by helicopter took considerable time, and the helicopter had to make two turns to evacuate everyone.
- It was very crowded on board the helicopter, and conducting medical tasks would be difficult.

6.17 Evacuation by helicopter: conclusions

Evacuating a large number of people by helicopter proved to be a relatively time-consuming endeavor. Due to the cold climate conditions, the participants wore survival suits, restricting movement. The restricted movement, in combination with a slippery lifeboat roof, resulted in added risk and time.

There were suggestions that the use of a helicopter to rescue people from a life raft would be easier; however, this is still not very efficient in a large-scale scenario.

If the helicopter base were to be 90 min. away, it would have taken theoretically 3.1 days to evacuate 700 persons onboard (the number of passengers and crew on a relatively small cruise liner) from enclosed lifeboats at the evacuation speeds experienced in the exercise. In a real scenario, the process could have been speeded up, but additional challenges like immobility due to injuries or hypothermia would have slowed down the process considerably.

During an operation lasting 3.1 days, refueling of the helicopter, crew resting time and technical issues on the helicopter would have caused the operation to be halted, causing further delays.

In a large-scale cruise ship scenario, evacuation by the MOB boats from KV Svalbard would be considerably more efficient, provided that a Coast Guard vessel was nearby.

Until there is technology available that enables helicopters to simultaneously lift a large number of people, a considerable length of time is to be expected in relation to helicopter evacuations. If the life raft were designed to be lifted by a single hookup point and the pressure inside the tubes were sufficient to prevent the life raft from collapsing, the whole life raft could have been lifted ashore or on to the deck of a SAR vessel. This would save considerable time, as it would only require one lifting operation, instead of one lifting operation for every two survivors.

7 RF LOCATION BEACONS TEST

7.1 Background

The 'heroic era' of polar exploration started with no electronic communication at all and ended with only marginally reliable HF radio. Classic terrestrial and celestial navigation was a standard positioning method until the last two decades of the 20th century, with radio navigation like Loran or Omega available only for ships and aircraft. Current instant accessibility to means of location, communication and tracking, together with the implementation of GNSS (Global Navigation Satellite Systems), is probably the most significant safety improvement in the Polar Regions in recent times.

7.2 Current technology

High latitudes of both North and South Polar Regions are served by the Iridium satellite communication constellation, located in Low Earth Orbit (LEO). Except for some locations with terrain obstacles, like narrow valleys, where the satellites may be out of 'view' for brief periods, the coverage is continuous, and the access is instant. The user stations are either hand-held devices with bandwidth of 2.4 kbps or larger, fixed installations (Iridium Pilot, Open Port), which allow up to 128 kbps. Circumpolar latitudes of less than approx. 70–75 degrees additionally benefit from access to satellites in geostationary orbit (GEO), like Inmarsat, Thuraya, or different V-SAT services. Most of these systems also provide devices with instant alarm capability (see below).

The international global system for alarm and location in distress is Cospas/Sarsat (C/S), with two fully functional constellations:

- GEOSAR - with space segment on geostationary satellites
- LEOSAR - with space segment on environmental satellites in polar Low Earth Orbits
- MEOSAR - currently under deployment and only partially operational

MEOSAR payloads will be on Galileo navigational satellites; the constellation will merge the advantages of LEO- and GEO-SAR and will provide additional functionality, e.g. confirmation of alarm reception by ground segment. At the present time, LEOSAR is currently the only constellation routinely accessible in high Polar Regions, and the reception and download of the distress signal may be delayed (in the Antarctic more than in the Arctic), in comparison with instant detection by GEOSAR. This delay would be in the order of minutes, maximal approx. 40 minutes.

Cospas/Sarsat user emergency beacons exist in three versions with identical operational principles:

- Emergency Locator Transmitter (ELT) for aircraft
- Emergency Position Indicator Radio Beacon (EPIRB) for marine craft
- Personal Locator Beacon (PLB) for personal use

They can be by activated by impact g-forces, by immersion, or manually. All modern beacons transmit an emergency signal at 406 MHz, with embedded user identification and GNSS-derived position, to C/S satellites, and a short-range homing signal at 121.5 MHz to direct the search craft.

In a nominal scenario, the information from the satellites will be downlinked to ground receiving stations, further to the respective Mission Control Centre (MCC) and from there relayed to SAR forces. In recent years, technology has been developed that allows the SAR craft to directly detect the signal from the distress beacon and decode the embedded information about the identity (vessel, aircraft, and individual). This gives the on-site Search and Rescue teams (S&R teams) essentially the same information as the MCC receives through the satellite. In addition, this technology allows direct homing in on the 406 MHz distress signal, which is about an order of magnitude stronger than that at 121.5 MHz. Such equipment can be either fixed installed onboard the vessel or aircraft or used on snowmobiles, ATVs, or even on foot by skiing search parties. Some of the beacon decoding and 406 homing equipment was tested during the SARex 2, in a joint effort with the Memorial University in Canada.

The communication (Iridium) and alarm (Cospas/Sarsat) equipment mentioned above is simple, portable (EPIRB and PLB), quite reliable and comparatively cheap. If properly used by a party in distress, it will significantly reduce the search component of the rescue mission and shift the focus onto assistance and retrieval. In some jurisdictions (e.g. Svalbard and Greenland), in order to obtain an expedition permit, all field parties are required to carry Iridium satellite phones, together with Cospas/Sarsat emergency transmitters. That makes sense, since such a combination, based on two technically completely independent principles and systems, will provide for sufficient redundancy in all reasonably possible scenarios.

It should be noted that the earlier Class 1 PLBs, rated to -40C, are no longer available on the market. The performance of Class 2 beacons (-20C rating) in very cold conditions is unknown, and an evaluation, in partnership with the Canadian Beacon Registry, is being proposed.

In the maritime community, 121.5 MHz rescue transmitters still survive but are of very limited use elsewhere, since the 121.5 MHz reception by the satellites was discontinued in 2009. They are still used as MOB (Man-Over-Board) alarm devices locally, on ships equipped with the proper receivers.

AIS (Automatic Identification System) transmitters and receivers are standard equipment on all commercial and other larger vessels, and AIS beacons can indeed be useful for the location of survivors. As with older 121.5 MHz beacons, they are confined to local use (line of sight between receiver-transmitter antennas). The reception of AIS transmission by satellites has been routinely used in vessel tracking but is not yet well implemented in the SAR community.

Search and rescue transponders (SART radar transponders), avalanche location beacons, VHF or cellular phones or any other means of RF signal transmission/detection may be also used to locate the individual in distress; their description is beyond the scope of this report.

7.2.1 Satellite Emergency Notification Devices

Satellite Emergency Notification Devices (SEND) are essentially modified satellite phones. The principle is based on reception of GNSS position signal, addition of distress party identification and re-transmission of such information to a user-defined receiving station. Typically, Iridium, Inmarsat, Thuraya, or Globalstar devices are used (e.g. Delorme InReach). The overall reliability of SEND is lower than that of Cospas/Sarsat, mainly due to signal path, less robustness, and non-global coverage, with the exception of SEND operating on Iridium constellation. Moreover, these location services are commercially operated, without clearly defined access to and agreements with international S&R structures. Cospas/Sarsat is the only organization with 24/7 available access to SAR resources on the global scale.

7.3 EPIRB test motivation

The Maritime Safety Committee added a new output (MSC 95/22, paragraph 19.9), instructing IMO's Sub-Committee on Navigation, Communications and Search and Rescue (NCSR) to review and update resolution A.810(19). The target completion year is 2017.

The USA was asked to submit a proposal for new performance standards for EPIRB. One suggestion was that the 121.5 MHz homing signal should have a duty cycle of not less than 33% (e.g. 0.75 seconds on and 1.50 seconds off); reference is made to article 4 in the annex to NCSR 4/19.

The EPIRB is often located on the sea surface. This is not an ideal situation with regard to 'line of sight' communication, as antenna location is not ideal, and the Fresnel Zone is heavily obstructed. SARex 2 wanted to assess the real functionality of EPIRBs being utilized in Arctic conditions.

Few tests have been carried out to see whether the reduced duty cycle has any effect on the homing of EPIRB. We wanted to assess the homing abilities of the 121.5 MHz signal with a reduced duty cycle. In addition, we wanted to assess the range of the signal and the effect of the obstructed Fresnel Zone.

We also wished to test how the performance of AIS SART compares with that of EPIRB.

7.4 Test

7.4.1 Test conditions

The tests were conducted in Krossfjorden, North of Ny-Ålesund, at the approximate position N79.2ºN, 11.8ºE. The area is sheltered, with mountains of an altitude of 700 meters to 1200 meters, obstructing the view in all directions, except out the narrow fjord in a southerly direction. The weather was good, with no precipitation.

EPIRB test conditions.

7.4.2 Test setup

For the test we had two EPIRBs with a reduced homing signal and one EPIRB without a reduced homing signal cycle. All EPIRBs were modified to send out no signal on 406 MHz.

We were also equipped with two AIS SARTs and two radar transponders.

The plan was to test the EPIRB, AIS SART and radar transponder from the lifeboat. The signals from the EPIRB were homed from the bridge of KV Svalbard, and the signal strength were also measured. For measuring the AIS SART, the **ship's** Electronic Chart Display and Information Systems ECDIS were used and, for the radar transponder, the ship's 9GHz radar was used.

Signal strength (max. values) was measured, utilizing a spectrum analyzer (TTI, PSA 1302), connected to a tuned half-wave dipole. The equipment was located at an altitude of about 15 meters, on the bridge wings, with a direct 'line of sight' to the transponders. The signal strength values were recorded manually.

The test started with KV Svalbard at a distance of 0.9 nm off the lifeboat, and all equipment was tested in the three positions before KV Svalbard moved to 2 nautical miles from the lifeboat. Then it moved to 3 nautical miles and thereafter to four nautical miles off the lifeboat.

Erik J. Landa deploying EPIRB.

7.4.3 Result from the tests

7.4.3.1 EPIRB – signal strength measurements

The recorded values were plotted against theoretical values. The theoretical values were obtained and estimated, based on a simplified version of the Friis transmission equation.

A simplified version of the Friis transmission equation can be expressed in the following relationship:

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$$

where:

- P_r = power received
- P_t = power transmitted
- G_t = gain transmission antenna
- G_r = gain receiving antenna
- λ = wavelength
- R = distance between antennas

Expressed in db, the formula is modified to:

$$P_r = P_t + G_t + G_r + 20\log_{10}\left(\frac{\lambda}{4\pi R}\right)$$

The gain of the receiving half-wave dipole antenna is estimated to be 2.15 db, and the power transmitted from the EPIRB is 100 mWatts. As the EPIRB transmission antenna is a shortened helical antenna used in normal mode, the antenna gain is estimated to 1 db.

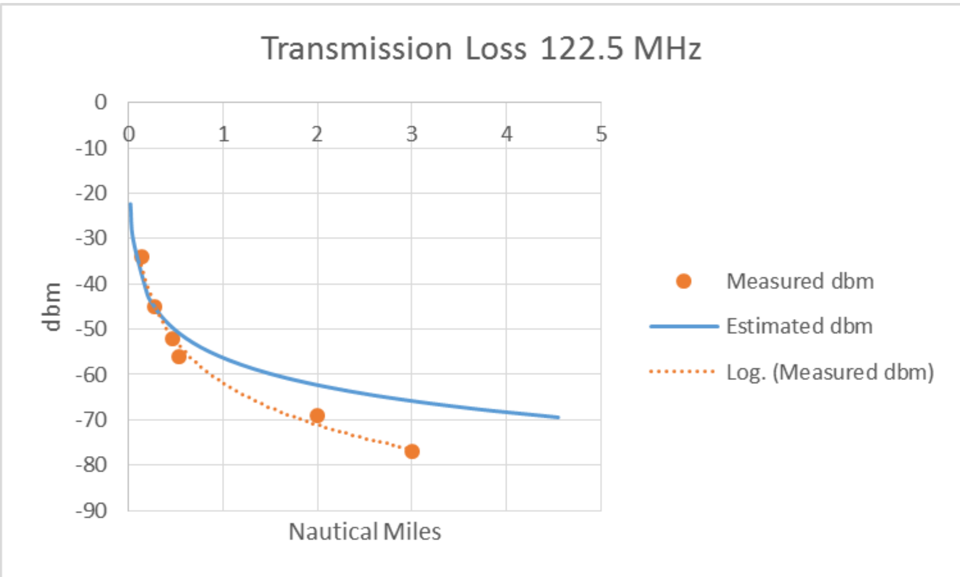

Figure 15 Transmission loss

Based on Figure 15 above, it is evident that there is considerable loss in the system, compared with an ideal system, as described by the Friis transmission equation.

7.4.3.2 Areas of loss

From an RF perspective, a free-floating EPIRB and a reception antenna located on the bridge of a SAR vessel is not an ideal setup. Several factors affect the occurrence of signal loss. The most dominant factors are:

- Transmission antenna characteristics – The transmission antenna mounted on the EPIRB is a shortened helical antenna used in normal mode. The antenna is shortened due to improved physical handling characteristics. Both the efficiency and the gain associated with this antenna setup is not optimal but is a balance between handling characteristics and range.
- Antenna polarization – The EPIRB utilizes a vertical helical antenna in normal mode, giving the unit vertical polarization. If the unit is free floating, the angle of the antenna (and polarization) will change with the angle of the water surface. In dead calm waters, the position of the antenna will be vertical, but in seas the angle will vary. To compensate for this effect, most EPIRB receivers are equipped with antennas with circular polarization. The theoretical loss incurred as a result of this change in polarization is –3db, which is equivalent to half the received power.
- Wave shadowing effect – During periods of high wave height, part of the time the EPIRB unit will be located at the bottom of the swells. This will result in the unit transmitting directly into the crest of the waves. The wave crests will efficiently attenuate the signals and practically block them from reaching a receiver located on a vessel.
- Precipitation – During periods of heavy snow and ice, the signals can be attenuated. The same effect can be observed during strong winds, as the transmission path will be heavily influenced by a high seawater content.
- Icing of transmission antenna – During periods of low temperatures, buildup of sea spray icing can occur on the transmission antenna. The icing will alter the antenna characteristics and also attenuate the signals. Both effects will result in reduced effective power being transmitted from the unit.

7.4.3.3 Multipath reception

Multipath reception occurs when the main signal, following the direct line of sight path (LOS), and reflections of the signal arrive at the reception with a shift in phase. If the signals are shifted by 180 degrees, they will cancel each other out. The difference in the direct path length and the reflected path length is called the excessive path length. The path lengths of concern are described through what is called the Fresnel Zone (Kamil Yavuz Kapusuz, 2014), Figure 16.

The Fresnel Zone can be calculated based on the following formulae:

$$F_{\mathrm{n}} = \sqrt{\frac{n\lambda d_{\mathrm{k}}(d-d_{\mathrm{k}})}{d}}$$

where

- F_n = Fresnel Zone
- n = zone number
- λ = wavelength
- d_k = distance from antenna to point of interest

- d = total distance

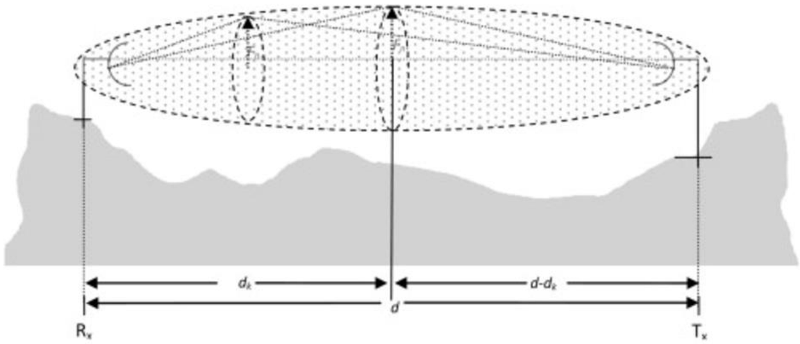

Figure 16 Visualization of Fresnel Zone (Kamil Yavuz Kapusuz, 2014)

For an EPIRB located on the sea surface at pt. (0.0) and a receiver located on the bridge of KV Svalbard at an altitude of about 15 meters at a distance of 6 km, 99% of the first Fresnel Zone is located below the water surface. As a general rule of thumb, obstructions are not to penetrate within 0.5 km of the first Fresnel Zone or multipath reception and signal degradation are expected to occur.

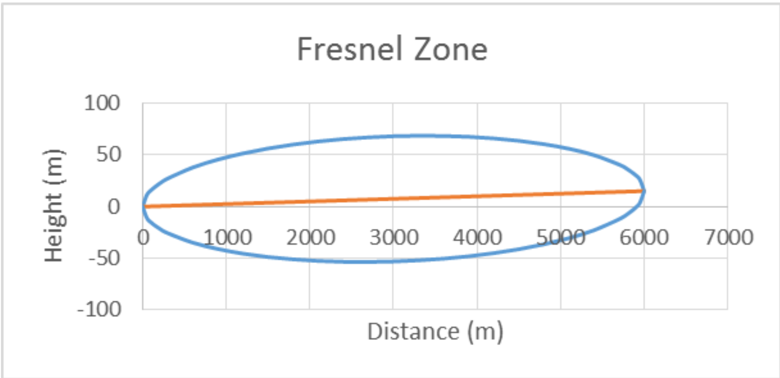

Figure 17 Fresnel Zone for an EPIRB located on the sea surface (0.0) and a reception antenna at altitude km 15 meters, 6 km away (6000,15).

Based on the graph in Figure 17 above, it is evident that a majority of the Fresnel Zone is obstructed by seawater. This will degrade the received signal due to the multipath reception. As the seawater surface is a constantly changing medium, the range of degradation will vary, depending on sea state.

It is also important to note that the longer the 'distance', the higher (in percentage) is the obstruction of the Fresnel Zone. This should result in a higher degradation of the signals at longer ranges. The effect of this phenomenon is to be observed as the increasing gap between the curve from the estimated signal strength (based on the Friis equation) and the observed signal strengths in Figure 15, "Transmission Loss 122.5 MHz".

7.4.3.4 EPIRB – Homing in on the signal

For homing in on the signal, KV Svalbard's standard homing radio was utilized.

At 0.9 nm, we received signals from all equipment in all positions. There was no difference in signal strength between the modified EPIRB with reduced duty cycle and the original, and we managed to home in on both PIRB.

With the EPIRB in the water, the signals were lost at a distance of less than 2 nautical miles.

At a distance of 2 nautical miles, with the EPIRB located on top of the lifeboat, we managed to measure the signal at the bridge. However, homing in on the signal was difficult, due to reflections from the mountains.

At a distance of 4.0 nautical miles, we did not receive any signals (EPIRB on top of the lifeboat or in the water), and we did not manage to home in on the EPIRBs.

7.4.3.5 AIS SART vs. radar transponder

We performed the same exercise for AIS SART and the radar transponder as we did for the EPRIB. We did not observe any difference in the signals on the instruments on the bridge. The signals were good at all times. After the exercise was finished, we received feedback from the joint rescue coordination center at Faroe Island that they had managed to track the AIS SART.

7.5 Discussion

Due to the practical application of utilizing an EPIRB homing signal for location identification, the RF system is not operating under ideal conditions. The combined effect of loss factors reduces the practical use of the system to about 2–3 nautical miles. It is important to note that this was when trying to obtain a bearing from a SAR vessel with an antenna mounted relatively close to the water surface. An airborne system should observe longer ranges. Based on the above observations, it is evident that increasing the height of the EPIRB transponder to as high as possible will increase the range of the signals, as it reduces the shadowing effects from the waves, the risk of icing and the blockage of the Fresnel Zone.

The performance standards for EPIRBs indicate that the designed range will be 3–4 nm. In the test, the system only worked up to these ranges under ideal conditions and with the EPIRB located on top of the lifeboat.

During the test, we did not manage to see any difference between the EPIRB with reduced homing signal and the original EPIRB. From a theoretical perspective, the range of the rf signal should not be affected by the reduced duty cycle. The effect of the reduced duty cycle is more a question of the setup of the receiver end of the system. Factors like update rate of the AGC (Automatic Gain Control), latency between received RF signal and displayed bearing and estimation of received signals strength (e.g. rms values vs. peak values) in the receiver will affect the operators' perception of the signal.

The test was located in a fjord, with large mountains on each side. There were problems with homing in on the EPPIRB from the bridge. Often, we received signals from other directions than the direct bearing to the lifeboat. This effect was caused by reflection from the mountains.

It was an interesting observation that the rescue center at Faroe Island managed to receive the signal from our AIS SART via AIS satellite. The AIS technology, used together with AIS satellites, can be a good alternative to the regular SART transponders (406 MHz) in the Arctic.

Key functional requirements obtained by EPIRBs:

- Transmit location
- Generate RF signal for homing
- Range
- Battery time

With today's technology, it is not a problem to code information into an RFf signal. Utilizing only the carrier wave of 121.5 MHz is very inefficient. A system utilizing a reduced duty cycle with information in the signal will fulfill all of the above requirements. In addition, the reduced duty cycle will contribute to longer battery time and/or increased range (transmit power), depending on system setup. This can be achieved by either utilizing the AIS signal for homing or encoding information into the 121.5 signal.

A change like that described above will, however, require the SAR suppliers to modify their existing systems to comply with the above alterations in the regime.

7.6 Conclusion

Based on the observations conducted in SARex 2, the following conclusions have been drawn:

- No differences in performance are observed between the suggested new performance standard for EPIRB, utilizing a reduced duty cycle, and a full duty cycle. It is, however, a question of receiver setup, and variations between different receivers (manufacturers/models) can be expected.
- The question of reduced duty cycle should be further tested with different receivers utilized by the SAR industry.
- It should be emphasized that the location of the EPIRB is of great importance, with regard to effective range, as the system is not operating under ideal rf conditions.
- Utilizing rf signals with encoded information will contribute to an enhancement of the whole system but will require modification to the equipment utilized by the SAR suppliers.

7.7 Further work

Based on the findings in SARex 2, the following suggestions for further work have been identified:

- Further assessment of implications caused by attenuating factors like precipitation, sea spray, antenna icing and obstruction of the Fresnel Zone for a range of EPIRBs.
- Assessment of the feasibility of the capabilities of dual voice communication, e.g. VHF and Satcom, and of dual tracking and location, e.g. Cospas/Sarsat 406 EPIRP/PLB and AIS, to be installed on any survival craft.
- The satellite communication channel connected to larger survival crafts, such as enclosed lifeboats, should allow low volume automatic data transfer, e.g. position, environmental conditions in and outside the craft as well as on-demand transmission of the basic physiological parameters of the survivors.
- Improved active detection of survivors by compulsory use of coded 406 MHz PLB during all outdoor professional and tourist activities, with contact to the multiple beacon activation working group at Cospas/Sarsat.
- Improved local detection capabilities of 406 MHz Cospas/Sarsat signal by portable and fixed 406 homing and beacon decoding equipment. This shall be done from aircraft, from large

SAR vessels and, optionally, from FRC (Fast Rescue Craft), in collaboration with the Memorial University in Newfoundland, CND.

- Comparison of detection of Cospas/Sarsat emergency beacons by LEOSAR and MEOSAR systems.
- The AIS SART should also be tested out to be an alerting system, so that the advantage of AIS satellites can be used.
- It would be very beneficial if equipment to increase the body temperature for those who were cooled down would be available in the rescue means.

8 OVERALL CONCLUSIONS

SARex 2 was an important venue for understanding the challenges of sustaining survival on board a lifeboat or a life raft in cold climate conditions.

8.1 Areas of key importance for survival

8.1.1 Air quality

It seems reasonable to compare air quality limits for a rescue vessel in a survival setting to those of a submarine environment, where limits are set at 10,000 ppm before commencing measures to reduce CO_2 (chalk filters), with maximum levels at 20,000 ppm. For O_2, minimum levels are set to 17%. It is important to consider the duration of exposure when determining the maximum levels.

8.1.2 Allocated space, reducing the ability to move

Maintaining the ability to move is essential for maintaining primary body functions and preventing medical conditions like blood clots.

The Life-saving Appliance (LSA) Code uses 75 kg as an average passenger weight and 430 mm for maximum linear width. It is not within the scope of this exercise to dispute those figures. However, the LSA Code also acknowledges that there may be large individual deviations from the average. As an example, lifejackets are designed to fit persons up to 140 kg. At the other end of the scale, there might be infants or children on board.

The 75-kg average weight makes some sense when maximum loads and the stability are determined, but for the necessary individual space (seats, in particular), demographic variations should be considered, and 430 mm is not enough space when considering a long-term survival situation. These variations would probably be less significant for cargo ships than for passenger ships.

8.1.2.1 Ergonomics

The LSA Code does not sufficiently consider the human element, especially the significance of human behavior when packed together on uncomfortable seating for a long period, such as five or more days. All exercise participants felt some degree of pain and discomfort with the seats provided in the lifeboat. Improvements to seating ergonomics should be considered. Backrests seem to be necessary, and the seats should be as deep as possible and upholstered using an insulating material. Seats with at least the same dimensions as for free-fall lifeboats (LSA Code 4.7.2.2) should be considered and would offer a great improvement, considering the expected time of rescue of five days.

The lifeboat we used for the exercise had three ‘beds’ for sleeping, giving each person three hours’ sleeping time in a 24-hour period. With improved seats, the need for such beds might be reduced, but provision of such beds would not only increase the comfort but also enable treatment of casualties with injuries or illness.

8.1.3 Ability to stay warm

Hypothermia represents one of the largest challenges associated with cold climate survival.

The ability to stay warm is highly correlated with human heat loss. To reduce the heat loss, it is important to consider the internal temperature of the rescue craft, including surfaces in contact with the personnel, in relation to the insulation layer provided by the personal protective equipment (PPE). In a cold climate environment, the maximum possible achievable insulation layer should be aimed for.

Due to the waterproof nature of PPE, condensation buildup inside the PPE is to be expected, and it is of great importance that the materials maintain their insulation abilities, despite being saturated with water. Condensation buildup should also be combated through operational means.

The ability to stay warm is also related to metabolism, which is correlated to both activity level and calorie/water intake. Increasing both activity levels and rations will significantly improve the probability of survival.

The challenge of hypothermia can be greatly reduced by the installation of heaters in the lifeboat.

8.1.4 Calorie/water intake

Most of the participants in this exercise lost about 2 kilo of body weight during the exercise. This loss is mostly generated by the loss of water. If the duration of the exercise were to be extended, all the participants would have experienced serious dehydration.

It is also believed that the calorie intake from the rations was not adequate to compensate for the energy required to counter balance the heat loss, especially in the life raft.

The combination of the above factors not only reduces the ability to stay warm but also negatively affects both the cognitive abilities and the motivation to survive.

8.1.5 Comfort – cognitive abilities and fatigue

Survival is dependent on the micromanagement of all the small details. Typical tasks include drying the inside of survival suits, maintaining enough rest and venting the rescue craft to prevent build-up of CO_2. To be able to prevent the development of fatigue and maintain the cognitive abilities required to conduct all the small tasks, a minimum of comfort is required. This includes:

- No high degree of intense body pain for a prolonged period of time. Pain can typically be caused by bad ergonomics or frostbite.
- Ability to move to prevent blood clots, claustrophobic reactions and the development of fatigue.
- Ability to communicate with other people in the rescue craft to prevent mental disorder.
- Ability to conduct basic human tasks (e.g. relieve themselves) to ensure the personnel maintain the feeling of being in control of the situation.

Maintaining cognitive abilities and preventing the development of fatigue for an extended period of time are not things that should be taken for granted, as there are large human variations with regard to mental robustness and the ability to handle stress.

8.2 Helicopter evacuation

There are many limitations, with regard to helicopter evacuations in a large incident scenario. Evacuation by helicopter alone is not a feasible solution, and marine SAR resources must be available at the scene of the accident.

8.3 EPIRB

It is evident that the range in which the 121.5 MHz beacon is functional is limited to a few nautical miles when being utilized in combination with a marine SAR capacity. Based on the tests carried out by SARex 2, a reduced duty cycle on the EPERB does not interfere with the direction-finding abilities on the rescue vessel.

It is, however, clear that, with today's technology, only transmitting a carrier with no information coded into the signal is not very efficient. Utilizing technology where the rf signal also contains information, e.g. an AIS signal, is more efficient. A technology like that described above will not only increase the battery time or transmission power, it will also enable the SAR organization to obtain the position of the lifeboat/life raft, either through the information coded into the signal or by homing in on the signal.

Adaption to the environmental conditions is essential for survival.

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Appendix I

Paper presented at International Conference on Ships and Offshore Structures

ICSOS 2017
11 – 13 September 2017, Shenzhen, China

Report from search and rescue exercises in the Polar Region.

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Abstract

With the implementation of the **Polar Code** in January 2017, the focus on search and rescue operations in polar waters have been increased due to a five-day survival requirement. This requirement poses strain on all rescue means and causes the needs for improved personal protection equipment (as survival suites), insulated lifeboats and insulated life rafts.

The paper reports on findings from search and rescue exercises north of Spitzbergen. The first exercise was carried out during late April 2016 and the second exercise was conducted with improved rescue means during the first week of May 2017. Focus is on survivability and the effectiveness of the improved rescue means. Furthermore, a discussion is given with respect to possible mitigation measures to ensure quick rescue to avoid that the evacuated persons be exposed to an unnecessary long stay in the rescue means. Of particular reference is the cruise industry and the industry's efforts to provide customers with visits to even more remote cruise locations.

Keywords: Polar Code, Spitzbergen, Survival exercise, Lifeboat, Liferaft.

1. Introduction

The polar conditions experienced during survival exercises at north Spitzbergen in April 2016 and May 2017 generated polar-specific challenges for the exercise participants and for the lifesaving equipment. These challenges were identified and assessed. It was planned to simulate relevant polar conditions, incorporating sea ice, sea swell, low air and water temperatures and remoteness. The detailed objectives of the exercises and the associated research programs were to:

- Assess the adequacy of the lifesaving appliances (lifeboats and life rafts) as required by the IMO Polar Code.
- Identify the gaps between SOLAS approved rescue craft (lifeboats and life rafts) and the requirements defined in the IMO Polar Code.
- Identify the gap between SOLAS approved personal protective equipment (PPE) and the requirements defined in the IMO Polar Code.
- Assess the personal/group survival kits as defined by the IMO Polar Code.

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- Train Norwegian Coast Guard personnel in emergency procedures in ice-infested waters, with reference to evacuation and rescue from cruise ships.
- Identify the effects of improved equipment during the 2017 exercise as compared to the 2016 exercise.

The following topics were therefore addressed in the exercises that took place in the marginal ice zone off the northern coast of Spitzbergen in late April 2016 and in an Arctic fjord (Kongsfjorden), West Spitzbergen May 2017:

- Functionality of life raft/lifeboat under polar conditions.
- Functionality of personal protective equipment (PPE) (e.g. thermal protection/survival suits).
- Additional training requirements for crew and passengers.
- Evaluation of Coast Guard's search and rescue procedures, including handling of mass evacuations in Polar Regions.
- Evacuation to sea ice (2016).
- Evacuation by helicopter (2017).
- Identification of the functionality of search equipment in Polar Regions (2017).

The full report from the 2016 exercise can be found on the University of Stavanger's homepage: http://hdl.handle.net/11250/2414815 (Solberg et al., 2016). A report from the 2017 exercise is under preparation.

The paper is organized as follows:

Chapter 2: The Polar Code

Chapter 3: The exercises

3.1 *Introduction to the exercises*

3.2 *The main topics addressed during the exercises*

Chapter 4: Conclusions

Chapter 5: Further work

2. The Polar Code

The International Code for Ships Operating in Polar Waters is referred to by many as the '*Polar Code'* (IMO, 2016a). The code is a supplement to existing IMO documents, and the intention is to mitigate the additional risks present for people and environment when operating in polar waters. Contrary to most of the existing IMO documents, the International Code for Ships Operating in Polar Waters is representing a risk-based approach, only stating *functional requirements*. This implies that the marine operators are to identify risks and mitigate them through a holistic approach. What is included in a holistic approach needs a proper interpretation based on the systems and activities involved.

Identification of risks is dependent on the mariners' knowledge and experience. This requires in-depth knowledge in relevant fields, e.g. areas of operation, vessel capabilities, crew competence and type of operation. The risk-based approach is already familiar to the industry in the ISM (International Safety Management) code. The Polar Code is, however, more specific, specifying sources of hazards. Nevertheless, the code indicates only to a slight degree the risk acceptance criteria and does not specify adequate mitigation measures. Use of a goal/objective based regulatory regime has positive experiences in the Norwegian offshore oil and gas industry. This might be explained by a stable relationship between the major actors, the operators, employees and authorities and by the economic resources available in the oil and gas industry.

As of today, there is no common industry understanding/interpretation of the Polar Code. There is also marginal ongoing official work to harmonize the interpretation of the code between different flag states or class societies. As a result, a degree of discrepancy in the interpretation should be expected in the coming years. For vessel owners/operators, this lack of consistency, transparency and predictability represents a major challenge. The challenge is cross-disciplinary and affects issues from availability of safety equipment, to adequately training of crew for operation of safety equipment. The economic impact associated with the implementation of the Polar Code does not only lie in the purchase, storage and maintenance of new equipment as there are huge economic implications in the possibility of having to reduce the passenger capacity of cruise vessels.

A reduction in the number of passengers could emerge because of additional equipment the Polar Code requires to be carried on board the rescue craft, e.g. personal survival kits, group survival kits and food and water for a minimum of five days. All rescue crafts have limitations about both available space and weight-carrying capacity. Most vessels have already stretched these capacities. Adding additional equipment required by the Polar Code will mean that the number of persons per rescue craft will have to be reduced. Decreasing the number of passengers on board a cruise vessel will, however, have a huge economic impact on the cruise operator, as it will affect their income.

In the Polar Code (IMO, 2016a), the Polar water operational manual (PWOM) and Life-saving appliances and arrangement, are given major attention. The definition in clause 1.2.7 related to the *maximum expected time of rescue* says*: "Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than five days".* For the exercises, we specifically addressed the life-saving appliances, which shall provide for safe escape, evacuation and survival in the polar conditions deemed as design scenarios.

3. The exercises

3.1 Introduction to the exercises

3.1.1 The 2016 Exercise

The exercise took place in Woodfjorden, North Spitzbergen (Figure 1). Twenty-four scientists and the crew from the Coast Guard vessel KV Svalbard participated. One standard SOLAS approved life raft and one standard SOLAS approved lifeboat (Figure 2) were filled with participants. Each participant wore standard SOLAS approved Personal Protection Equipment (PPE), ranging from life jackets to insulated survival suits. The weather during the exercise was ideal, with an ambient air temperature of about -9 °C, a water temperature of about -1 °C and little wind. These are considered representative weather conditions for the cruise ship season in Svalbard. Due to the favourable weather conditions, seasickness was not an issue for any of the participants.

Prior to the exercise, a cross-disciplinary team, comprised of medical doctors, suppliers, regulators and users, assessed the Polar Code. There was a special focus on the interpretation of Chapter 8: Lifesaving Appliances and Arrangements. The following definition was established as the overarching goal of the chapter:

'The equipment required by the Polar Code is to provide functionality that enables the casualty to safeguard individual safety, which means to maintain cognitive abilities, body control and fine motor skills for the maximum expected time of rescue'.

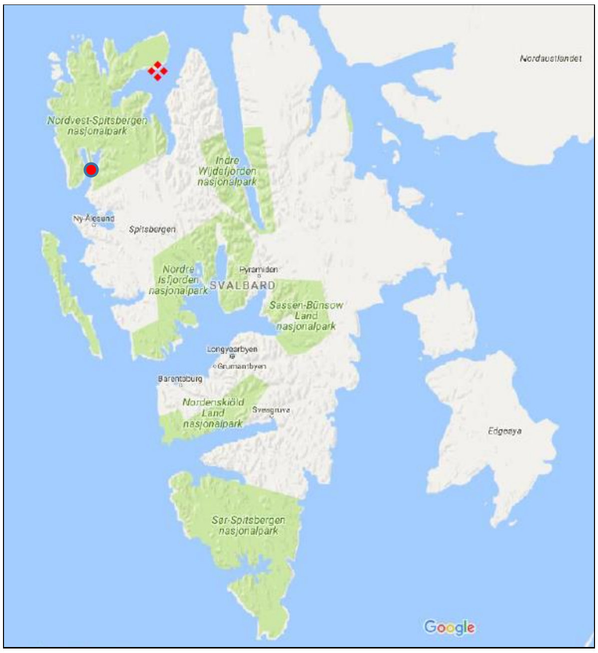

Figure 1: Location of the 2016 exercise (Woodfjorden) and the 2017 exercise conducted in a fjord north of Ny Ålesund.

Figure 2: Lifeboat used for exercise 2016 and 2017.

(2017: With considerably improved insulation and heating arrangement).

3.1.2 The 2017 Exercise

The exercise in early May 2017 took place in Kongsfjorden north of Ny Ålesund (Figure 1) on the initiative of Norwegian Maritime Directorate, the Norwegian Coast Guard and University of Stavanger. A life raft that was considerably improved compared with the one used during the 2016 exercise by implementing a double bottom to ensure an air gap was maintained between the seawater the floor. The raft also had a high canopy, which enabled the participants to stand upright inside the raft. Furthermore, the lifeboat used in the 2016 exercise (Figure 2) was improved with insulated seating, an improved heating system and improved ventilation. The rescue crafts were filled with participants. It should be noted that both the raft and the boat (in 2016 as well as in 2017) were filled to half capacity and that the exercise participants were fit cadets from the Coast Guard vessels and relatively fit scientists. In 2017 all the participants were equipped with flotation suits.

The weather during the exercise was to some degree harsher than in 2016 with some waves which caused movements of the exercise means, however, the ambient air temperature varied between +2°C and -9°C, while the water temperature was at about +2°C. Seasickness was not an issue for any of the participants as all took seasickness pills prior to entering the raft and the lifeboat.

Prior to the exercise, risk analysis and safe work analysis were conducted to minimize the risks during the exercise. No difficulties during the exercise were observed except for challenges to enter the lifeboat from the Coast Guard vessel's mob boat.

3.2 The main topics addressed during the exercises

3.2.1 Functionality of life raft/lifeboat under cold climate conditions

The evacuation from the Coast Guard vessel was performed with the help of the vessel's man-overboard boats (MOB) and did not represent a valid exercise topic. The transfer of the "survivors" from the lifeboat and life raft to the vessel was also carried out by MOB boats. It should be noted that all those participating in the exercise were taken back to *KV Svalbard* as soon as one or more of a predefined abortion criterion was met. Most of the participants said that they would have been able to extend their stay for a longer time without any health issues. The predefined abortion criteria were defined as:

- Loss of cognitive abilities.
- Loss of body control (e.g. uncontrollable shivering).
- Loss of fine motoric skills.

In the lifeboat, air quality and low oxygen levels were issues during the 2016 exercise, as the ventilation system required the engine to be operating. Regarding "survivability" during the 2016 exercise, see Figure 3 below. The personnel experienced extensive heat loss from the structure (floor, seat and backrest) of the lifeboat.

Improvements with respect to insulation of the lifeboat structure, the seating and the heating arrangement were implemented in the 2017 exercise. After a stay in the lifeboat of 27 hours, most participants were still fit and the exercise was abandoned with the conclusion that most participants would be in position to survive for an extended stay. Those who left earlier had some special issues with bad back or indication of a beginning flu.

A *test of the air quality* on board the lifeboat was carried out during the 2017 test while the boat was stored on the deck of KV Svalbard. With 49 participants on board (capacity 55 persons), the level of O_2 reduced to 18.4% after 27 minutes (recommended level is above 19%) while the level reduced to 17.2% after 24 minutes when the participants were doing some physical exercise. When the ventilation ducts were opened, the O_2 level very quickly returned to normal.

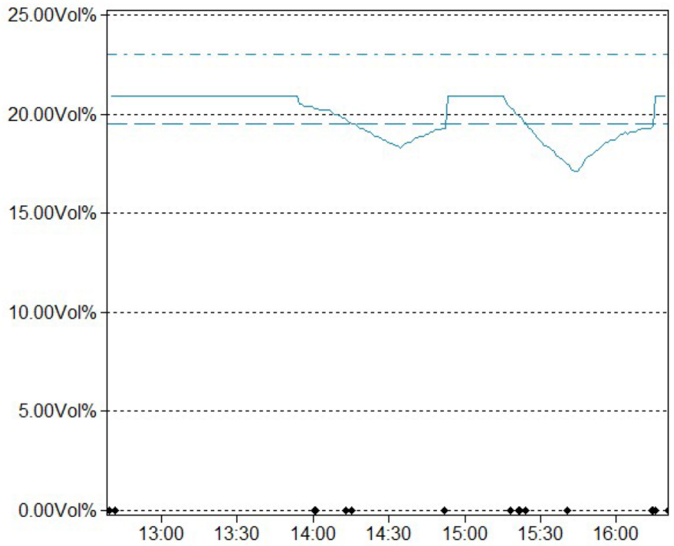

Figure 3: O_2 level (percentage of O_2) in the air inside the lifeboat. The dashed lines represent the recommended O_2 level.

More critical was the build-up of CO_2. The level increased from 600 ppm initially, to about 23 000 after 27 minutes when the participants were relaxing. In the second run, the participants were told to exercise and have maintain a high pulse. This was done to simulate the shivering induced by the body's cold response. This condition would typically occur when the body core temperature reaches about 35C.

The CO_2 level increased to 37 000 ppm after 30 minutes. Note that according to Norwegian health, safety and environment regulations the level is not to exceed 5000 ppm. According to the regulations (peacetime) for naval submarines the CO_2 level is to be kept below 10 000 ppm, and if the CO_2 level exceeds 20 000 ppm the submarine is to surface and replenish all air on board. As these levels were exceeded within a very short time, frame ventilation systems are to be regarded as a necessity on board rescue crafts.

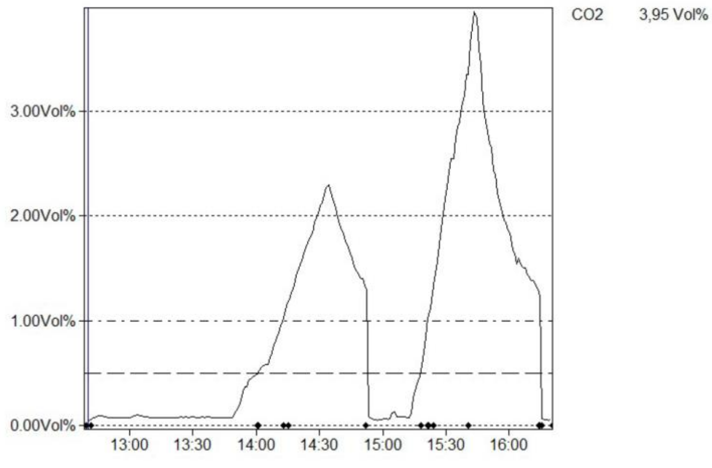

Figure 4: CO_2 build-up (percentage of CO_2) in the air inside the lifeboat as function of time.

The personnel in the life raft experienced in the 2016 exercise a major heat loss through the bottom of the life raft. This became especially evident when sitting or lying down, regardless of the type of personal protective equipment. The life raft canopy was kept closed to retain heat. The lack of ventilation caused the air to be moist, and extensive condensation developed. Due to the combination of condensation and sweat, survivors suffered from wet insulation layers in their personal protective equipment, followed by loss of insulation and freezing. The raft had, furthermore, to be vented frequently, losing a significant amount of heat in the process. The congestion inside the raft was a problem, causing reduced ability to move, triggering reduced blood circulation in the body's extremities, resulting in freezing of hands and feet. It became evident that it is unlikely that most of the people evacuated to the non-insulated life raft would survive for a minimum of five days according to the Polar Code criteria.

The resulting time when the participants stayed on board the raft and the lifeboat during the 2016 exercise is shown below in Figure 5. The time to loss of cognitive abilities, uncontrollable shivering or loss of functionality of extremities was used as criterion for leaving the rescue means. The exercise was aborted after 24 hours. Two persons were in very good physical condition (using best available survival suites) and could have continued onboard for several more hours. The remaining "survivors" were frozen and were taken out following the advice of the medical team.

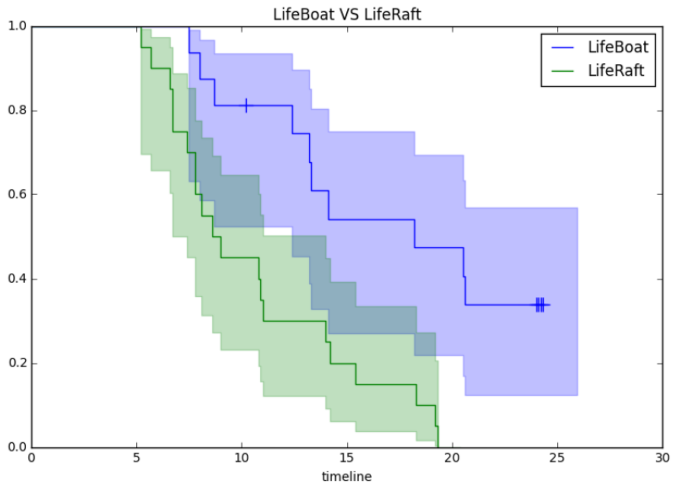

Figure 5: The relative number of participants remaining onboard the rescue means as function of time. Results from the 2016 exercise.

For the 2017 exercise, the raft was considerably improved with double bottom that was filled with air and the roof consisted of double layer with insulating air between. An issue was leakages of water from the floor reminding that the quality of the raft must be maintained at high level. The results of the 2017 exercise showed a clear improvement from the 2016 "survivability rate". The main issue was cold hands and the participants stayed on board from 24 to 29 hours. At 29 hours, all felt they should abandon the raft and it is unlikely that many would have had the ability to stay for a prolonged time without meeting one or more of the predefined criteria.

The presence of a well-trained lifeboat/life raft captain proved very important for maintaining both the safety and the morale of the personnel on board. This is especially important when the duration of the stay is long (a minimum of five days, along the lines defined in the Polar Code).

It should be noted that most of the participants involved in the evacuation exercises were either young and fit persons (cadets from the Coast Guard vessel) or mature persons with good physical health. The lack of elderly or disabled persons involved in the exercises renders the results on the positive side, as the participants were fitter and in better physical and physiological shape than the average seafarer/ passenger. Seasickness was not an issue in these exercises, as noted above.

3.2.2 Functionality of personal lifesaving aids (e.g. thermal protection/ survival suits)

The personal protective equipment (PPE) helped the participants to maintain an adequate body core temperature. The build-up of moisture in the insulating layers inside the survival suits, however, caused a considerable loss of insulating capabilities. On board the lifeboat during the 2017 exercise, the heating was adequate and most participants opened their PPE to avoid built-up of moisture.

The available standard life jacket with thermal protection (neoprene arms) most commonly utilized on cruise/passenger vessels did not provide the adequate thermal protection required to maintain satisfactory core body temperatures on either the lifeboat or the life raft.

When utilizing personal protective equipment for a prolonged period, the functionality of the hands (fine motor skills) is of key importance. To conduct tasks requiring fine motor skills when wearing neoprene gloves proved difficult. Medical doctors did tests during the 2017 exercise and when leaving the life raft, most of the participants experienced cold hands and feet.

The exercises also proved the importance of the participants/passengers becoming familiar with the personal protective equipment prior to a potential abandon-ship situation in order to ensure correct sizes and functionality.

3.2.3 Water and rations

The participants were issued the rations supplied with standard SOLAS approved equipment. Based on subjective ratings most people considered thirst a bigger problem than hunger, Figure 6. It came as a surprise that the participants in the life raft experienced a higher degree of thirst than the participants in the lifeboat, despite the interior temperature being lower in the life raft.

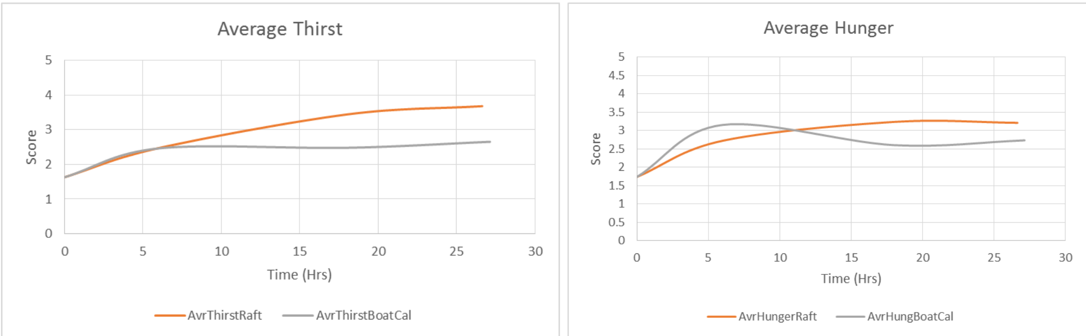

Figure 6: Subjective ratings on thirst and hunger on board the lifeboat/life raft during the 2017 exercise. (On a scale of 1 to 10 where 10 would mean starvation).

Based on measurements done by the medical doctor (Eivinn Skjærseth) there was identified a considerable participant weight loss during the exercise. The mean weight loss (Figure 7) for the persons in the life raft was 1,8 kg, range 3,6 to -0,2 kg, opposed to 2,0 kg, range 3,5 to 0,7 kg, for the persons in the lifeboat. Factors affecting weight loss are intake of food and water, sweating and other insensible water losses.

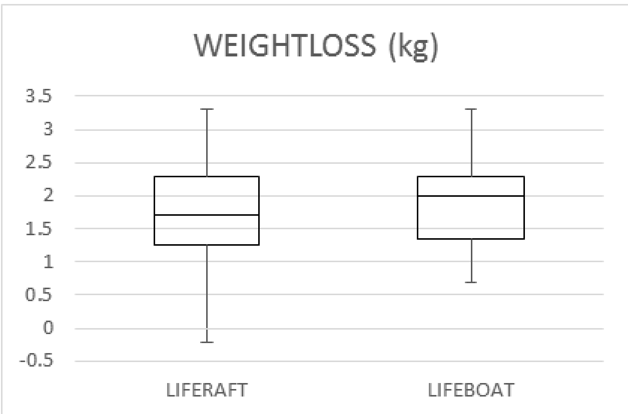

Figure 7: Box plots showing the average and the quartile distribution of all participants' weight loss throughout the 2017 exercise. Comparison between the participants in both vessels. (Eivinn Skjærseth).

The participants' further dehydration contributed to increased freezing of extremities due to lack of blood circulation and reduced general participant medical condition. The effect of reduced participant medical condition was visible on skills test and subjective ratings conducted throughout the exercise as a majority or the participants showed a negative development.

3.2.4 Handling of mass evacuation in Polar Regions

One element of the 2016 exercise required the Coast Guard staff to conduct a mass evacuation from the rescue craft onto the Coast Guard vessel. A large number of the evacuated personnel simulated a hypothermic state. Establishing, implementing and conducting regular training on the procedures for handling disabled, wounded and immobile passengers when evacuating a large group of people is of great importance for ensuring an efficient evacuation. Evacuating a large number of immobile casualties takes an excessive amount of time and put a great strain on the staff on board the Coast Guard vessel. The medical state of the casualties will be of key importance in determining the time required to evacuate personnel from a lifeboat/life raft on to a rescue vessel.

The potential of involving those casualties who are in good condition in monitoring/aiding the caretaking process of the patients should be emphasized. Heavily injured persons require considerable resources from the ship's crew. As there are limited resources available on a vessel like *KV Svalbard*, strict principles of triage must be exercised. Conducting an efficient triage requires clear procedures and puts great mental pressure on the individuals involved in the task. It is important to distinguish between the number of casualties a rescue vessel can carry and the number of heavily injured/hypothermic casualties for whom the rescue vessel can provide medical treatment. It is of great significance to recognize the limited on-board capacity available for the medical treatment of heavily injured/hypothermic patients when determining the SAR capacities in a large accident.

During the 2017 exercise, an additional evacuation test of 30 persons with use of SAR helicopter was carried out close to Longyearbyen. The distance to the helicopter base was only 6 miles. The participants had to jump into water or were hoisted from the roof of the lifeboat. The duration of the exercise was several hours and to evacuate 700 persons with helicopter 90 minutes away from base would for example take an estimated 3.1 days of continuous operations.

3.2.5 Survivability on sea ice

In addition to evacuation on to the ice, personal and group survival kits were evaluated during the 2016 exercise. The survival kits were heavy and voluminous. The capacity of both the lifeboat and the life raft would be exceeded if the prescribed number of persons were to be carried in addition to the personal and group survival kits. Utilizing the survival kits also required full functionality of the fingers/hands. This proved difficult, as most of the personal protection equipment had integrated gloves or thick neoprene gloves. As a result, all activities had to be carried out using bare fingers, which resulted in frostbite. Many of the activities related to the survival equipment, e.g. pitching a tent and utilizing a stove, require training and familiarity with the equipment.

The life raft, on the other hand, proved easy to pull onto the ice with the assistance of only a few persons. On the ice, the life raft served as a tent in a much more comfortable way than the special tent provided for the purpose.

3.2.6 Conclusions regarding the probability of survival

The aim of the functional requirements stated in the Polar Code is to mitigate the additional risks present in the Arctic/Antarctic environment. From a lifesaving perspective, there are two dominant factors influencing the probability of survival in the areas applicable to the Polar Code, exposure to the cold environment and time to rescue.

Exposure to low air and water temperatures represents a major challenge for the human body. The risk represented by low temperatures can be divided into two:

- Hypothermia – reduction in body core temperature, inducing shivering, loss of cognitive abilities and ultimately death.
- Freezing of body extremities – during extreme low temperatures, freezing of body extremities can be induced after only minutes of exposure. This will result in loss of functionality in the affected limb, which again reduces the probability of survival.

Exposure of the body to sub-zero temperatures will reduce the survival time substantially compared to survival in more temperate zones, in the case of the 2016 exercise only two out of the 20 participants stayed in the lifeboat after 24 hours of exposure. In the case of the life raft, only one person was fit to stay longer than 24 hours. The improvement of the equipment experienced in 2017 accounted for a considerable extension of “survival time”: Most participants stayed on board the lifeboat for 27 hours, with a potential for a considerable further extension in the survival time. On board the life raft, typically, most participants had to leave after 24 hours and few would like to extend the stay beyond 29 hours. The situation should be compared to the relative number of participants remaining onboard the rescue means as function of time during the 2016 exercise, see Figure 3.

In 2017, equipment modified to handle cold climate conditions was utilized, while in 2016 standard SOLAS approved equipment was utilized. Comparing the results from the two exercises (Figure 8) has to be done with caution as the participants were not the same and the metocean conditions were not identical. Note that each blue dot represents the temperature at start and at finalization of the stay in the rescue means. (2017 exercise). Each orange dot represents the temperature at the finalization of the stay in the rescue means. (2016 exercise).

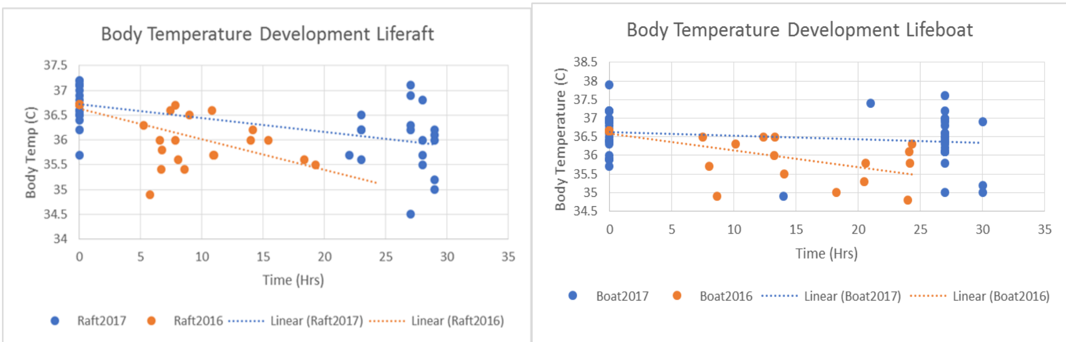

Figure 8: Body temperature measurements for life raft and lifeboat in 2016/2017.

Disregarding the differences in both participants and metocean conditions, there is a clear trend indicating that the survivability in the rescue crafts utilized in 2017 was much higher than in 2016. Based on our observations this is mainly due to the following improvements:

- Heating installed in lifeboat caused an internal temperature of about 20C.
- Improved insulation of PPE for the participants in the life raft.
- Air gap between life raft floor and seawater.
- Increased knowledge among the participants on critical factors influencing survival, especially ability to keep the insulation layers dry.

In addition to the low temperatures, several distinct features of the Arctic/Antarctic environment represent additional challenges for persons who experience an abandon-ship situation. These challenges are typically the risk induced by sea ice/icebergs to the rescue craft, hostile wildlife and unpleasant sea state and weather conditions. In the case of the 2016 exercise, a walrus showed much interest in the life raft. The animal could have punctured the raft causing a very dangerous situation during the exercise.

3.2.7 Time to rescue

Due to a low concentration of infrastructure in most of the areas where the Polar Code is applicable, the rescue time is long. Currently, many of the search and rescue suppliers base their approach on helicopter evacuation. These have limitations, not only about weather but also, more importantly, with regard to range and capacity to carry survivors (Jacobsen and Gudmestad, 2013). As a result, much of the area where the Polar Code is applicable is outside helicopter range. Within the areas where there are helicopters available, the capacity to carry survivors is limited typically to a maximum of 10 to 20 persons.

For marine accidents involving a substantial number of casualties, quick access to the site of the accident by other maritime resource is essential. Due to large distances and relatively low vessel concentrations for a larger part of the year/areas, the time to rescue can be relatively long. In the case of the Maxim Gorkiy incident, however, a successful rescue operation was carried out by the Coast Guard vessel *KV Senja* on 20 June 1989 when the cruise liner *Maxim Gorkiy* collided with an ice floe on its way from Iceland to Magdalenafjorden, Svalbard, and was close to sinking. Many of the 995 passengers and the ship's crew left the vessel in open lifeboats, while some were standing on ice floes when *KV Senja* arrived on the scene only three hours after the incident. *KV Senja*, which was assisted by three Sea King helicopters, rescued everyone. It should, however, be noted that it was only by chance that the Coast Guard vessel was in the area at the time of the accident.

The combination of high vulnerability to the environment and a long time to rescue represents the major challenges about survival in those areas where the Polar Code is applicable. It is clear, however, that the largest discrepancy from an accident occurring in more temperate parts of the world is the vulnerability to the environment, causing a large expected reduction in survival time. The recommended way to combat the vulnerability to the environment is through vessels being self-sufficient, carrying lifesaving appliances that are fit for purpose, providing adequate protection. This applies to the rescue crafts as well as to the group and personal protective equipment. Furthermore, a cruise ship operator needs to develop survival strategies for the crew and passengers also in the evacuation phases. An alternative is that two or more vessels are in the same area (a "buddy system") representing rescue possibilities should one of the vessels need help. It is, however, important to consider the special challenges related to this alternative, e.g. personnel transfer.

Chapter 8 of the Polar Code (IMO, 2016a) states that a vessel is to provide equipment that enables the passengers to survive a minimum of five days or the anticipated time of rescue. As the requirements are functional, a holistic approach is required. The holistic safety management approach implies that the vessel owner considers all relevant conditions, factors and parameters. As many of the conditions, factors and parameters are interrelated and dynamic, the task must be carried out with margins of allowance for the uncertainty associated with the quantities. The following list of conditions, factors and parameters are to be considered when assessing the probability of survival:

- Governing metocean (meteorological and oceanographic) conditions for the area of operation.
- Remoteness.
- Available SAR infrastructure.
- Performance of SAR operators.
- Energy required to maintain the core temperature of the persons.
- Water/food required to maintain an adequate metabolism for human heat generation.
- Insulating properties of the rescue craft.
- Insulating properties of the PPE.
- Number of passengers.
- Physical condition of the passengers.
- Cumulative weight of group and personal survival equipment.
- Carrying capacity of survival craft.
- Abandon ship activities.
- Survival strategies on board the evacuation vessel.
- Survival craft management.

4. Conclusions

The cruise industry's efforts to provide customers with visits to even more remote cruise locations may represent a large challenge in case there is a need to evacuate the cruise ships. Of particular concern is survivability in poorly insulated rescue means in Polar Regions.

A search and rescue exercise (SARex I) north of Spitzbergen during April 2016 was, therefore, conducted to assess whether standard SOLAS (IMO, 2016b) rescue equipment would satisfy the five days survivability requirement of the **Polar Code** which was implemented in January 2017. We have concluded that this requirement poses strain on all rescue means and causes the needs for improved PPE (personal protection equipment, for example improved survival suites), insulated lifeboats and insulated life rafts.

A follow up search and rescue exercise (SARex II) was thereafter conducted in Kongsfjorden on West Spitzbergen during the first week of May 2017 with improved rescue means. In this paper, we have reported on findings from the exercises and documented relatively large effects of insulation of rescue means, heating of lifeboat, use of improved personal protection equipment and limiting the number of personnel onboard the rescue means (because of the bulkier PPE needed for survival in Polar Regions).

Our focus has been on survivability and the effectiveness of the improved rescue means. Furthermore, we have pointed to possible mitigation measures to ensure quick rescue to avoid that the evacuated persons be exposed to an unnecessary long stay in the rescue means.

5. Further work

There is currently no recognized interpretation of Polar Code requirements. Only SOLAS (IMO, 2016b) has prescriptive requirements concerning lifesaving appliances, and it provides no indications of functionality or survival time. Further work will be required to assess and to close the gap between regular SOLAS approved life-saving equipment & appliances and the functional requirements defined in the Polar Code. This work would incorporate the following topics:

- Identifying key parameters critical for human survival.
- Developing methodology for assessment of the safety chain through a holistic approach, identifying:
  - Heat balances.
  - Water/energy required for personnel to maintain body temperature.
  - Insulating abilities required by PPE to ensure that body heat is not leaking to the cold air.
  - Insulating abilities required by rescue craft.
  - Air quality (temperature, humidity, O_2 level and in particular the CO_2 level).
  - Required/ideal amount of equipment in PSK/GSK.
  - Heating needs inside the lifeboat (and potentially inside the raft).
- Identification of psychological aspects of long stays in rescue craft.
- Case study – design of lifeboat in compliance with Polar Code requirements.
  - Analysis of heat loss occurring from the lifeboat and the possibility to insulate the passengers from the cold penetrating into the bodies through the seating.
  - Note that the results of the 2017 exercise are very promising and we expect that the results of the 2017 will be carefully studied by the cruise industry.
- Case study – design of life raft in compliance with Polar Code requirements.
  - Analysis of heat loss occurring from the life raft.
  - Note that the results of the 2017 exercise are encouraging, although not sufficient to meet the Polar Code requirements.
  - Analysis of the generation of moisture inside the raft.

Acknowledgements

The SARexI and II exercises conducted north of Spitzbergen in April 2016 and West Spitzbergen in May 2017, respectively, were made possible through the cooperation between the Norwegian Coast Guard and Norwegian official and academic institutions as well as industrial companies.

We appreciate in particular the positive response of the Norwegian Coast Guard to participate and contribute in organizing the exercise. We also appreciate the attitude and interest of all the crew and officers on board the Coast Guard vessel *KV Svalbard* during the planning and execution of the exercises.

The involvement of the 23 scientists, professionals and students on board KV Svalbard in 2016 and the 29 persons on board in 2017, representing the scientific institutions and industrial companies, furthermore, made the exercise a success by meeting all its planned objectives.

We also appreciate the full support of the Faculty of Science and Technology at the University of Stavanger during the planning of the exercise.

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Appendix II

Individual contributions by SARex 2 participants

Notice/ disclaimer: The individual contributions are delivered to the SARex 2 by the individual exercise participants and do not necessarily represent the opinion of the SARex 2 organizing committee.

THE POLAR CODE

Background to and implementation of the Polar Code in relation to SARex 2

Turid Stemre, Norwegian Maritime Authority, Haugesund, Norway

Shipping activities in Polar waters have been going on for decades. These have mostly involved fishing and research activities but, more recently, polar cruises have become available and increasingly popular.

Due to global warming, larger areas in Polar waters have become accessible for longer periods. This could lead to an increase in these areas of ship operations, related to tourism, exploitation of the seabed and the carriage of cargo.

Prior to the Polar Code, there were additional regulations in, for example, the MARPOL Convention, for specific sea areas, as they were declared “special areas” under various annexes of MARPOL. However, developing a full set of additional safety and environmental protection regulations within defined geographical boundaries was new in the International Maritime Organization (IMO).

Given the number of additional risks associated with operations in Polar waters, from both a safety and an environmental protection point of view, it was generally agreed that there was a need for some kind of mandatory provisions to address safe and environmentally sound operations in Polar waters.

Consequently, in 2009, both the Maritime Safety Committee (MSC) and the Marine Environment Protection Committee (MEPC) agreed to a proposal from Denmark, Norway and the US to develop mandatory regulations for ships operating in Polar waters. The regulations were to address both safety and environmental protection and strive to find a balance between safe and environmentally sound operations and the need for maritime activities in the areas.

The safety related provisions of the Polar Code were adopted by MSC in 2014, the environmental provisions of the Polar Code were adopted by MEPC in 2015, and the Polar Code came into force on 1 January 2017.

Even before the Polar Code came into force, those of us working with it already knew that there would be challenges in the implementation of some of its provisions. There is a lack of test standards for very low temperatures and a lack of performance standards, taking into account the perceived increase in time to rescue. The working group at IMO pointed this out a couple of years before the code took effect. Nevertheless, it was decided that test standards and performance standards could not be developed before the content of the code was agreed.

One area specifically addressed in the safety part of the Polar Code is life-saving appliances; particularly for survival craft, test standards and performance standards are needed to ensure “survival” and the required “habitable environment” after abandonment of a ship in Polar waters.

Our first question was “What is the state of the art?” The International Life-Saving Appliance (LSA) Code contains requirements for testing but only for a specific range of temperatures and not down to the temperature that can be foreseen in Polar operation. The required amount of fresh water, nutrition and anti-seasickness medicine in survival craft may not be sufficient in low temperatures and over an extended period. A “habitable environment” in the Polar Code is defined as “a ventilated environment that will protect against hypothermia". What is needed to ensure this? The LSA Code has no specific requirements for ventilation or heating.

Luckily, the Norwegian Maritime Authorities were not the only ones asking these questions. The University in Stavanger and the Norwegian Coastguard had the same questions, and they took action to determine the "state of the art" through "SARex I", an exercise that took place last year, using one fully enclosed lifeboat and one raft of types commonly used.

The outcome of that exercise showed that the "state of the art" is far from meeting the expectations in the Polar Code. In fact, given the conditions under which the test was carried out, the "state of the art" is far from meeting expectations in waters in other places in the world. The most important findings were poor air quality and the fact that some of those taking part in the test were exposed to hypothermia after less than 10 hours.

Hence, based on proposals from NMA, the University in Stavanger and the Norwegian Coastguard decided to carry out a new exercise, "SARex 2", which took place outside New Aalesund in Svalbard's coastal waters in May 2017. The equipment manufacturers were challenged to come up with upgraded equipment to improve the results from last year, and they did.

My personal experience with the exercise can be summarized as follows:

- There was no problem with the temperature inside the lifeboat. It was too warm to keep the survival suits on. On the other hand, the survival suit I carried was probably not "state of the art" for the passengers. I also assume the temperature could be better adjusted if people are to wear their suits in the lifeboat.
- As we all took off the suits, it became very chaotic inside the lifeboat, with the suits taking up a lot of space.
- The air quality was OK, but I was happy to be seated close to one of the hatches so that I got some fresh air when the doctors came to check on us. I also developed a headache after a few hours, probably due to a mix of heavy air and not drinking much.
- Although I had seasickness plaster, I was a bit sick for the first few hours as we had some rough sea. This improved when the sea calmed. Had I become really seasick, a number of others would have followed.
- The portable toilet did not work very well, as it had to be emptied through one of the main hatches. That would be too risky in a real situation.
- The worst part for me was that, after just a couple of hours in the seat, I was in so much pain that it was difficult to sit. Even with only 24 persons in the boat, I had little space to move around, and, due to the boat's movements and the lack of anything to hold on to, I could not stand up. The pain itself was not lethal, but it was so intense that I had enough to cope with myself and did not care about the people around me, which is not good if you are to try to help and support the person in charge of the lifeboat. It also adversely affected the time taken to get me out of the lifeboat and the amount of help I needed, which again in a real situation would increase the time needed to transfer people from the lifeboat.
- I left the lifeboat after only 14 hours, due to my aching butt and back. From air quality or temperature perspective, I could have stayed much longer.

How can “SARex 2” help the implementation of the Polar Code?

The cold facts emanating from SARex I showed us that the “state of the art” for survival craft is not sufficient. SARex 2 gave us examples of how some of the challenges may be met, and it will be helpful in developing performance standards for survival craft to ensure global and consistent implementations of the LSA requirements in the Polar Code. It also showed us other challenges that in the past have been poorly treated, and it will be valuable in future work on general requirements for survival craft, not only those in Polar waters.

Up until now, regulators have focused on the equipment itself, paying little attention to the people who are expected to survive using the equipment. Performance standards are needed to overcome these gaps.

Some challenges more easily solved than others are air quality and temperature inside a survival craft, along with amount of water and food needed and sanitary equipment.

Another challenge is the comfort of those in the survival craft. Obviously, there are limits to the comfort in a survival craft, it is not made for holidays, but some basic comfort is needed to help those in distress to maintain their cognitive abilities. If people lose their cognitive abilities in a small, crowded boat, no one knows what may happen.

We are not talking about expensive, sophisticated equipment. It could be a hook for the survival suit above the seat, a small net under the seat to store water and nutrition and a handle or a rail in the ceiling to enable people to get up.

In finding good solutions to these challenges, we must realize that some of the additional equipment will take up space and reduce the number of people a survival craft can carry, but that is a price the industry will have to pay if we want people to survive in the case of an accident resulting in abandonment.

Also arising from the outcome of SARex 2 is the experience gained with the life raft. As I was in the lifeboat, I have not discussed the issue here, but, at some point, we need to consider the suitability of the use of rafts in Polar waters.

CLASSIFICATION SOCIETY'S IMPLEMENTATION OF THE IMO POLAR CODE

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Introduction

Due to an increased interest of the polar frontiers together with an increasing cruise industry, showing interest to operate here, it is even more important that the Regulatory bodies and the classification societies, which are having the role as the recognized organisations are having a vast competence of polar water operations and perform their work effectively and consistent. In their role as Recognized Organizations, Class societies are doing the Polar Code statutory certification and issuing the Polar Ship Certificates on behalf of flag states. The process consists of:

- reviewing the operational assessment as to what risks are relevant and how they shall be addressed (technical solutions and/or operational procedural solutions)
- evaluating/surveying the ship and its equipment (i.e., the technical solutions)
- reviewing the Polar Water Operation Manual, PWOM (i.e., the operational procedural solutions).

In addition to this it needs to be emphasized the importance of evaluating actual emergency response and response time to the area of the operations, taking the effect of having large amounts of people in need of help with very limited rescue resources, into consideration. Most of the areas of interest in Arctic and Antarctic have no effective rescue resources available that could handle a severe incident with more than 100 persons in distress within an acceptable time.

Today guidelines including competence about necessary required standard and methods of life saving appliances (LSA) for polar waters are missing, the existing equipment on-board most of the vessels are not sufficient for a survival in remote areas. It is extremely easy to go into the trap of thinking “conditions are not that bad” when you are sitting in a comfortable office or thinking “this isn't so different from survival on the other oceans”. Unfortunately, that is the real case, it is totally different! Therefore, need the requirements reflect the harsh conditions, be risk based functional requirements and it should be beneficial to qualify the LSA equipment and methods by testing in relevant conditions gaining vital experience.

Development of relevant operating procedures

The polar water operation manual (PWOM) need to be developed by companies/personnel with experience from polar water operations. By just attending the 2 STCW courses for polar waters are not sufficient and the whole company structure need to embrace the hazards relevant and have contingency in order. The normal safety philosophies in normal shipping are necessarily not at all covering hazards related to polar operations without or limited back-up from normal civilizations SAR response. The typical mistake we often do, living in our “safe home environment” is the difficulty to foresee scenarios and consequences in these remote areas and harsh environment necessarily not designed for the comfortable citizen where personal ability and survival techniques are crucial.

Here the Classification Societies initiatives are crucial, interpreting the rules of the Polar Code statutory certification and issuing the Polar Ship Certificates on behalf of flag states. The societies are all different with various experience, ambitions, and it is obvious the quality of the approval and certification work, and the interpretation of requirements, will differ amongst them. A qualification scheme for Polar Code governed by an IMO appointed commission could be a solution to “keep up the lowest level”.

Assessment of operational risks

Competence of operations in remote areas is not easy to gain and maintain. The number of people with this background are few and very valuable. To perform such planning, the emergency response capacity need to be included in the assessment as if travelling in remote areas with many people alternative evacuation possibilities may need to be considered (i.e. ships operating tandem covering each other). As an example, a scenario with a lost ship in helicopter distance from civilization will necessarily not be easy if the ship has many people (>100).

Selection of appropriate Life Saving and related equipment, including protection of polar wildlife

To have correct and proven equipment, as well as training in using them, when trying to survive in polar waters are essential. The IMO Polar code present lists of suggested personal equipment and group equipment which shall complement the ordinary life saving appliances (LSA), such as lifeboats or life-rafts, but the requirements to the LSA are the ordinary SOLAS. Today's minimum requirements are not at all in line with known needs in polar waters and there is room for improvements of lifeboats and life-rafts related to insulation, ventilation, visibility, sitting comfort, communication, navigation etc.

It is a risk the lists presented will be used as the "only" required equipment and that adaption to the actual conditions are disregarded. It is necessary the required equipment is adapted accordingly to the risk assessment scenarios and the decided survival strategies and multiple scenarios (lifeboats, rafts, survival on ice and survival on land). The requirements to testing and qualifying the equipment and the survival strategies need to be further developed and instead of presenting lists maybe one should present some case scenarios where survival strategies and equipment should be adapted for.

When surviving in Arctic protection of polar wildlife is necessary and every operating unit, lifeboat, raft, tent or group, should have their own protection maintained always. Training of handling groups of people in dangerous situations with polar bear and walrus contact, including shooting tests, safe handling of weapons and maintenance, need to be mandatory and continuously renewed through a certification scheme. One rifle is not enough for 2 groups and the threat is not only polar bears, also curious walruses are dangerous when sitting in a life-raft or on the beach.

In a critical situation with many days of survival the possibility to use natural resources for food and hydration are possible, the standard rations of food and water on-board the LSA are evidently not sufficient in polar waters.

----------- Quote from IMO Polar Code ------------------------

9 Additional guidance to chapter 8 (Life-saving appliances and arrangements)

9.1 Sample personal survival equipment

When considering resources to be included with the personal survival equipment, the following should be taken into account:

Suggested equipment
Protective clothing (hat, gloves, socks, face and neck protection, etc.)
Skin protection cream
Thermal protective aid
Sunglasses
Whistle
Drinking mug
Penknife
Polar survival guidance
Emergency food
Carrying bag

9.2 Sample group survival equipment

When considering resources to be included in the group survival equipment, the following should be taken into account:

Suggested equipment
Shelter – tents or storm shelters or equivalent – sufficient for maximum number of persons
Thermal protective aids or similar – sufficient for maximum number of persons
Sleeping bags – sufficient for at least one between two persons
Foam sleeping mats or similar – sufficient for at least one between two persons
Shovels – at least 2
Sanitation (e.g. toilet paper)
Stove and fuel – sufficient for maximum number of persons ashore and maximum anticipated time of rescue
Emergency food – sufficient for maximum number of persons ashore and maximum anticipated time of rescue
Flashlights – one per shelter
Waterproof and windproof matches – two boxes per shelter
Whistle
Signal mirror
Water containers & water purification tablets
Spare set of personal survival equipment
Group survival equipment container (waterproof and floatable)

---------- Unquote ----------------

HOW TO COMPLY WITH THE POLAR CODE

To comply with the Polar Code, a ship and its crew must be certified for operations in polar waters. When in polar waters, the ship must be operated within the limitations stated on its Polar Ship Certificate and follow the operational requirements in the Code.

Regulatory requirements

Ship owner and operator need to take a number of actions for achieving compliance with the Polar Code requirements, including:

PART I-A:

- carrying a Polar Ship Certificate on board,
- developing and carry a polar water operation manual on board,
- carrying the right training certificate from the respective flag state on board as required by the Polar Code § 12 and STCW, and
- performing voyage planning before every voyage to polar waters following the instructions in the PWOM as required in Polar Code §11.

PART II-A:

On-board documentation concerning pollution prevention needs to be updated to take operation in polar waters into account, including requirements from MARPOL Chapters I, II, IV and V.

The Polar Ship Certificate

SOLAS ships operating in polar waters will require a Polar Ship Certificate. This is a new statutory certificate issued by a vessel's flag administration or its authorized representatives.

The Certificate attests that the ship complies with the ship safety requirements in Part I-A of the Polar Code. To obtain a Polar Ship Certificate, the owner must:

- conduct an operational (risk) assessment of the ship and its intended operations in polar waters;
- prepare a Polar Water Operational Manual (PWOM) specific to the ship, its arrangement and its intended operation in polar waters;
- have the ship surveyed to verify its compliance with the relevant requirements of the Polar Code; and
- apply to its flag administration or authorized representative for the Polar Ship Certificate.

DNV GL is an authorized representative for most flag administrations. We will assist you with the steps above and either issue the Polar Ship Certificate directly on behalf of your flag administration, or issue you a certificate of compliance.

More information on our certification services are outlined in the table on page 9.

POLAR CODE SERVICES FROM DNV GL

Step	Requirements	Polar Code reference	Statutory certification services (required)	Advisory services (optional)
1	Operational assessment report	Part I-A § 1.5	Review the owner's operational assessment	Assists owners in conducting the operational assessment, define the ship's polar operations capabilities, and set a Polar Service Temperature
2	Determination of polar ship category equivalency	Part I-A § 3	Review/approve the ice class equivalency (for non-IACS polar ice class ship seeking Category A or B designation)	Assist owners in conducting a structural equivalency analysis of an existing ship to determine its equivalent polar ship category
3	Documentation of systems and equipment	Part I-A § 1.5	Review/approve the ship system and equipment documentation	Assist owners in assessing the ship's systems and equipment against the requirements of the Polar Code and identify what documentation will be needed
4	Intact stability calculations that include allowance for icing	Part I-A § 4.3.1	Review/approve stability calculations	Calculate the icing load and stability calculations for relevant loading conditions
5	Polar Water Operational Manual (PWOM)	Part I-A § 2	Review the PWOM	Assist owner in preparing the PWOM, customized to the needs of each ship
6	Ship survey to confirm compliance with Polar Code	Part I-A § 1.5	Conduct the statutory survey*	
7	Issuance of Polar Ship Certificate (PSC)	Part I-A § 1.5	Issue the PSC on behalf of the vessel's flag administration	
8	MARPOL certificates	Part II-A § 1	Reissues the appendix to the IOPP certificate to indicate compliance with the environmental requirements of the Polar Code. Other MARPOL certificates are unaffected.	

*Usually harmonized with the renewal or intermediate survey of the vessel's other SOLAS certificates

CONTACT (FOR ALL SERVICES)	
For customers: DATE - Direct Access to Technical Experts, via *My DNV GL*	**Others:** Send email to PolarCode@dnvgl.com

HOW DOES THE CODE APPLY TO MY SHIP?

The Polar Code is a functional, goal-based code. It applies to ships differently, depending on how a ship is constructed and how it will be operated in polar waters.

Fit for purpose?
A key objective of the Polar Code is to ensure a ship is fit for its intended operation in polar waters. The Code does not provide a one-size-fits-all solution. The Code's requirements derive from the capabilities a ship will need to have to carry out its intended operations safely and responsibly. This is highly dependent on where, when and how it will operate in the polar regions and what environmental conditions it will likely encounter while there.

Polar operating profile
The first step in understanding how the Code applies to your ship is to define its polar operating profile. This includes where the ship is intended to operate, what seasons it will operate there and what type of activities the ship will conduct.

Ideally, the profile is tailored to reflect the ship's known or planned range of operations in the polar regions. If this isn't known, then a generic operating profile can be formulated instead.

Operational risk assessment
Next, you need to conduct the operational assessment required by the Polar Code (Part I-A § 1.5).

It is a type of risk assessment that

- defines the anticipated range of operating and environmental conditions for the area and season of operations,
- identifies the relevant hazards associated with the ship's polar operating profile,
- identifies the capabilities the ship requires to perform satisfactorily under these conditions,
- assesses the ship's design and equipment arrangement against these capabilities, and
- identifies additional technical and operational measures needed to comply with the Polar Code.

Certain key choices in a ship's polar operating profile and key conclusions from the operational assessment will determine which parts of the Polar Code apply to your vessel. These are:

- operation in ice,
- operation in low air temperature,
- operation in high latitude, and
- maximum expected time of rescue.

Operation in ice
The Polar Code assigns a ship to one of three categories – Category A, B or C – based on the type of ice for which it is designed to operate, if any. A ship's category determines the applicability of some requirements and regulations in the Code, as some apply to a Category A ship only, others to Category A and B ships for example.

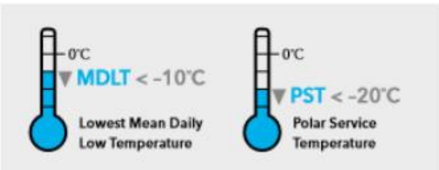
A ship's ice class is used to determine its polar ship category (see page 13). The Polar Code does not associate a ship's category with geographic operating areas. Rather, a ship owner should ensure that the ship's ice class is appropriate for the anticipated ice conditions and operate it within those limits.

Operation in low air temperature
Low air temperature adversely affects human and equipment performance, survival time and material properties.

The Polar Code divides ships into two categories with respect to air temperature: those intended to operate in low air temperature, and those which are not.

A *ship intended to operate in low air temperature* means a ship intended to undertake voyages to or through areas where the lowest Mean Daily Low Temperature (MDLT) is colder than -10°C. For such a ship, a *Polar Service Temperature (PST)* shall be specified and shall be at least 10°C colder than the lowest MDLT for the intended area and season of operation in polar waters (see page 12 for an explanation of the lowest MDLT and PST.)

The Polar Code contains specific requirements for a ship intended to operate in low air temperature. These include general requirements that systems and equipment required by the Code must be fully functional at the PST. Survival systems and equip-



ment also must be fully operational at the PST during the maximum expected time of rescue.

Operation in high latitude
Operating in high latitudes limits the performance and availability of standard navigation and communication systems, and may affect the quality of ice imagery information.

The Polar Code requires additional communications and navigation equipment for vessels proceeding to high latitudes.

Maximum expected time of rescue
Remoteness and the lack of infrastructure in the polar regions affects the availability and timeliness of rescue and assistance to ships in distress.

Ships operating in remote polar waters must be prepared to wait for some days before SAR resources arrive on scene.

The Polar Code requires a ship owner to determine the *maximum expected time of rescue* for their intended operations in polar waters. This determines the type and amount of survival equipment the ship must carry on board.

The Code requires that this must be at least five days. When operating in some remote areas, it may be considerably more than five days.

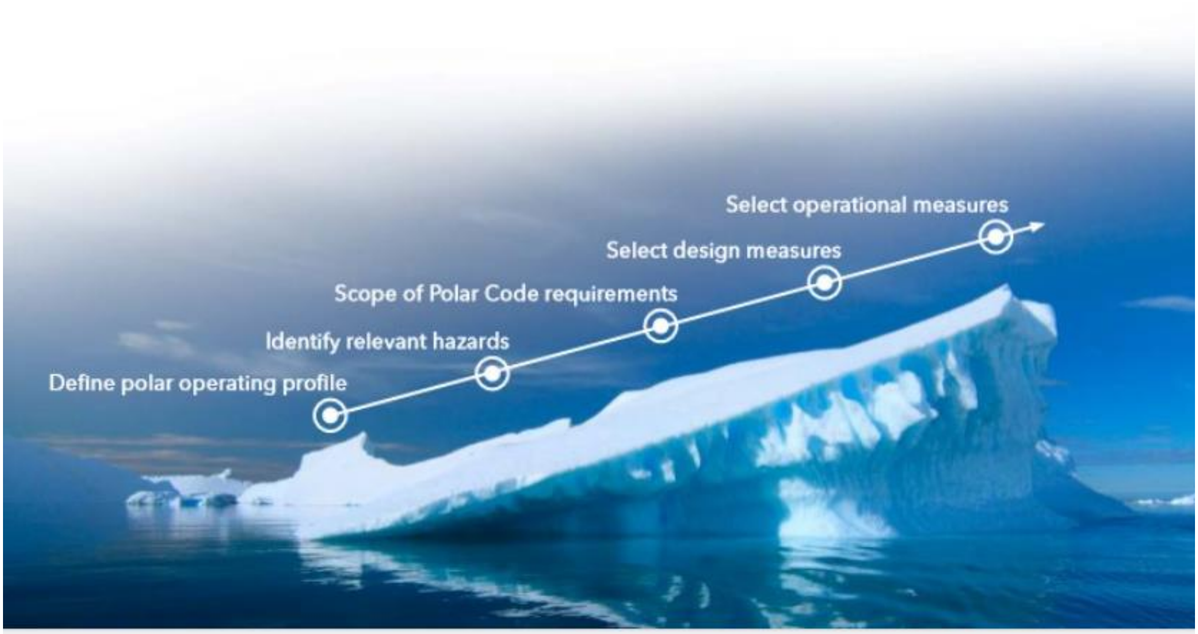
Setting this value for a ship is a key element of the operational risk assessment required by Part I-A § 1.5 of the Code.

Determining individual requirements
Once the polar operating profile and operational risk assessment have been performed for a ship, we can determine which requirements in the Polar Code apply to it.

Some requirements must be met by design measures and some by operational procedures. For others, the owner may choose either design or operational measures, or a combination of both, to comply.

There is no single prescribed solution for what is considered "acceptable" in meeting many of the functional requirements of the Code. In this way, the Polar Code is similar in approach to the International Safety Management (ISM) Code and the International Ship & Port Facility Security (ISPS) Code, which rely heavily on the owner/operator to develop processes that adequately address a ship and operation.

DNV GL is ready to assist you in this process. We can help you define a polar operating profile, conduct the operational assessment, determine which parts of the Code apply to your ship, and evaluate alternative design and operational measures to comply with them.



CHAPTER 8 – LIFE-SAVING APPLIANCES AND ARRANGEMENTS

The goal of this chapter is to provide for safe escape, evacuation and survival in polar environments.

This chapter sets requirements for all ships, with additional requirements for new ships and ships intended to operate in extended periods of darkness.

To ensure safe and immediate **escape**

- All ships must have means to prevent or remove ice and snow from escape routes, muster and embarkation areas, survival craft and their launching appliances.
- New ships must arrange escape routes so as not to hinder passage by persons wearing polar clothing.

To ensure safe **evacuation** off the ship

- All ships must have the means to safely evacuate people and deploy survival craft and equipment when operating in ice-covered waters.
- All ships must be able to operate life-saving appliances independently of the ship's main source of power.

To enable **survival** after abandoning ship

- All ships shall provide adequate resources to support survival after abandoning ship, whether to sea, to ice or to land, for the maximum expected time of rescue. These resources shall provide a ventilated environment that will protect against hypothermia, sufficient food and water to sustain life, and the ability to communicate with rescue assets.
- Everyone aboard shall be provided thermal protection and personal survival equipment that adequately maintains core body temperature and prevents frostbite of extremities.
- Survival craft and group survival equipment shall provide effective protection against direct wind chill for all persons aboard.
- Lifeboats must be partially or totally enclosed.
- Group survival equipment is required if there is a potential for abandonment onto the ice or to land.
- Where required, personal and group survival equipment will be provided for 110% of the persons aboard, stowed in easily accessible locations in or near the survival craft.
- Containers for group survival equipment shall be floatable and easily movable over the ice.
- For ships operating in extended periods of darkness, lifeboats shall be equipped with searchlights for detecting and identifying ice.

Technical interpretations

For escape routes on new ships, an unobstructed width of not less than 900 mm may be considered sufficient to ensure unhindered passage by persons wearing polar clothing.

Free-fall lifeboats cannot be safely launched in free-fall mode in ice-infested waters. Ships must be arranged with an alternative lowering mechanism and adequate means for the crew to safely access the lifeboat.

Survival systems that use ship's power (such as launching appliances) shall be arranged from the emergency switchboard.

Life rafts are inferior to lifeboats for supporting survival in a polar environment. Where a ship's lifeboat capacity is insufficient for the entire complement, those personnel designated for evacuation in life rafts must be provided thermally insulated immersion suits.

Life-saving appliances must be fully operational at the PST during the maximum expected time of rescue (see explanation on page 11).

- The standard IMO test criteria for life-saving appliances is -30°C in stowage and -15°C in operation. As the PST may be colder than these temperatures, additional testing or qualification may be required.
- The standard IMO lifeboat engine starting test is -15°C. If the PST is colder, then the engine may either be tested to the PST, or the lifeboat may be heated sufficiently to ensure the inside temperature is ≥ -15°C when the outside temperature is at PST.

Containers for group survival equipment shall be designed such that two people can lift them from the water up onto an ice floe (a vertical distance of approx. 0.5 metres). Container weight should not exceed 25 kg.

CHAPTER 10 – COMMUNICATIONS

The goal of this chapter is to provide for effective communication for ships and survival craft during normal operation and in emergency situations. This chapter contains three groups of requirements.

For all ships, the Polar Code requires:
- ship-to-shore voice and data communications to relevant rescue coordination centres and tele-medical assistance services, and for receiving ice and meteorological information;
- ship-to-ship voice communications; and
- ship-to-air voice communications (on 121.5 and 123.1 MHz).

These must take into account the limitations of communications systems in high latitudes and the anticipated low temperature that is available at all points along the intended operating routes.

For ships intended to operate in low air temperature, the Polar Code requires additional communications equipment for survival craft.

Rescue boat and lifeboats, when released for evacuation, shall each carry:
- a device for transmitting ship-to-shore alerts (EPIRB),
- a device for transmitting signals for location (SART), and
- an on-scene radio communication device (VHF).

Life rafts shall each carry:
- a device for transmitting signals for location (SART), and
- an on-scene radio communication device (VHF).

Icebreakers that provide escort services shall have a sound signalling system (horn) that faces astern to indicate manoeuvres to following ships.

Technical interpretations

When planning the vessel's communication systems, high latitude limitations need to be considered.
- The theoretical limit of coverage for geo-stationary satellites is 81.3°N/S, but experience shows they have challenges as low as 70°N/S. Many factors influence the quality of service offered by geostationary systems.
- GMDSS Sea Area A3 is acceptable for operations up to 70°N/S. Ships travelling this area must carry either an Inmarsat F77, B or C ship earth station, or a DSC-equipped HF radio-telephone/telex.
- GMDSS Sea Area A4 is required for operations above 70°N/S. Ships travelling these polar regions must carry a DSC-equipped HF radiotelephone/telex.
- Non-GMDSS systems, such as Iridium, may be available and can be effective for voice and data communication in polar waters.

The effects of cold temperature on battery life for survival craft communication systems must be considered to ensure they can remain available for operation during the maximum expected time of rescue.
- Procedures to preserve battery power must be developed and included in the PWOM.
- Spare batteries should be provided and kept in a warm location to preserve their power.
- A separate battery pack for the radio equipment or an arrangement that allows charging them from lifeboat power systems is recommended.

All required communication equipment must be fully functional to the PST.
- Most fixed electronic communication equipment is already tested to -25°C under standard industry testing regimes such as IEC 60945. Where the PST is colder, additional testing or qualification may be required.
- Most portable electronic communication equipment is tested to -20°C under standard industry testing regimes such as IEC 60945. Where the PST is colder, portable equipment should be kept in a warm environment, or additional testing/qualification may be required.

Tip!
For updated information on interpretations and frequently asked questions, please visit our website at www.dnvgl.com/polar.

POLAR WATER OPERATIONAL MANUAL

The Polar Code requires SOLAS ships operating in polar waters to carry a Polar Water Operational Manual (PWOM). The Manual provides ship-specific guidance on how to safely operate the vessel within its design capabilities and limitations.

What is the purpose of the PWOM?
The Polar Water Operational Manual (PWOM) is a ship-specific reference document that describes in detail how the ship shall be operated in polar waters. The procedures address operations under both normal and emergency conditions.

If you operate a SOLAS-certified ship in polar waters, then you must have a PWOM and it must be carried aboard the ship.

The goal of the PWOM is to inform the master and crew about the ship's capabilities, limitations and essential operating procedures when in polar waters. It is intended to help them take sound operational decisions and actions to protect the ship, its crew and passengers, and the polar environment.

What shall be in the Manual?
The Manual must address each hazard identified as relevant in the ship's Polar Code operational risk assessment. This might include sea ice, cold temperatures, topside icing and high latitudes.

Where equipment is used to mitigate a hazard, the PWOM must explain how to operate it. Where procedures are used, the PWOM must spell them out.

The Manual must include (or refer to) specific procedures that the crew shall follow under the following conditions:

- During normal operations, to avoid encountering conditions that exceed the ship's capabilities
- In the event the ship encounters conditions that exceed its capabilities and limitations
- In the event of an incident in polar waters
- When operating in ice, either independently or with an icebreaker escort (if ice-capable)

What types of procedures must it contain?
The requirements for the PWOM are found in Part I-A § 2 of the Polar Code. Among others, the PWOM must contain procedures for the following:

- Voyage planning in polar waters
- How to assess ice conditions and determine whether it is safe for the ship to proceed
- How to receive and use ice forecasts
- How to operate equipment and maintain system functions during freezing temperatures, topside icing and sea ice
- What to do if the ship encounters ice or cold temperatures that exceed its design capability
- What to do in case of an emergency, including how to contact emergency response providers

What does an approved Manual look like?
Many different types of ships operate in the polar regions. They differ widely in their design and ability to operate in ice and cold temperature. Some can operate year-round in multi-year ice, while others do not operate in ice at all.

Because the PWOM must be tailored to each ship, its arrangement and its intended operation, there is no single example or template for an acceptable Manual.

Appendix 2 to the Polar Code contains a model table of contents for a PWOM. This can be used as a beginning point in organizing a Manual for your ship.

Who is responsible for the Manual?
The owner is responsible for providing a PWOM. Ideally, the Manual should be prepared by those who best know the ship and its crew, its operations in polar waters, and the company's safety management system.

DNV GL can help you
DNV GL Maritime Advisory can assist owners in preparing a PWOM tailored to the needs of their ship and its intended operations.

LIFESAVING AND EMERGENCY EQUIPMENT; PRESENT SITUATION ON SHIPS OPERATING IN POLAR WATERS

Jahn Viggo Rønningen, Norwegian Ship Owners' Association, Oslo, Norway

The Polar Code entered into force 1st January 2017. The code's safety matters are mandatory for all vessels above 500GT in international trade, while environmental protection matters are mandatory for all ships regardless of size. The code covers the full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in polar waters.

The Polar Code's requirement to lifesaving and emergency equipment

1.2.7 Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than five days.

8.2.3.3 Taking into account the presence of any hazards, as identified in the assessment in chapter 1, resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the maximum expected time of rescue. These resources shall provide:

1 a habitable environment;
2 protection of persons from the effects of cold, wind and sun;
3 space to accommodate persons equipped with thermal protection adequate for the environment;
4 means to provide sustenance;
5 safe access and exit points; and
6 means to communicate with rescue assets

Common recommendations for ships operating in polar waters

Ships intended for operation in polar waters must be equipped with winterised lifesaving and emergency equipment. Additional equipment may be need on board as well. The survival equipment supplied on board must be intended for the survival of minimum 5 days according to the Polar Code requirements. Ships that have been approved with a winterisation class notation and maybe achieved a Polar Ship Certificate have implemented certain operational and equipment requirements on board. These requirements can be as follows:

- Lifeboats, if required to be carried, should be of a totally enclosed design with engines capable of being started in sub-zero temperatures. Lifeboats should be provided with heating and trace heated doors.
- Fuel used in survival and rescue craft should be of Arctic grade or equivalent, suitable for use in low temperatures without waxing.
- The correct operation of equipment such as lifesaving appliance davits and winches, breathing apparatus, life rafts and man overboard boats should be assured in the anticipated low temperature conditions.
- Adequate supplies of protective clothing should be available, including thermal insulating materials such as immersion suits for the expected conditions.
- Consideration should be given to the provision of Personal Survival Kits (PSK) for the number of persons on board, when the mean daily temperature is less than 0°C. PSK can include, but not limited to: socks, upper and lower underwear, gloves, cap, sitting pad, hand warmers and waterproof bag (clothing in wool or similar).
- Consideration should be given for the need of Group Survival Kits (GSK) for 110% of the total number of persons on board, where ice may prevent the lowering of survival craft.

- Containers for GSK should be designed to be easily movable over ice and be floatable.

As mention above, ships operating in polar waters can be fitted with both Personal Survival Kits (PSK) and Group Survival Kits (GSK). GSK is survival equipment intended for evacuation to ice and can include, but not limited to, equipment such as:

- Tents for shelter
- Sleeping bags
- Mattresses
- Wool blankets
- Thermal blankets
- Extra set of protective wool base layer/underwear
- Provisions
- Water containers and water purification tablets
- Drinking mugs
- Liquid fuel stove/primus
- Pan for liquid fuel stove/primus
- Skin protective cream/cold cream
- Toilet paper
- Rope and tent plugs for securing life rafts
- Shovels
- Knifes
- Flashlights
- Batteries for flashlights
- Matches – water/wind proof

Other relevant safety recommendations implemented on ships operating in polar waters

Safety and lifesaving equipment

It is recommended that all life rafts are rated for safe operation according to the environmental conditions likely to be experienced. Arctic-rated life rafts and Hydrostatic Release Units (HRU) are available with internal electrical heating elements to ensure functionality and prevent icing. Ice accretion should be regularly removed from the life rafts, cradles, cradle release pins and launching equipment to retain their preparedness for launching and inflation.

Similar precautions may be taken for lifeboats, rescue boats and their launching appliances, if carried. Inspections should be made to ensure that brake release securing pins are maintained free to move and capable of being extracted.

It is recommended that an ice removal mallet is readily available in the vicinity of the survival craft. Care should be exercised when using mallets to avoid inadvertent damage to the equipment. Manual inflation pumps, proven to work in the anticipated temperatures, should be provided for the life rafts and stowed in a warm space in the vicinity of the life rafts.

The overall condition of the gel coat of lifeboats should be regularly inspected for any damage, particularly penetration of the gel coat and fibre substructure. This should be done in good time prior to entering the cold zone, due to the hygroscopic nature of fibreglass. If the repairs are undertaken in a warm dry climate, this will limit water ingress which, if subjected to freezing, can cause severe damage to the boat’s structure.

Lifeboat engines
Lifeboat engines should at all times remain available for immediate use within two minutes of starting in the environmental conditions likely to be experienced. The process of starting an extremely cold engine is quite different from normal starting procedures. It is recommended that the correct procedure is drawn to the attention of all persons likely to be involved to ensure they are familiar with the operation. The routine of test run the engine should also be increased in cold climate. Manufacturer's instructions for the oil grade should be followed and spare oil should be readily available in the lifeboats.

If fitted, sump or space heaters in lifeboat engines may be used. Consideration may also be given to fitting trace heating around the doors of enclosed lifeboats to ensure that they do not freeze in the closed position. It should be recognised that the performance of the starting batteries in cold conditions might be diminished.

Lifeboat fuel systems
An appropriate grade of Arctic diesel or gas oil may be used to prevent waxing in fuel systems. Waxed fuel can lead starting problems and impaired reliability of the engine. When replacing the fuel grade, it is recommended that the fuel tank is drained properly and replaced with the appropriate fuel grade. The fuel in the fuel lines should also be changed before entering cold climate and flushed with the engine running on the new fuel.

Lifeboat cooling water systems
Where the lifeboat cooling water system is self-contained and recirculating, it should be adequately protected with an anti-freeze solution. If the system is not self-contained, it should be checked to ensure that no obstructions or contamination prevent the natural drainage of the system.

Lifeboat water spray systems
The spray systems, including pumps, on the lifeboats should be drained of water. If the spray pump is frozen on some lifeboat types, it can prevent the lifeboat engine to start by locking the propeller shaft.

Lifeboat water rations
Precautions should be taken to avoid the freezing of water rations stowed in lifeboats. This may include storing them in a warm area. If not stored in the lifeboat, one person must be designated on the muster list to collect the water rations and bring them during an emergency situation.

Rescue boats with water jet engines
The rescue boat should be maintained in a condition that will allow immediate use but also protected from the extreme weather.

Immersion suits
Commonly supplied immersion suits have a design operational range in immersed seawater temperatures from -1.9°C up to +35°C. Available immersion suits on the market have enhanced insulation properties.

If evacuated on to ice, special caution should be made when wearing an immersion suit as the it does not provide feet protection against cold and do not have anti slips soles.

Thermal Protective Aids (TPA)
TPAs should be effective within a temperature range appropriate to the temperatures likely to be encountered.

Lifebuoys
Lifebuoys should be maintained so that they are not frozen in storage position and are free to be removed and used.

External pyrotechnics
Bridge wing lifebuoy/smoke float release pins should be well greased to ensure their proper operation.

Emergency position-indicating radio beacons (EPIRB)
EPIRBs should be maintained ice free.

Breathing apparatus and oxygen therapy units
The use of compressed air/oxygen breathing or resuscitation apparatus should be considered with care in sub-zero conditions. Freezing of the demand and exhale valve can lead to uncontrolled gas flow from the air bottles or failure of the system. Lung exposed to low temperature (below -4°C) over time can lead to frostbite of the lung tissue. Moisture content of the compressor output should be checked when refilling the air bottles.

Example of a ship operating in polar waters
The vessel MS Polarsyssel is Sysselmannen on Svalbard’s service vessel and has the DNVGL class notation ICE-1B Winterized Basic. The vessel is intended to operate on regular inspections around the Svalbard islands, perform Search and Rescue (SAR) operations including fire on external ships, oil and environmental pollution to sea, emergency towing, salvage of ships and personnel in connection loss of power, grounding and collision. Polarsyssel can also function as a helicopter base under helicopter operations.

Polarsyssel’s survival equipment consists of Viking life rafts and two Polar circle work boat/FRC. Both FRCs are winterized but one is kept in an enclosed and heated area, while the life rafts are winterized with built-in silicone rubber heating mats inside the container to prevent over-icing.

Viking winterized life rafts is also equipped with:
- Heated hydrostatic release unit.
- The exterior supply box can heat up to three containers simultaneously. Its built-in short circuit protection and power indicator provide total reliability.
- When the ambient temperature rises above approx. 5°C, the heater automatically deactivates.

EXECUTION OF THE EXERCISE

Risk analysis for evacuation of vessels in the Arctic waters

Konstantinos Trantzas, MSc student, University of Stavanger, Norway

In this chapter the risk analysis related to the evacuation of the vessels in the Arctic waters will be presented. To conduct the risk analysis, we will use a Preliminary Hazard Analysis (PHA) and the findings will be presented in risk matrices to better understand the risk levels.

The Preliminary Hazard Analysis (PHA) is a qualitative or semi-quantitative analysis that is conducted to:

1. Identify the potential hazardous events related to a scenario
2. Rank the aforementioned hazardous events according to their severity
3. Identify possible risk reducing measures

During the PHA it is common to split the analysis object into modules to give a clearer picture of the different stages. A flow chart showing the methodology of a PHA is illustrated in the figure below:

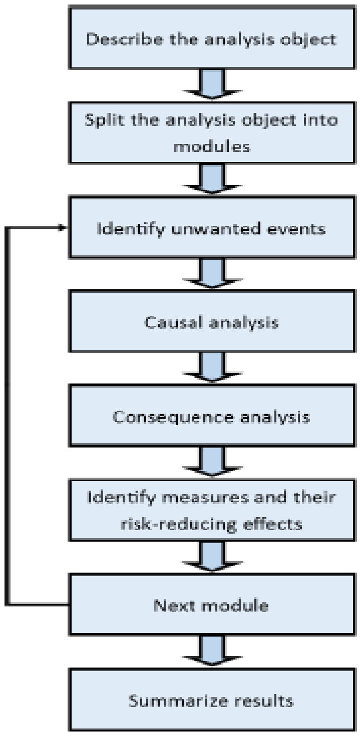


Figure 1: PHA methodology, presented from Aven (2008)

The risk matrix is used to assess the risk in a structured approach that identifies which risks are more critical. A risk matrix is a tool that presents a visualization of the risk. To produce a risk matrix, some basic rules should be followed according to Ni et al (2010).

- The basis for risk matrix is the standard definition of risk as a combination of severity of the consequences occurring in a certain accident scenario and its probability. That means only two input variables are required to construct a risk matrix. The output risk index is determined only by the severity of the consequences and its probability.
- The severity of consequences, probability and output risk index can be divided into different levels, respectively, with qualitative descriptions and scales.

- The calculation process of matrix producing is presented by the logic implication as: IF probability is p AND severity of consequence is c THEN risk is r.

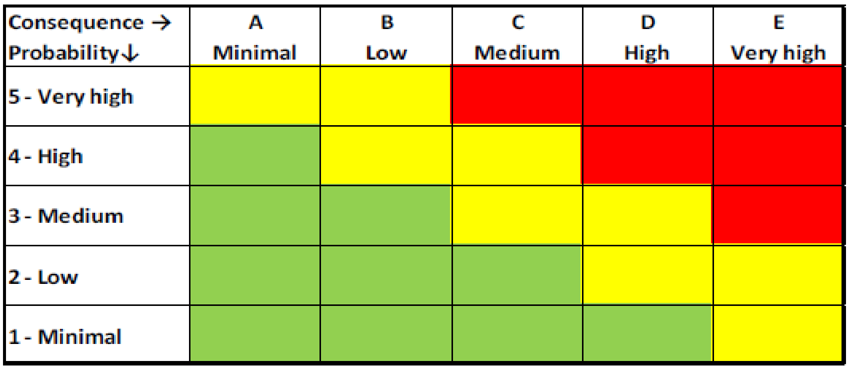


Figure 3: Risk matrix example

The PHA of this chapter was initially prepared during the planning stages of the project. During the SARex 2 trip, a risk assessment work group was conducted before the exercise and a summarizing meeting after the exercise, where the initial PHA was enriched with additional hazards and risk reducing measures. In both meetings the analysis group consisted of all the participants from the SARex 2 team.

The analysis object of our case is the evacuation of a cruise ship in the arctic waters after an accident. In our scenario the passengers had to perform an evacuation from a cruise ship in the Arctic, using lifeboats and life rafts and survival suits, and survive for at least five days.

The analysis object was split into five phases, to simplify the process. The separation of the phases was conducted according to the time, dividing the period from the "Alarm" to the "Rescue" into five phases and is presented below:

- Phase one: Alarm to Muster station
- Phase two: Boarding (Lifeboats and Life rafts)
- Phase three: Launching of Lifeboat or Life raft
- Phase four (a): Operation and Survival (Lifeboat)
- Phase four (b): Operation and Survival (Life raft)
- Phase four (c): Survival Logistics
- Phase five: Rescue

Phase one: Alarm to muster station						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
1.1	Passengers attend wrong muster station or cannot find the muster station	- Lack of information before starting the cruise - Poor information regarding evacuation routes onboard - Lack of clear thinking from the passengers due to dangerous/ stressful situation	- Delay on evacuation - Passengers do not reach the correct muster station	**Probab.: 3 Conseq.: B**	- Proper passengers' training programs (e.g. via e-learning) - Better crew training - Posters showing the evacuation routes	**Probab.: 2 Conseq.: B**
1.2	Slippery/ crowded/ blocked passageways, stairs and other routes used on evacuation	- Wet or iced surfaces caused by atmospheric or sea spray - Nonfunctional areas due to smoke, accidents, etc. - Overcrowded areas	- Passengers get trapped and do not reach the muster station - Injuries from falling	**Probab.: 3 Conseq.: C**	- Sheltered and heated outside areas (passageways, muster stations, etc.) - Friction materials used on the floor of outside areas - Wider passageways that can serve more passengers at the same time	**Probab.: 1 Conseq.: C**
1.3	Unavailability of a muster station	- Blocked route to the muster station - Muster station damaged and nonfunctional	- Not enough space in the other muster stations -Not enough evacuation means and equipment in the other muster stations (lifeboats/ life rafts, personal equipment, etc.)	**Probab.: 2 Conseq.: C**	- Alternative plan to organize passengers in the other muster stations - Extra evacuation means and equipment in each muster station	**Probab.: 2 Conseq.: B**

Phase one: Alarm to muster station						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
1.4	Inadequate passenger evacuation equipment (e.g. survival suits, inappropriate/ not woolen clothing, PSK, GSK, etc.)	- Lack of clear thinking from the passengers due to dangerous/ stressful situation - Captain/ crew error of not checking PSK and GSK availability - Polar Code risk assessment does not require PSK/ GSK	- Reduced survival period of the evacuated passengers	**Probab.: 4 Conseq.: D**	- Better crew training - Polar Code requirements - Woolen underwear fit with the survival suits - Survival suits, PSK/ GSK adequate and easy accessible	**Probab.: 3 Conseq.: B**
1.5	Insufficient number of lifeboats/ life rafts or lack of capacity	- Poor planning - Ship-owner/ Captain did not follow the regulations for the proposed number and capacity of lifeboats and life rafts - PSK, GSK and the survival suits need extra space	- Some passengers are not evacuated - Chaotic situation (all the passengers will try to get on the lifeboats/ life rafts) - Possible loss of human lives - Overcrowding existing lifeboats and life rafts which would eventually be dangerous for all the passengers	**Probab.: 3 Conseq.: D**	- Follow regulations regarding the proposed number and capacity of the lifeboats/ life rafts - Proper planning of the capacity needed including PSK, GSK and survival suit	**Probab.: 1 Conseq.: D**

Phase two: Boarding (Lifeboats and Life rafts)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
2.1	Passengers not capable of evacuating without assistance	- Minor or major injuries - Elderly or people with movement problems that need assistance for evacuating to lifeboat or life raft - Complicated boarding procedure	- Delay on evacuation - Some passengers are not evacuated - Chaotic situation	**Probab.: 5 Conseq.: B**	- Proper passengers' training programs (e.g. via e-learning) with special information for elderly or people with movement problems - Better crew training - Easy accessible evacuation routes and procedures for all the passengers	**Probab.: 3 Conseq.: B**
2.2	Panicked passengers	- The evacuation situation is considered stressful for the passengers	- Minor or major injuries - Overcrowded lifeboats and life rafts	**Probab.: 5 Conseq.: A**	- Proper crew training for crowd control situations - Clear and easy evacuation procedures that will reduce passengers' panic	**Probab.: 3 Conseq.: A**
2.3	Lifeboats/ life rafts not usable	- Lifeboats/ life rafts damaged (due to collision, fire, etc.)	- Some passengers are not evacuated - Chaotic situation (all passengers try to get on the lifeboats/ life rafts) - Possible loss of human lives - Overcrowding existing lifeboats and life rafts which would eventually be dangerous for all the passengers	**Probab.: 2 Conseq.: C**	- Alternative means of evacuation (e.g. extra life rafts)	**Probab.: 2 Conseq.: B**

Phase two: Boarding (Lifeboats and Life rafts)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
2.4	Not enough officers for boarding in each lifeboat/ life raft (at least one is recommended to lead each evacuation mean)	- Poor crew training - Many officers are unable of evacuating	- Lack of experience and leadership during all the stages of survival - Reduced survival period of the evacuated passengers - Possible loss of human lives	**Probab.: 5 Conseq.: B**	- Proper passengers' training programs informing them how to get organized in the lifeboat/ life raft (e.g. via e-learning) - Better crew training	**Probab.: 4 Conseq.: A**
2.5	Injuries of passengers while boarding	- The boarding procedure is complicated and need physical competences - Lack of clear thinking from the passengers due to dangerous/ stressful situation	- Reduced survival period of the injured passengers	**Probab.: 4 Conseq.: B**	- Easy accessible evacuation routes and procedures for all the passengers	**Probab.: 3 Conseq.: B**
2.6	PSK/ GSK not brought along in lifeboat/ life raft by the evacuated passengers	- Lack of information before starting the cruise - Lack of clear thinking from the passengers due to dangerous/ stressful situation		**Probab.: 3 Conseq.: C**	- Proper passengers' training programs (e.g. via e-learning) - Proper crew training in order to make sure that the passengers have their survival equipment	**Probab.: 2 Conseq.: C**

Phase three: Launching of Lifeboat or Life raft						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
3.1	Mechanical failure (Lifeboat)	- Icing on mechanical components of the ship or lifeboat (e.g. crane) - Poor maintenance -Material fatigue/ corrosion	- Lifeboat launching cannot be conducted -Cables break - Uncontrollable fall into the sea - Injuries and/ or loss of human lives	**Probab.: 3 Conseq.: D**	- Proper maintenance - Sheltered/ heated mechanisms and components related to launching	**Probab.: 1 Conseq.: D**
3.2	Failure of inflating system (Life raft)	- Icing on mechanical components of the ship (e.g. inflating system) - Poor maintenance -Material fatigue/ corrosion	- Life raft launching cannot be conducted - Uncontrollable fall into the sea - Injuries and/ or loss of human lives	**Probab.: 3 Conseq.: D**	- Proper maintenance - Sheltered/ heated mechanisms and components related to launching	**Probab.: 1 Conseq.: D**
3.3	Impossible launching of the lifeboat/ life raft	- Thick ice around the ship - Ship tilt to one side make launching from this side impossible	- Impossible launching of lifeboat/ life raft	**Probab.: 2 Conseq.: C**	- Use alternative evacuation techniques to evacuate passengers on the ice - Use the equipment on the other side of the ship	**Probab.: 2 Conseq.: B**
3.4	Uncontrollable movements of lifeboat during lowering	- Ship motions - Harsh weather conditions - Unbalanced spreading of the passengers in the lifeboat	- Smashing of the lifeboat with the ship or other lifeboats/ life rafts - Injuries and/ or loss of human lives	**Probab.: 3 Conseq.: C**	- Proper spreading of the passengers in the lifeboat - Dumping systems on the side of the lifeboat that can reduce the consequences of a possible crush - Passengers using seatbelts when onboard	**Probab.: 3 Conseq.: B**

Phase three: Launching of Lifeboat or Life raft						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
3.5	Power shutdown for the launching procedure	- Power/ Electricity of the ship is out because of the accident	- Lifeboat/ life raft launching not possible	**Probab.: 2 Conseq.: D**	- Emergency power system - Alternative system for launching (e.g. gravity systems)	**Probab.: 1 Conseq.: D**
3.6	Passengers jumping into the sea to board in the life rafts	- Lack of inflatable slide to safely transfer passengers into the sea - Lack of clear thinking from the passengers due to dangerous/ stressful situation	- Injuries and/ or loss of lives	**Probab.: 4 Conseq.: C**	- Ensure inflatable slides to safely transfer passengers from the ship to the sea	**Probab.: 4 Conseq.: B**

Phase four(a): Operation and survival (Lifeboat)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4a.1	Engine failure	- Poor maintenance - Icing on mechanical components of the lifeboat - No fuel	- Lifeboat unable to maneuver away from the ship - Lifeboats unable to tow life rafts away from the ship - Lifeboat stuck in sea ice - Lifeboat drifts uncontrollably in the sea (danger of getting crashed from sea ice) - Heating system cannot function without the engine - Reduced survival period of the passengers	**Probab.: 3 Conseq.: C**	- Proper maintenance of the lifeboat - Back-up engine -Ensure that lifeboats are equipped with fuel	**Probab.: 2 Conseq.: B**
4a.2	Fire	- Engine fire - Electrical fire	-Loss of propulsion, heater - Smoke in vessel - Need to abandon lifeboat	**Probab.: 2 Conseq.: E**	- Install fire extinguisher connected directly to engine compartment - Install extinguishing hole to the engine department to extinguish fire without opening the door of the compartment	**Probab.: 2 Conseq.: C**

Phase four(a): Operation and survival (Lifeboat)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4a.3	Discomfort due to sitting position	- Poor seating design - Extended period in same sitting position	- Health problems and injuries such as: Pain (back, bottom) reduced blood circulation, headache, irritability, cold extremities	**Probab.: 4** **Conseq.: A**	- Handles to hold onto above seating area giving the possibility to stretch, move and change seating position with other passengers at certain intervals - More ergonomic design for seats (inclination angle for back rest)	**Probab.: 3** **Conseq.: A**
4a.4	Condensation	- No insulation between cold outside air and warm inside air - Lack of condensation management system (collection etc.) - Warm temperature created from the heater and the survival suits leading to increased sweating	- Poor visibility through windows (navigational issues) - Discomfort	**Probab.: 3** **Conseq.: A**	- Possibility to utilize heat from heat-exchanger to defrost window (valves from heated fan onto window) - Insulate windows and top of boat - Improved condensation management and possibility to collect condensation (can be used for drinking water) - Hatch on roof of vessel for improved ventilation and navigational purposes	**Probab.: 2** **Conseq.: A**
4a.5	High temperature inside the lifeboat	- Survival suits -Heater - insufficient ventilation	-Sweating and associated condensation - Discomfort	**Probab.: 4** **Conseq.: B**	- Temperature management	**Probab.: 3** **Conseq.: B**

Phase four(a): Operation and survival (Lifeboat)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4a.6	Low temperature inside the lifeboat	- Low outside temperature - Heating system not working - Few people	- Core body temperature decreases (hypothermia)	**Probab.: 3 Conseq.: C**	- Survival suits and PPE requirements of Polar Code -Insulated seats - Tarp or canopy to isolate empty areas of lifeboat and maintain heat	**Probab.: 2 Conseq.: B**
4a.7	Insufficient/ blocking of ventilation system	- Warm humid air condenses on cold surfaces	- Condensation from ceiling - Poor air circulation	**Probab.: 2 Conseq.: B**	- Improved ventilation design	**Probab.: 1 Conseq.: B**
4a.8	Poor visibility	- Condensation inside - Icing on the outside of windows - Fog, snow	- Poor visibility leading to navigational issues	**Probab.: 4 Conseq.: B**	- Anti-icing, heated and angular windows - Improved ventilation system -Insulated windows and walls - Hatch in roof of cockpit - Searchlights	**Probab.: 3 Conseq.: B**
4a.9	Maneuvering and navigation difficulties	- Lack of navigational information - Harsh weather conditions - Insufficient maneuvering during towing of the life rafts due to the small distance between rudder axis and towing point	- Running aground - Collision with other lifeboats/ life rafts or icebergs - Difficulty in optimizing heading to minimize movement	**Probab.: 3 Conseq.: B**	- Hydrographic, weather and ice information - Optimized lifeboat design for arctic conditions	**Probab.: 2 Conseq.: B**

Phase four(a): Operation and survival (Lifeboat)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4a.10	Sea spray	- Open hatches (e.g. for extra ventilation, saving people from the sea, etc.)	- Passengers get wet and cold - Water inside the lifeboat	**Probab.: 4 Conseq.: A**	- Improved ventilation design - System for draining water from the lifeboat	**Probab.: 3 Conseq.: A**
4a.11	Icing	- Sea spray or rain combined with low temperatures	- Hatches, hinges and other components get stuck - Blocking of ventilation system	**Probab.: 3 Conseq.: B**	- Winterized lifeboat design	**Probab.: 3 Conseq.: A**
4a.12	Internal communication	- Noisy environment - Poor visibility from operating station/ cockpit	- Difficulty distributing information	**Probab.: 4 Conseq.: A**	- Speaker, whistle, megaphone depending on the size of the lifeboat	**Probab.: 1 Conseq.: A**
4a.13	External communication	- Communication device not available/ working - Poor visibility	- No detection during search	**Probab.: 2 Conseq.: C**	- AIS-transponder - Brackets for transponder on roof for increased range	**Probab.: 1 Conseq.: C**
4a.14	Lack of sleep	- Disorganized area - Uncomfortable seating - Stressful situation	- Fatigue	**Probab.: 4 Conseq.: B**	- Vessel capacity should adhere to ergonomic needs. Storage for personal belongings (food, water and survival suit). - More ergonomic design for seats (inclination angle for back rest) - Sleeping pills	**Probab.: 3 Conseq.: B**

Phase four(a): Operation and survival (Lifeboat)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4a.15	Seasickness	- Excessive vessel motions (especially roll) - Reduced visibility	-Dizziness, apathy, vomiting, cognitive impairment, reduced positivity	**Probab.: 4 Conseq.: C**	- Anti-seasickness medicine - Vessel design (bilge keels), possibility to see outside vessel	**Probab.: 2 Conseq.: C**
4a.16	Injuries while using the pyrotechnics	- Use of flares etc. for signaling purposes	- Major or minor injuries -Fire	**Probab.: 2 Conseq.: E**	- Need for PPE in the pyrotechnical container (gloves and glasses) - Additional first-aid equipment	**Probab.: 1 Conseq.: D**
4a.17	Insufficient/ obsolete and loose equipment	- Lack of basic equipment	- Unable to dry wet areas - Other function difficulties	**Probab.: 3 Conseq.: A**	- Include sponges, trash bags, sea-sickness bags, paper towels, sunglasses (polarized) for crew for watch-keeping purposes	**Probab.: 2 Conseq.: A**
4a.18	Insufficient/ obsolete medical equipment	- Injured passengers - Passengers that need special medication	- Unable to treat injured - Possible loss of human lives Unable to dry wet areas. House-keeping onboard. Snow blindness	**Probab.: 3 Conseq.: D**	-Supply lifeboat with basic medical equipment - Passengers that need special medicines should be advised during the training to carry their medicine with them Include sponges, trash bags, sea-sickness bags, paper towels. Review existing list of required loose equipment. Include sunglasses (polarized) for watch-keeping purposes	**Probab.: 2 Conseq.: C**

Phase four(a): Operation and survival (Lifeboat)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4a.19	Lack of diesel fuel or clogging of the filter	-Diesel fuel not made for cold climate - Not enough fuel for maximum expected days of survival	- Diesel engine stop working - Heater stop working	**Probab.: 4 Conseq.: C**	- Winterized fuel and/or heating of lifeboat at all times in storage position	**Probab.: 3 Conseq.: C**
4a.20	Potentially dangerous wildlife (e.g. polar bear, whale, etc.)	- Wild animals can attack from hunger, curiosity, injury, feeling threatened, etc.	- Damaging lifeboat - Injury and/ or loss of human lives	**Probab.: 1 Conseq.: C**	- Weapons - Lookout patrols - Bear sprays	**Probab.: 1 Conseq.: B**
4a.21	Lack of food/ water	- The LSA requirement not enough for 5 days survive - Poor distribution of the food/ water in rations	- Starvation - Dehydration	**Probab.: 5 Conseq.: D**	- Ensure lifeboat has enough food/ water for the maximum passenger capacity for a 5 days survive - Proper training of the crew	**Probab.: 2 Conseq.: D**
4a.22	Operational management	- Inadequate training and instructions - Inefficient communication	- Reduced positivity, physical health, house-keeping	**Probab.: 4 Conseq.: C**	- Increased training with emphasis on the importance of effective management in cold climate operations (Passengers may not be aware of relevant needs for survival)	**Probab.: 3 Conseq.: C**

Phase four(b): Operation and survival (Life raft)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4b.1	Discomfort due to sitting position	- Difficulties in standing and moving around - Extended period in same sitting position - Overcrowded	- Health problems and injuries such as: Pain (back, bottom) reduced blood circulation, headache, irritability, cold extremities - Falling and stumbling	**Probab.: 4 Conseq.: A**	- Handles and grips on the tubes to hold onto above seating area giving the possibility to stretch, move and change seating position with other passengers at certain intervals - Limit the amount of passengers	**Probab.: 3 Conseq.: A**
4b.2	Condensation	- No insulation between cold outside air and warm inside air - Lack of condensation management system (collection etc.) - Warm temperature created from passengers wearing the survival suits	- Water comes into the raft - Discomfort	**Probab.: 3 Conseq.: A**	- Double layer fabric all around the life raft - Improved condensation management and possibility to collect condensation (can be used for drinking water)	**Probab.: 2 Conseq.: A**
4b.3	Water leakage from the floor or the roof	- Leakage from valves in the floor - Floor of raft was in contact with the water	- Passengers getting cold - Food and equipment getting wet	**Probab.: 5 Conseq.: C**	-Double bottom floor - Improved valves and waterproof zippers - Centralized drainage system and manual drainage pumps - More and bigger sponges and buckets	**Probab.: 3 Conseq.: B**

Phase four(b): Operation and survival (Life raft)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4b.4	High temperature inside the life raft	- Survival suits - Insufficient ventilation	-Sweating and associated condensation - Discomfort	**Probab.: 3 Conseq.: B**	- Temperature management	**Probab.: 2 Conseq.: B**
4b.5	Low temperature inside the life raft	- Low outside temperature - Few people	- Core body temperature decreases (hypothermia)	**Probab.: 4 Conseq.: C**	- Survival suits and PPE requirements of Polar Code -Insulated pads - More survival bags - Personal heating systems (e.g. heat-bags for the hands)	**Probab.: 3 Conseq.: B**
4b.6	Poor visibility	- Lack of windows - Condensation inside - Fog, snow	- Poor visibility leading to navigational issues	**Probab.: 4 Conseq.: B**	-More lookout windows - Transparent material on the side and the roof - Searchlights	**Probab.: 2 Conseq.: B**
4b.7	Maneuvering and navigation difficulties	- Lack of navigational information - Harsh weather conditions - Lack of oars	- Running aground - Collision with other lifeboats/ life rafts or icebergs	**Probab.: 4 Conseq.: A**	- Hydrographic, weather and ice information - Optimized lifeboat design for arctic conditions - Include oars - Include towing and lifting point considering the full capacity of the life raft	**Probab.: 3 Conseq.: A**
4b.8	Sea spray	- Non waterproof zippers allow water inside the life raft	- Passengers get wet and cold - Water inside life raft	**Probab.: 5 Conseq.: B**	- System for draining water from the life raft -Waterproof zippers	**Probab.: 4 Conseq.: B**

Phase four(b): Operation and survival (Life raft)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4b.9	Icing	- Sea spray or rain combined with low temperatures	- Zippers get stuck	**Probab.: 3 Conseq.: B**	- Winterized life raft design	**Probab.: 2 Conseq.: B**
4b.10	External communication	- Communication device not available/ working - Poor visibility	- No detection during search	**Probab.: 3 Conseq.: C**	- Include AIS-transponder - Brackets for transponder on roof for increased range	**Probab.: 2 Conseq.: C**
4b.11	Lack of sleep	- Disorganized area - Uncomfortable seating - Stressful situation	- Fatigue	**Probab.: 4 Conseq.: B**	- Vessel capacity should adhere to ergonomic needs. Storage for personal belongings (food, water and survival suit). - Sleeping pills	**Probab.: 3 Conseq.: B**
4b.12	Seasickness	- Excessive vessel motions (especially roll) - Reduced visibility	-Dizziness, apathy, vomiting, cognitive impairment, reduced positivity	**Probab.: 4 Conseq.: C**	- Anti-seasickness medicine - Vessel design (bilge keels), possibility to see outside vessel	**Probab.: 2 Conseq.: C**
4b.13	Injuries while using the pyrotechnics	- Use of flares etc. for signaling purposes	- Major or minor injuries -Fire	**Probab.: 2 Conseq.: E**	- Need for PPE in the pyrotechnical container (gloves and glasses) - Additional first-aid equipment	**Probab.: 1 Conseq.: D**
4b.14	Potentially dangerous wildlife (e.g. polar bear, whale, etc.)	- Wild animals can attack from hunger, curiosity,	- Damaging life raft - Injury and/ or loss of human lives	**Probab.: 1 Conseq.:**	- Weapons - Lookout patrols - Bear sprays	**Probab.: 1 Conseq.:**

		injury, feeling threatened, etc.		**E**	- If possible use only lifeboats	**D**
Phase four(b): Operation and survival (Life raft)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4b.15	Insufficient/ obsolete and loose equipment	- Lack of basic equipment - Lack of storage space	- Unable to dry wet areas - Missing and wet equipment - Breakage of equipment (passengers sitting on top of the equipment)	**Probab.: 3 Conseq.: A**	- Include sponges, trash bags, sea-sickness bags, paper towels, sunglasses (polarized) for crew for watch-keeping purposes, throwing rope, holding rope - Storage nets on the roof and walls	**Probab.: 2 Conseq.: A**
4b.16	Insufficient/ obsolete medical equipment	- Injured passengers - Passengers that need special medication	- Unable to treat injured - Possible loss of human lives	**Probab.: 3 Conseq.: D**	-Supply life raft with basic medical equipment - Passengers that need special medicines should be advised during the training to carry their medicine with them Include sponges, trash bags, sea-sickness bags, paper towels. Review existing list of required loose equipment. Include sunglasses (polarized) for watch-keeping purposes	**Probab.: 2 Conseq.: C**
4b.17	Operational management	- Inadequate training and instructions - Inefficient communication	- Reduced positivity, physical health, house-keeping	**Probab.: 4 Conseq.: C**	- Increased training with emphasis on the importance of effective management in cold climate operations	**Probab.: 3 Conseq.: C**

					(Passengers may not be aware of relevant needs for survival)	
Phase four(b): Operation and survival (Life raft)						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4b.18	Lack of food/ water	- The LSA requirement not enough for 5 days survive - Poor distribution of the food/ water in rations	- Starvation - Dehydration	**Probab.: 5 Conseq.: D**	- Ensure lifeboat has enough food/ water for the maximum passenger capacity for a 5 days survive -Improved water gathering systems inside the life raft - Proper training of the crew	**Probab.: 2 Conseq.: D**

Phase four (c): Survival logistics						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
4c.1	Lifeboats and life rafts spread around uncontrollably	- No towing of the life rafts - Lack of communication	- Some lifeboats or life rafts move away from the rest creating problems in finding that during the rescue	**Probab.: 4 Conseq.: C**	- Attach life rafts to lifeboats - Maintain a communication schedule between all the lifeboats and life rafts	**Probab.: 3 Conseq.: C**
4c.2	Lack of communication	- No communication devices in the life rafts - Break down of communication device in lifeboat	-Lack of important information - Some lifeboats or life rafts move away from the rest creating problems in finding that during the rescue	**Probab.: 4 Conseq.: C**	- Include communication devices in the life rafts - Improved communication device in lifeboat - personal communication devices (included in the PSK)	**Probab.: 3 Conseq.: C**
4c.3	Lack of officers and / or doctors in a lifeboat or life raft	- Not enough officers or doctors	- Passengers have no experienced or properly trained personnel to lead them - Lack of doctor in case of emergency	**Probab.: 4 Conseq.: B**	- Reorganizing the people and the equipment (medicines, clothing, etc.) from one lifeboat/ life raft to the other according to the needs - Try to maintain constant communication with a lifeboat that has an experienced officer if there are not enough to cover all lifeboats/ life rafts	**Probab.: 3 Conseq.: B**

Phase five: Rescue						
Hazard code	**Hazard**	**Cause**	**Possible consequences**	**Pre risk reducing measures risk**	**Risk reducing measures**	**Post risk reducing measures risk**
5.1	Transfer of people from lifeboat/ life raft to rescue vessel or helicopter	- Insufficient design of lifeboat to transfer people to another vessel or helicopter (e.g. small hatches – injured people need stretchers, older people need extra help) - Reaction of people (e.g. getting anxious or impatient to be rescued) - Harsh weather conditions	- Injuries and possible losses of human lives -Time consuming process - Falling into the sea (from boat or helicopter)	**Probab.: 4 Conseq.: D**	-Improved lifeboat/ life raft design to accommodate rescuers - Improved lifeboat/ life raft design for easy access with stretchers	**Probab.: 3 Conseq.: D**

After identifying the possible hazards, each one of them was assessed in terms of their probability to occur and the severity of its consequences. The probability was ranked from 1 to 5, which stand for minimal to very high. The consequences where ranked from A (minimal) to E (very high). The assessment of the probability and the consequences in included in the PHA. Based on the assigned probability and level of consequence each hazard was placed in a 5x5 risk matrix to better illustrate its risk. Depending on the placement, it can be in the green, yellow or red area. The colors indicate the different levels of risk. For simplicity, a code is assigned to each hazard. The risk matrix below illustrates the level of risk for each hazard:

Consequence→ Probability↓	**A Minimal**	**B Low**	**C Medium**	**D High**	**E Very high**
5 – Very high	2.2	2.1, 4b.8	4b.3	4a.21, 4b.18	
4 – High	4a.3, 4a.10, 4a.12, 4b.1, 4b.7	2.5, 4a.5, 4a.8, 4a.14, 4b.6, 4b.11, 4c.3	3.6, 4a.15, 4a.19, 4a.22, 4b.5, 4b.12, 4b.17, 4c.1, 4c.2	1.4, 5.1	
3 – Medium	4a.4, 4a.17, 4b.2, 4b.15	1.1, 4a.9, 4a.11, 4b.4, 4b.9	1.2, 2.6, 3.4, 4a.1, 4a.6, 4b.10	1.5, 3.1, 3.2, 4a.18, 4b.16	
2 – Low		4a.7	1.3, 2.3, 3.3, 4a.13	3.5	4a.2, 4a.16, 4b.13
1 – Minimal			4a.20		4b.14

Figure 3: Risk Matrix, pre risk reducing measures

Risk reducing measures were suggested for all the potential hazards. A new level of probability and consequence severity was assigned to each hazard after the implementation of the risk reducing measure. The new risk levels are pictured in the risk matrix in the figure below:

Consequence→ Probability↓	**A Minimal**	**B Low**	**C Medium**	**D High**	**E Very high**
5 – Very high					
4 – High	2.4	3.6, 4b.8			
3 – Medium	2.2, 4a.3, 4a.10, 4a.11, 4b.1, 4b.7	1.4, 2.1, 2.5, 3.4, 4a.5, 4a.8, 4a.14, 4b.3, 4b.5, 4b.11, 4c.3	4a.19, 4a.22, 4b.17, 4c.1, 4c.2	5.1	
2 – Low	4a.4, 4a.17, 4b.2, 4b.15	1.1, 1.3, 2.3, 3.3, 4a.1, 4a.6, 4a.9, 4b.4, 4b.6, 4b.9	2.6, 4a.2, 4a.15, 4a.18, 4b.10, 4b.12, 4b.16	4a.21, 4b.18	
1 – Minimal	4a.12	4a.7, 4a.20	1.2, 4a.13	1.5, 3.1, 3.2, 3.5, 4a.16, 4b.13, 4b.14	

Figure 4: Risk Matrix, post risk reducing measures

SAREX 2 LIFEBOAT TESTS

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SAREX 2 "Lifeboat tests"

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CONTENTS

1. BACKGROUND, PURPOSE AND SCOPE

1.1 Background

Norsafe, was contacted in November 2016 to participate in the SAREX2 expedition which was organized to follow up the findings made in SAREX1 that was executed May 2106. Together with NMA a scope was set up and a request was send to Norsafe with a "lifeboat function wish list". January 2017 the SAREX2 program was released. Besides survival simulations inside the lifeboat, the program also included evacuation exercises in ice infested waters on the north side of Svalbard in May 2017.

1.2 Purpose

The purpose of Norsafe's participation is to evaluate a lifeboat which has modified design basis and is adapted with solutions based on lessons learned from SAREX1. The solutions reflect the newly introduced requirements in IMO POLAR CODE which is an amendment to existing IMO instruments.

From a lifeboat's perspective the following polar code elements are focused upon in this evaluation and report:

8.2.3 – Survival, thermal protection

8.2.3.2 – LSA equipment shall take account of the potential of operation in long periods of darkness.

8.2.3.3 – Survival support following abandoning the ship to either water, ice or land for the maximum expected time of rescue (minimum 5 days). LSA resources shall provide:

- a habitable environment
- Protection from effects of cold, wind and sun.
- Accommodation space for persons incl. thermal equipment.

1.3 Scope

The goal of the Polar Code is to increase the safety of ships' operation by mitigating the impact on the people and environment in these remote and harsh conditions. RISK mitigation can only be evaluated by understanding the risks involved in such operations. These tests and exercises are specifically designed and organized to create proper understanding and risk identification and awareness.

As the polar code is a RISK based guideline, a RISK assessment was used as input for the trials and summarized after the exercise as a handbook for future product and evacuation procedure evaluations. This report is a combination of Norsafe's individual findings during the exercise with focus on technical elements in the lifeboat combined with possible solutions to mitigate RISK's that are summarized in the RISK analysis.

2. LIFEBOAT DESCRIPTION

2.1 General

During previous winterization projects Norsafe has gained a strong basis with understanding the implications of using LSA equipment in cold conditions. Prior to SAREX-1 Norsafe was aware of the limitations of a standard (SOLAS design basis), however by using such a product in these initial tests, valuable data and experience was gained.

Norsafe and NMA agreed that the most interesting approach for SAREX-2 would be to modify the standard SOLAS (SAREX-1) lifeboat with technical adaptions in order to mitigate the findings from SAREX-1. A selection was made based on available resources and a modified lifeboat was shipped to Spitsbergen in April 2017.

During SAREX1 the below issues were identified:

- Low temperature when engine was not running
- Bad air quality when engine was not running
- High air humidity resulted in condensation and ice building up on cold surfaces and poor visibility.

Description of the SAREX 1: Standard SOLAS design basis conventional (davit launched) lifeboat:

This lifeboat type, called Miriam 8,5 is an 8,5-meter 55 persons lifeboat.

This specific lifeboat was available from stock, it is a 2013 model boat, which was originally delivered with serial number 16849. External GA can be seen in figure 1, Internal GA in figure 2.

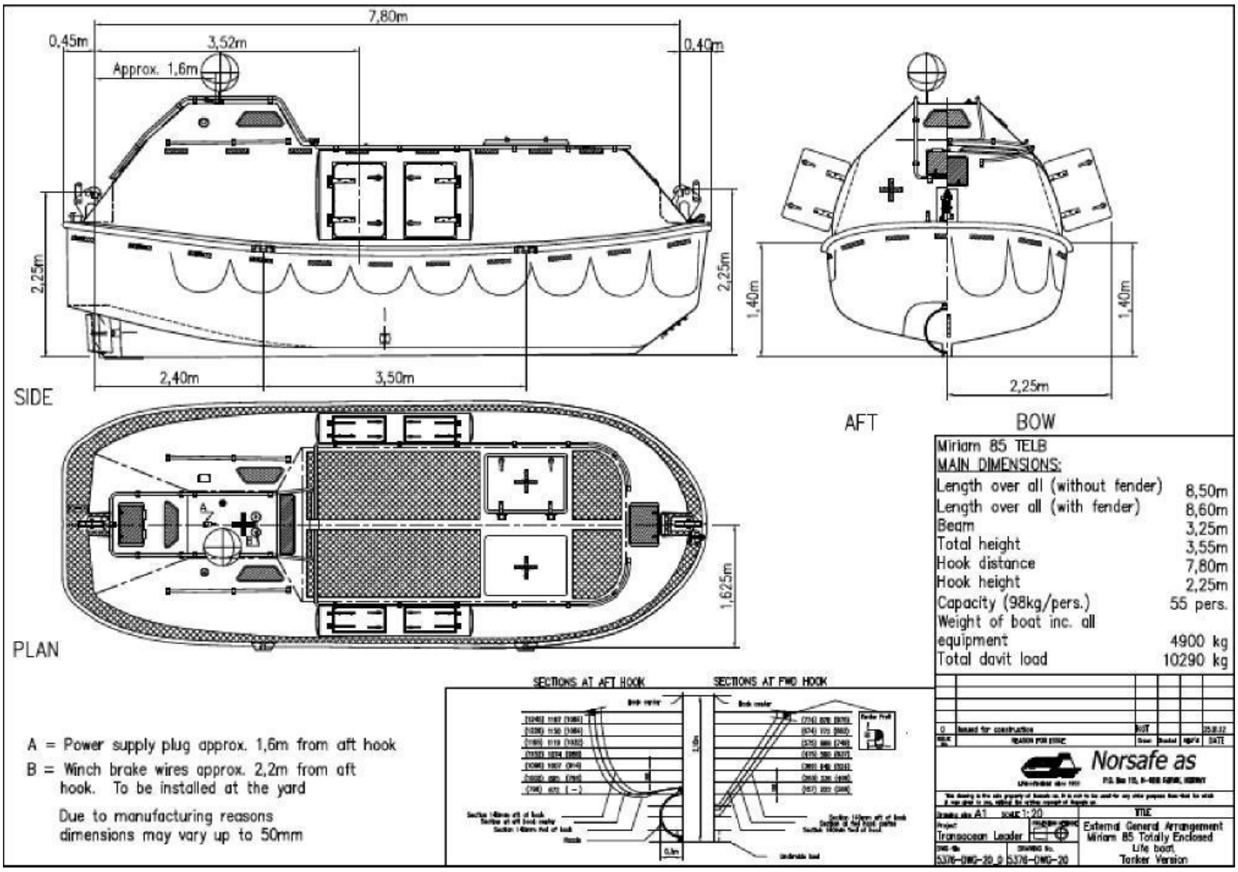


Figure 1: External general arrangement of the Miriam 8,5 with serial number 16849.

2.2 Standard Lifeboat (as used in SAREX 1)

- Miriam 8,5 is a type of lifeboat (totally enclosed) that is mainly used on merchant vessels. Norsafe believes this boat type are in favor of partly enclosed lifeboats which are typically used on ferries and passenger vessels, when evaluating polar code solutions. The main differences between these boat types when compared are:
  - Boat is totally enclosed and gives a better habitational environment.
  - Boat is equipped with a backrest and a safety harness for all PAX.
  - Boats are built to be self-righting and can therefore be operated in a very harsh environment and in extreme weather conditions.
- 4 large hatches (2 on either side) make for easy access when water borne, as well as safe operations during the exercise.
- The sprinkler system fitted on the lifeboat makes it possible to operate the lifeboat during 10 minutes through fire or toxic gasses. The lifeboat can be defines as a habitat and has compressed air available sufficed for its personnel and engine. It is also proven

that the sprinkler system can be used as a deicing system as long as the water is >+2 degrees.

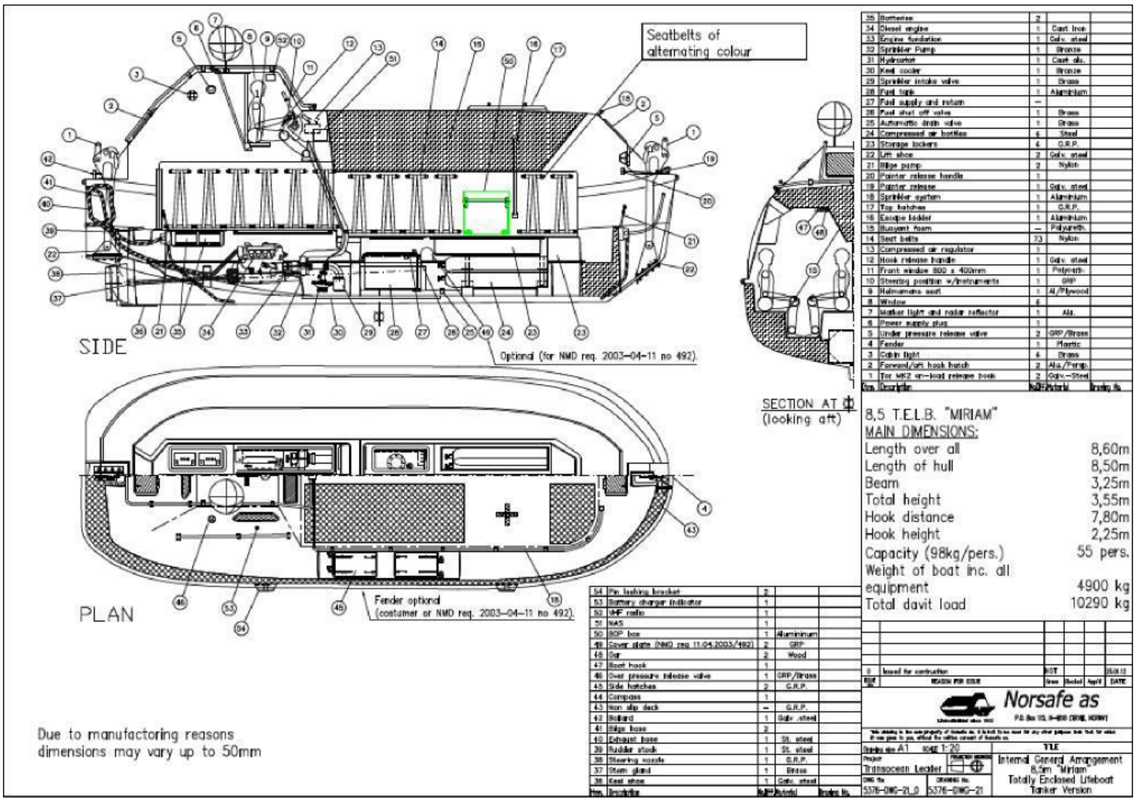


Figure 2: Internal general arrangement of the Miriam 8,5 with serial number 16849. Total boat weight incl. standard SOLAS equipment and fuel = 4900 kg. Adding 55 x 98 kg personnel makes the total weight = 10290 kg

2.3 The following modifications are made to prepare this boat for SAREX-2

2.3.1 Heating system

- Standby heating system 400 W (0,55 Liter diesel/hrs @max speed)
- Heating system consisting of Ebersprächer heater (4 kW) and heat exchanger
- Fuel tank (Diesel) for heating system (53 liter capacity)
- Electrical cabin heater (1200 W) - standby
- Engine heater - standby

2.3.2 Ventilation system

- Two separate fans
- Adjustable from 400 m^3/h to Zero (16 m^3 per person per hour)
- Volume of lifeboat is 30 m^3 (volume of 24 people is 2.16 m^3 – gives a total exchange rate of 14,3 exchanges per hour)
- Cold air is sucked in from the cockpit roof and transported via a duct down to the heat exchanger. After heating the warm air is distributed to the flooring of the craft (4 outlets)
- When internal temperature allows, cold air is sucked from the Stern of the lifeboat and distributed without preheating to the lifeboat cabin.
- The combination of the two fans give a balanced ventilation and heating system, with the task to maintain air freshness and temperature setting.
- Separate consumption battery for electric system (12.8 V lithium ion phosphate 90 Ah)

  - Primarily for ventilation system
  - Special generator fitted to engine with upgraded capacity (90 A)
  - Special charger electronics for power management
  - Temperature control system for battery

2.3.3 Other:

- Insulated seats (26)
  - Based on best existing back rest positions
- Toilet (compact carry-on design)
  - Toilet curtain for privacy
- Sleeping bench (capacity 3 persons including sleeping bags and sleeping mats)
- Activity pack
  - Cards, games, books, reading material
- LED-lighting inside craft
- Reinforcements to hull and keel.
- Protections for ice to nozzle, cooling lines etc.
- Protections for ice buildup on critical openings such as bilge relief valves in bulk heads etc.

2.4 Changes not made due to limited resources:

- HVAC to engine room
- Solution for removing air humidity
- Isolation on single skin surfaces
- Improved First aid kit
- Protection nozzle/rudder/propel
- Cockpit window de-icing
- Ice removal from canopy
- More than 3 sleeping places

3. AIR QUALITY AND VENTILATION TEST

3.1 Normal "pulse" test

3.1.1 How was the test done

Test date 02.05.2017.

1. The Lifeboat was stored on the aft deck of KV Svalbard,
2. Standby heating was disconnected,
3. Hatches where closed except the 2 side hatches,
4. Lifeboat was embarked by 49 persons,
5. Hatches where closed,
6. After 45 min. ventilation was started
7. After 63 min. test aborted.

3.2 High "pulse" test

3.2.1 How was the test done

Test date 02.05.2017.

1. Lifeboat was ventilated with all hatches open (after first test 3.1.1),
2. Hatches where closed except the 2 side hatches,
3. All participants did physical exercise so they increased heartbeat,
4. Lifeboat was embarked by 49 persons,

5. Hatches where closed,
6. All participants where exercising in the lifeboat each 5 min. during 1 min.,
7. After 30 min. ventilation was started,
8. After 61 min. test aborted.

3.3 Summary of the 2 air quality and ventilation tests

During the test CO_2 and O_2, temperature and humidity was measured, monitored and recorded. Results can be found in Table 1 and diagram 1 to 3. See specific appendix for CO_2/O_2 levels.

CO_2 is increasing rapidly during embarkation and reach level around 5200-5700ppm before the hatches are closed. There are no specific acceptance criteria for the level of CO_2 on which ventilation shall be started and/or tests should be aborted. Therefore it shall be discussed what is acceptable. During the tests it can be reported that, when the ventilation system was started the CO_2 levels improved rapidly.

During the test 2 (high pulse) CO_2 levels where much higher in a shorter time frame.

Table 1. Test 1 Embarkation of 55 persons to lifeboat with 49 persons with normal pulse

Test 1 Embarkation of 55 persons to lifeboat with 49 persons with normal pulse			
Time in Min.	**CO_2 level in ppm**	**Comments**	**Temp. in ^0C**
0	700	Boat prepared for embarkation	+5
13	5.200	At this point hatches where closed	
25	10.000		
33	15.000		
42	20.000		
45	22.800	Ventilation started	+17
63	13400	Abort the test	
Test 2 Embarkation 55 persons to lifeboat with 49 persons with high pulse			
Time in Min.	**CO_2 level in ppm**	**Comments**	**Temp. in ^0C**
0	700	Boat prepared for embarkation	+13
5	5.700	At this point hatches where closed	
8	10.000		
12	15.000		
15	20.000		
19	25.000		
24	30.000		
30	39.500	Start ventilation	+21
61	12.400	Abort the test	

4. SURVIVAL TEST

4.1 How was the test done

Test date 03.05.2017 kl.14.00 to 04.05.2017 kl.20.00

1. Lifeboat was standing on deck of KV Svalbard with standby heating connected.
2. Lifeboat was inspected prepared for launching

3. Lifeboat was lifted to the sea
4. Lifeboat was embarked by 24 persons which were transported to the lifeboat by the rescue boat. (kl.14.00)
5. Hatches where closed and boat was operated
6. Raft was attached behind the lifeboat
7. The lifeboat was connected to the stern of KV Svalbard after a view hours operation. Raft was still connected to the lifeboat.
8. Lifeboat engine was started 01.00 to 02.15 AM to charge the consumption battery.
9. Several exercises where executed after 09.00 AM.
10. At kl.20.00 Test was abort.

4.2 Results of the inspection before launching the lifeboat to the sea.

a) Status at 03.05.2017 Kl.12.00
b) Inside temperature 4°C and Humidity 75%.
c) Level engine diesel tank on 3cm from the top
d) Level heater diesel tank on 5 cm from the top
e) Consumption battery 100%

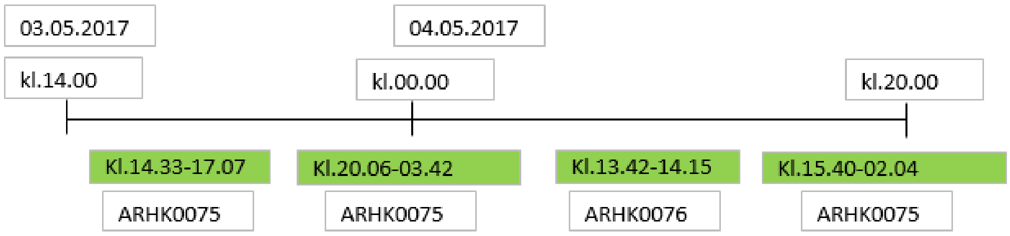
4.3 Results of the inspection after the 30 hours survival test:

a) Status at 04.05.2017 Kl.22.00
b) Level engine diesel tank on 6,5cm from the top
    i. Engine has been running 14,8 hours. (9,8 hours during the survival test)
    ii. 4,8L/cm => 6,5-3) x 4,8= 16,8 liters used which gives a consumption of 1,1 L/hour. Total capacity is 160/1,1= 145 hours or 6 days. > 5 days as required. It should be noted the engine has not been running max RPM. The figure gives only an indication it is possible to operate the boat 6 days in the same way as was done during the test.
c) Level heater diesel tank on 10 cm from the top
    i. Heating system has been running on max 35 hours (30 hours during the survival test)
    ii. 2L/cm => (10-5)x2= 10 liters used which gives a consumption of 0,3 L/hour. Total capacity is 50L/0,3 = 166 hours or 6,9 days. > 5 days as required.
d) Consumption battery 100%

4.4 Air quality during 30 hours survival test:

CO_2, O_2 and NO_2 were measured during the test. In addition, we have monitored the temperature, humidity and wind speed.

Measuring was done with 2 devices (ARHK0075 and ARHK0076) and a total of 4 logs are documenting the results.
See separate files for the original logs for CO_2, O_2 and NO_2.
CO_2 levels have been under 5000ppm with some short peak periods up to 6000 and 7000ppm.
30 hour survival test CO_2 and O_2 document by below log files.
Lifeboat engine has been running at below time intervals.



03.05.2017

Running from kl.14.30 to kl.15.00

Running from kl.15.40 to kl.16.15

04.05.2017

Running from kl.01.00 to kl.02.15

Running from kl.09.20 to kl.10.00

Running from kl.10.10 to kl.10.30

Running from kl.12.30 to kl.13.00

Running from kl.14.10 to kl.16.00

Running from kl.17.00 to kl.21.00

Diagram 1 (Air quality and ventilation test)

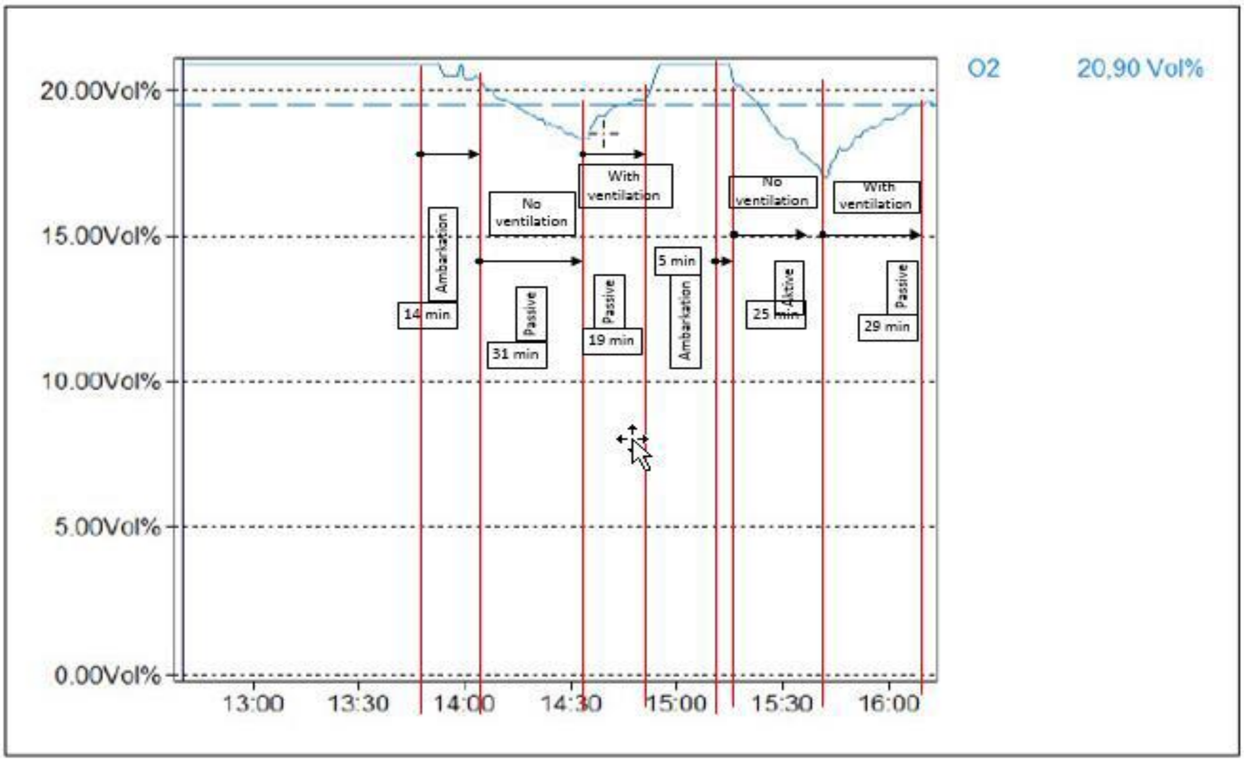


Diagram 2 (Air quality and ventilation test)

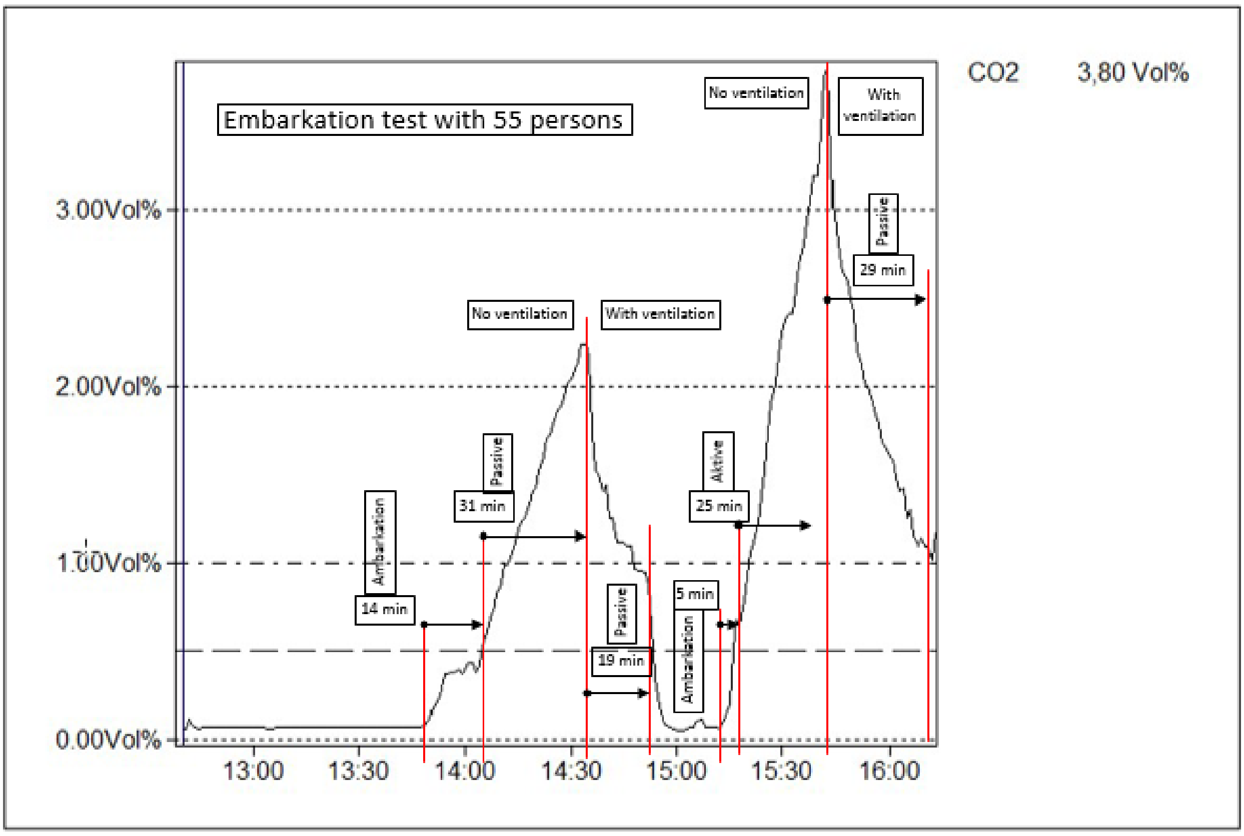


Diagram 3 (Temperature, Humidity and Wind speed log during the total exercise)

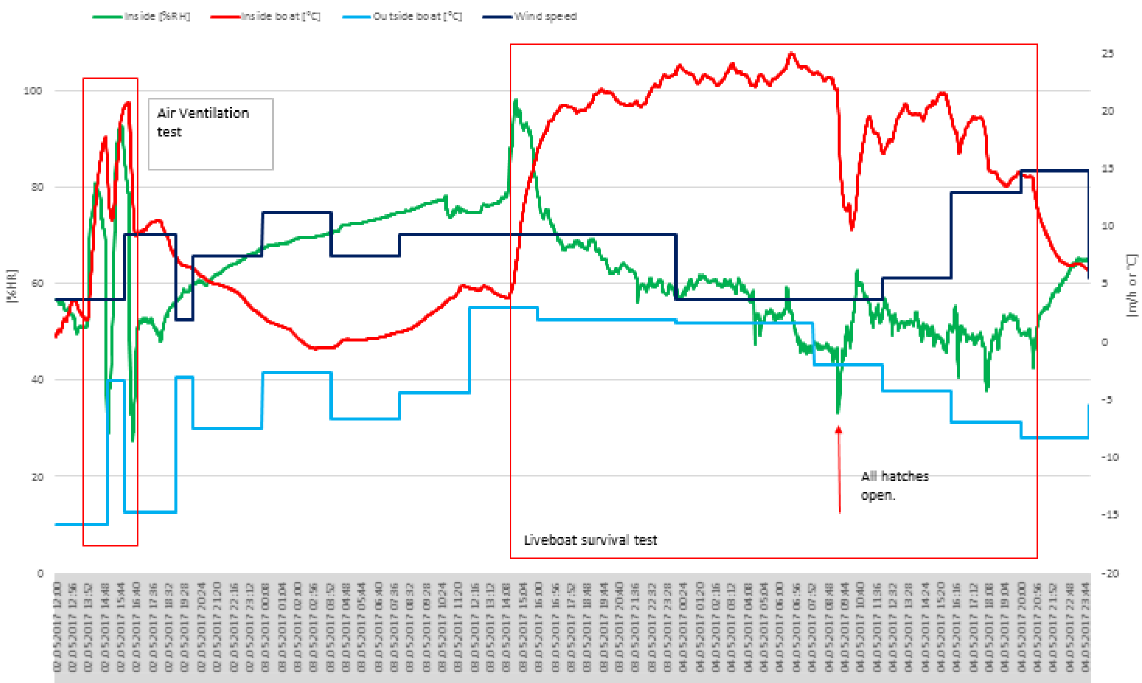


Diagram 4 (30 Hours survival test)

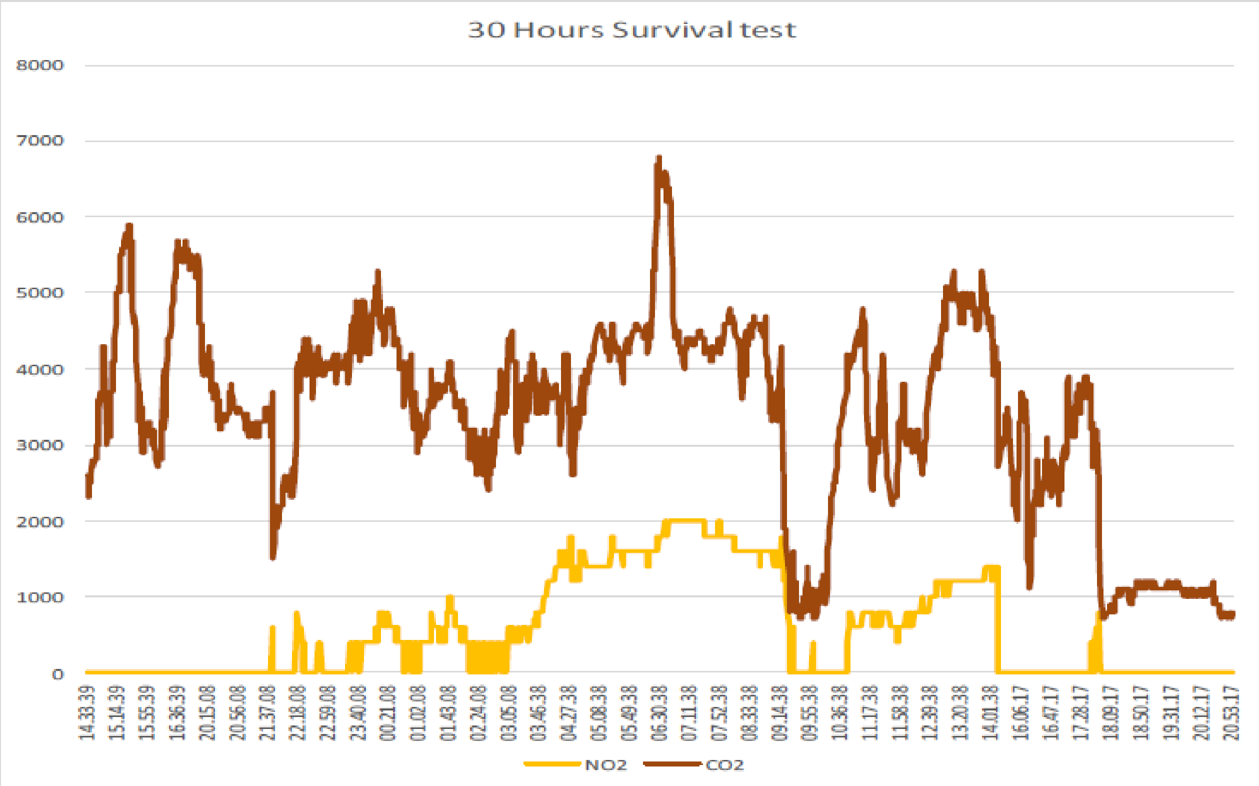


Diagram 5 (30 Hours survival test)

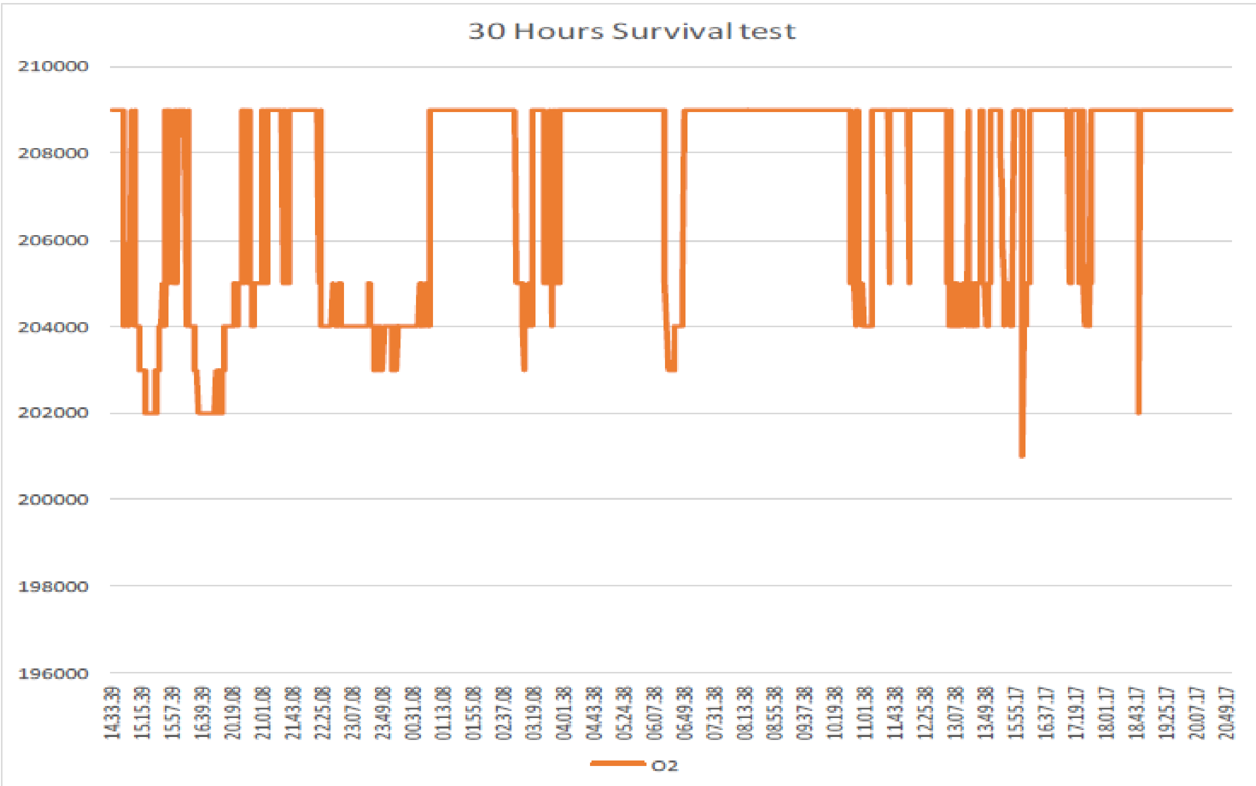
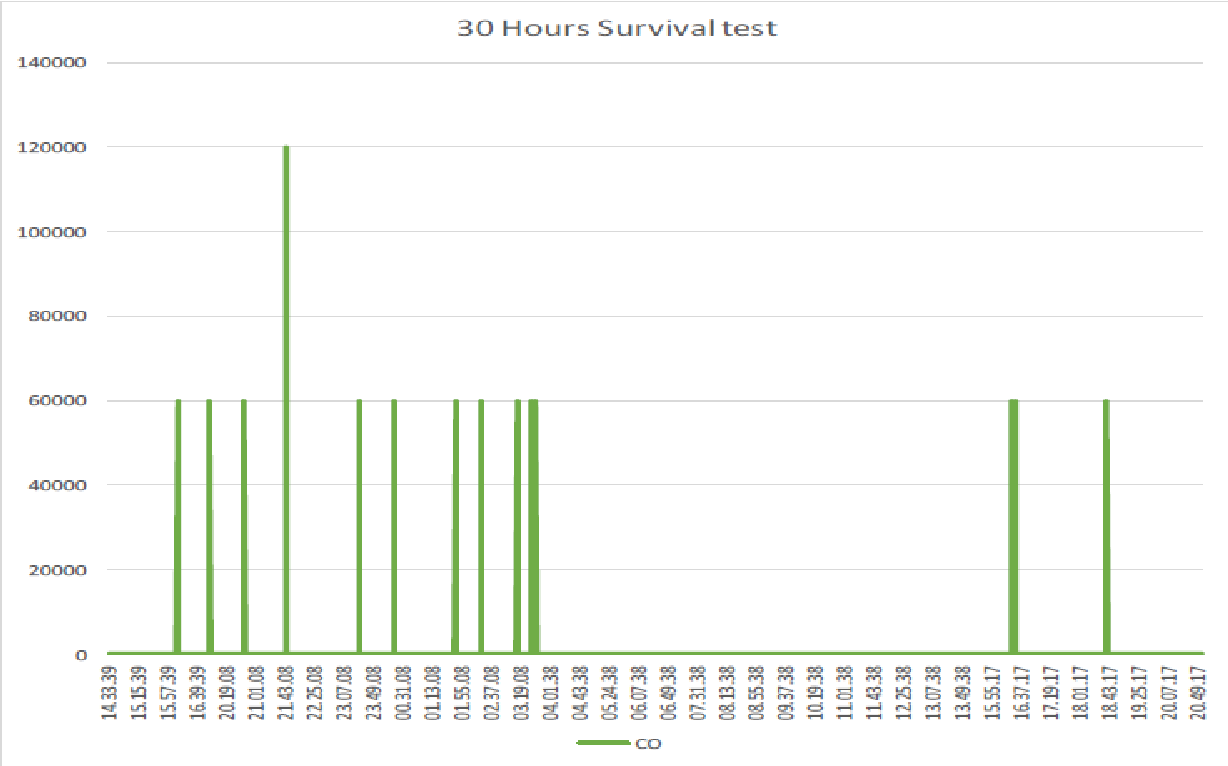


Diagram 6 (30 hours survival test)



5. OVERALL CONCLUSION

The overall reason of the lifeboat survival test at SARex 2 was to document if it was possible to survive 5 days while evacuated in the different means of equipment. For the lifeboat and based on the medical conditions of the persons inside the it should be concluded the test was successful, when we agree that the first 30 hours are representative for a full survival period. Nobody aborted during the test due to medical criteria. When compared to SAREX 1, the design changes are successful and have made it more likely that survival will be successful for all passengers.

As the amount of medical data and available tests are significant, both from these and other tests, results need to be analyzed. This might give valuable information which again could result in future design changes and requirements for the lifeboat design.

Norsafe had 2 persons inside the lifeboat. Based on their experience and findings, the following areas of focus and concern remains:

- **How much space per person or group of persons need to be seen as minimum?**

There are no requirements related to space, the term” sufficient” does not give enough guidance to those specifying type/size lifeboat which should be ordered for a specific vessel or installation.

Due to the fact the size of lifeboat directly connected to the cost and other installation limitations of the lifeboat and its launching arrangement it is not easy to convince owners/purchasers to order a lifeboat with a large capacity. Any capacity increase over 5% is in reality difficult. However, based on how Norsafe has experience the tests this should be between 30 and 50% depending on the length of the potential expedition/remoteness.

Norsafe has been using 30% over-capacity as recommendation during sales, but after the SARex 2 this has been increased to 45%. Norsafe has informed NMA regarding this.

Experience from SARex 2;
The 55 persons lifeboat with only tested with 24 persons. We concluded space was not used optimal. However, we also considered that 30% reduction might be too low. 70% of 55 persons= 38 persons, in case of 38 persons space will be limited to move and not enough to create sleeping places. A 3 hours sleep each 24 hours should be a minimum. For the boat tested a more realistic figure will be max. of 30 persons with gives a capacity reduction of (55-30) / 55= 45%.

NMA has forwarded below;
"When the lifeboat is loaded to its maximum capacity of persons and equipment, all persons (average adult person) regardless of where they are seated, shall be able to stand up and move to a place on board where there is ample space to stretch/do knee bending or similar, put on/take off their TPA/Survival suits. Everybody should also be able to reach the toilet. It is accepted that others needs to stand up or move to give way for the person who is moving."

6. RECOMMENDATIONS

The SARex 2 survival test was evaluated directly after the test. An internal report is available. Norsafe has added several other improvements during the last 2 months based on customer specific requirements, concerns and request for answers.

Table 2: Green marked boxes shall be solved in a polar code lifeboat amendment, yellow marked should be included.

Concern	Effect	Cause	Improvement Suggestions	Regulatory Implications	Comments
Discomfort due to sitting position	Pain (back, bottom), reduced blood circulation, headache, irritability, cold extremities	Poor seating design, extended period in same sitting position	Possibility to stretch and move, handles to hold onto above seating area. Change seating position with other passengers at certain intervals. More ergonomic design for seats (inclination angle for back rest) Enough sleeping places are needed. 3-4h per day as a minimum. Sleeping will take the load of the back.	Possibly amended performance standards, allocate more space per person	Regulations do not prohibit improved solutions or design variations

Not enough space	Difficult to move	Limits space, not affective use of the available space, not enough storage space for personal items	We estimate approx. 30% reduced capacity, but this will need to look in to large reduction in combination with effective use of space. Specially arranging for sleeping and storage of personnel equipment.		Personnel equipment like, food/water PSK.
Heat when dressed in survival suit	Sweating and associated condensation	High temperature in lifeboat	Temperature management	Operation management and training procedures	See concern: Insufficient space
Condensation	Poor visibility through windows (navigational issues). Discomfort	No insulation between cold outside air and warm inside air. Lack of condensation management system (collection etc.). Warm temperature leading to increased sweating.	Possibility to utilize heat from heat-exchanger to defrost window (valves from heated fan onto window). Insulate windows and top of boat. Improved condensation management and possibility to collect condensation (can be used for drinking water). Hatch on roof of vessel for improved ventilation and navigational purposes. Optimize design to reduce condensation.	Possibly amended performance/test standards and operational procedures and training.	
Insufficient ventilation system	Condensation from ceiling, dripping on to passengers	Warm humid air condenses on cold surfaces. Poor air circulation (uneven).	Improved ventilation design.	Note: ongoing discussion in IMO	Number and location of vents. Air quality.
Visibility from cockpit	Poor visibility leading to navigational issues.	Condensation inside. Icing on outside of windows.	Anti-icing and angular windows. Improved ventilation system. Insulated windows and walls. Heated windows. Hatch in roof of cockpit.	Possibly amended performance standards for visibility standards (LSA code)	Possibility to stand when navigating craft

Navigation	Running aground, collision with KV Svalbard. Difficulty in optimizing heading to minimize movement	Lack of navigational information	Hydrographic, weather and ice information	Possibly new carriage requirements	Charts, chart plotter, VHF-AIS
Internal communication	Difficulty distributing information	Noisy environment, poor visibility from operating station	Speaker, whistle, megaphone (pending size of lifeboat)	Possibly new carriage requirements	
Insufficient space	Uncomfortable, messy, difficulty moving	Disorganized, survival suits take up space, individuals sleeping in aisles.	Vessel capacity should adhere to ergonomic needs. Improved management. Storage for personal belongings (food, water and survival suit).	Procedures and functional space requirements.	In cold climate conditions it is even more important to ensure that passengers have the necessary polar equipment and enough space to move about in order to maintain circulation. Organization and marking of individual seating area could be beneficial.
Sea-sickness	Dizziness, apathy, vomiting, cognitive impairment, reduced positivity.	Excessive vessel motions (especially roll). Reduced visibility.	Vessel design (bilge keels), possibility to see outside vessel	Increased sea-sickness pill rations to adhere to Polar Code requirements (minimum 5 day rations)	Important to provide sea-sickness pills ASAP
Injuries	Need for first aid.	Excessive vessel motions (especially roll).	Vessel design (bilge keels), handles and rails. Harnesses/seat belts. Possible additional first-aid equipment.	Possible new add-on to existing regulations	
Use of pyrotechnics	Injuries	Use of flares etc. for signaling purposes	Need for PPE in the pyrotechnical container (gloves and glasses)		There were two incidents with burns (1 first degree, 1 second degree)

External communication	Detection during search.	Not possible to detect vessel during SAR operations	AIS-transponder, brackets for transponder on roof for increased range.	Possible new add-on to existing regulations	
Insufficient or obsolete loose equipment	Unable to dry wet areas. House-keeping onboard. Snow blindness		Include sponges, trash bags, sea-sickness bags, paper towels. Review existing list of required loose equipment. Include sunglasses (polarized) for crew for watch-keeping purposes, bad quality/ damaged fish line, broken oar, Medical kid including products which chines texts, translation paper included. No de-icing equipment		Sunglasses may already be in PSK
Insufficient maneuvering during towing	Problematic keeping and changing course when towing life raft.	Small distance between rudder axis and towing point	External towing guide		
Diesel fuel filter clogging	Diesel engine or heater stopping	Due to diesel fuel not made for cold climate	Require winterized fuel and/or heating of lifeboat at all times in storage position		
Operational management	If effective management does not exist, this will result in reduced positivity, physical health, house-keeping. In this case there may also be an inability to handle unexpected situations should they occur.	Inadequate training and instructions. Inefficient communication.	Increased training with emphasis on the importance of effective management in cold climate operations (Passengers may not be aware of relevant needs for survival)		Make sure passengers communicate personal condition, consume necessary rations and move to maintain circulation. The management should also Maintain morale.

Fire	Loss of propulsion, heater. Smoke in vessel. Need to abandon vessel.	Engine fire, electrical fire etc.	Reduce consequence by installing fire extinguisher connected directly to engine compartment		
Allergies food/water	People on boat getting sick or dying	Trace of Nuts in the food	Supply food without nuts	Add change to regulations.	
Unsecured area for helicopter pickup	Falling from roof of lifeboat in to the water	No supports or rails on roof	Add supports/rails		
No sufficient flow of warm air	Boat will not be able to be warmed up	Valves can be blocked due to immersion suits are stored on the floor.	Increase warm air higher from the floor		Valves can be closed. Closing arrangement was broken due to personnel stand on it.
Toilet not used and insufficient capacities	Some people will not use toilet due to privacy issue.	Toilet is placed in same area as all other survives are placed.	Install toilet in own room.		
Cold Air intake in front of the lifeboat	Personnel located in the front of the lifeboat exposed by cold air.	Direct cold air from outside is blown in to the lifeboat	Why do we need this cold are inlet? It should be possible to use same ventilation as the heated air. (We need to control air temperature coming out of the heater. In addition, we need to consider to increase amount of air. 20M3/hrs or more.		
Ice on the cockpit windows	No visibility	One 400kw standby heater is insufficient	1600 kw is presumably needed for this boat to keep the temperature over zero.		If HVAC is installed and working standby heating is second mitigation
Condense water	Personnel and equipment can get wet.	Condense water is collected at the lowest point an	Isolate single laminate for a reduce condensation. Dry outside air used for heating. Consider lowest points and take care water can be removed easily.		
Rader reflector not possible to mount in support	Not possible to install radar reflector	Ice blocking the mounting bracket	Check design to pin in outside not pipe.		

SARREX 2017: USE OF VIKING LIFE-SAVING EQUIPMENT IN POLAR REGIONS

Jørgen Dyrholm and Andreas Tolstrup Laursen, Viking Life, Denmark

Objective

The expedition shall demonstrate how it is possible to survive 5 days in a life raft as required in Resolution MSC 385(94), the Polar Code.

General findings

The expedition demonstrated that it is possible to survive for 5 days. It is important that correct decisions with the aim to cope with the expected environment are made by the vessel operators during planning of the voyage. Decisions related to staying warm and dry can have an impact on both the life raft, the protective suits and any additional life-saving equipment used. The means are already available on the market and certified by existing rules for survival equipment. The expedition demonstrated that by choosing the correct equipment as immersion suits, life rafts are still relevant as part of the survival equipment portfolio in Polar areas.

Data for equipment supplied by VIKING

Life raft used for test:

- 25 DKSN, 25 persons self-righting life raft with inflatable floor
- Serial no.: 12121911
- In addition to standard equipment, extra-long paddles and USCG approved TPAs were included
- 19 persons participated in the test

Additional equipment:

- 12 x VIKING PS5002 standard immersion suits
- 2 x VIKING PS5002 immersion suits with extra insulation at the lumbar area
- 2 x VIKING PS5002 immersion suits with extra insulation at the lumbar area and outer fabric made in GORE-TEX™
- 4 X Viking PS4170 Anti-exposure, work and immersion suits in GORE-TEX™ fabric
- Dräger X-am 5600 CO_2 and O_2 alarm
- 20 DKF, 20-person davit launched life raft
- 6 x Asivik self-inflatable sitting mates

Favorable observations during the test

Water and air temperature was at the beginning of the test above 0°C. The temperature inside the life raft was around 15°C. Participants was successive taken out of the test after 23 hours, so the number of people inside the life raft decreased. The outside temperature also dropped and wind increased. Still the inside temperature was steady at the same value, probably due to less need for ventilation as fewer people creates less CO_2.

The heat loss through the bottom of the life raft was the main source of heat loss in the life raft.

Another source to cooling was the ventilation of the life raft. To keep ventilation to a minimum, the oxygen and carbon dioxide levels were monitored. The ventilation was increased when the oxygen level got below 19% or when the carbon dioxide level climbed above 0,5%. At 1 %, the CO_2 alarm could not turn off. Using this type of alarm, it is possible to maintain the highest possible temperature level inside the life raft, by the least ventilating as required.

During the stay, most participants had to open their protective suits as they were too warm to wear. Due to the ventilation in the open suits, most participants were dry inside their suit when they returned to the KV Svalbard.

Since the life raft was of the self-righting type, there was sufficient space inside to change position, sit on the upper tubes, stretch one's legs and stand up. For a 5 day stay, moving around and changing position is important for maintaining blood circulation.

All participants were aware that this was a drill, and not a question of life and death. Therefore, nobody panicked or lost control. Still everyone got excited and experienced some heat stress during the first hour. Everyone found it nice to receive the drinking rations on the first day, rather than after 24 hours as recommended in the life raft instructions.

Participants who were on board the life raft during SARex 1 confirmed that the inflatable floor was an improvement compared to the closed cell insulated floor used last year.

The intended leaks made between the canopy and upper buoyancy tube was efficient in draining the moisture impact on the canopy.

- Unfavorable observations during the test

The life raft took in water. This was not intended, and the specific areas have been investigated and have been solved for future tests.

The water collector was placed in same side as the crowfoot, which caused seawater seeped in through the water collector during towing.

Female and male test participants were transported to the KV Svalbard for visits to the toilet when needed. The last trip in the MOB boat took about ½ hour in heavy wind. Several participants were cooled due to the stay in the MOB boat and then returned to KV Svalbard. To avoid cooling one of the participants urinated in the "anti-vacuum tubes" in the life raft which seemed to be an acceptable solution.

During the test, the medics returned small groups of participants several times to the KV Svalbard. This ventilated the life raft more than intended, and lowered the temperature unnecessarily inside the life raft.

The Helly Hansen suit had gloves that are integrated into the suit. When the person had to operate e.g. water bags, food rations etc. the suit on the arm had to be removed. It was an advantage for the rest of the persons that the gloves where not attached to the suit.

With 15 participants left in the life raft, the pyrotechnic appliance was fired. The process took about ½ an hour, and during the firing, the door was fully open and the temperature decreased significantly. In a real survival situation, the door would/should not be fully open.

- Suggested improvements from participants

Specific recommendations related to life rafts used in accordance with Resolution MSC 385(94), the Polar Code

During a 5 day stay it is important to have the possibility to exercise. Due to the shape of the canopy the self-righting life rafts provide the possibility to stand up and move around. On self-righting life rafts, the upper side of the buoyancy modules can be used as extra accommodation/seating area.

A standard life raft should be downgraded about 20% in terms of capacity to have space for personal survival equipment, and for exercising.

Self-righting technology is recommended ease entering in the life raft, hence reducing the time staying in the water.

The use of an inflatable floor or similar is recommended.

The use of seating mats or similar is recommended. Seating mats could be a part of the personal survival kit. The participants using the seating mats were satisfied with their performance. Seating mats should be supplied for everyone.

It is recommended that TPA with heat reflective inside is applied.

CO_2 or O_2 alarms system to keep ventilation to a minimum can be added as extra equipment e.g. together with the on-scene communication.

An improved safety briefing on the ship before starting a voyage in Polar Regions is recommended. A lack of instructions might cause greater risk.

Water as per existing ration for 3 days should be increased to 5 days. Food as per existing ration for 4 days should be increased to 5 days. Extra rations can be part of the Personal Survival Kit (PSK). There is already food and water in Vikings PSK, and therefore solving this.

Observations relating to operate in cold conditions:

Consider protecting the zipper for icing, which might complicate closing the door.

It was difficult for the towing boat to catch the crowfoot. Consider a crowfoot in every corner which would make it possible to catch one no matter how the life raft turn to the wind. The crowfoot can also be used as guy line, if the life raft is used as a tent on the ice.

Consider handles on arc tubes make it safer to move around and to stand or sit in the door openings. The possibility to move around and stretch one's legs is important, especially for a prolonged stay.

The hand pump can build up pressure to boost the inflatable floor. Over-pressure valves should be considered.

Joint points in the inflatable floor are not insulated. Joining points are single-layer fabric and here, the evacuees are sitting closer to the cold water. Even though the floor is placed between the buoyancy tubes, it is still below water level.

Two viewing ports is preferred since viewing in the other direction must otherwise take place through the open door.

The viewing port was difficult to close with gloves. A different system that can be operated with gloves should be considered.

The inner and outer canopy sticks together due to condensed water. Something to maintain distance is needed.

The zipper is difficult to operate at high wind velocities. Improved closing facilities to be considered.

General observations:

Consider removing the "24-hour rule" before using the food rations from the immediate precautions manual. 8 hours after embarkation first ration was distributed and then each 8 hour. Due to the early intake of food the participants fell less hunger when evacuated. The medics monitoring the participants during the test was not able to explain the 24-hour rule.

Consider toilet facilities inside the life raft using the anti-vacuum tubes or similar.

Many appliances such as pyrotechnics, first aid kit, torch, on-scene communication etc. are laying around on the floor. A mesh or pockets in the arc tube should be considered.

Consider replacing viewing port by a window. Unfortunately, plastic windows do not have the same level of strength as the canopy fabric and two layers of material is required.

Consider improving instructions as the small letters in the instruction “immediate precautions” are difficult to read. Some people are not able to read the instructions without glasses.

The sponge was not able to last for 5 days with the amount of water penetrating the drain tunnels in the life raft. However, a solution to eliminate the water entering the life raft has been found.

The canopy catches a significant amount of condensed water due to humidity. The water can be collected like in the rainwater collector. Some of the participants believed that the rain water collector was in fact meant to collect condensed water.

Consider improving the opening in order to reduce the water (rain) entering the life rafts.

Findings and suggestions for improvements are rated in a FMEA scheme and enclosed in appendix 1.

- Personal Protective Equipment (PPE)

During the test inside the life raft and lifeboat, several suits were used. The suits were distributed between the life raft and the lifeboat, this was done so that the data could be compared afterwards.

Immersion suits are dependent on their insulation approved for one or six hours submerged in water. During this time, a person should be able to stay in the suit submersed in water, without losing more than 2°C of body temperature.

Data regarding which suits where in the lifeboat and the life raft respectively, enclosed in appendix 2.

PPE IN THE LIFEBOAT

In the lifeboat, the indoor climate was set by heaters to 20°C. Therefore, the participants removed their suits after a short while. The suits used in the lifeboat were sorted and therefore, data about survival in the lifeboat related to PPE cannot be used.

PPE IN THE LIFE RAFT

In the life raft 6 different suits were used.

- 1 x Helly Hansen protective suit was used on both SARex1 and SARex2 by the same person. It is a non-insulated type (1-hour insulation). The suit has also been used for several demonstrations on board the ship. At SARex1, this suit was on the life raft for 17 hours, at SARex2 the suit stayed on for 23 hours.

- 10 x VIKING PS5002 immersion suits, which is the top-of-the-line suits from VIKING. Datasheet appendix 3. The insulation of the PS5002 is twice of standard insulated immersion suits, approved for 6 hours in cold water. The persons wearing these suits were taken out between 23 to 30 hours.
- 4 x of older VIKING PS4062 suits. This type of suit is utilized by the Norwegian Navy and Coast Guard, and is used with standard uniform / stipulated clothing. They are made with a minimum insulation layer, and approved for 1 hour in cold water.
- 2 x VIKING PS4170 a combined anti-exposure, work and immersion suit approved for 6 hours in water. Datasheet appendix 4. Both suits were in the life raft at the end of the exercise.
- 1 x of a special test edition of the VIKING PS5002 referred to as TEST 1. With an offset in the experience gained during SARex1, this suit was reinforced with extra protection in the lumbar area and made from GORE-TEX™ material. The reason being that cooling and humidity was the key factors investigated at SARex1.
- 1 x test edition of the VIKING PS5002 referred to as TEST 3. Similar to TEST 1, this suit had extra protection in the lumbar area, but was made in the standard VIKING PS5002 material.

The 19 participants were taken out in four groups. The first three groups were taken out when the medics decided that condition of the persons was below acceptable level. The last group were taken out to minimize risk due to rough weather.

The time of the groups leaving was: Group 1 – 23 hours, Group 2 – 28 hours, Group 3 - 29 hours, and Group 4 - 30 hours.

Suit \ Group no.	**1**	**2**	**3**	**4**
Helly Hansen	1			
PS4170				2
PS5002	2	3	3	2
Test			1	1
PS4062	2	1		1
Grand Total	**5**	**4**	**4**	**6**

The test suits TEST 1 and TEST 3 had an average on board time of 29,5 hours, and PS4170 had an average on board time of 30. This means that these suits ranked amongst the best means of survival.

The suits with low insulation, the Helly Hansen and the PS4062 were amongst the lowest with a total average time of 25,4 hours. Bear in mind that as described later some results was influenced by sitting mats.

The VIKING PS5002 was present in all the group that left the life raft, with a total average of 27,7 hours. This number was also influenced by the use of the sitting mats.

Some participants did not know the use of closed cell gloves. When the gloves got wet and cold inside, the participants preferred not to use them because they did not know that the gloves are easily warmed up due to the closed cell foam. Some participants used their own woollen gloves.

SITTING MATS

Two of the persons wearing the VIKING PS4062 suits and four of the persons wearing the VIKING PS5002 did also get a sitting mat. The sitting mat was provided by VIKING for the SARex 2 as a test tool. The sitting mats are made by the manufacturer Asivik.

It was observed that the persons in possession of a sitting mat, had a longer survival time.

Two of the persons wearing the VIKING PS4062 had a sitting mat and two persons with PS4062 did not. The two persons with VIKING PS4062 and without sitting mats, was among the first participants to be taken out of the test at around 23 hours.

For the VIKING PS5002 results were more diverse, but still with a tendency to stay on board for longer if having a sitting mat. The two persons with the VIKING PS5002 and without sitting mats was among the first participants to be taken out of the test.

Suit \ Group no.	1	2	3	4
PS5002	**2**	**3**	**3**	**2**
With sitting mat		2	1	1
Without sitting mat	2	1	2	1
PS4062	**2**	**1**		**1**
With sitting mat		1		1
Without sitting mat	2			
Total with sitting mat	**0**	**3**	**1**	**2**
Total without sitting mat	**4**	**1**	**2**	**1**

We can conclude that extra protection against cooling from the water extend the survival time. When looking at the suits and the sitting mat, we see a clear tendency to extended survival time for suits having the sitting mat compared to suits without. On average, the sitting mat increased the time in the life raft by 4 hours / person.

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The lifeboat driver's experience and considerations

Quartermaster Simen Øen Strand, Navigator KV Svalbard, Norwegian Coast Guard.

Background

On the basis that I had served as the lifeboat driver during SARex1, it was desirable that I should occupy the same position in this exercise (SARex2) as well. This would give me a good basis for comparison between the experiences from the two exercises. The experience as a lifeboat manager during SARex1 helped me to be prepared for my stay in the lifeboat. I assumed that the modification of the lifeboat would change some factors on board, but was uncertain to what extent. Therefore, I assumed as a starting point that the experiences from SARex1 would largely be the reality.

In my opinion, as a Marine officer, one should possess the knowledge required to take the lead in a rescue craft after a relatively short time, or without any warning. Therefore, I did not want to make any specific plans for the actual implementation, but decided to adapt along the way based on knowledge and past experience.

For me, this exercise once again became an opportunity to demonstrate in practice what is required of a rescue vessel leader in an Arctic climate.

Discussion

After completing two exercises as a lifeboat leader, it is my opinion that the stay in a rescue craft can be divided into three main phases; establishment, survival and rescue. Each phase sets different requirements to the manager and the personnel on board.

1. Establishment

From 1500 we embarked the lifeboat with the help of the mob boats from KV Svalbard. The transfer itself went painless and everyone boarded dry. Based on the experience from the previous exercise, I intended to establish contact with all persons on board early in order to jointly form a plan for our stay. In this initial phase, I wanted to manoeuvre the lifeboat myself to get acquainted with the lifeboat and obtain control over the area in which we were navigating. However, this is a very unfortunate position for a leader if one is to have the ability to communicate and keep track of the condition of the lifeboat. Noise from the machinery makes it impossible to communicate with anyone other than those close to you. Relatively small sea also creates a lot of movement in the vessel, making it difficult to move around. I learned that my position in the driver's position was unfortunate during the establishment phase as the need for communication and overview of the situation in the lifeboat may be greatest in the beginning. It was therefore decided to place another to manoeuvre the vehicle. Due to the actual weather conditions, a lot of manoeuvring was needed in the initial phase. I experienced this as very unfortunate as it did not allow me to communicate freely, and sometimes interrupted tasks already initiated. It was decided to moor to KV Svalbard so that we could turn off the machinery and focus on the actual establishment inside the lifeboat. After the machinery was stopped, I decided to conduct a presentation round focusing on the background and relevant experience of the situation we were in. I also wanted to encourage personal announcements to establish contact and knowledge between the persons on board at an early stage. This presentation round was also intended to map the competence of the individuals.

The next step was to establish watch routines on board. These I based on experience from the previous exercise and the possibility of resting horizontally in the lifeboat. From SARex1, I found that a higher level of activity was needed throughout the evening and night as the temperature dropped. I therefore wanted to strive for sleep when we had the opportunity so that we could be active at night when needed. In the lifeboat there was now the possibility that 3 persons could lie horizontally in a sleeping bag at any one time. Therefore, a 3-hour guard roll was established, during which 3 persons at any one time rested horizontally and 3 persons were responsible for the lookout. Those on board were therefore divided into 8 groups, each consisting of 3 people. During a 24-hour period, everyone on board would be guaranteed to spend 3 hours resting horizontally in a sleeping bag. This would also allow the watch-out team to roll on the lookout post as they themselves saw it necessary. Experience from SARex1 indicated that more frequent rolling was necessary as the temperature dropped. The driver's position is the place in the lifeboat that holds the highest temperature and the only position from which one can look out without opening hatches. The chair is, however, placed inaccessible and without any good means of entering. It proved to be a challenge to roll on the guards, especially among guard teams that were located further ahead in the craft as access to and from the driver's position was demanding even for persons with good physics. I had not in advance set up a rolling plan for which groups to rest and be on duty at what time. The plan was that those who had rested in the sleeping bags should go directly to the guard duty, as they most rested on board. The purpose was to, during the first 24 hours, to base the rolling on who was most in need of rest. I therefore only informed which group was the next to rest so that I could assess the rolling continuously for the first 24 hours. The first group consisted of persons who were apparently seasick and at risk of vomiting. These were better after three hours of horizontal rest. During the second rolling, a situation arose where a sleeping space was left vacant. The person intended for this place did not want to rest horizontally as it was earlier than normal bedtime and the person felt commanded to sleep. The sleeping area was therefore left vacant during this guard roll.

Sub-conclusion

The establishment phase forms the very basis for the further stay on board and is thus perhaps the most important. This phase requires a lot of communication and practical arrangement of the situation on board. In this phase, the leader should have a central role and be able to communicate freely with everyone on board. It is therefore unfortunate if a leader here will be occupied with, for example, maneuvering the vehicle. The first few hours of the stay may be the only period when everyone is awake and rested at the same time. This is therefore the best opportunity to map the resources on board. Many persons on board want input and suggestions for establishing the stay in the lifeboat and as a leader you should use this time to play on as many resources as possible. After the establishment phase, everyone on board should have a common understanding of what their task and responsibilities are for the next part of their stay.

2. Survival

The heating system on board ran continuously and we strived to keep all hatches closed. We then reached a temperature of about 22ºC. This temperature lasted during the rest of the exercise. As a result, it became necessary to remove the rescue suits to prevent moisture from forming inside the suits. This also made us more mobile so we could move around inside the lifeboat easier. However, it proved difficult for the individuals to keep positive control of their personal rescue equipment. One possibility I considered was that each one should have the rescue suit on their legs as a minimum. This would help to put on the suit faster if necessary. However, this hampered the ability to move so it did not apply. Towards the end of the exercise where everyone had to put on life-saving suits and lifejacket at the same time, there were persons who did not find their rescue equipment and it took a long time before everyone was dressed and ready for evacuation.

The constant high temperature in the lifeboat meant that there was no need to stay active in order to maintain body temperature. It therefore appeared possible to rest relatively comfortably in all parts of the lifeboat. With 24 people on board, it was possible for all off duty to rest more or less horizontally. Essentially, most of the persons were resting large parts of the exercise. Socialization was more prominent in the initial phase, but decreased during the evening and remained so for the rest of the exercise.

From the water supply on board I had calculated 1 litre per persons each 24 hours. My plan then was to distribute 1 pack of 0.5 litres every 12 hours. It was then up to each individual to drink this ration over the next 12 hours. At the distribution of the second water ration, it turned out that several persons on board had not yet drunk what they had been awarded. This was due to misunderstandings related to the ration plan, but also that some simply did not feel thirsty and therefore did not drink. It then became necessary to clarify the water ration plan for everyone on board. There were at any time sleeping personnel on board. This complicated common information messages. With more frequent distribution of smaller water rations to be taken immediately, better control of the water intake would have been achieved. One would then not have to store your own water ration so that one did not mix the ration with others' or lose it.

Sub-conclusion

The survival phase is the phase of waiting for the rescue and having to pass the time. The basis that was formed during the establishment of the life on board will be decisive for the way the stay goes for the manager and the persons onboard. As a leader you will be able to have a more secluded role during the survival phase. With well-established routines, there is no need for a manager to manage life on board in detail. You then have the opportunity to step in as another person on board with a focus on rest and trivial pursuits. On the other hand, it will be necessary to make adjustments to the plan along the way as conditions may change and it is therefore important that the manager constantly monitors the actual conditions on board. With drastic changes, it will again be necessary to emerge in a more distinct role. As a leader, you should also have been given the responsibility in advance for certain tasks that must be followed up continuously. For example, being the responsible person for distribution and control over rationing.

The case of fire or water penetration in a rescue vehicle may require a rapid evacuation. If the personnel on board are not wearing their personal rescue equipment at all times, the evacuation will be time consuming. One can imagine that some must evacuate without personal rescue equipment. There should be a dedicated space on board where each person can store their personal rescue equipment. This will help all to have positive control over one's own equipment and be able to put it on faster. The survival phase places great demands on the individuals to take care of themselves and follow the plans and guidelines that have been set. You have to make certain that over time you will not become a burden to the others on board. The situation will require that, at times, one's own needs must be set aside in order for one to be able to jointly save all in the best possible way. At the same time, one must take every opportunity to get sufficient rest so that one is prepared if conditions on board change dramatically.

3. Rescue

During this exercise, several factors made us continually to plan how to evacuate persons from the lifeboat in the best possible way in case the original plan was no longer feasible. This was a situation I, as a manager, felt the need to have positive control over, both with respect to the activity and the communication internally and externally. Upon receiving a message of imminent rescue, I experienced a relief among the persons on board. It was then ordered that everyone should wear suits and be ready for evacuation in no time. During this process, several persons on board spent a great deal of time gaining control over their personal rescue equipment as it could have been moved or put into use by others.

Sub-conclusion

The rescue phase will depend on the weather conditions, the condition of those on board and how it will be implemented in practice. It is of course experienced as a relief when confirming that one will be saved within a short time. However, this can also be considered a very critical phase. As a leader, you will have to have a great deal of detailed control on how to effectively carry out the rescue. Assistance from others on board with maneuvering and communication internally and externally will be required.

Conclusion

My impression is that the biggest difference between the two exercises I have participated in is discipline and care for each other. Disregarding obvious technical and practical differences, I noticed a major change in attitudes on board. During SARex1, cold and lack of sleep were a major problem. This, I think, contributed to a better discipline on board in relation to guard rolling, rest and, otherwise, the routines on board. Each then had a greater understanding of what was required to survive in the prevailing conditions for as long as possible. I also experienced closer cohesion among the participants under SARex1. I believe this was due to a greater need for care and follow-up of each other when temperature and rest became a challenge. As an example, in SARex1 we had more body contact with each other to keep us warm.

The measures needed to survive for as long as possible under SARex1 were largely not required during SARex2. I think this contributed to a "duller" discipline on board. As an example, it was seen that several failed to take the assigned water rationing within the stipulated time. Nor did the buddy system on board catch that several were below the minimum recommended amount of liquid intake. During SARex2, no one on board was cold or wet, and everyone had the opportunity to rest adequately. My impression is therefore that under these conditions you can actually forget the seriousness you are exposed to. You can forget to take care of yourself, and you forget to take care of others because you seem to be doing well. In fact, my impression is that I experienced a higher morale on board during SARex1 where cohesion and discipline were more important.

As a leader, I have experienced the importance of communication and adaptation in a demanding environment. As a leader in this situation, one will have to switch between different forms of leadership depending on the situation. Clear commands and orders will sometimes be required. On the other hand, you want more persons to rely on, so that it will be possible to delegate a lot of responsibility. It is important that you as a leader in a lifeboat keep an overview of the total conditions on board. Therefore, one does not need to do too many tasks, but rather use the resources that are available among the others on board. Changes in the prerequisites can occur quickly and there will always be a need for major or minor adjustments in the routines on board. As a leader in a rescue vehicle, one must at all times adapt to the actual conditions, even if they do not meet expectations. At the same time, one must think long term and make the best plan for everyone to survive for as long as possible.

Sarex2. Can one survive 5 days in a life raft in the Arctic?

Anders Christensen, Norwegian Coast Guard.

Background

In my profession as a navigator at sea, I am expected to be able to guide others in an emergency. I should be able to safeguard my own and others' safety under e.g. an evacuation to a life raft.

On a daily basis I am the youngest navigator on the Coast Guard vessel KV Svalbard, and during SARex1 in 2016 I got to try myself in the role of fleet commander of a life raft. This was a very educational experience, and I was again appointed as a fleet commander during the follow-up exercise SARex2 in 2017. My qualifications for leading such an operation are probably somewhat better than those of the regular navigator, as I repeatedly during my management training in the Armed Forces have led others during pressured situations. Like last year, I was also aware this time that this was just an exercise, which would take place over a given period of time and included personnel medically cleared for the exercise. Not least, my crew of 19 men in the fleet was calm and motivated, and not afraid and did not panic. Of course, these were factors that made my job as a life raft manager easier. After last year's 19 hours in the fleet, I also had some experiences I could bring with me into a new exercise. This time, therefore, I was refreshed again, and knew what I was going to.

The fleet itself had been upgraded and many of the points we called for after last year's SARex1 were implemented. Most significant was the double bottom, but also the design of this fleet was upgraded, which allowed us to alternate between sitting up on the floating hoses arranged around the edge, rather than just sitting down on the floor.

Fleet Crew.

During SARex1, the group that joined in the fleet consisted largely of privates I knew well and a handful of outsiders. This time around, a major re-prioritization of personnel was made and the fleet was filled with civilians and only two private soldiers. This led me to make some quick changes to my mindset into the exercise. If the entire fleet was full of privates, by virtue of my position I would have some authority. I would have been both older and of higher rank. With the new crew, I was suddenly the youngest, and the authority I would have had in case of talking to an ordinary private was gone.

I also had to appoint a new deputy commander, and my choice fell on one of the participants who joined last year as well.

One thing I noticed was that I had several foreigners in the fleet. Thus, I chose to switch to English as the primary language during communication within the fleet. This made communication much more strained, and made me less able to explain choices and priorities in a good way. Leaving the mother tongue costs efforts.

The Exercise

Exercise start

Initially in the fleet, I prioritized last year to obtain personnel control. How many were we? Last year we tried different counting techniques and found that the rounds where everyone says their number in the series is the best. This method we kept the exercise out.

While the first minutes of last year were calm, quiet and clear, this time we had to take some immediate action. Water penetrated through the bottom of the raft and I prioritized getting it under control quickly. As soon as this was under control, I briefly introduced myself. I also mentioned my deputy's name and asked him to say a few words about himself.

Equipment

In a situation where you are trapped in a fleet, it is important to get an overview of the resources available at the earliest possible time. I therefore distributed the equipment and asked everyone to read the instruction manual so that they could present the equipment to the others in a few minutes. In a real situation, shock and panic can be major challenges, and by providing simple work tasks you can keep the shock under control. In the case of a car accident, it may be appropriate to give people with shock simple tasks such as counting pebbles and the same can be done in a raft. In an initial phase, it is also important to calm down an aggravated situation and by doing so in this way everyone would be activated and the focus would be shifted towards being saved as early as possible. Persons will react differently in such situations, and some will go deep into themselves. This may well be allowed, but not in the first phase, where a survival plan must be laid down, and a common understanding of the measures that must be taken must be established.

In this way, I also made sure that the competence was spread among everyone in the fleet. I also got everyone talking in front of everyone at the earliest possible time. The moment you find yourself in a life raft waiting for being rescued, *we are more important than I am*, and by breaking social barriers as early as possible, I hoped that good ideas would come out. The fear of saying something "stupid" will persons take with them into the grave, and the longer you sit quietly for yourself, the worse it will be to come up with the "stupid" idea that actually can be crucial to being saved.

In retrospect, I see that I should have given a little better time to prepare for this scene, especially in light of the fact that the idea generation was in English. I stated early on that if someone was not comfortable speaking English, they were welcome to speak Norwegian, then others should translate.

Last year, I let everyone in the fleet be responsible for the equipment they were given during the rest of the exercise. They had to find a good way to keep the equipment easily accessible. This method I left this year and considered it appropriate that the equipment be collected again and put in the bag so we had control. Thus, we avoided leaving equipment lying around, with the danger of being destroyed.

Personnel

As soon as all the equipment was presented, I proceeded by initiating a presentation of the personnel in the fleet. I asked all of them to talk about themselves, and to share what knowledge they possessed that they thought might be of use to us in this situation. To the extent that I felt someone needed some help in finding something to say, I asked some follow-up questions. Here I felt it slipped out a bit, and I should have made sure to summarize what resources we had in the fleet when we had gone the entire round.

After the presentation round was completed, I took the opportunity to allocate some work assignments. The one with the most medical experience I appointed as the naval doctor, responsible for the distribution of sea sick tablets, among other things. I also asked them to familiarize themselves with the medicine we had available in the fleet. The waste manager was also appointed. I think it is important to keep the fleet tidy, both to maintain a sense of control, but also to more easily find essential material at short notice. You have to avoid a situation where you are looking among rubbish to find the rescue rocket.

I then divided the persons in the fleet into pairs, and made instructions what to look for. I also emphasized the importance of going to the toilet. This was done during the exercise from the coastguard's light boat.

When this initial phase was completed, we had been in the fleet for about two hours, and I encouraged those who managed, to get some sleep. Unlike last year, the temperature in the fleet was comfortable, and I rejected my initial plan based on last year to stay active through the cold night, and sleep while it was warmer during the day. As I read the situation around 1800, it would be appropriate to maintain a most normal 24-hour rhythm. That is to sleep from midnight to 0800, approx. In this way, we utilized the fact that the body was prepared to sleep during this time. I therefore shifted the distribution of sea sickness tablets to an hour to 2400.

Food and water

At 2000, I handed out the first ration with food and water. In the instruction for the fleet it is written that you should not drink or eat for the first 24 hours. This I chose to disregard, as it would only make our stay in the fleet more uncomfortable and not interesting for the experiment.
I made up my mind early regarding food and water rationing plan. It was relatively easy to calculate how much water and food was intended for each participant per day. So, I had the choice to distribute daily rations, ration for 5 days or to distribute several meals during the day. I chose the latter for several reasons:

- You can easily check that everyone gets nutrients and fluid.
- This prevents theft and clutter by leaving supplies to fling. I think stealing can potentially become a problem in a fleet over time. When the survival instinct sets in, I think one can easily steal some decilitres of water from somebody in the raft. I was also anxious that some could risk crushing pieces of food and water bags with their body so that something went to waste.
- At the same time, I achieved arranging meal sessions; Food every 8 hours, and water every 4 hours so all had short-term goals to look forward to. In this way, we divided the day into the periods we are accustomed to, creating a kind of structure and routine in an abnormal situation. "Soon it's lunch, only 2 hours to dinner" are such phrases we could use. Banal expressions, but familiar expressions that helped establish a sense that we were in control of the situation.
- Fairness. I also believe that such a firm structure in the management of water / food helps to ensure that the distribution is perceived as fair. In this way you avoid dissatisfaction. “You get this bag of water now. In 4 hours, you get another one. Make sure you have drunk this one until then”. I didn't want it to be perceived as if I didn't have full control on water and food management. I could have delegated this task; someone could have been a “chef”. But I thought that for my position as leader, the power over food and water would be extremely important, and my credibility as a leader would be enhanced through my handling of the situation.

As a leader in an emergency, one must be able to master different management styles. From specific and direct in an initial phase, to caring and inclusive later. This I explained to my crew on board, and I presented my plan for fleet watch and asked for input. "Is this a reasonable setup, or should we do it in a different way?". I received no input, but had the impression that all appreciated having their opportunity to voice their say. I also made it clear that I wanted input on solutions along the way. My idea was that the guard system would consist of rolling three-man teams, which were on watch for two hours, before the next team took over. They were told about the following responsibilities: Keep a lookout, answer the VHF, follow the oxygen meter. Ventilate if necessary and keep the raft dry.

I consistently gave the radio-connection to one in the guard team. I thought it was important that as many persons as possible could operate the radio-connection, while the radio-connection became a symbol of the guard function. Thus, the guard team was on alert, so that the others could rest. I wanted the guard team to have a fixed place at the entrance to the fleet, while the other teams slept in the same place. In this way, I hoped that as few persons as possible would be disturbed by the shifts. I kept myself out of this schedule. I think it is important that the manager is watch-free and can have an overall overview and energy enough to lead if the situation worsens. No one questioned this. Maybe one would have had to defend this in a real situation.

Management.
As soon as we entered the fleet, I made sure to get the highest possible seat in close proximity to supplies and equipment.

Last year the low temperature was a much bigger problem and we couldn't sleep. Thus, I could at any time come up with suggestions, stories or activities to focus on something positive. This year the comfort was much better and already after an hour someone began to fall asleep. At the same time, the wind was strong and loud and the noise from the flickering cloth on the raft made it difficult to hear. I thus had only short periods of time where I had everyone's attention, and was hindered by noise and the requirement to speak English. In light of this, the fixed meals became important. At these times, everyone was awake, and one could take the opportunity to give messages, or ask how others felt. I reminded several times about the buddy service, and followed up with questions as much as possible. In particular, I tried to contact those who were in a quiet period. Why were they quiet? And what could I do to investigate their condition? It is difficult to judge the condition of those who sleep or sit quietly with their eyes closed, and I made sure to get everyone to chat as often as possible. I also discovered that if I started a conversation with someone it could be good entertainment for the rest, and lead to more conversations that in turn served as stimuli, even for those who sat only as passive listeners.

Communication.
I noticed during the exercise that we did not use the first names when addressing each other. I addressed this by asking everyone to find an animal with the same initial letter as in their first name. E.g. Anders Antelope, or Per Pitbull. I also asked them to refer to an animal that could remind them of themselves. When everyone had thought a little, we took the round where everyone was allowed to say their name. Eventually, I challenged them to mention the names of everyone around the circle, with impressive results. After that, we used consistently first names, and I felt this eased communication on board.

Follow-up from medical personnel this year was far more extensive and I felt to a degree that I was deprived of some initiative in the leadership role as the doctor's visits came so frequently. Among other things, I was of the opinion that a certain person should be sent back, while the medical team judged oppositely. Maybe I should have cut through here, but as a layman you often listen to medical personnel.

Sleep.
This year we had 19 persons who spent the night in the fleet. Thus, there were 16 guard-free at all times trying to sleep. This was a far from pleasant experience, and especially the feeling of being stuck to others was a bit claustrophobic. We never got to experience night number two, but I think the exhaustion would have made sleep come easier.

External influence.
During the exercise, the weather changed from no wind and calm sea to a gust of hurricane strength

and 1 m of sea. I have already mentioned the effect of the wind on the noise level in the fleet. In extreme wind conditions, this flicker will be deafening, yet the constant rocking of the raft and the sharp movements will be factors that contribute greatly to the wear and tear of personnel in the fleet. The risk of pinching injuries on board also would have increased significantly. Getting water from a bag without spilling would have been difficult, and keeping the raft organized would have been virtually impossible. We would have strived to keep at our dedicated place. The drift off of the raft would also be huge.

During the exercise, the fleet had several times to be pulled away from ice which came drifting at great speed. Without external help and with only the help of paddles, we would have been hit by large chunks of ice, with the danger of puncturing the raft. We would also have drifted ashore within a short period of time, thus becoming vulnerable to polar bear attacks. The exercise took place in a fjord, and in a real situation, however, I, as a fleet leader, would have to consider whether it would be appropriate to try to get ashore and settle there.

Cold.

Unlike last year, the temperature inside the fleet was uniform throughout the exercise. One of the reasons for this was probably that we were more persons on board for a longer period, as opposed to 2016. The fewer on board, the fewer heat sources and an accompanying falling temperature. At the same time, the double bottom made a difference, although I think it was the opportunity to pull up from the raft bottom and sit on the floating pontoons that was the biggest advantage. This also meant that all had a larger opportunity to adjust their position, move further away from the water and accommodate those who wanted to sleep. This year, as during last year, the air quality on board quickly became poor, and it was necessary to vent well at regular intervals. Without the O_2 meter that alarmed during low oxygen values, I am afraid the low O_2 level could represent a risk. I also emphasized the importance of opening up suits if persons felt they were about to sweat, which would punish them later at falling temperatures.

The last part of the exercise.

After about 24 hours, my second in command was taken out of the exercise. By this time, we had become a well-functioning team. My first thought was that I should appoint a new deputy, but after thinking a while, I turned this idea away. The reason for that was the following: I felt that we had reached such a high level of cooperation that everyone understood what was needed to be done to maintain life in the fleet. I considered everyone to be good candidates for a possible deputy role, but I feared that if I were to appoint one of them at this time, I would deprive the others of some of the initiative. Also, I knew that if I were taken out, they were more than capable to make this choice themselves. Thus, we continued for the last few hours without any deputy, and I noted a high degree of motivation among the remaining. At the same time, I struggled with severe headaches, which I think came from lack of caffeine. I prioritized handing out painkillers to the others who struggled with headaches, and should probably also have given myself a dose. In the afternoon we were told that we would be picked up in two hours. From that point on, the motivation for releasing water from the raft fell, and we took a bit easier on all tasks. This could have been a scary trap, as in a real situation you may find that help is on the way, but must give up or be delayed due to e.g. worsening weather. That I allowed this fall in morale by default, is probably what I regret most in retrospect.

Conclusion

Being left to oneself in a life raft in Arctic waters is not a scenario you want to come into. Firstly, it will get cold over time, and with little room to move, little can be done to regain body heat. You will be exposed to motions with subsequent seasickness and exhaustion. You will be in danger of being hit by drift ice, and you have no way to protect yourself from polar bears and walruses that will be attracted to the sight and the smell of a life raft. In addition to the challenges the climate around will pose, without the necessary knowledge, you will be at risk of being suffocated inside a closed fleet when using up the air. When it is freezing on board and even colder outside, aeration will not necessarily be the first priority. A standard fleet has no equipment to warn of falling air quality.

This was just an exercise, and I, the leader, did not have to deal with questions about whether we would be saved? We knew this, and I didn't have to reassure the doubters. Thus, this exercise largely revealed the physical aspects of life in the fleet, while the real challenges for a leader would be the mental ones. I believe that by being consistent, caring, but at the same time demanding on the others in the fleet, you achieve the best results. If one is able to gain a common understanding of what one must do in order to survive, it will be easier when some start to doubt later. After 29 hours we were cold, but mostly tired. One day more in the raft, we would have started to get exhausted and might not have been able to take the necessary measures to endure. At the same time, one should not underestimate the forces that can be mobilized when it comes to question about live or die

With 19 hours in the fleet last year and 29 this year I have been able to feel on the body what life in the fleet entails. And yes, with good weather, good leadership and a tight fleet, you might have survived 5 days. But I think it's likely that the regular cruise passenger would have perished long before that time.

Anders Christensen

28.06.2017

SAFE TRANSFER AND STAY IN THE LIFE RAFT

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Disclaimer

The views expressed in this report are solely based on personal experience from SARex 2, and does not necessarily reflect the official view of the Norwegian Maritime Authority (NMA).

Background:

The Polar Code regulations 8.3.3.3.2.2 and 8.3.3.3.2.3 are some of the regulations that has to be met by all ship companies operating in Polar waters:

> *8.3.3.3 In order to comply with the functional requirement of paragraph 8.2.3.3 above, the following apply:*
>
> > *.2 taking into account the assessment referred to in chapter 1, appropriate survival resources, which address both individual (personal survival equipment) and shared (group survival equipment) needs, shall be provided, as follows:*
> >
> > > *.2 personal survival equipment in combination with life-saving appliances or group survival equipment that provide sufficient thermal insulation to maintain the core temperature of persons; and*
> > >
> > > *.3 personal survival equipment that provide sufficient protection to prevent frostbite of all extremities*

The regulations above are based on the functional requirements in 8.2.3.3:

> *8.2.3.3 Taking into account the presence of any hazards, as identified in the assessment in chapter 1, resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the maximum expected time of rescue. These resources shall provide:*
>
> > *.1 a habitable environment[2];*
> >
> > *.2 protection of persons from the effects of cold, wind and sun;*
> >
> > *.3 space to accommodate persons equipped with thermal protection adequate for the environment;*
> >
> > *.4 means to provide sustenance;*
> >
> > *.5 safe access and exit points; and*
> >
> > *.6 means to communicate with rescue assets.*

[2] Defined in the Polar Code as “a ventilated environment that will protect against hypothermia”.

Transfer from mother vessel to rafts.

This report will focus on experiences made during SARex 1 and 2017 related to transfer and stay inside the life raft.

1. Transfer to / from the raft was done by use of the coastguard vessel's FRC. In a real situation this will not be an option and the evacuation process will be far more challenging and dependent of the environmental conditions as temperature, Ice cover, wind, sea / swell, visibility.

Several systems for launching of life rafts are available and varies between different vessel types. These are free fall (throw overboard) davit launch and MES with or without controlled descend of rafts.

A MES system with controlled descend of the rafts will in my opinion be the safest way of launching the life rafts in areas partly or fully covered with ice. This system will reduce the risk of damage to the raft due to impact with ice, and allow safe boarding via the MES system. Anyway, the chance for damage of the raft in areas with ice will always be present, since they are not constructed to withstand the forces created by ice pressure or by impact with ice.

Abandonment by use of lifeboat will in most cases be a better and safer option, and should be the preferred way of abandonment in Polar areas where the possibility of ice is present.

If the situation allows abandonment onto solid ice, the use of MES and life raft would be an alternative to the lifeboat, both in way of abandoning passengers to the ice and to serve as shelter during the time waiting to be rescued.

Life raft

In addition to the provision of a safe place other than the ship, the main function of the Polar Code-compliant life raft seems to be maintaining core temperature of persons dressed in appropriate personal lifesaving equipment. Referring to the functional requirements, this means provision of a habitable environment protected from the effects of cold, wind and sun, with enough space to accommodate the persons including additional clothing as necessary.

The life raft used for SARex 2 was a 25-person raft, upgraded as follows based on experiences from SARex 1.

- Double bottom to improve insulation between floor and sea surface
- Double tent canvas in order to reduce condensation problems from ceiling, and to allow venting without losing too much heat inside
- Bailing system to allow for rapid removal of seawater
- Bigger volume inside the tent, allowing more movement and change of sitting position.

The modifications done to the raft, in combination with use of insulated survival suits showed to be effective, and allowed us to stay inside the raft for 24 hours or more without dramatic reduction of the body core temperature. It is my opinion that in these conditions, combined with good leadership and organization of the passengers would allow survival for 5 days without a dramatic reduction of the body core temperature.

The fact that the test persons was made aware of the importance of keeping the survival suits open from time to time in order to reduce condensation inside the suit, contributed (together with the upgrades) to reduce the heat loss.

Another important factor was the shape of the tent, which allowed us to change position from the floor to the pontoon. This was beneficial both to reduce the heat loss to the raft floor, and to keep up the blood circulation, and the cognitive abilities.

It was a total 19 persons in a 25-person raft. Even with this number of persons the raft was filled up, and leaving limited space for movement. Adding another 6 persons would have reduced the ability to move the body, and the risk of reduced cognitive function would increase significantly. A fully loaded raft would surely benefit to reduce the chance of survival for 5 days.

The number of persons in the raft should be reduced when operating in polar areas, both in order to maintain a habitable environment during 5 days or more, and in order to allow space for additional load on board as PSE and GSE.

Personal survival equipment

Insulated survival suits must be worn if you should be able to survive for 5 days or more in a life raft in polar areas. It will not be possible to keep the temperature inside the raft high enough over time to allow poor quality survival suits. This is off course due to the construction of the raft and limited possibilities to insulate or supply heated air, or to maintain the human generated heat inside the raft.

Additional to the survival suit, the proper underwear should be used. The available woolen underwear kept in the PSE should as far as possible be taken on prior to disembarkation from the mother vessel. This will help to absorb the humidity from the body and prevent heat loss. In order to reduce the humidity, it is important to make the personnel aware of the need to open up the suit regularly to get some circulation inside the suit.

18 of the persons in the raft used insulated survival suits with detachable gloves.

1 person used a suit with fixed three finger gloves. This person was the first one leaving the raft due to loss of body temperature. This was mainly due to the fact that it was nearly impossible to open and eat / drink the emergency rations wearing these gloves, and it was necessary to undress in order to get the hands free to grab the rations, further it was necessary to undress the upper body in order to get rid of body fluid outside the raft. In fact, you are more or less incapacitated with these gloves. Additionally, the rubber gloves kept your hands cold due to constant humidity inside the gloves. These factors also benefited to increased discomfort.

Lesson learned is that such kind of suits should not be allowed in Polar areas, or maybe in general.

Habitable environment

The weather was quite unstable during the exercise. At the time of launching/embarking the raft the outside temperature was around +5 and sea temperature +2. The wind was around 25 knots with choppy sea. At the time of disembarking, the temperature was -10 and wind gusting 40 knots.

As the raft was filled up we tried to organize and to get control of the bag with survival equipment, before it was buried under our bodies and hard to get hold of.

All crew took a sea sickness tablet prior to boarding. This I believe was under the actual weather conditions, a major contributor to avoid seasickness and a lot of discomfort. Seasickness tablets was taken regularly throughout the stay both in order to avoid seasickness, and to be able to get some sleep when needed as the tablets made you kind of drowsy.

During the first hour we experienced a rise in temperature inside the raft due to the induced body heat, then it stabilized and started to decrease gradually and stabilized around 14 degrees. This was mainly due to less activity inside the raft and venting in order to keep the o2 and co2 levels within acceptable limits.

Opening the tent in order to get rid of body fluids with regular intervals was also a contributing factor to the low temperature inside. Body heat was also lost during these activities as it is necessary to open the suits during the process.

As the weather was kind of choppy causing lot of movements of the raft, small amount of seawater entered the raft via the bailing arrangement. The raft was not designed to allow natural drainage of this water and the shape of the raft floor contributed to collection of water in small puddles. A lot of effort was used to dry up these puddles by use of a sponge. The puddles of water had a negative effect, as it was not possible to avoid that anyone sat or laid down in these puddles causing discomfort and negative effect on the body temperature.

The problems related to O_2 and CO_2 levels inside the raft was also this time experienced, but the increased volume of the tent, and the awareness of the problem reduced the frequency of ventilation. The problem might have been further reduced if the vent possibilities of the double tent was fully utilized.

Space to accommodate all persons and personal survival equipment.

The requirements for space include a rather vague expression, which is open for all kinds of interpretations. As we are discussing survival, not comfort as such, we need to clearly and define what we do need space for. It is not only a question of space, but also how the space is used. There should be an increased focus on the human element, including demographic variations, when designing new life rafts.

In Norway's submission for SSE (SSE 4/15/1), the following view regarding space was expressed:

> *When determining the capacity of the survival craft, consideration should be given to ensure ample space for the persons on board to move sufficiently to maintain sufficient blood circulation, and to ensure access to the toilet facilities.*

It will never be comfortable to stay inside a life raft for a longer period of time, especially when the number of people on board is approaching the max capacity. The LSA code uses 75 kg as an average, somewhat depending on nationality the average weight of a cruise passenger would be more than this. Experience from SARex 1 and 2017 shows that filling up the raft to max number of persons will make it impossible to move and the loss of cognitive abilities and discomfort will have impact on the survivability.

This time there was 19 persons in the raft. With this number we had the possibility to organize in a way that made it possible to move around and keep up the blood circulation.

Even with this number of persons on board it would be a challenge to find space for additional PSE and food / water rations for 5 days of survival.

Ergonomics.

It is very hard to find a comfortable way to sit or lay down inside a raft. All of us felt some degree of discomfort during the stay onboard. The increased volume inside the tent compared to the raft used in SARex 1, gave us more possibilities to change positions and even rise up. This ensured some blood circulation in numb extremities and reduced the feeling of discomfort. The sleeping part is maybe the worst part if you at all manage to fall asleep. You wake up in the same position as you fell asleep and maybe with other person's limbs on top of you.

Arranging a system where you vary between short periods of sleep and watch keeping might be the best way to handle this, you will then have a chance to maintain the cognitive functions.

Food and water was divided into rations to last for 5 days. One unit of food/ water was given every 6 hours or so. Seasickness tablets was distributed at the same time in order to avoid seasickness and to help people sleep.

The food rations were for me enough to avoid the feeling of hunger. The feeling of thirst was a bit more pronounced, and will obviously be a challenge if you have to stay for several days. Only during the 24 hours in the raft the body weight was reduced with 2 kg, mostly caused by loss of body fluid.

It takes a good deal of discipline to ensure that all onboard is given the possibility to alter between sitting / laying position, and good sleeping positions the bad spots and the more #comfortable# spots. Such discipline is matter of necessity in order to increase the possibility for survival. To achieve such a discipline a strong leadership is of vital importance. A lot of training and character is required to manage this task in a good way.

Managing of resources / training of personal

Survival in a life raft for 5 days or more demands for a strong leader onboard with great knowledge of the risks and challenges you will face, and how to solve them.

Specific training beyond what is offered in today's standard STCW training is required and of great importance.

Proposed best practice

Based on our experience from SARex 2, I have tried to outline a proposed best practice for passenger ships that is not intended for operating in low air temperatures (-10)

Based on our experience, I would propose that passenger ships provide on each mustering station lockers containing waterproof grab bags with at least the following equipment. The grab bags should be sorted in separate shelves or lockers based on the size of the clothes and TPA, covering various sizes from infant to adult of 140 kg/chest girth of up to 1,750 mm.

- long thermal underwear and top (wool)
- wool gloves, hat, socks and buff/multifunctional headwear
- thermal protective aid
- bottled water (and anti-seasickness medicine)

All items listed above should preferably be put on before entering the life raft if possible. In addition, a light woollen blanket, earplugs, mitten, headgear, polar survival guidance should be brought.

Identifying possible improvements

- It should be looked into how to construct the raft to allow best possible sitting /lay down positions.
- Handholds to allow people to stand upright should also be implemented.
- Pocket to store safety equipment as rockets / flares and other important equipment after deployment should be arranged.

- Possible ways to get rid of body fluids without having to undress and open the tent should be investigated.
- Possibility to keep lookout both in forward and aft direction should be ensured.
- Effective ways of draining water away from the raft floor should be looked into.
- The quality of the emergency equipment needs to be reviewed
- Safety placard is unreadable for grown up people. (letter far to small)
- Description on drugs needs to be in a understandable language understandable also for an average passenger.
- Food and water rations to be upgraded (and space made available) for survival in 5 days.

SAFE STAY IN AND TRANSFER FROM LIFEBOAT

Jan Reinert Vestvik, Norwegian Maritime Authority, Haugesund, Norway

Disclaimer

The views expressed in this report are solely based on personal experience from SARex, and does not necessarily reflect the official view of the Norwegian Maritime Authority (NMA).

Background

The Polar Code regulations 8.3.3.3.2.2 and 8.3.3.3.2.3 are some of the regulations that has to be met by all ships operating in Polar waters:

> *8.3.3.3 In order to comply with the functional requirement of paragraph 8.2.3.3 above, the following apply:*
>
> > *.2 taking into account the assessment referred to in chapter 1, appropriate survival resources, which address both individual (personal survival equipment) and shared (group survival equipment) needs, shall be provided, as follows:*
> >
> > > *.2 <u>personal survival equipment in combination with life-saving appliances</u> or group survival equipment <u>that provide sufficient thermal insulation to maintain the core temperature of persons</u>; and*
> > >
> > > *.3 <u>personal survival equipment that provide sufficient protection to prevent frostbite of all extremities</u>*

The regulations above are based on the functional requirements in 8.2.3.3:

> *8.2.3.3 Taking into account the presence of any hazards, as identified in the assessment in chapter 1, <u>resources shall be provided to support survival following abandoning ship</u>, whether to the water, to ice or to land, <u>for the maximum expected time of rescue</u>. These resources shall provide:*
>
> > *.1 a habitable environment[3];*
> >
> > *.2 protection of persons from the effects of cold, wind and sun;*
> >
> > *.3 space to accommodate persons equipped with thermal protection adequate for the environment;*
> >
> > *.4 means to provide sustenance;*
> >
> > *.5 safe access and exit points; and*
> >
> > *.6 means to communicate with rescue assets.*

The functional requirements can be useful for the interpretation of the regulations, and off course in case of evaluation of alternative design and arrangements. The overall goal of chapter 8 is to provide for <u>safe escape, evacuation and survival</u>. Any means or measures taken should contribute to the achievement of this goal.

[3] Defined in the Polar Code as "a ventilated environment that will protect against hypothermia".

Personal survival equipment

The regulations make a difference between personal survival equipment (clothes, buoyancy aids etc.) and lifesaving equipment (lifeboat, life rafts etc.). However, in my opinion the two are dependent on each other. The regulations require personal survival equipment in combination with life-saving appliances to provide sufficient thermal insulation to maintain the core temperature of persons.

With the results from SARex 2016 in mind, the survival suits alone do not effectively protect persons from hypothermia. Hence, the following reflections are based on a modified lifeboat, capable of maintaining 20 °C inside air temperature (either by insulation or by active heating device or a combination). Our experience from the lifeboat in SARex 2017 is that the ability to open up or even take off the survival suits for periods of the time had positive effect, especially with regard to perspiration/wetness due to sweat.

We did not test the use of TPA instead of survival suits. However, taking into account that we did not use the suits most of the time, it is plausible that TPA would be sufficient in a lifeboat capable of maintaining 20 °C inside air temperature.

The clothes that persons wear under the TPA/suits will further influence the ability to maintain core temperature. The Polar Code does not set any specific requirements for clothes, but requires an assessment in chapter 1.5, and hence, wool clothes or similar might be a possible solution based on that evaluation.

For cargo ships, we could probably expect the crew to have proper warm clothes on board. For passenger ships, the passenger's prior experience with cold climate may vary, and we should not expect persons to be dressed in other than casual indoor clothes under the survival suit or TPA, unless the company provides essential warm clothes.

Lifeboat

In addition to the provision of a safe place other than the ship, the main function of the Polar Code-compliant lifeboat seems to be maintaining core temperature of persons dressed in appropriate personal lifesaving equipment. Referring to the functional requirements, this means provision of a habitable environment protected from the effects of cold, wind and sun, with enough space to accommodate the persons including additional clothing as necessary.

The test lifeboat was equipped such that it was not necessary to open any hatches for extended periods, and was in line with the intentions in a proposal made by Norway for IMOs Sub-Committee on ship systems and equipment (SSE) in march this year[4]. The basic intention of that proposal was to minimize the need for exposure to cold air.

1. Habitable environment

The first test we did on board KV Svalbard was to fill the lifeboat with 49 persons (max capacity) and close all hatches. The measurements show that the CO_2-level will increase rapidly. Hence, forced ventilation is necessary in order to survive.

During the long-term test, we experienced that it was possible to open hatches for short periods to install radar reflector, to marshal the life raft or other necessary duties. This did not reduce the inside temperature below tolerable values. We kept one small hatch in the front and one in the aft slightly open for a long period to vent out the humid air. This did not reduce the temperature noteworthy, but as the wind picked up, we had to close the front hatch to avoid sea spray inside the boat. We also

[4] SSE 4/15/1 and SSE 4/15/1/Corr.1

tested keeping all hatches open for a period and it reduced the temperature quite fast. It took a while to reheat the inside air, and even more time to recover a normal body temperature, as we were sitting quite still in our seats. Combined with the findings from SARex 2016, I would conclude that ventilation by use of the hatches would increase the possibility of hypothermia for the persons on board the lifeboat, unless there is an oversized heating source on board.

In this lifeboat, we had a Webasto heater that heated the intake air, and distributing it through four nozzles near the floor. Another fan near the ceiling was blowing air out of the boat. It could also be reversed if necessary. We tested that, and as this second fan did not have any heating, it was quite cold to sit near the vent nozzle when used.

In order to comply with 8.3.3.3.2.2 of the Polar Code, it seems to be necessary to be able to control both ventilation and temperature by *active* means.

It was a great advantage to be able to keep an inside temperature of 20 °C, as we could take the suits completely off and did not worry about any wetness from sweat.

It is necessary actively to manage the ventilation and heating system to optimize the climate in the boat at all times and to extend the survival time (fuel and battery capacity). Lifeboats should be fitted with thermometer and hygrometer, and possibly portable O_2- and CO_2-alarms to help the lifeboat captain maintaining a habitable environment and at the same time be able to save as much fuel/battery as possible by keeping the air quality on a “survival level” rather than a “comfort level”.

2. Space to accommodate all persons and personal survival equipment

The requirements for space includes a rather vague expression, which is open for all kinds of interpretations. As we are discussing survival, not comfort as such, we need to clearly define what we do need space for. In my opinion, it is not only a question of space, but also how the space is used. There should be an increased focus on the human element, including demographic variations, when designing new lifeboats.

In Norway’s submission for SSE (SSE 4/15/1), the following view regarding space was expressed:

> *When determining the capacity of the survival craft, consideration should be given to ensure ample space for the persons on board to move sufficiently to maintain sufficient blood circulation, and to ensure access to the toilet facilities.*

In addition to that, there is a finding from SARex 2017 that we cannot completely ignore, with respect to the poor seating comfort, which can lead to pain, discomfort, lower morale and possibly more serious medical issues when seated for many days.

Human element

The LSA Code uses 75 kg as an average passenger, and it is not within the scope of this exercise to dispute that number. However, the LSA Code also acknowledges that there may be large individual deviations from the average. As an example, lifejackets are designed to fit all persons from infants to persons up to 140 kg[5].

The 75-kg average makes somewhat sense when maximum loads and the stability is determined, but for the necessary individual space (seats, in particular), variations should be considered. These variations would probably be less significant on cargo ships.

[5] LSA Code paragraph 2.2.1.3

Ergonomics

The LSA Code does not sufficiently consider the human element, especially the significance of human behaviour when packed together on uncomfortable seating for a long period, such as five or more days. All exercise participants felt some degree of pain and discomfort with the seats provided in the lifeboat. Seating ergonomics should be considered improved. Backrest seems to be necessary, and the seats should be as deep as possible and upholstered using an insulating material. In my opinion, seats with at least the same dimensions as for free-fall lifeboats (LSA Code 4.7.2.2), would offer a great improvement in polar lifeboats, taking into consideration the expected time until rescue.

The lifeboat we used for the exercise had three “beds” for sleeping, giving each person 3 hours sleeping time in a 24-hour period. With improved seats, the need for such beds might be reduced, but provision of such would increase the comfort. In case of injuries or illness, a few bunk beds might be reasonable. Providing the same bed per person ratio in a 150-person lifeboat means 19 beds.

Inside environment

Some participants brought up the issue about the noise inside the lifeboat (when engine was running). In my opinion, this is not crucial for survival, but the provision of earplugs seems to be a cheap and easy way to deal with that.

The inside of the lifeboat had a light grey colour, in accordance with LSA Code requirements. Some participants proposed a more colourful environment.

We discussed if more windows would be beneficial, for example in order to avoid sea-sickness if persons are able to see the sea and the horizon. I am sure it would not hurt to have windows, but the value in a survival perspective seems somewhat marginal. More windows could reduce the need for electrical lights inside the boat.

Storage space

Notwithstanding the choice of insulated survival suits or TPA and lifejackets, the personal survival equipment will be taken off inside the lifeboat during the period of five or more days until rescue. I consider it more likely to maintain body temperature with the suits off than on, as it is easier to stay dry without them, and it will probably reduce the fluid loss. Hence, the need for space to accommodate the suits/TPA and lifejackets should be considered.

As most of us did not wear the survival suits all the time during the exercise, it was quite messy on board, and in that mess, it would not have been possible to accommodate the maximum number of persons that there were seats for (49).

In cases where TPA is an alternative, it will require less space inside the boat compared to survival suits. However, there will be a similar space issue when the lifejackets are taken off inside the boat. It is not realistic that people would keep the lifejacket on for five days.

Cockpit

We experienced that the cockpit was not very functional. We had to be seated in the cockpit, which gave less mobility to move about and see all directions. The windows were very small, and there were no means to ensure clear view. We had to wipe the inside of the windows continuously to be able to see anything. I would had preferred the possibility to stand up, perhaps with a foldable seat etc. There should have been a hatch to look out and to ventilate the dew.

Rations

I had anticipated that the worst part of the exercise was hunger. However, I was wrong, as the worst part was the thirst.

We were given 500 ml water in 50 ml bags every twelfth hour. I tried to drink an average of approximately one bag of 50 ml every hour. However, when trying to eat the food rations, I had to consume more water to be able to swallow the rations. I decided not to eat more than necessary in order to save water. This was no problem for the period we stayed in the lifeboat, but would probably have been more of an issue if we had to stay there for a longer period. I ate one ration bar (two tablets), equal to 250 kcal, and did not feel very hungry. Nine bars (500 g) equals the LSA Code requirements of 10.000 kJ energy per person.

In a real situation, with only 3 l of water per person, we could not have got more than 0.6 l per day if the expected time of rescue is five days. According to our medical personnel, this would be the absolute minimum amount needed for survival. However, the average fluid loss was approximately 2 l during the entire stay in the lifeboat. The water rations should be increased.

Managing of resources / training of personnel

At one point, the temperature reached 24 °C. For me, this was uncomfortable warm, taking into account the limited access to drinking water, and quite warm clothing.

Such "waste" of diesel would also shorten the survival time. Hence, a strict management of resources, including diesel and battery power, is necessary. This will require specific training of personnel.

Transfer from lifeboat

Survival crafts are not meant to be navigated to a safe harbour themselves, and are reliant on external assistance. The regulations of the Polar Code and in SOLAS, does not rely solely on the Contracting Government's SAR resources, but requires any Master of any ship to assist persons in distress[6]:

> *The master of a ship at sea which is in a position to be able to provide assistance on receiving information from any source that persons are in distress at sea, is bound to proceed with all speed to their assistance, if possible informing them or the search and rescue service that the ship is doing so. [...]*

Ordinary merchant ships are not specially equipped for rescuing persons from lifeboats, and they will probably need to use their own lifesaving appliances in unconventional ways.

Merchant ships have different equipment depending on type and size of the ship. In many cases, their rescue boat will be a small boat with capacity to transfer only 3-4 persons from the survival craft at a time. During this period, the hatches will have to be opened many times, and as the survival craft empties, the temperature will decrease.

The safe transfer from survival crafts to a rescuing vessel should be considered a part of the survival phase regulated by the Polar Code, and any identified hazards should be mitigated.

Proposed "best practice"

Based on our experience from SARex 2017, I have tried to outline a proposed best practice for passenger ships that is not intended for operating in low air temperatures (-10 ^{o}C)

Based on our experience, I would propose that passenger ships provide on each mustering station lockers containing waterproof grab bags with at least the following equipment. The grab bags should

[6] SOLAS Chapter V, Regulation 33

be sorted in separate shelves or lockers based on the size of the clothes and TPA, covering various sizes from infant to adult of 140 kg/chest girth of up to 1,750 mm.

- long thermal underwear and top (wool)
- wool gloves, hat, socks and buff/multifunctional headwear
- thermal protective aid
- bottled water (and anti-seasickness medicine)

All items listed above should preferably be put on before entering the lifeboat, if possible. In addition, each seat or sitting place inside the lifeboat should be provided with a small seat pocket or similar, containing a light wool blanket, earplugs, polar survival guidance etc.

Recommended ways to conduct research exercises in Arctic waters

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o Introduction

Conducting research in any setting requires expert knowledge and a methodical approach to planning and execution of the plan. Planning sea trials in southern latitudes can be challenging as the research team must ensure all required personnel and equipment are on-board before leaving port, since returning to port is generally not an option given the cost mobilizing a ship, crew and research team. However, in Arctic waters, there are a greater number of technical, environmental and safety considerations for research exercises, particularly when human participants are involved in the tests. This report outlines some of the considerations for planning and conducting research exercises in Arctic waters. It draws on the author's experience planning and executing sea trials to study towing of inflatable life rafts in realistic seas, manoeuvring tests of totally enclosed lifeboats in managed sea ice, trials to determine the real-world performance of personal locator beacons in realistic sea conditions, measurement of offshore supply vessel crew rescue performance and collection of evacuation time for large numbers of passengers on cruise ships and ferries following on-board alarms.

o Identifying the Research Questions

The main research questions must be clearly outlined early in any research project, but particularly so for research in Arctic settings, given the challenging nature of the environment, the remoteness when in the field and the associated logistics of planning. Research questions should be identified along with sub-questions where necessary and should be as specific as possible so that the data acquisition plan can be developed, the required skill-sets for the research team identified and the team assembled. The primary research questions, along with any sub-questions will guide the development of the research plan in a way that allows the team to produce meaningful results when the research is completed.

o Background Literature

An important first-step in the planning and execution of research trials in Arctic water is to carry-out a thorough review of literature relating to the research. This should include not only a review of the available literature that is relevant to Arctic-specific settings but also that which might provide relevant information for situations reasonably similar. For the trials conducted, for example, there was a need to better understand the ventilation requirements inside a totally enclosed lifeboat for long exposure situations in a cold environment. For this very specific situation, little published information exists, however much could be learned by reviewing literature relating to ventilation of public spaces, as well confined spaces in non-Arctic settings such as lifeboats in open ocean conditions and the mining industry. Such literature will provide the team with a better understanding of the risks associated with exposure to confined spaces and ventilation needs, as well as the physiological requirements for human habitation in such spaces and methods for reliable data collection.

Without a thorough review of literature, the team runs the risk of duplicating research that has already been conducted rather than advancing the current state-of-the-art. Given the cost of performing field research in the Arctic, as well as the logistical challenges associated, it is important that trials not waste time or resources in repeating what is already known and understood.

Test Location and Support Ship

The selection of a test location should be based on the needs of the research plan so that the research questions can be answered but also the logistics of mobilizing the research team and equipment. The location should be accessible and capable of providing the conditions needed for the research planned. The location should be chosen so that alternate sites can be easily reached if the primary location becomes unsafe or unavailable. The test location should be chosen so that it is reasonably proximate to the departure port, if possible.

Ship time, if by paid charter, can be expensive so the support ship must be chosen so that it meets the minimum team and research requirements. It should provide all the necessary protection from the environment, as well as appropriate meeting space, laboratory space and workshop space. The ship should have appropriate launch and recovery areas for when the team is away from the ship and the Captain and crew should have experience in executing the operational expectations of the research plan. Given the high cost of ship time (whether it is by paid charter or provided to the project as in-kind), it is quite important that the research plan be executed as efficiently as possible to avoid the risk of not completing the critical tasks.

Data Acquisition

Following identification of the research questions and a review of the background literature, a detailed data acquisition plan should be developed. The data acquisition plan will identify:

1. *The specific parameters to be measured*, which can be categorized, for instance, according to environmental parameters, engineering performance parameters and human performance parameters.
2. *The sensors or data sources to be used for measuring the parameters identified*, which can include data collection installations that are already available (such as weather reports) or which can be paid for by subscription (environmental data collection operated by private or public organizations), as well as sensors that are procured or already owned by the research team. This could include load cells, physiological measurement devices and air quality monitoring devices. The data acquisition plan should be specific in identifying the make and model of the device and background information should be well understood about operation, installation and retrieval of data before entering the field. Any specially-required setups or installations required (e.g. additional battery power or setup inside waterproof cases) should be carried-out before entering the field.
3. *The frequency of sampling required* will depend on what is needed to answer the research questions identified. Sampling frequency should be carefully chosen based on the nature of the parameter to be measured and so that a reasonable balance is found between the minimum of what is needed and excessive amounts of data. Sampling frequency should also consider the nature of the data source and any frequency-based biases that might affect the reliability of measurements made.
4. *The method of logging data*, which needs to determined based on the environment in which it is being collected and whether electronic logging means are available or if data will be manually recorded from non-logging instruments. If the latter, the person writing the manual record should have a clear understanding of the data required and the parameters to be written. He/she should also be equipped with devices that will actually work in Artic maritime settings (e.g. waterproof paper, pen/pencil that will not freeze or be affected by moisture).
5. *Environmental effects on the equipment being used* is quite an important consideration in harsh Artic settings, given the possibility of damage to equipment, as well as battery life issues for sensors exposed to cold conditions. In addition, ice accumulation and exposure to water must be considered as they relate to waterproofness of equipment and potential for

development of condensation inside cases moving from warm, humid environments to the cold (for instance, the installation of desiccant packages inside equipment cases)

The above considerations should always be supported by a hand-written log by a designated member or members of the research team, for the different areas of operation. It is also very important that data collected be assessed at stages throughout the project execution in order to determine if any bias is present in the collection methods but also to ensure that the data required is actually being collected and that collection methods are working as expected.

- Research Team

Based on the research questions asked and the background literature review, the research team should work together to develop a detailed research plan. The team should be capable of working together for long periods without inter-team conflict and complement each others' skill sets as much as possible. The research should also have some built-in redundancy in certain key areas in the event that individuals in these positions become ill or unavailable to perform required duties. The research team in the field should have regular meetings to brief everyone of the plan for each activity, as well as regular debriefings to present data collected and discuss any issues experienced or observed. The sub-sections that follow outline (a) the skill sets typically required for Arctic field research and (b) the key roles and responsibilities for the different team members.

- Required Skill Sets

In additional to the ship's officers and crew who perform a wide range of important duties to ensure the ship and all on-board are safe and capable of collecting data (including protection from any dangerous wildlife that may be encountered in the field, such as polar bears), the following skill-sets are required to successfully execute field research in maritime Arctic settings:

- *Scientific expertise:* to ensure the research activities meet with the range of scientific requirements of the project and that decisions can be made in the field about these scientific needs. One or more individuals with a strong understanding of research methods and detailed knowledge of the research questions and research plan can fill this role.
- *Project management:* to ensure research activities are carried-out in accordance with the project requirements so that the project objectives are met and in accordance with established schedules.
- *Electronics expertise:* to ensure that during field work, the operations and maintenance support is in place so that all equipment is operating as it should and can be repaired at sea if the need arises.
- *Field trials experience:* to ensure that the team has an understanding of the physical, regulatory, shipboard and Arctic environment and the risks associated with working and conducting research in this region.
- *Analysis of data:* to ensure the team can undertake basic analysis of datasets collected each day of testing so that equipment or methodological problems can be corrected as soon as they are detected.
- *HSE in Arctic maritime settings:* to ensure the team can adequately assesses the risks associated with performing research trials at sea and in the Arctic and mitigate these risks to work safely. Where relevant, this should also include at least one individual with medical training to be able assess and support the research team and any human subjects in the event of illness or injury.
- *Operations and technical support:* to ensure the team is capable of preparing and deploying equipment for testing and retrieving the equipment when testing is complete.

Roles and Responsibilities

The roles of each individual team member involved in the trials should be clearly identified so that all involved have an understanding of what is expected of them during the execution of the research plan both in preparation for departure as well and when in the field. This should include, at a minimum:

- Name of the individual
- Representing organization
- Contact information (email and phone)
- Primary and any secondary or tertiary roles
- List of specific responsibilities for the different aspects of the research plan and operations/data collection
- Individuals supporting from shore, if required

Equipment

An important part of the planning process includes identifying the equipment which should be brought to the field. This includes all data acquisition equipment, as identified in Section o and any required spares or components for maintenance and repairs in the field. The equipment also includes any devices or assets that tests are to be performed on (e.g. lifeboats, liferafts, personal protective equipment), as well as any required safety equipment. The required amount of equipment in each category and whether equipment identified is already owned, must be procured or if it is to be borrowed from a collaborating institution or manufacturer. In addition, it should be clear who will supply the equipment and how it will reach the ship prior to departure. For large or valuable items, it is important that shipping costs be considered, along with any customs or duty charges that may arise and insurance in case of damage or loss. A backup plan should be in place for delicate or critical equipment in case it becomes damaged or lost during transit so that the field work can still take place if this happens. Given the remoteness of the Arctic region, it is important that shipping of equipment be considered early in the planning process.

Hazard Assessment and Mitigation

Given the risks associated with operating in the Arctic region, a detailed hazard assessment should be carried-out prior to entering the field. This should identify the main hazards associated with the different research activities planned, their likelihood of occurrence, the impact on personnel and the environment and control measures to mitigate the hazards.

Education requirements for the different roles and responsibilities of team members should be identified and if additional training is required, this should be provided at an appropriate time either before departing for the field or as soon as possible when on-board the vessel. A procedure should be established for reporting hazards not previously identified, along with accident/incident reporting methods and investigation of incidents, if required.

A safe job analysis should be carried-out before entering the field and control measures established for controlling hazards identified for the different activities and areas of work. Safe work procedures should be developed and discussed so that the team is fully aware of and complies with the minimum personal protective equipment requirements for field operations. Tool box talks should be held as part of the regular briefings to remind the team of the hazards and the control measures put in place.

If research is to be conducted with human participants, ethical considerations must be made that allow the volunteers to provide informed consent to participate in the trials and to remove themselves from the exercise without negative consequence. In addition, protection of personal information collected (including video and photographs) should be well planned and explained to volunteers.

Finally, as with all field work on-board ships the Captain has ultimate responsibility for the safety and protection of his/her officers, crew supernumeraries (research team) on-board, the ship and the environment in which the ship is operating. As such, it must be understood that the Captain has the authority to stop any activity at any point and for any reason, regardless of the needs of the research team.

- Environmental Considerations

The remote Arctic environment can present challenges for human activities and operation of equipment, but also for clean-up of pollution of any type. The preceding sections have identified operational issues and challenges related to operations in the Arctic environment. It should be well understood by the project team that Arctic environmental conditions can be unpredictable. As such, the research team should plan trials that consider the **typical** or historical conditions for the time of year in their operational location. The research plan should also consult regularly the local weather forecasts for the planned test time and area of operation, as well as reports from other vessels in the region. With this approach, the team should be able to plan for the required data collection activities so that the conditions are what is needed but also so that the team remains safe when in the field or away from the ship.

Consideration must also be given to the development of a research plan for Arctic maritime field work so that the environment is not polluted or harmed in any way. This should include release of pollutants or loss of research equipment, particularly for equipment that may release dangerous chemicals or compounds if damaged or lost but also release of fuel oil or other contaminants to the air, ground, ice or water in the Arctic. A wide range of regulations exist to prevent such occurrences but due care from the research team must be part of all aspects of the research plan when developed, as well as the regular team briefings and debriefings.

- Detailed Trials Plan and Procedures

For Arctic field research programmes, the research team lead should take the time to develop a detailed research plan and procedures that consider the sections presented above. The plan should present a field schedule which outlines the required information and tasks that should be undertaken in the following time categories:

1. *Months before the field work dates:* should include long-term or big-picture plans and activities that require more time to complete, such as:
   a. Procurement and setup of equipment
   b. Establishing the team and communications with individuals in key roles (such as the ship's Captain)
   c. Determination of any rules and regulations that must be followed
   d. Understanding the implications of shipping equipment, insurance and customs/duty charges and processing times
   e. Hazard identification and mitigation planning
2. *Weeks before the field work dates:* should include medium-term planning and preparation activities such as:
   a. Final shake-down of any equipment in a 'near-field' setting so that adjustments can be made if necessary
   b. Confirm the availability of team members and ensure all have the necessary training to be in the field
3. *Days before the field work dates*: should deal with the final preparations for boarding the ship and entering the field, such as:
   a. Knowing the precise boarding location and arrival times for the research team

   b. Receiving all equipment and ensuring it is on-board the ship
   c. Adjusting the field plan for any last-minute unexpected issues that arise
4. *During the in-field activities:* should be well-defined from the sections described above and will provide a clear plan for the trial activities when the ship is in the field, such as:
   a. What and when different activities will take place
   b. Who will be involved in the different activities and where they will take place
   c. How the research data collection will occur
5. *Days after the trials have been completed:* should provide the team with details on what will happen in the days immediately following the team's return to port, such as:
   a. How and when equipment and supplies will be returned
   b. Disembarkation of the research team and return home
   c. Data backup and distribution to relevant team members
   d. Outlining who will perform analysis and prepare different sections of the report and the associated deadlines
6. *Weeks and Months after the trials:* should clearly outline the plan for data analysis and report generation, such as
   a. Identification of any issues or problems experienced during the trials that require remedial actions
   b. Dates for team meetings/conference calls to discuss progress, identify challenges or issues experienced and to discuss interesting or unusual findings in the data
   c. Future plans for the research, documentation produced, dissemination activities and future field trials.

Conclusions

This short report outlines the wide range of activities that require consideration when conducting Arctic maritime field trials. The details presented are based on the author's experience from previous maritime-based field work that is relevant for the type of activities carried-out during this project. While details are provided here in terms of planning and scheduling of field work in the Arctic, it should be recognized that for any field exercises, there may be additional or fewer plan requirements, depending on the nature of what is being planned. The sections provided are meant to give an overview of the necessary areas of consideration.

The importance of having a detailed research plan is clear. The plan should define the research questions, provide a review of the available relevant literature, give a detailed plan of the equipment and data acquisition requirements and methods, outline the research team skills, roles and responsibilities, provide a hazard identification and mitigation plan that ensures the safety of those on-board and considers the nature of the environment and the need for the team to act responsibly to prevent environmental damage in the pristine, remote Arctic. Having a detailed test plan that considers these different issues will enable the team to be most effective in answering the research questions in a safe and reliable way.

Results

a) Medical

SAREX 2: HUMAN RESPONSE OF PARTICIPANTS INVOLVED IN EVACUATION TO SURVIVAL CRAFTS IN A COLD CLIMATE ENVIRONMENT

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Introduction

The International Code for Ships Operating in Polar Waters (the Polar Code) came into effect on January 1st, 2017. These regulations, from the International Maritime Organization (IMO), state important additions to the general SOLAS regulation for ships sailing in polar waters. Key elements of the Polar Code, from a medical point of view, are:

- Rescue time will be no less than five days.
- Protective equipment shall constitute a habitable environment and enable maintenance of core temperature and prevention of frostbite.

A survival situation in polar waters will pose many challenges to the survivors:

Temperature: The low ambient air and sea water temperature in the Arctic environment, in combination with unpredictable, rapidly changing weather conditions, predisposes subjects to hypothermia and frost related injuries. Loss of function appears rapidly in cold air, and this will negatively affect the ability to perform tasks necessary for survival.

Air quality: In an enclosed space containing people, there will be a build-up of CO_2 and consumption of O_2. The amounts of produced CO_2 and consumed O_2 will depend on the metabolic rate of the individuals present[7]. In a cold climate survival situation, hypothermia can develop, and this may elicit shivering, known to increase normal metabolism up to fivefold, for as long as energy reserves are sufficient. Limits reflect requirements in a working environment and express values for shorter and longer periods. A build-up of CO_2 will rapidly affect clarity of mind and aptitude to sustain survival skills. O_2 is a lesser challenge and is easy to replenish by air intake. The need for ventilation in a cold climate survival situation must be weighed against the risk of hypothermia.

[7] Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants

Subcommittee on Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants, Committee on Toxicology, National Research Council

ISBN: 0-309-10661-3

It seems reasonable to compare air quality limits for a rescue vessel in a survival setting to those of a submarine environment, where limits are set at 10,000ppm before commencing measures to reduce CO_2 (chalk filters), with maximum levels at 20,000ppm. For O_2, minimum levels are set at 17%[8].

Water: Weight and space considerations will cause limited water availability when boarding a rescue vessel. Water is a crucial resource for maintaining vital functions over time.

Sea sickness: High seas and lack of view predispose survivors to severe sea sickness, which often causes nausea and vomiting, electrolyte disturbances and dehydration. Sea sickness also exacerbates the development of hypothermia.

Mobility: Lack of space will cause limb and back stiffness, reduced functionality and pain. The sleep cycle will be affected, and the resulting fatigue will increase the risk of error and faulty decision making.

Hunger: The lack of food will affect the survivor but, for most people, will not be critical in the first five days.

Elimination: Establishing a routine and system for the disposal of urine and feces on-board a rescue vessel is a necessity in a real situation. Protective suits are not ideal for elimination, often necessitating partial or complete doffing and causing exposure to cold. Individual privacy needs may cause an effort to retain both urine and feces, affecting hypothermia development and causing discomfort[9].

In sum, all challenges will affect the survivors at different stages, but the impact will increase and accumulate with time. Our aim was to assess, by simple function tests, vital parameters and a questionnaire, how contextual challenges affect tactile, physiological and psychological measures after up to three days in a lifeboat or life raft in an extreme polar maritime environment.

Method

The sample consisted of volunteers, joining the expedition due to personal or business-related interest in the topic, and conscripted privates serving on board the Norwegian coastguard vessel “KV Svalbard”.

The survival exercise was set up with a lifeboat carrying 24 persons and a life raft with 19 persons.

The lifeboat, produced by Nor-Safe, Norway, was certified for 55 persons and modified after experience harvested during SAR ex I in 2016. The modifications included thin isolation padding on seating areas, ventilation capacity of 400m^3/hour and an air/air heat convection unit with temperature regulation and a dehumidifier. Further, a toilet was integrated into the forward seating area, with a textile curtain to provide some privacy.

The life raft was produced by Viking Life-Saving Equipment, Denmark. The raft was a high canopy raft, certified for 25 persons, with an inflatable floor and improved stairway.

In the lifeboat, participants’ mean age was 27.6 years, median 21, range 18–61. BMI was mean 26.2, ranging from 20.9–40.9. There were five females and 19 males.

[8] Submarine regulations, Royal Norwegian Navy
[9] Essentials of Sea Survival, Frank Golden, Michael Tipton, Human Kinetics, 2002, ISBN 0736002154

The participants in the life raft had a mean age of 40.0 years, range 21–59. BMI was mean 26.6, ranging from 21.2 to 32. There was one female and 18 males. All individuals were without current health concerns.

The overall limitation was the absolute safety of the participants, causing extraction from the exercise of any individuals showing significant objective affection by any of the named challenges above and, specifically, affection of fine motor skills, presence of uncontrolled shivering and reduced cognitive skills.

Skill tests

Throughout the survival exercise, the participants were tested using three different skill tests.

1. Penny transfer test. This is a fine motor skills test, extracted from the "Bruininks-Oseretsky Test of Motor Proficiency, Second Edition"[10]. The task was to move pennies from a board with one hand, transferring them into the other hand before dropping them into a cup. The participants were given 20 coins and 20 seconds to fulfill the task.
2. Grip strength. This test evaluates gross motor skills, by using a Baseline hydraulic hand dynamometer, recording the best result of three attempts on each hand in kg.
3. Subtraction test. This was performed to evaluate cognitive skills by subtracting sevens from one hundred to zero, with no time limit. The outcome was either complete or incomplete.

The hypothesis was that cold temperature and lack of sleep, water and food would impair the participants' functional level with regard to fine- and gross motor as well as cognitive skills. The tests were performed before the survival exercise, every 12 hours during the exercise and at the end of the exercise (end ex). The skill test results were interpreted by estimating a linear trend of the data from each skill test. Thus, a negative value ($a=\frac{\Delta y}{\Delta x}$) of the collected data from each participant and test (y) versus time (x) would be characterized as a negative trend.

Subjective reporting

The participants also reported subjective scores on seven different factors believed to impact on the ability to survive. This was performed four times throughout the exercise. The scores were reported on a numerical rating scale, with scores ranging from 1 to 10: with 10 indicating that the participant was most affected by the factor, and 1 least affected. The scores were subdivided into mild (1–3), moderate (4–6) or severe (7–10) affection by the factor[11]. The factors assessed were cold sensation, fatigue, hunger, thirst, discomfort, positivity and nausea. Assessments of these factors are not previously referenced, but they are thought to have a negative effect on chances of survival[12].

Vital parameters

The participants´ vital parameters were mapped, monitoring epitympanic temperature, oxygen saturation (SpO_2) and heart rate, before the exercise, every six hours during the exercise and after

[10] Res Dev Disabil. 2015 Jun-Jul;41-42:40-51. A review of five tests to identify motor coordination difficulties in young adults. Hands B et al.

[11] Boonstra AM, Stewart RE, Köke AJA, et al. Cut-Off Points for Mild, Moderate, and Severe Pain on the Numeric Rating Scale for Pain in Patients with Chronic Musculoskeletal Pain: Variability and Influence of Sex and Catastrophizing. *Frontiers in Psychology*. 2016;7:1466. doi:10.3389/fpsyg.2016.01466.

[12] Essentials of Sea Survival, Frank Golden, Michael Tipton, Human Kinetics, 2002, ISBN 0736002154

the exercise. Blood pressure was only measured before and after the exercise. The participants´ bodyweight, wearing one layer of wool underwear, was documented before and after the exercise.

Results

Skill tests were performed as planned throughout the exercise. The results show that the skill tests generally improved throughout the exercise. There was little difference between participants in the two vessels, both in average and range. There was a general positive trend of average for both vessels. We observe that more than one third of the participants trended negatively on one or more of the skill tests during the survival exercise (Fig. 1). The results from the skill tests seemed to be unaffected by type of vessel (Fig. 2) We note that, despite ideal conditions, after one day, more than one third of the participants already showed a negative trend in the performance in skill tests affecting motor functionality. The results from the subtraction test showed a positive trend in both vessels.

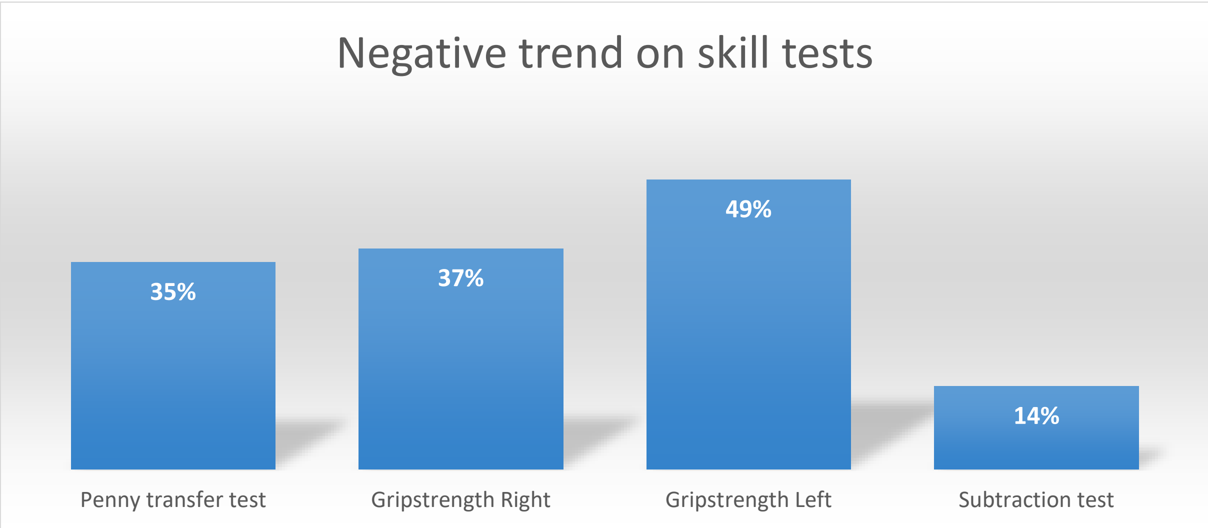


Fig. 1. Bar chart showing percentage of participants with negative trend in skill tests throughout the exercise.

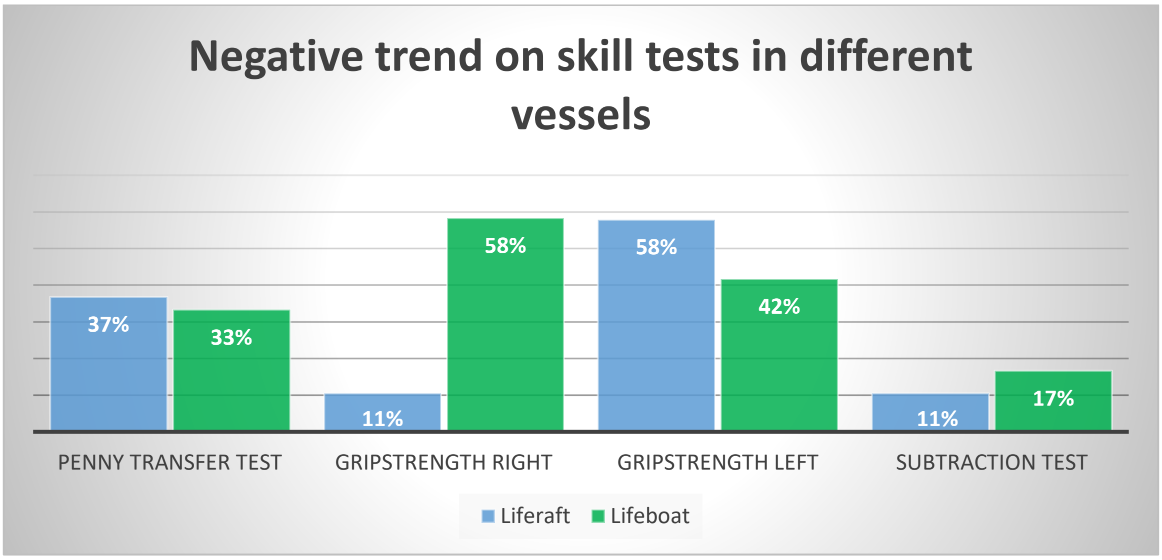


Fig. 2. Bar chart showing percentage of participants in each vessel, with negative trend in skill tests throughout the exercise

Subjective scoring on numerical rating scale

Subjective scoring on seven factors affecting survival ability was performed four times throughout the exercise: at baseline, after six and 18 hours and at the end of the exercise. There were few extreme values but, nevertheless, a finding of a higher percentage of negative trends in the life raft compared to the lifeboat (Fig. 3). The findings are illustrative of many important differences between the two vessels.

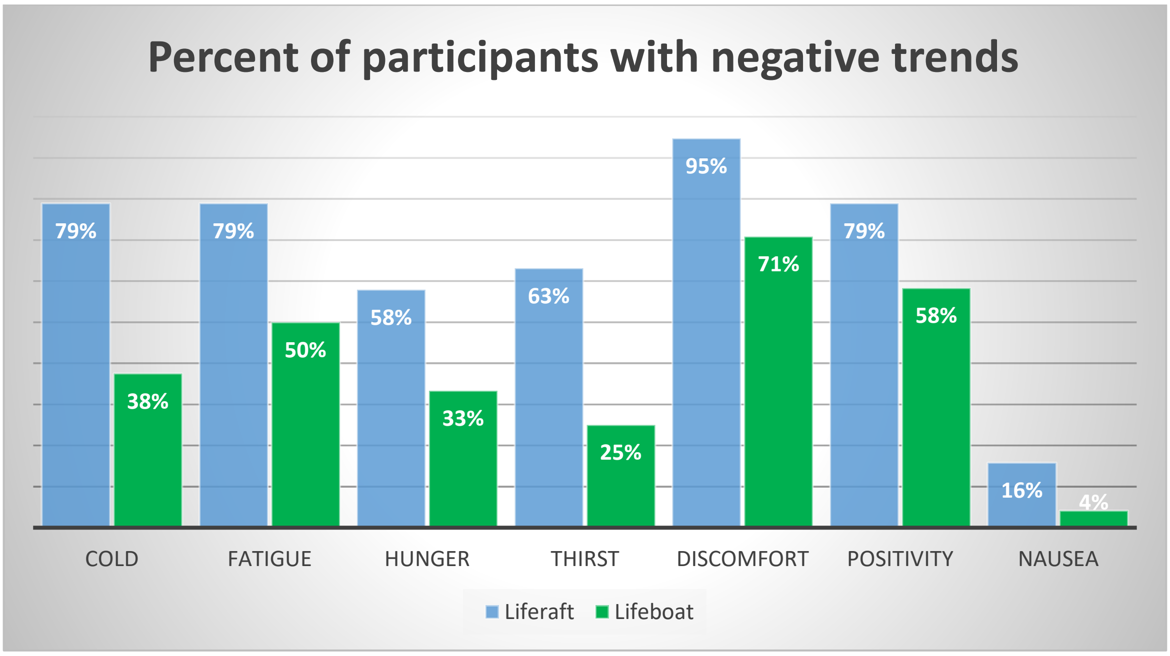


Fig. 3. Percentage of participants in each vessel with negative trend in self-reporting NRS-form, scoring seven factors influencing survival throughout the exercise. Life raft participants trend more negatively than lifeboat participants in all factors.

Cold sensation

The general perception during the exercise was that cold was almost eliminated as a problem in the lifeboat. With heating, temperature regulation and sufficient ventilation capacity for the 24 persons on board, the internal environment seemed well controlled. Looking at the subjective scores, the distribution during the exercise is informative. At the beginning of the exercise, subjective scores revealed no or only mild cold sensation, but the shift towards the right is obvious (Fig. 4). In the life raft, at 18 hours, 47% of the participants experienced moderate cold sensation, while one participant was already experiencing severe cold. At the end of the exercise, 57% of those in the life raft experienced moderate cold sensation and 21% severe cold sensation. The distribution for those in the lifeboat is less severe, with only three (12.5%) participants exceeding mild cold sensation at 18 hours and at the end of the exercise. The score of one of the three indicated severe cold sensation.

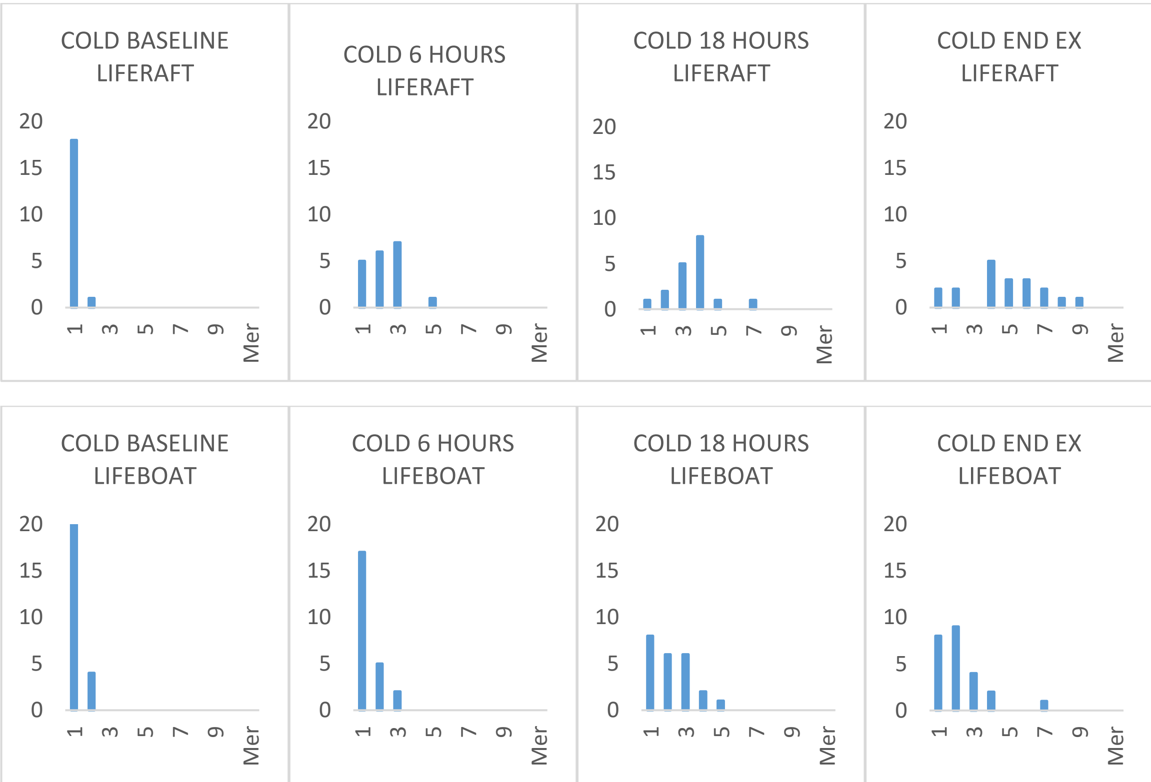


Fig. 4. Subjective scores on cold sensation, reported by participants throughout the exercise, from baseline to end of exercise (end ex), show a clear distribution from mild (1–3) to moderate (4–6) and severe (7–10) cold sensation in the life raft. The participants in the lifeboat experienced far less cold sensation, but the tendency in this group to shift to the right should not be ignored.

Fatigue

All life raft participants started off scoring mild fatigue, and there is a clear shift toward the right in the following hours (Fig. 5). Moderate fatigue is scored by 16% at six hours, 39% at 18 hours and 47% at the end of the exercise. At 18 hours, the first participants score severe fatigue (11%); this number persists until the end of the exercise.

In the lifeboat, the participants started off with greater fatigue from the offset. On baseline scores, eight (33%) of the participants report moderate fatigue, and the distribution continues shifting to the right throughout the exercise. Moderate fatigue is scored by 33% at six hours, 39% at 18 hours and 42% at the end of the exercise. One participant scores severe fatigue at six hours, five participants score severe fatigue at 18 hours and at the end of the exercise. When the eight participants scoring moderate fatigue at the baseline are analyzed, only three of them have a negative trend for fatigue throughout the exercise.

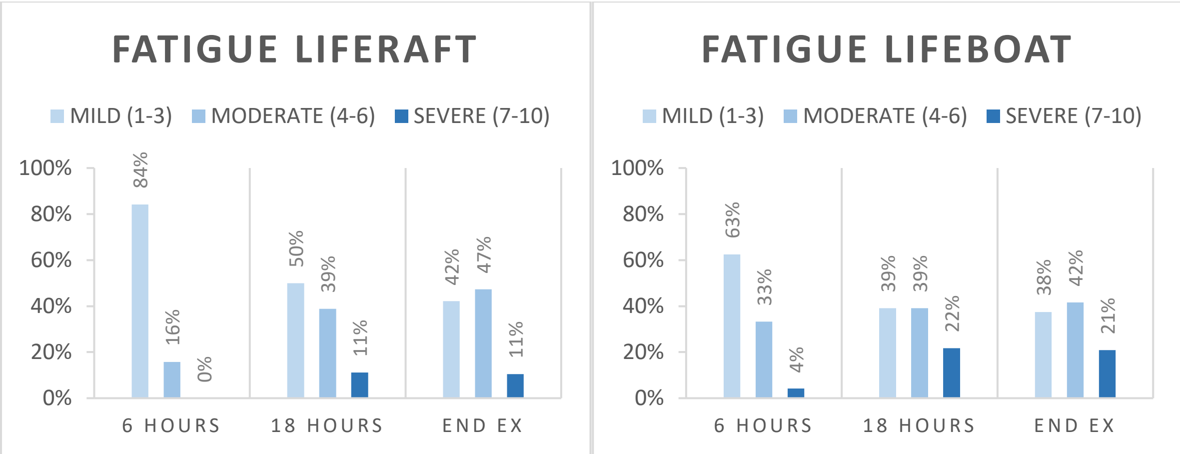


Fig. 5. Percentage of participants in each vessel scoring mild (1–3), moderate (4–6) or severe (7–10) fatigue throughout the exercise. The bar chart shows the distribution of fatigue intensity throughout the exercise.

Thirst and hunger

Thirst and hunger were also perceived differently in the two vessels, with an earlier right shift of scores in the life raft (Fig. 6). The distribution of thirst intensity in the raft is very gradual, with mild thirst being scored by 84% at six hours, by 63% at 18 hours and by 53% at the end of the exercise. Moderate thirst is experienced by 16% at six hours, by 26% at 18 hours and by 37% at the end of the exercise. Severe thirst is experienced by 11% of the participants at the end of the exercise. The distribution pattern is more irregular in the lifeboat, but the results at the end of the exercise are similar. Also note the average thirst scores in Fig. 7, where the life raft average is increasing more than in the lifeboat.

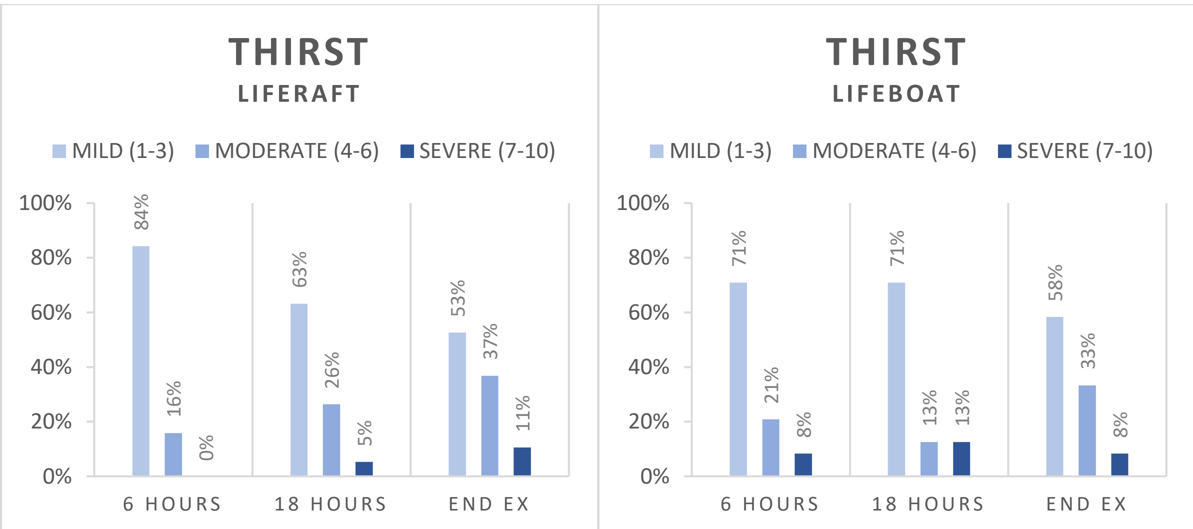


Fig. 6. Percentage of participants in each vessel scoring mild (1–3), moderate (4–6) or

severe (7–10) thirst throughout the exercise. Observe an earlier distribution in the life raft, before both groups show a similar distribution at the end of the exercise (end ex).

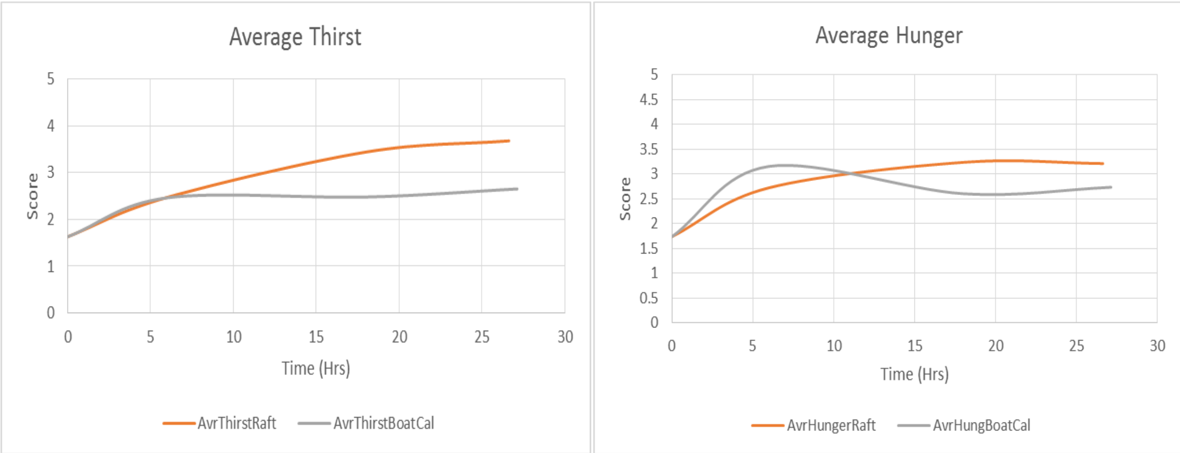


Fig. 7. Averaged NRS-scores on hunger and thirst, comparing participants' scores in the two vessels (K. E. Solberg).

Discomfort

It might seem odd to evaluate discomfort in a survival setting. We believe that discomfort will be ignored in the initial phases of a real survival situation, but it is evident that discomfort will also become an issue, negatively influencing the ability to survive, and adding negative stress, in a real situation. From Fig. 8 we see that discomfort was an issue in both vessels. More life raft participants show a negative trend, but, as can be observed from the scores, the lifeboat participants experience more discomfort. At six hours 25% score moderate discomfort, while 17% score severe discomfort. In comparison, the life raft participants score 21% moderate and 0% severe discomfort at six hours. At 18 hours, the figures are 38% moderate and 25% severe discomfort in the lifeboat, and 37% moderate and 11% severe for the life raft. At the end of the exercise, 46% of "lifeboaters" score moderate and 21% severe discomfort, while the life rafters score 53% moderate and 16% severe.

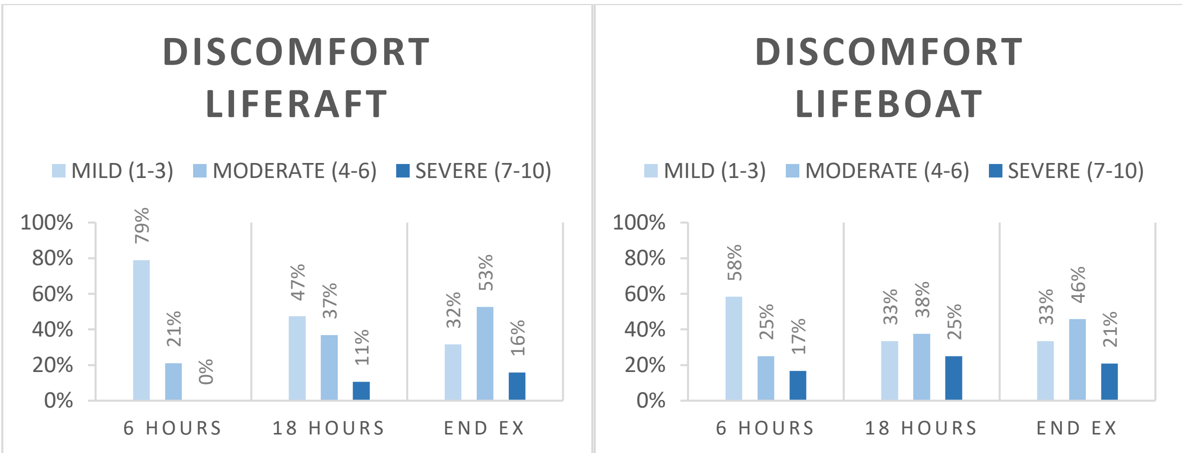


Fig. 8. Percentage of participants in each vessel scoring mild (1–3), moderate (4–6) or severe (7–10) discomfort throughout the exercise.

Positivity

Positivity was scored on the same NRS-form, but the scale was inverted; in other words, far right scores indicated more positivity. This confused some of the participants and has made it difficult to interpret the scores with high reliability. With obvious or declared reverse reporting, the numbers were corrected to inverted scores. The results show a more apparent negative trend in the life raft (Fig. 9).

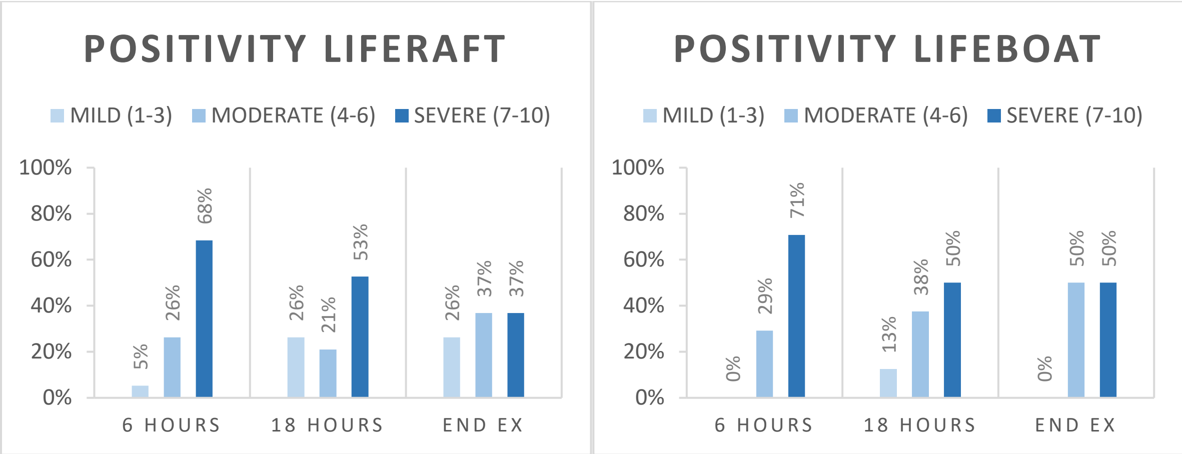


Fig. 9. Percentage of participants in each vessel scoring mild (1–3), moderate (4–6) or severe (7–10) positivity throughout the exercise. Note the left shift indicates negative development in this chart, as opposed to the right shift in the other charts.

Nausea

Nausea turned out to be a minor problem for the participants throughout the exercise. Only one participant in the raft and one participant in the lifeboat reported moderate nausea toward the end of the exercise.

Physiological parameters

When the measured physiological parameters are examined (Fig. 10), the results indicate a minor difference between the two vessels. Both groups seem to experience a rise in heart rate after commencing the exercise. This response is far less than would be expected to be observed in a real-life event, but every participant expects some degree of discomfort during this exercise, and this increased heart rate may illustrate this. The next heart rate measurements reflect the activity level in the two vessels. There are more tasks and planned activity in the lifeboat, whereas in the life raft the activity level reflects attempts to conserve energy. During the night, it seems that the life raft participants could relax more, illustrated in a marked collective lowering of the heart rate. The following morning, on waking, they experienced increased cold sensation and discomfort. Some of the participants describe difficulties in regaining a comfortable temperature. There was little effort made to increase activity to produce heat.

Epitympanic temperature was measured throughout the exercise but, due to equipment failure, measurements at the scene were discarded. Ear temperature in the life rafters is markedly lower than in the “lifeboaters” at the end of the exercise. This supports the subjective reports on the numeric rating scale on cold sensation, where the life raft participants score markedly higher on cold sensation than their lifeboat counterparts. There is also a slight decrease in ear temperature in the lifeboat participants.

Blood pressure was measured before and after the survival exercise; again, there is a difference between vessels: the systolic blood pressure seems higher and more spread in the lifeboat participants at the end of the exercise, compared to baseline values.

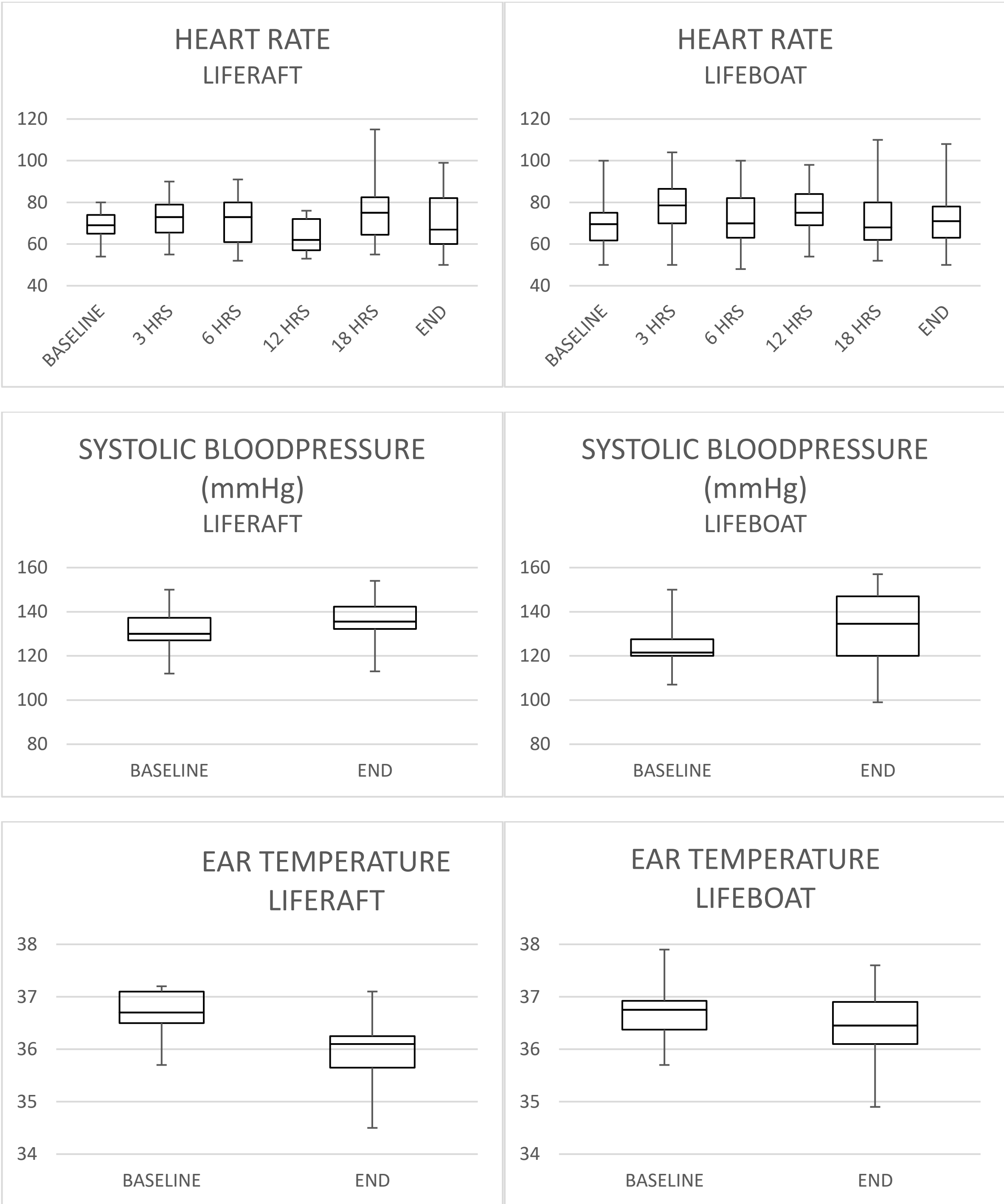


Fig. 10. Box plots showing quartile distribution of vital parameters throughout the exercise, comparing participants in the two vessels.

Tempus Pro

Two participants were equipped with a patient monitor (Tempus Pro monitor by Remote Diagnostics Technologies Ltd.), set to perform longitudinal monitoring of vital parameters throughout the exercise. We were interested in seeing this monitor in use in a polar climate, to assess the usefulness and eventual limitations in a cold, moist and challenging environment on board a life raft. We extend our gratitude to the logistics branch of the Norwegian Army (FLO) for their loan of this equipment.

Both participants were placed in the life raft for comparability, with the Tempus Pro monitor placed inside the survival suits. The monitor was set in tactical mode, to avoid alarm sounds disturbing the participants on the life raft. Non-invasive blood pressure (NIBP) measurements were set at 30/60-minute intervals to save the battery. The chords were collected and secured below the umbilicus, to avoid stretch and dislocation of the ECG leads, and the pulse oximetry probe was placed through the survival suit arm, onto the fourth finger of the non-dominant (left) hand. We were able to obtain a consistent set of data, though some of the NIBP measurements were lost due to participant position or movement.

The first profile, (Figure 11) is of a male, 56 years of age, BMI 30.2. Some desaturations are observed, the lowest reaching 89%. These episodes probably occur during sleep. The monitoring continued without interruption until the exercise was ended after 27 hours. The monitor suffered no problems in providing monitoring and data capture.

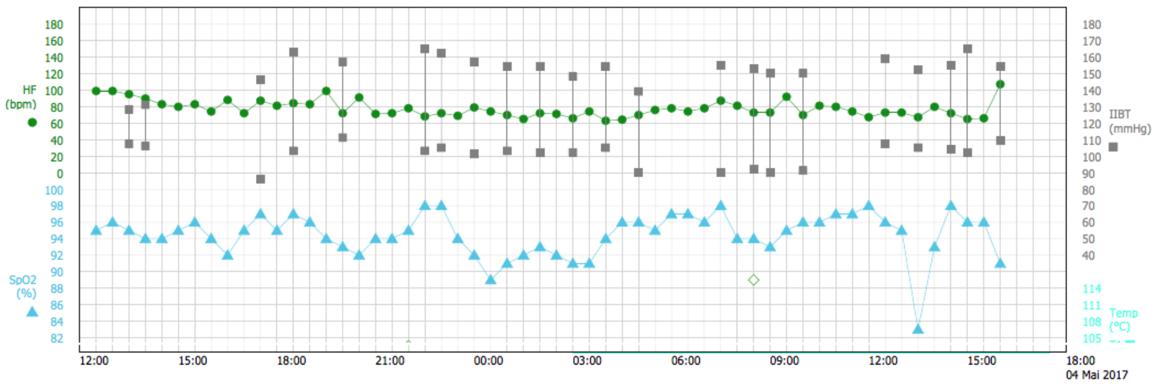


Figure 11 Patient monitor data, male 56 years old

The second profile (Figure 12) is of a male, 21 years old, BMI 22.6. The NIBP interval was set at one hour. Here we observe a nearly complete set of data. There is a reduction in heart rate, with some reactive increases, most evident after 05:00, when the participant is woken up for vital parameter measurements. The drops in saturation are artifacts, caused by removing the saturation probe from the finger. The monitoring was stopped when the participant left the life raft after 23 hours due to hypothermia and lack of motivation.

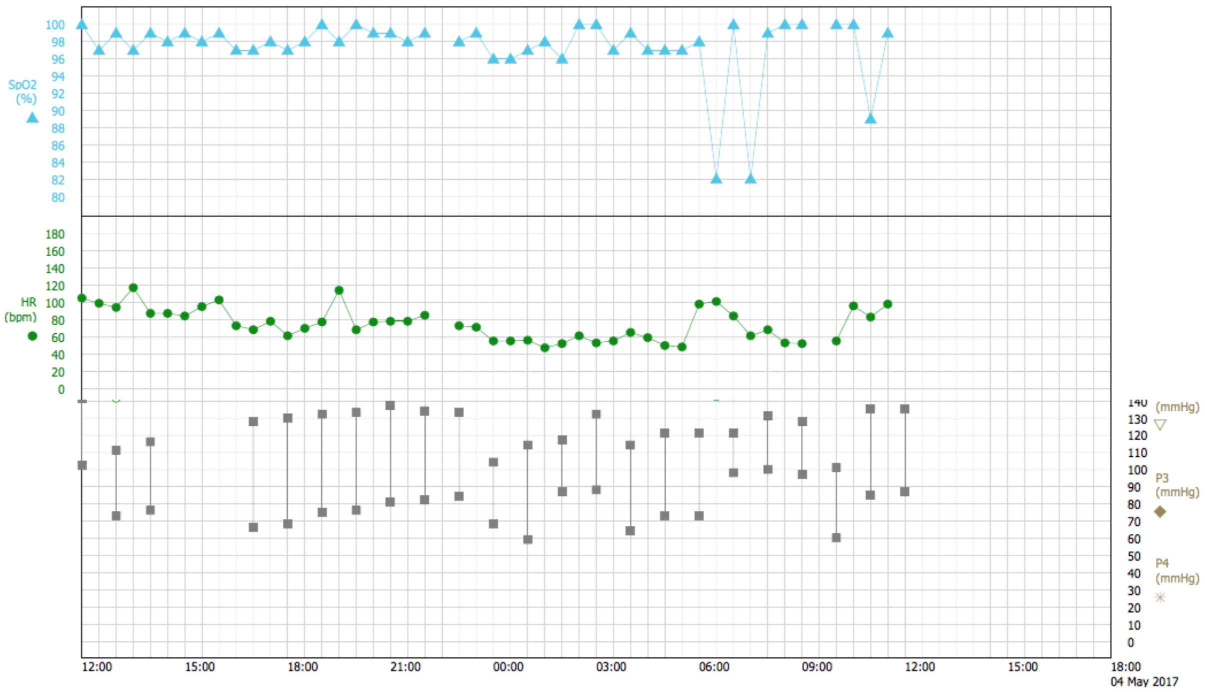
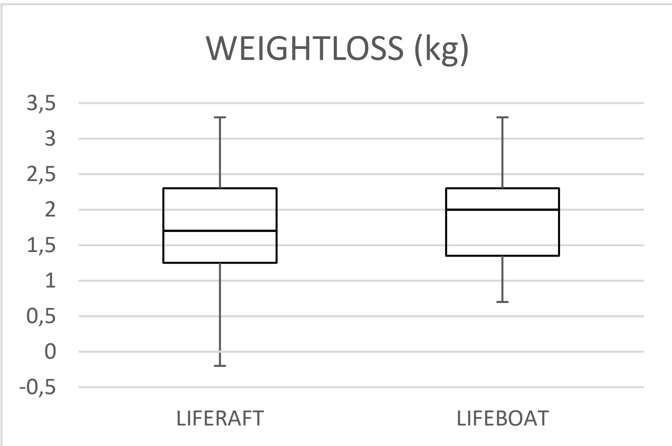


Figure 12 Patient monitor data, male 21 years old

Weight loss

The participants weighed in just before donning the survival suits, wearing one layer of clothes. They were again weighed when returning to "KV Svalbard", wearing the same one layer. The mean weight loss for the life rafters was 1.8 kg, ranging from 3.6 to -0.2 kg, opposed to 2.0 kg, ranging from 3.5 to 0.7 kg, for the "lifeboaters" (Figure 13) Factors affecting weight loss are intake of food and water, elimination, sweating and other insensible water losses. We were surprised to see the magnitude of the weight loss in such a short time, but we choose to see it as a reminder of the necessity for adequate amounts of drinking water in a survival situation in polar waters.

Fig. 13. Box plots showing the quartile distribution of all participants' weight loss throughout the exercise.



Comparison between the participants in both vessels.

A deviation from the optimal scenario

One individual had noticeably worse subjective report parameters throughout the survival exercise: cold reached a score of 9, fatigue 7, thirst and discomfort 8 at the end of the exercise. In addition, his fine motor skills were negatively affected. It was necessary to investigate this case further. It was quickly discovered that this person had been unlucky and damaged his survival suit. This subject matched the scheme with the highest scores on the NRS self-report schemes (Fig. 14), as well as a very negative trend in the penny transfer test, assessing fine motor skills. The defect/damage in his protective equipment allowed water to enter the suit, and, due to the high risk of hypothermia, he was extracted from the exercise 23 hours after boarding the life raft. The damaged suit negatively affected several aspects of his survivability; this serves as a reminder of how little it takes to severely decrease the probability of survival for a longer period under the conditions experienced.

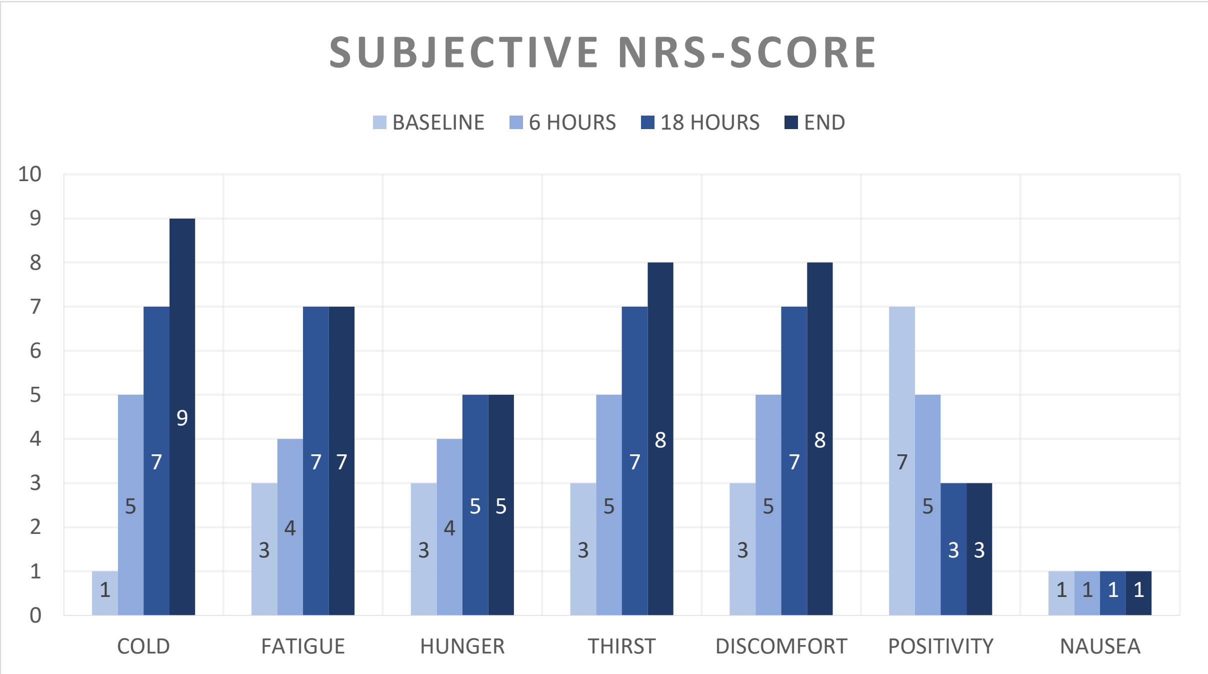


Fig. 14. The NRS-scores from participant no. 26 with a defect in his rescue suit, causing water intrusion and cooling. The increased effort necessary to cope with the challenges causes increased fatigue, thirst and discomfort. The insight into the possible consequence of the defect suit also severely affects the participant's positivity.

Discussion

Survival in cold climate areas poses substantial challenges to humans. Knowledge on factors influencing survival under these circumstances is important. There was no point creating a worst-case scenario; rather, it was important to test a close-to-ideal scenario and to evaluate whether survival for the extent of five days would be possible. The participants had no current health problems and a mean age far below that of the average cruise passenger. The participants were a mix of voluntary expedition members, in general highly motivated to participate in the exercise, and navy privates, who had a different perspective and thus a different level of motivation. As a result, for many participants, this became a waiting game rather than a pursuit of margins that would increase the chance of survival.

Three skill tests that could demonstrate loss of function during the survival exercise were introduced, but, at the same time, due to participant safety and the remote location where the exercise took place, it was stated that participants would not be allowed to be clinically affected by the elements. This introduces a difficulty in achieving convincing results in the tests performed over the time span of the exercise. However, a negative development throughout the exercise would indicate a tendency of decreased function. Such a negative trend was demonstrated in more than a third of the participants, in both vessels. This finding is a mere indication of the beginnings of a development toward reduced function, which in turn will affect ability to survive.

The skill tests used did not show an apparent loss of function during the observation period. It was expected that real hypothermia development would affect the test results and, in the absence of such results, it might be stated that the results confirm that the participants were kept in a physiologically safe range.

The subtraction test did not seem to offer any helpful indication on impaired cognitive skills, as results were highly random. In hindsight, it might have been a better idea to give a score describing the number of correct calculations from 100 towards 0.

The numerical rating-scale scores on factors influencing survival are descriptive of the development in the two vessels and demonstrate clear differences between the two environments.

The development of increasing cold sensation aboard the life raft was expected, as the temperature in the raft was lower. There was a constant need to ventilate CO_2, reducing the temperature in the raft. The only heat source was the participants themselves, and this became more evident as the number of participants was reduced throughout the exercise. The lifeboat also experienced increased cold sensation. This was surprising, as the lifeboat was equipped with a heater and controlled ventilation. The participants were instructed to sit strapped in their seats, but this was observed not to be the case, as they needed to move around a bit. The temperature toward the outer wall of the seating zone was markedly lower than toward the central seating area. Participants were not wearing survival suits, only one layer of wool underwear. It is interesting that those experiencing increasing cold sensation did not don survival suits to conserve necessary heat but rather accepted the increased cold sensation.

It is likely that the differences in environment in the two vessels explain differences in thirst. The ambient temperature in the life raft was constantly lower than in the lifeboat. The air in the lifeboat was dryer. Five participants on the lifeboat had moderate thirst at baseline score. These factors are believed to influence the thirst scores, but it is surprising that the difference already appears on the first day. On further investigation, it became clear that the commanders of the two vessels distributed the rations in different ways. The life rafters received 500ml/24 hours, the “lifeboaters” 1000ml/24 hours. Thus, the raft participants received less water and food than the participants in the lifeboat, which could explain the earlier right shift in the life raft. The lifeboat participants received all their rations at the beginning of the exercise, but there were differences as to when they consumed the rations. This was done in a more controlled way and at regular intervals in the life raft. Differences in distribution and consumption could explain the more gradual change among the life raft participants and the irregular change in the lifeboat. At the end of the exercise, both groups show a very similar distribution pattern, indicating that both groups would need more generous water rations, to increase the chance of survival over a minimum period of five days.

Findings on discomfort were also unexpected. It was expected that the life raft would be the less comfortable vessel, but the participants in the lifeboat scored more intense discomfort throughout the exercise. The debrief session made it clear that multiple factors contributed to discomfort in each vessel. In the lifeboat, the hard seating and lack of spaces to lie down caused back pain and unease. The only relief was to stand up every now and then. Most participants in the lifeboat experienced headaches and felt unwell after the exercise, for unknown reasons. In the life raft, the main factors causing discomfort were low ambient temperature, humid air, wet floor, waves and lack of space to move.

When it comes to fatigue, the two groups had different offsets. Eight of the lifeboat participants already scored moderate fatigue in the baseline report. Fifteen of the lifeboat participants were conscripted privates serving on “KV Svalbard” and, being part of a duty schedule on the ship, this may have affected the offset fatigue levels. Discomfort also influences fatigue and may explain the higher scores in the lifeboat group. The reason why fewer participants on-board the lifeboat experienced a negative trend in fatigue may be due to the duty rotation, formed in the lifeboat soon after the exercise started. This structured rotation allowed three participants to sleep for three hours at a time. There was no similar duty structure on board the life raft, where most participants were relaxing most of the time. It is also probable that the inflated structures on the life raft allowed more comfortable relaxation than the harder seating areas in the lifeboat.

All participants were given tablets containing 25 mg meclozin (Postafen™) to prevent seasickness. This is standard equipment in rescue kits for sea survival. The pills were given one hour before the exercise started and were administered every 12 hours on board the vessels. This preventive measure, as well as quite calm sea conditions, made nausea an ignorable factor in our exercise. There are reasons to believe that nausea will be an important factor affecting survival in rougher sea conditions.

Conclusion

Survival in a cold climate environment is a very challenging endeavor, influenced by many factors. SAR ex 1 and SAR ex 2 have carried out observations in the very environment in which the rules of the Polar Code apply. After one day in a survival craft, the participants were already showing symptoms and signs caused by exposure to the elements. The survival exercise was ended after 27–30 hours. It seems very unlikely that all participants would have been able to survive for an additional four days inside the survival craft, with the personal protective equipment and rations provided, despite the exercise having been performed with healthy, relatively young individuals under quite optimal conditions.

This leaves little doubt that survival for five days in a cold climate environment would be an extremely challenging endeavor when utilizing the equipment provided in this exercise.

It seems vital to provide increased insulation of vessels, heating capability and controlled ventilation. In addition, more generous water supplies in the rations, and the creation of greater space in which to move around by reducing certified capacity in each rescue vessel, would contribute to increased probability of survival.

SOME REMARKS TO ARCTIC SURVIVAL

Milan Cermack, MD, Newfoundland, Canada

Summary
In the last two centuries the ethnic profile of permanent and temporary circumpolar inhabitants changed significantly and their lifestyle shifted from an efficient utilization of on-site resources to almost complete reliance on outside support and on artificial infrastructure. The humans historically developed as hot to moderate climate dwellers; their direct physiological mechanisms of adaptation to severe cold are only poorly developed and their capability to cope with accidental hypothermia is very limited. Well-functioning assistance structures are currently required to support the human presence in the extreme Polar Regions and some of the important factors in the survivability of accidental exposure in these environments are briefly discussed below.

The conditions

1. Exposed populations

Physical and mental capabilities of present urban populations to live unassisted in any natural environment are very limited. An accidental, or even planed exposure to polar environment bears several risks, but no universal recipe for “Arctic survival” exists, because the geographical conditions and circumstances of exposure can vary significantly. The potentially exposed individuals can be classified as:

Permanent residents, indigenous and non-indigenous, with variable degree of knowledge and experience with the polar environments, with different lifestyles and behavioral responses to the same situation

Professional industrial groups on land and at sea, typically oil and gas exploration and extraction, fishing, commercial sea and land transport, military and research. This is the most rapidly growing segment of circumpolar dwellers. Safety preparatory courses (albeit at sometimes very different levels) are usually a prerequisite for all personnel, the survival equipment is often, but not always, regulated by law and the individuals passed through, at least a rudimentary, medical screening.

Tourism and sport activities; this group encompasses the whole spectrum between very fit and trained individuals on adventure trips (Greenland crossing, South Pole, High Arctic) and tourists on South and North polar cruises who have no previous polar experience or training at all. While the “serious adventurers” are better prepared to cope with the environment, are usually required to be equipped with means of emergency assistance and to prove some knowledge and experience to obtain expedition permits, the totally unprepared leisure tourism groups remains the main concern with regard to survival strategies and rescue and recovery assistance.

Air transport, crew and passengers on freight, military, research and airline flights. Several nonlethal crashes in the Polar Regions happened in the past and an emergency landing of a large aircraft on the interior icecaps of Arctic islands would be technically possible. Such scenario might result in large number of survivors, many of them possibly seriously injured, all of them completely unprepared and almost totally unprotected. In any of these groups, the survivability will essentially depend on the following factors:

2. Type of environmental exposure

Which may be classified by

• the medium as wet with total or partial immersion, dry, or combination thereof

• the ambient temperature as extremely cold (less than -35 C, often with added wind chill factor e.g. interior plateaus of Greenland and Antarctica or winter in north Asian mainland), cold (approx. -25C to -5C, e.g. Arctic spring) moderate cold, (around and above 0C, summer circumpolar shipping or tours in Canadian Arctic Archipelago)

• the total duration of exposure as short, minutes and hours and long, days and weeks

• the onset of exposure as sudden e.g. accidental immersion, gradual, e.g. dry exposure on the ice floe, or slow, e.g. exhaustion on several-weeks lasting ski trip
• the season, with influence on weather patterns, temperature and length of daylight
• the geographical location surface characteristics, with extremes ranging between tundra and boreal forest in the summer and Arctic Ocean or Greenland Icecap in the winter.

3. Circumstances of exposure
• following existing planed and prepared emergency scenarios, including personnel drills with survival equipment. A typical example is different EER (Evacuation, Escape and Rescue) scenarios and assisting technologies developed for Arctic oil and gas platforms. The survival strategy depends almost entirely on proper use of technology, protective equipment and adherence to emergency procedures.
• existing and agreed-upon contingency scenarios, but mostly ad hoc decisions, survival with means locally available. A typical example would be deterioration of weather conditions injury, loss of crucial equipment etc. by small exploration groups or sporting parties. The performance of the whole group would be very similar, including the physical and mental preparation for dangerous and unexpected situations.
• existing emergency scenarios, which were either never practiced before by the involved personnel in a reality e.g. emergency landing on the icecap, or done only in theory e.g. cruise ship evacuation (imagine Costa Concordia in the Arctic.) There would be a large number of unprepared individuals, with no previous experience and potentially either without or only with marginal means of protection. Their reaction to the exposure can be unpredictable and potentially detrimental to survival.

4. Logistic and other factors
• available means of outside assistance like S&R transport vehicles (air, land, sea) and accessibility of the accident sites (helicopter, fixed wing a/c, icebreaker, hovercraft, airdrop)
• experience of S&R personnel and their technical capabilities, e.g. special rescue procedures like avalanche search or crevasses rescue
• local weather conditions
• presence of additional risks, like toxic contamination in industrial accidents, or wildlife
• resources available to the survivors, e.g. food, protective garments, shelters and receiving facilities in case of mass accidents
• physical condition, experience and training of the exposed persons

The human factor
The history of early polar exploration provides many examples of failures with lethal outcomes, mostly due to accidents, insufficient preparation and lack of knowledge. Successful, long term survival in different polar environments by non-indigenous people was achieved either by mastering the art of living-of -land (J. Rae in the 19th century) or by careful preparation and organization, combined with far above average physical and mental performance in the “heroic era of polar exploration” from Nansen to Amundsen and Shackleton. The examples of modern “beyond the limits” expeditions in the 1990s are Fiennes/Stroud unsupported crossing of Antarctica and Weber/ Malakhov first unsupported North Pole return. Both were using human power only and were in the border zone of physiologically and mentally possible. The profiles of average Arctic survivors today would be quite different and the expected outcome of their interaction with the environment would be much worse.
Death by cold exposure is typically a consequence of failed thermal homeostasis and of depletion of energetic reserves on the body. Impairment or loss of manual dexterity and mobility, induced directly by cold or by frostbites, together with cold-induced irrational behavior patterns, survivable injuries, and other health issues will further reduce the survival times. In extreme cases, a cardiorespiratory

failure following unprotected immersion in very cold water "cold shock" may be a fast and direct cause of death, especially in individuals with pre-existing health problems.
Under normal circumstances, human thermoregulation is primarily achieved by two mechanisms:

A/ Behavior: Adjustment of activity, avoidance of excessive exposure and creation of microclimate by the use of shelters and protective garments. This mechanism is directly proportional to experience and knowledge, but happens also spontaneously in all animals, including humans, as natural protection mechanism against discomfort, e.g. turning away from the cold wind and into the wind if it is too hot.

B/ Physiological responses that are four, spontaneous and simple: Vasoconstriction/ dilatation for both heat and cold, heat dissipating by sweating for hot, shivering and non-shivering thermogenesis for cold. Sweating is limited by available body water, shivering by exhaustion of body glycogen.
The behavioral response is by far the most important, but should it be limited or impossible due to circumstances, the physiological responses will prevail.
Some other factors may have secondary effects, either positive or negative, like the age (worse vaso-motoric response, but better experience with increasing age) ratio of body surface area to body mass (obese better insulated with more energy storages, but less mobile than lean if mobility is necessary), the level of physical training and endurance, the psychological profile and the mental attitude to cope with the survival situation. The ethnic origin has measurable influence on cold response. In general Negro populations respond better to heat by more efficient sweating production, but are worse at producing metabolic heat by shivering. The reverse is true for Caucasian and Eskimo subjects, who are better at shivering and have also been shown to have higher metabolic rate at rest. It is important to realize that the heat generating effect of shivering in cold water is much less than conductive loss of heat due to water contact; less shivering may not be as bad at all. Polar populations also exhibit better Cold-induced Vasodilatation (CIVD) which is a paradoxical response to very cold exposure and is helpful in protection against frostbites. However, there is no evidence that repeated hand immersion in cold water systematically improves the peripheral circulation
Exposure to cold dry environment may improve the metabolic response (better heat production), but there is no evidence for beneficial effects of repeated exposure to cold water immersion. The main benefit of repeated exposures to any extreme environment is habituation, which is a reduced response or sensitivity to repeated stimuli. Therefore, indigenous populations or seasoned polar explorers may show better tolerance to cold than the average population, but the main reason is a higher tolerance threshold due to habituation and familiarity with the interaction between their bodies and the environment rather than some profoundly different physiological patterns. Another benefit of habituation is less distraction by cold -induced discomfort, which, in turn, results in more focused attention to survival tasks and in better survival outcome. The core temperature has been a standard parameter measured in research, but the skin temperature is the primary indicator of individual discomfort and, like the core and brain temperature, effects also the behavior.
Hence the importance of selection of protective garments and especially of the layer in contact with skin.
Preventive monitoring, of individual physiological parameters during professional activity in cold and risky environment is an emerging trend in Arctic occupational safety. The data, acquired by wearable sensors arrays, can be analyzed locally and remotely to keep the personnel within safe range, or to provide a status information for treatment of survivors in an emergency. The feasibility of the procedure was tested during SARex 2 with very satisfactory results and more detailed follow-up study is proposed.
It is not surprising that little research data is available on physiological responses and survivability of unprepared, ethnically, gender- and age- different groups in polar conditions. For legal and ethical reasons, most exposure experiments nowadays terminate either at a level of participant's subjective discomfort, or at pre-set value of some parameter (e.g. core temperature) which is still well within a safety zone. The research subjects know the test conditions and can be safely withdrawn from the

experiment to go home and have a beer; this is fundamentally different from an accidental exposure. Simulation of survival reality is practically impossible. The research in preventive field of acclimation and adaptation suffers from lack of consistent methodologies and no universally valid strategies in this area have been formulated. The recommendations for mitigation of effects of specific exposures and the guidelines for rescue and treatment are mostly procedure-oriented. They are typically based on analysis of previous survival situations, interpolated from experience in mountain, avalanche and drowning accidents and transferred from research done for the industry, or by armed forces and similar groups, which are mostly younger, predominantly male and certainly fitter than average polar tourists.

Leadership by someone with verifiable level of Arctic knowledge and suitable leader profile is extremely important for a group of unprepared survivors, very beneficial even in a group of trained professionals and should be made mandatory for tourist adventure group. Currently, very few regulations are in place, especially in the international waters of Arctic Ocean, great individual differences in leadership qualities exist and some individuals, who pose as "Polar Guides" on adventure trips should simply not be there. The UNIS in Longyearbyen requires its students to pass an Arctic Survival Course – this could be used as a model for an Arctic training standard.

The human acclimation strategies may be important in long term for increased Arctic population or for extreme physical activities in Polar Regions. For any other purpose, our polar survival will depend much more on available technology, which is described elsewhere in the report, on proper preparation and adequate behavioral patterns, rather than on any sort of physiological response.

The supporting technologies

1. Communication, alarm and location

The "heroic era" of polar exploration started with no electronic communication at all and ended with only marginally reliable HF radio. Classical terrestrial and celestial navigation was a standard positioning method until the last two decades of 20th century, with radio navigation like Loran or Omega available only for ships and aircraft. Current instant accessibility to means of location, communication and tracking, together with implementation of GNSS (Global Navigation Satellite Systems) are probably the most significant safety improvement in Polar Regions.

High latitudes of both N and S Polar Regions are served by satellite communication constellation Iridium, located in Low Earth Orbit (LEO). Except for some location with terrain obstacles, like narrow valleys, where the satellites may be outside of "view" for brief periods the coverage is continuous and the access is instant. The user stations are either hand-held devices with bandwidth of 2,4 kps, or larger, fixed installations (Iridium Pilot, Open Port), which allow up to 128kps.

Circumpolar latitudes of less than approx. 70-75 degrees additionally benefit from access to satellites in geostationary orbit (GEO), like Inmarsat, Thuraya, or different V-SAT services. Most of these systems also provide devices with instant alarm capability (see below.) Thus, the communication is normally not a risk factor in polar survival.

The international global system for alarm and location in distress is Cospas/Sarsat (C/S.), with two fully functional constellations: GEOSAR with space segment on geostationary satellites and LEOSAR, with space segment on environmental satellites in polar Low-Earth Orbits. The third component, MEOSAR, is currently under deployment and only partly operational. MEOSAR payloads will be on Galileo navigational satellites, the constellation will merge the advantages of LEO-and GEO-SAR and will provide additional functionality, e.g. confirmation of alarm reception by ground segment. At present time, LEOSAR is currently the only constellation routinely accessible in high Polar Regions and the reception and download of the distress signal may be delayed (the Antarctic more than the Arctic) in comparison with instant detection by GEOSAR.

This delay would be in order of minutes, maximal approx. 40, and is irrelevant in the overall time frame of Arctic S&R operations.

Cospas/Sarsat user emergency beacons exist in three versions with identical operational principles: ELT for the aircraft, EPIRB for marine craft and PLB for personal use. They can be by activated by impact g-forces, by immersion, or manually. All modern beacons transmit emergency signal at 406

MHz, with embedded user identification and GNSS -derived position, to C/S satellites and short-range homing signal at 121,5 MHz to direct the search craft.
In a nominal scenario, the information from the satellites will be downlinked to ground receiving stations, further to respective Mission Control Centre (MCC) and from there relayed to S&R forces. In the last years, a technology has been developed that allows the S&R craft to directly detect the signal from the distress beacon and decode the embedded information about the identity (vessel, aircraft and individual.) This gives the on-site S&R teams essentially the same information as the MCC receives through the satellite. In addition, this technology allows direct homing on 406 MHz distress signal, which is about an order of magnitude stronger than that at 121,5 MHz. Such equipment can be either fix installed on-board the vessel or aircraft, used on snowmobile, ATVs, or even by walking of skiing search parties. Some of the beacon decoding and 406 homing equipment was tested during the SARex 2 in joint effort with the Memorial University in Canada with very satisfactory results. Additional, more rigorous tests with more devices added, are proposed for next Sarex in 2018.
The communication (Iridium) and alarm (Cospas/Sarsat) equipment mentioned above is simple, portable (EPIRB and PLB), quite reliable and comparatively cheap. If properly used by a party in distress, it will significantly reduce the search component of the rescue mission and shift the focus on assistance and retrieval. In some jurisdiction (e.g. Svalbard and Greenland) all field parties are required carry Iridium satellite phones together with Cospas/Sarsat emergency transmitters to obtain an expedition permit. That makes perfectly sense, since such combination, based on two technically completely independent principles and systems will provide sufficient redundancy in all reasonably possible scenarios. It shall be also used for any serious undertaking in other remote areas outside the Polar Regions.
It should be noted that the earlier Class 1 PLBs, rated to -40^{0}C, are no more available on the market. The performance of Class 2 beacons (-20C rating) in very cold conditions is unknown and an evaluation, in partnership with Canadian Beacon Registry, is being proposed. Some of the other alarm devices in use include: Satellite Emergency Notification Devices (SEND.) These are essentially modified satellite phones. The principle is based on reception of GNSS position signal, addition of distress party identification and re-transmission of such information to user-defined receiving station. Typically, Iridium, Inmarsat, Thuraya, or Globalstar devices are used (e.g. Delorme InReach.) The overall reliability of SENDs is lower than with Cospas/Sarsat, mainly due to signal path, less robustness, and non-global coverage with exception of SENDs operating on Iridium constellation. Moreover, these location services are commercially operated without clearly defined access to and agreements with nternational S&R structures. Cospas/Sarsat is the only organization with 24/7 available access to S&R resources on the global scale. 121,5 MHz rescue transmitters still survive in the maritime community, but of very limited use elsewhere, since the 121,5, MHz reception by the satellites has been discontinued in 2009. They are still used as MOB (Man-Over-Board) alarm devices locally on ships equipped with the proper receivers, but their use in polar and other S&R operations is on decline. AIS (Automatic Identification System) transmitters and receivers became standard equipment of almost all commercial and other larger vessels and AIS beacons can be, indeed, well used for location of survivors. As with older 121,5 MHz beacons they are confined to the local use (line of sight between receiver-transmitter antennas). Reception of the AIS transmission by satellites has been routinely used in vessel tracking, but is not yet suitable for location of individual survivors. The system has no use and is unknown outside of maritime community. SART radar transponder, avalanche location beacons, VHF or cellular phones or any other means of RF signal transmission/ detection may be also used to locate the individual in distress; their description is beyond the scope of this paper.

2. Passive search methods

An old-fashioned, visual search from aircraft, vessels, or from the ground is still routinely used and is extremely important if the electronic means of alarm fail. Obviously, it is limited by darkness and other adverse light conditions. The human vision can be enhanced or replaced by:

• Image intensifiers, which still require at least minimal amount of ambient light
• Thermal infrared cameras (TIR), which are detectors of temperature differences between objects
• Multi- and hyper-spectral sensors, which detect spectral signature of the surfaces
The intensifiers "night goggles" are the oldest, cheapest and most widely used method, which has been later supplemented by TIR. Hyper-spectral sensors are slowly penetrating into the S&R applications, mostly as experimental projects. All methods can be used in the Arctic for detection of object and survivors, but important differences exist between the detection on land, in water and in image interpretation.
The TIR was used on-board the KV Svalbard during SARex 2 for detection of living persons on land and in water, of simulated dead bodies in the water, and for thermal imaging of survival rafts and life boats. The results were very satisfactory and partly surprising. Immediately after Sarex, another similar, comparative experiments were made using airborne TIR on S&R helicopter in Longyearbyen. Since this activity was more a feasibility check, rather than a controlled experiment, it has been agreed that a systematic comparison of all three detection methods should be done for both air-borne and ship-borne search. There is no evidence that such investigation has been so far performed elsewhere and the proposal is in preparation.

3. On-site assistance
The survivors can be evacuated directly, or may be required to remain temporarily at their location, either in survival craft, or on land and on the ice. The dry location would be preferred if available and even sufficiently comfortable life boats can be brought to the shore or anchored to ice floes if circumstances allow. In such situation, they can be supported by airdrop of shelters, supplies and other necessities and sometimes the by the rescue personnel parachuted to them.
Freezing to death happens much faster than starving to death and creation of thermo-protective microclimate is always a priority in polar survival situation. The survivors might have their own tents destroyed e.g. skiing parties in severe storm, end up only with the wreckage of their craft as improvised refuge, or have nothing at all. In such situations a rapidly deployable shelter would be the most valuable item to be delivered. Basic design of most large tent-like structures is 50 and more years old. They have been developed primarily for the use in military applications or for disaster relief, are heavy, bulky and making them work on site can be quite problematic without assistance of trained personnel. The procedure usually requires a coordinated effort of a small, trained group as with the military, but would be very difficult to do by individuals without training and experience in polar conditions.
Inflatable shelter structures would partly alleviate the problem. Products with improved material properties and better volume/mass ratios are becoming common in different branches of industry, in recreation, in space exploration and are commercially available from different suppliers, e.g. Norwegian company NorLens. Alternatively, designs and demo-prototypes of extraterrestrial (orbital and planetary surface) habitats can be considered. For polar survival conditions, rigorous testing of several products with focus on size, fast and safe anchoring, shape, air supply, autonomous deployment and compatibility with different delivery vehicles would be necessary.
The list of requirements, testing protocols and first practical test of different solutions on sea ice could be one of the research objectives of SAREX 3. There are enough designers and manufacturers capable of making a completely new product, once the user requirements and needs are defined and the market exists.
For survivors of ship accidents, the life raft is the obvious and amphibious example of an inflatable emergency habitat. It would need only slight modification in handling and anchoring to be used on land and ice. Preliminary tests have been already done in Sarex1, but further evaluation and performance comparison against purpose-built, inflatable land shelters is necessary. An additional equipment for the surface use of life rafts in the Arctic could be included in the regulations.
Delivery of food, clothing, medical supplies and others would be straightforward. Instruction for the use of any item possibly unfamiliar to the survivors must be short, clearly readable in low light conditions, written in a language understandable to them and in big letters, since reading glasses

might have been lost in the evacuation process. A decrease in survivors' manual dexterity due to cold or frostbites must be considered in any design of handling interfaces and procedures.

4. Retrieval
The final, and perhaps most important aspect of the assistance chain, is the retrieval of survivors. The logistic aspects thereof, like availability and types of aircraft and icebreakers, distances for deployment of S&R resources, their organization in different jurisdictions, their operational status qualification and equipment, budgetary constraints in keeping the Arctic S&R operational, regulations in industrial and leisure activities in polar regions and other issues of political and organizational nature might be the crucial element in survivability of an emergency in the Arctic. Our lives out there may depend more on a decision of a politician, who never saw an iceberg, rather than on our food, tent and clothing.

Conclusion
There is a surprising lack of consistent data related to adaptation and acclimation to Arctic conditions and to survival that could be reasonably applied to situations following big ship or aircraft accidents in the Polar Regions. Technologies in support of search and rescue operations and protective devices are developing rapidly, but their implementation is much slower. Suggestion for improvement or for further research may include:

- Development and testing, in real conditions and by real users, of rapidly deployable, inflatable, modular shelters, their functionality, on-site handling and safety and the optimal methods of airborne delivery. These shelters could be tested together with region-specific arctic survival kits.
- Suitability of existing resources on ships, in particular life-rafts for survival on the ice floes and on land, including their slight modification for arctic conditions, like anchor points, anchoring material, floor reinforcement, etc.
- Feasibility of dual voice communication, e.g. VHF and Satcom and dual tracking and location, e.g. Cospas/Sarsat 406 EPIRP/PLB and AIS, capabilities to be installed on any survival craft.
- The satellite communication channel on larger survival craft, like enclosed life boats, should allow low volume automatic data transfer, e.g. position, environmental conditions in and outside the craft and condition and on-demand transmission of basic physiological parameters of survivors.
- Improved active detection of survivors by compulsory use of coded 406 MHz PLB during all outdoor professional and tourist activities, contact with multiple beacon activation working group at Cospas/Sarsat.
- Improved local detection capabilities of 406MHZ Cospas/Sarsat signal by portable and fixed 406 homing and beacon decoding equipment. This shall be done from the aircraft, from large SAR vessels and, optionally, from FRC (Fast Rescue Craft) in collaboration with the Memorial University in Newfoundland, CND.
- Comparison of detection of Cospas/Sarsat emergency beacons by LEOSAR and MEOSAR systems in collaboration with CMCC Trenton and Memorial University.
- Further testing of survivors' detection in the water and on the ice by thermal infrared (TIR) multi-spectral (MSI) and other imaging methods using air-borne and ship-borne equipment.
- Further identification and elimination of potential design shortcomings in the survival equipment (rafts, boats, suits, etc.) with focus on polar conditions under exposure longer than 96 hrs.
- Compulsory certification in polar survival of selected crew members on passenger ships, and of other relevant personnel similar to Arctic Safety Courses at UNIS in Longyearbyen.
- Collecting representative data by wearable physiological data monitors from individual exposure while wearing the standard Passengers Arctic Suit in the water, among the ice floes, following an exit on ice/land, with and without a shelter. Ditto for personnel in potentially hazardous situations.
- Testing the physiological and psychological response, in different real and long-term exposure to Arctic conditions (water, land, combined) of a representative group of potential survivors of ship and aircraft accidents.

While most of these recommendations are simple and without obvious legal obstacles, the last two might be not so straightforward. With current ethical restrictions on human research, which are sometimes on the verge of ridiculousness, we may as well wait for “something big” to happen and process ex-post the real information from real accidents.

- Proposal: Thermal infrared and multi-spectral detection of persons in the ocean and in snow

Background

The common methods of search from aboard aircraft or ships are based on passive or active target detection in different portions of electromagnetic spectrum:

- Visible, including image intensification for low light conditions
- Multi-spectral imagery in visible and in near infrared spectrum
- Thermal infrared imaging (TIR)
- Radiofrequencies in kHz/MHz range if targets are equipped with location beacons
- Radar detection, which requires that targets carry appropriate radar reflectors
- Combination of any of the above

Most of these techniques are mature and have been routinely used in search and rescue operations; the multi-spectral imaging is in the experimental phase. The potential of thermal imaging has been successfully demonstrated in military applications and in law enforcement; the technique is now rapidly penetrating into various civilian domains.

Rationale:

The theoretical limits of TIR detection can be defined for each specific instrument and depend essentially on spatial and spectral resolutions of the sensor and on differentials in emitted radiation between the object that has to be detected and its environment.

The real situation is more complex. In maritime search applications, the viewing geometry will be influenced by the motion of swells and waves and by rapidly changing relative positions between the sensor and target, even with instruments mounted on 3-D stabilized platform. The thermal differential between the outer layer of the survival suit and the water decreases with time and a protective hood will decrease the amount of energy radiated by the head above the water. The convective heat transfer in strong winds and the presence of water spray or fog may further reduce thermal signatures of immersed persons.

Any individual that is partly covered by snow on land will be gradually approaching thermal equilibrium with a snow layer and the thermal gradient will be significantly reduced, as data available from snow and avalanche research suggest. Hence, the better insulation properties of protective garments would result in less distinct infrared thermal signatures.

To this date, very little information is available from the real survival situations, especially for such with a significant signal attenuation in maritime environments. Since the acquisition of reference data in real conditions would be difficult a simulation in quasi-real conditions is envisioned as the first step. The facilities and the expertise at the NRC – IOT in St. John’s are well suited for this task. These results would be used to optimize the selection and performance of TIR cameras (and of multispectral sensors if applicable) and to outline the limits of detection in specific situations prior to ship-borne and air-borne field tests.

Proposed research consortium

PLEASE ADD POTENTIAL PARTICIPANTS FROM NORWAY

This would include the Memorial University with the Faculty of Medicine and Applied Ocean Technologies at the Marine Institute in St. John’s as scientific research lead. The Canadian Centre for Remote Sensing would be engaged for research advisory and pool facilities at National Research Council (NRC) in St. John’s would be used for simulations. FLIR Canada already confirmed its interest as primary industrial partner; other manufacturers of multispectral sensors could be added to the consortium if necessary.

Expected results and potential end-users

The main outcome shall be a realistic assessment of passive multi-spectral remote sensing as a tool in maritime search and rescue in adverse conditions. The results could provide operational recommendations to the offshore industrial stakeholders and guidelines for S&R procedures; they can be useful for training of FLIR operators. The TIR cameras could be also extensively used in immersion hypothermia research performed at survival training facilities. Among the potential end-users would be the S&R units on land and at sea, offshore industry, Coast Guard, etc.

Proposed project stages /WPs

The project duration should be 12-18 months with potential start in the autumn 2017 to allow for field testing in all four seasons. . The total budget and allocation of tasks and resources will be determined among consortium's members whether the project should focus only on TIR, or include multi-spectral detection modes should be discussed in the first partners' meeting

1. Background information

1.1. Sensor technology : Current use of TIR & multispectral sensing in S&R, state of the art and literature survey, available sensors in NL, their thermal, spectral and spatial resolutions.

1.2. Thermal balance and heat transfer of humans in immersion survival suits under different conditions; state of the art and literature survey.

1.3. As above for condition in snow and on the ice, standard winter clothing, different ambient conditions

1.4. Incorporation of external research results from Swiss Federal Institute for Material Research and Testing (EMPA) - heat transfer in different garments and different ambient conditions, from Swiss Federal Institute for Snow and Avalanche Research - location, survival and rescue techniques and from Swiss Air Force - TIR on UAV.

2. Data acquisition for TIR (multispectral) in laboratory conditions

2.1. Implementation of theoretical models for immersion situations and measurement of surface temperature and heat emission using thermal manikins. Tests in simulated conditions, at close range (NRC, and MI facilities), in different temperatures and with simulated rain, spray and wind.

2.2. Measurements as above, with human volunteers.

2.3. Typical spectral signatures of different survival suits (visible, NIR) – optional

3. Field tests

3.1. Open ocean, ship borne and airborne, in best possible conditions with none or minimal signal attenuation due to environmental factors. Temperature range shall be representative of real conditions offshore NL. Rigid and/or 3-D stabilized sensor platform, TBD with the a/c operators and sensor manufacturer(s).

3.2. As above, with gradually increasing signal attenuation due to atmospheric conditions (rain, fog, wind, water spray, etc.) and due to the action of waves and swells.

3.3. Land, only airborne detection, with focus on adverse atmospheric conditions, or at night. External data (see 1.4.) could be used as baseline.

INFORMATION FROM THERMOGRAPHIC CAMERAS, GENERAL EXPERIENCE ON HEAT LOSS AND USE OF THESE DATA

Daniel Kristoffer Johnsen Swart., MSc student, University of Tromsø, Norway

Human Responses to Cold

Human responses in cold environment are dependent on the temperature, wind, humidity, winter darkness, and physical isolation, additionally these factors have a profound influence on human performance. The human body strives to maintain thermal balance at all time. However, these physiological processes related to heat loss are highly affected by the cold environment. When the human body is exposed to cold and in combination with decreased temperature on the periphery and other areas of the skin surface, the body responds by conserving heat by vasoconstriction, which is a reduction of blood flow to periphery areas and thereby prioritising the core [2].

The environmental factors have considerable influence on the rate of heat loss and cooling of the body core, i.e. thermoregulatory responses, these factors are presented in Table 1. Table 2 presents physical and physiological factors which affect the rate of cooling.

Table 1 Physical and physiological factors affecting the rate of body core cooling [1] [2] [3] [4] [5] [6]

PHYSICAL / PHYSIOLOGICAL FACTORS	DESCRIPTION
AGE	People above 60 years is less tolerant to cold due to reduced vasoconstriction and heat conservation, elder people also experience a decline in physical fitness. They fatigue sooner and have a blunted thermal sensitivity to cold. These factors result in a higher risk of hypothermia for this group.
GENDER	Heat loss is greater in women due to smaller surface-to-volume ratio and less insulation by muscles compared to men. Moreover, menstrual cycle does also affect the thermoregulatory responses negatively.
BODY MORPHOLOGY	Composition and size of the body influence heat loss. Fat acts as insulation, which is beneficial when exposed to cold.
SURFACE-TO-VOLUME RATIO	The rate of heat loss is determined by the ratio of the area of the skin surface to the volume of the body, in that way, having a larger body is beneficial when exposed to cold. This analogy can also be adapted to the extremities; heat is lost faster from e.g. fingers and feet because they have a proportionally greater surface area compared to the upper body. Individuals with high combined subcutaneous fat, % fat and muscle mass have the better prerequisite to maintaining core temperature compared to people with less fat and muscle.
ACTIVITY LEVEL	Activity at an elevated level can maintain core temperature at or above 37°C when being exposed to cold.
GOOD PHYSICAL FITNESS	Good physical fitness increases the ability for heat production and good circulation as the metabolic rate may be higher and thereby contribute to maintaining normal core temperature.

COLD ADAPTATION	Thermal adaptation to cold takes approximately two weeks. The physiological responses to cold are often attenuated when the body is adapted to cold. Typical forms of cold physiological adaptation are increased, either or both: • Insulative – *this restricts heat transfer from the internal organs to the skin, resulting in a decrease in surface temperature, which in turn results in a reduction in body heat loss* • Metabolic – *results in an increase in metabolic rate, thus increasing heat production.*
CLOTHING	The demand for clothing insulation is dependent on activity intensity, workload and the wind chill. Typical cold weather clothing consists of three layers; an inner layer which wicks moisture to the outer layers, a middle layer which insulates and an outer layer which protects against wind and precipitation and allows moisture transfer to the air. Clothing should not be tight as this can decrease blood flow, whether it is shirt, socks or shoes. Trapping air inside clothing is helpful as air acts as an insulator. However, proper clothing may add weight and decrease mobility, additionally this increase bulkiness and muscular strain which in turn may reduce the performance and efficiency.
FOOD AND FLUID INTAKE	An increase in energy spent is expected when exposed to cold weather due to the combination of extra weight from clothing and extra energy generation to keep warm. The demand of hydration is reduced when exposed to cold, as the blood excrete water due to the increased blood pressure, which in turn increases the urine flow rate. The increase in urine flow sends a signal to the brain that the body is hydrated, however, in an cold situation it may not be hydrated, which means that the body is likely to get dehydrated if not aware of these signals and the certain sitiuation.

Table 2 Environmental factors affecting the rate of body core cooling [1] [3] [4] [5] [7]

ENVIRONMENTAL FACTORS	DESCRIPTION
AMBIENT TEMPERATURE	Temperature affects the heat production system in the body.
HUMIDITY	In general, dry air isolates compared to humid air which conducts heat, thus the heat loss is increased as the humidity increases. Cold air with relatively high humidity creates a colder sensation as the humidity enhances the conduction of heat loss from the body. Low humidity combined with the cold affects the lungs and bronchial airways, which makes breathing hard, particularly during physical or exhausting activity.
WIND	The wind pulls away heat from the skin surface.
MEDIUM	Water has higher thermal conductivity than air. Water has approximately 70-times higher conductivity efficient compared to water.

Human cooling has several negative consequences, changes in specific organs are presented in Table 3.

Table 3 Changes in specific organs [3] [8] [42] [43].

ORGAN	CHANGE
MUSCLES	Mild cooling cause muscle tissue to stiffen and uncoordinated movements. Profound cooling may affect the ability to contract effectively and responses. This result in jerky, staggering and loss of the ability to perform simple tasks.
BRAIN	Mild cooling affects thinking processes and decision making. Individuals may become apathetic, irritable and disagreeable. Mental function is impaired to a far extent when hypothermic, which leads to confusion, disorientation and erroneous decision making. If severe hypothermic, slurred speech occurs.
CIRCULATORY SYSTEM	When hypothermic there is a reduction in blood flow and oxygen transport to a level below that is needed for normal function. This decrease affects brain and heart as the blood is not adequately oxygenated. The cold and insufficient oxygenated blood also influence the kidney by decreasing the ability to conserve water, which results in a higher output of urine production.
HEART	When the body gets cold, or even more severe, hypothermic, the heart becomes slower, getting stiff and weak, consequently the heart rate decrease. The consequence is an incomplete metabolism due to insufficient oxygenation of the tissues and blood. There will be an increase of lactic acid in the blood due to the reduced oxygenated blood, and the accumulation of acids in tissues and blood causes acidosis, which is lowered pH-levels, which causes the heart to contract weakly and erratically. A hypothermic heart is in danger of ventricular fibrillation, whereas the heart stops beating due to unsynchronized and uneven rhythms in the heart. Older individuals are more disposed to develop ventricular fibrillation, on the other hand, young people do not develop fibrillation, but the heart slows down until it stops.
LUNGS	Ventilation of air is expected to be adequate until core temperature has decreased to about 30-32°C, at temperatures below, there will be an accumulation of carbon dioxide in the blood, which results in acidosis. Usually, this increase of acids in blood is counterbalanced by increased ventilation, though when severe hypothermic, this respiratory compensation does not occur. In general, cold, dry air may cause constrictions of upper airways. Heavy workload increases the ventilation, thus a greater risk of constriction of the upper airways.
OTHERS	Coagulation is to be expected in a hypothermic state, whereas the clotting components in blood do not function normally at low temperatures. Further, this may lead to severe blood loss, and in worst case result in death.

Effects of Cold on Performance

SINTEFs' ColdWear-project (2008-2012) revealed by testing in chambers the hands and finger fine and gross motor skills are impacted by decreased performance when the ambient temperature is at -5°C. These findings were verified when SINTEF had a visit at Melkøya, Statoil LNG production unit in Hammerfest, where the workers claimed that they have to postpone work because of the cold and the wind conditions whereas the fingers are not functioning anymore [9], other studies support these findings as well [10].

Low tissue temperature impairs nerve-motor function, and several studies have proved that there is a clear relationship between skin temperature and manual performance, as presented in Table 4.

Table 4 Effects of cold on manual performance [11]

HAND SKIN TEMPERATURE °C	EFFECT ON PERFORMANCE
32-36	Optimal hand and finger function
27-32	Effects on finger dexterity, precision and speed
20-27	Impaired performance in work with small details, reduced endurance
15-20	Impaired performance of gross finger work
10-15	Reduced gross muscle strength and coordination, pain sensation
<10	Numbness, manual performance reduced to simple gripping, pushing, etc.

Additionally, cold exposure affects the human performance, vigilance, alertness, decision-making, perception and situation awareness.

UiT Experiment with James Mercer

There was conducted an experiment autumn 2017 on how the blood flow regenerate heat in the fingers and hands after being exposed to cold and how quickly the skin reheats after exposure, n=4. The hands were exposed to 20°C water in one minute before to monitoring with a thermographic camera.

With the hands being exposed to 20°C water in one minute, the hand temperature was reduced from 36°C down to approximately 25°C. Figure 1 visualizes how the fingers reheat from the tip of the fingers and back towards the wrist. Table 4 presents that the threshold for manual dexterity is 10-15°C and with our experiment, we would have an impaired performance in work with small details. The performance was however not tested in depth in this study, on the other side, the candidates verified that the endurance was slightly reduced as proposed in the previous table. If the heat loss would be more severe or exposure time was extended, the candidates would most probably feel discomfort on the hands.

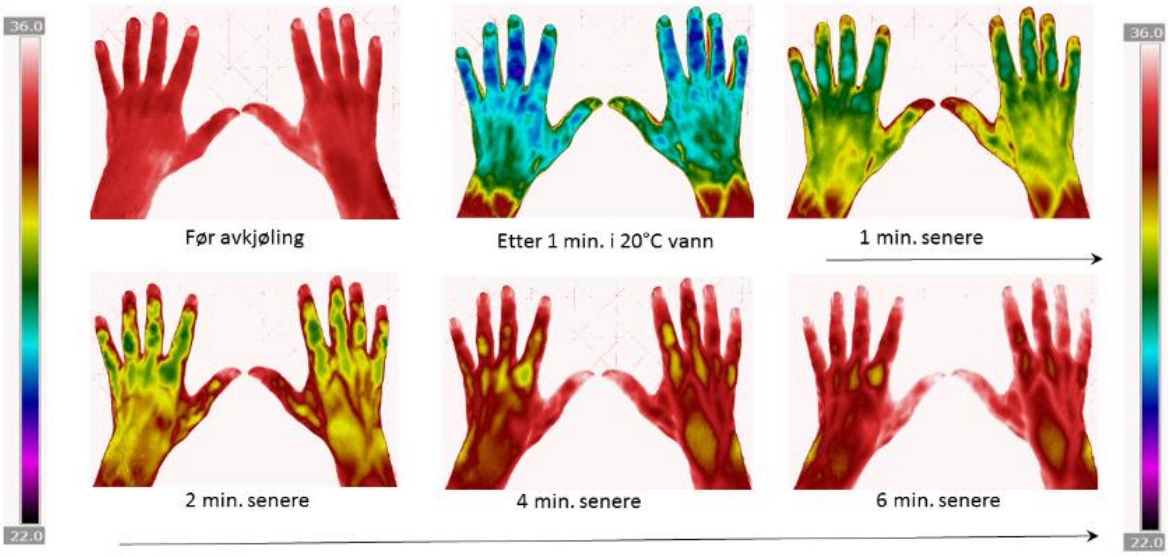


Figure 1 Experiment: Cooling of hands - Illustration: James Mercer

SARex Experiment

Figure 2 visualizes the hand temperature data for the candidates in the life raft, the average temperature data is presented in Table 5, n=15, Endex n=9. The decrease of participants measured at Endex is due to the author had to stay a while at the infirmary. All temperature measurements were taken in the middle of the palm of the hand.

The average temperature was 33°C prior to entering the life raft. The first measurement, approximately 12hours into the exercise, there had been an average decline in hand temperature by 3.6°C during the night in the life raft the average hand temperature had decreased with 6°C. The great decline in temperature from the second and Endex measurements are due to the fact that the hand temperature was measured after the participants had been shipped to KV Svalbard from the life raft, additionally the participants hands was exposed to various degrees to the environmental factors, e.g. sea spray, wind and cold temperature. In addition, some participants did not wear gloves during the transit. In retrospect, the temperature should obviously have been measured prior to leaving the life raft.

There were great differences of what people brought on board to the life raft for conserving heat on the head, feet and hands. One candidate used woolen mittens, and the result is visualized in the following chart with a grey colour that stands out on 2nd measurement and Endex. This indicates that "strikkavotta"/mittens and headwear made of wool may the best for conserving heat and maintaining sufficient hand temperature over time; that is throughout the test period's ~ 30 hours. However, a thorough study is needed to support this indication.

The six last persons who left the boat wore some kind of hat, not neoprene as the survival suit was equipped with. As the head is where the most heat loss is expected to occur, this may have had an impact on how long the candidates was able to stay in the life raft.

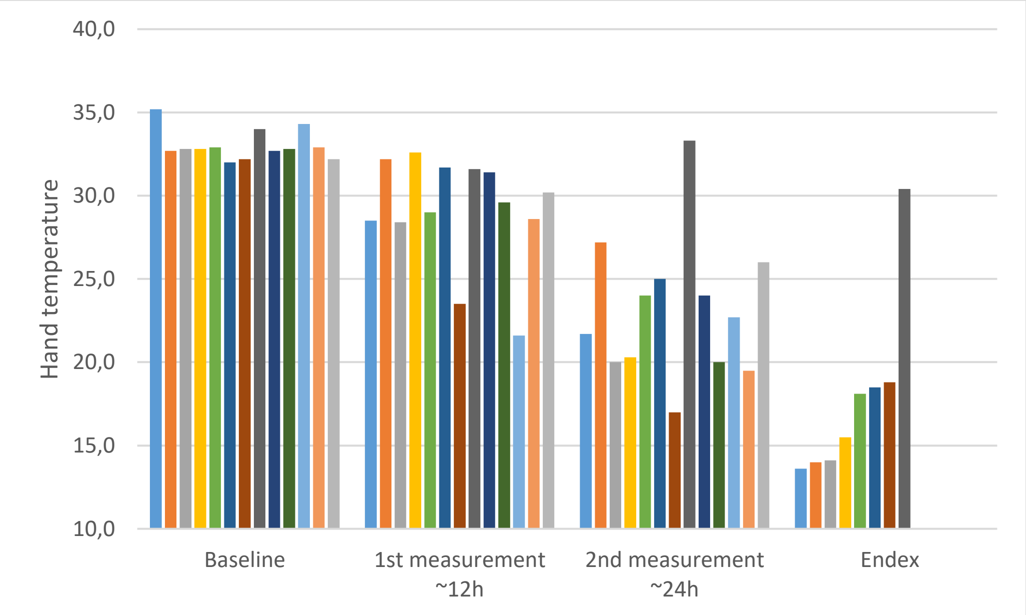


Figure 2 Hand temperatures on participants during test in life raft

Table 5 Measurements from life raft

	Baseline	*1st measurement ~12h*	*2nd measurement ~24h*	*Endex*
Average temp	33,0	29,5	23,5	18,0
Minimum temp	32,0	21,6	17,0	13,6
Maximum temp	35,2	32,6	33,3	30,4

Decrease in temp - Average

Baseline → 1st	***1st → 2nd***	***2nd → Endex***
-3,6	-6,0	-5,5

Most of the heat was proved to be lost through the bottom, head, hands and feet's. This, in combination with the findings discussed above, implies that the suits should be equipped with an extra hat and gloves made of wool whereas the suit does not retain heat well on the periphery parts.

It was experienced that refreshing air into boots is sufficient for the feets, this was achieved by channelising/venting air from the upper body to the feets by loosening the foot-strap which is supposed to stay strapped when walking. An inflatable part at the bottom area of the survival suits would be beneficial, whereas this could be emptied and filled on demand, i.e. by a hand-pump system, as to provide additional insulation towards the floor where considerable heat loss was experienced.

The survival exercise was to be reflected on elder people in an emergency, and in this case, it is important to keep in mind that elder people tend to be brittle, have less muscle mass and reduced motion paths due to ageing, thus their performance to execute certain tasks may be reduced. Moreover, elder people are more prone to cold compared to younger people, consequently, they are more likely to have impaired finger performance as presented in Table 4. The cooling of hands will reduce their ability to help each other with the zippers on the survival suits, which are indeed hard to zip and unzip. Furthermore, the cooling will have a negative impact on operating the equipment that is provided in the life raft and for maintaining the life raft to ensure survival, amongst others.

Shared experience post-exercise

The general agreement after test of survival suits in the life raft and lifeboat was that there should be implemented additional headwear and mittens made of wool equipped inside the survival suits to ensure adequate performance and endurance over time. A few of the participants experienced impaired performance of gross finger work when handling zippers and small details in the life raft.

The leaders for the survival crafts should be trained in cold risk management and how to regenerate heat and channelize heat, additionally a guide on how-to-survive with instructions to handle the cold and keep warm to be implemented in the rafts. The reduction of food and water intake could be compensated by movement/activities to increase the microclimate temperature and increase periphery circulation. Use of neoprene gloves and hat may give a feeling of getting moist on the skin, and the users may therefor undress the neoprene clothing. However, they do insulate heat better than not wearing them, and should be used as addressed by the craft leader. A last point to make is that the limited intake of food and water had a negative impact on retaining heat over time.

It must be addressed that the exercise was tested in a best situation scenario regarding weather and clothing. Furthermore, the participants could prepare both mentally and physically in advance of the exercise.

Action points

- Add sitting plates to the life raft
- Complement survival suits with hats and gloves made of wool
- Add how-to-survive instructions to retain heat
- Supplement group survival kit with chemical heaters for hands/feets to regenerate heat
    - Operating time ~5h
- Ensure cold risk management training for leaders

- Larger and easier handling watch-out holes among others are required. Small details are inappropriate when people are getting cold and have reduced endurance and performance to handle details

Post-exercise reflections

It would have been interesting to use an advance FLIR-camera to investigate:

- heat loss through the bottoms of the participants
- heat loss through the floor of the life raft
- where the survival suits suffer from heat loss

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RESULTS

b) Search Robustness

EMERGENCY SEARCH IN ARCTIC WATERS

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- Disclaimer

The views expressed in this report are solely based on personal experience from SARex, and does not necessarily reflect the official view of the Norwegian Maritime Authority (NMA).

- Background

The Maritime Safety Committee added a new output (MSC 95/22, paragraph 19.9) that instructed NCSR to review and update resolution A.810(19). The target completion year is 2017.

USA was asked to send in a proposal for new performance standard for EPIRB. One of the suggestions were The 121.5 MHz homing signal should have a duty cycle of not less than 33% (e.g. 0.75 seconds on, 1.50 seconds off), reference is made to article 4 in annex to NCSR 4/19.

There has not been done many tests to see if this has any effect on the homing of EPIRB. That is why we wanted to test this during SAREX 2. We also wanted to test how the performance of AIS SART is compared to Radar SART in ice.

How the test was done

For the test we had two EPIRB with reduced cycle of the homing signal and one EPIRB without reduced cycle of the homing signal. All EPIRB`s were modified so that they did not send out any signal on 406 MHz. We had also two AIS SART and two Radar transponders. All the equipment where delivered from Jotron AS.

The plan was to test the EPIRB, AIS SART and radar transponder from lifeboat. They were going to be tested from outside the lifeboat on top and in water, inside at navigating position and from floor to see if there were differences in the signal from where the equipment is placed. The signals from the EPIRB where homed from the bridge of KV Svalbard and the signal strength were also measured with equipment from ashore. The antenna for this equipment was mounted on aft deck with free line of sight to the lifeboat. For measuring AIS SART the ships ECDIS were used and for Radar transponder the ships 9GHz radar were used.

The test started with KV Svalbard at a distance of 0,9 nm of the lifeboat and all equipment were tested in the three positions before KV Svalbard moved to 2nm from the lifeboat. Then it moved to 3 nm and thereafter to four nm of the lifeboat.

RESULT FROM THE TESTS

EPIRB

At 0,9 nm there we received signals from all equipment in all position. There was no difference in signal strength between the modified EPIRB and the original. From the bridge we managed to home the both EPIRB`s. When we moved the vessel to 2,0 nm of the lifeboat we started to home and measure the signal. We measured the signal good and in the right direction. For the homing there were problems in the beginning to home. First the signal was static. We turned off the equipment and the on again. Then we managed to get homing but the position of the signal was on port side off vessel. The vessel moved away from the lifeboat with a distance of 3,0 nm. We started measuring the signals again. We started the test with the EPRIB`s in the water. For both EPIRB`s we did not receive any signals. Then we moved the EPIRB to the top of lifeboat. Then we managed to measure the signal. For homing it was difficult to get a signal. We were unsecure if the signal we saw were from the EPIRB with reflection from mountains or if the signal were false. We continued with testing inside lifeboat. We managed to receive signals but not as good as on top. At 4,0 nm away from the vessel we did not receive any signals and we did not manage to home the EPIRB`s.

AIS SART vs. Radar Transponder

The plan was to do the test with AIS SART and Radar transponder in ice conditions to see which equipment would be best to locate. The theory was that the AIS SART would be better since it uses VHF to send signals while Radar transponder sends on the frequency of 9GHz radar. Unfortunately, we were not able to test this due to the safety of the lifeboat. Therefor we did the same exercise for AIS SART and Radar transponder as we did for the EPRIB. We did not see any difference in signal on the bridge for the two equipment. The signals were good all the time. After the exercise was finished, we got feedback from the rescue center at Faroe Island that they managed to track the AIS SART.

DISCUSSION

During the exercise, we did not manage to see any difference between the EPIRB with reduced homing signal and the original EPIRB. The performance standard for EPIRB say that the strength of the signal from EPIRB shall be off 0,5 watts and the designed range will be 3-4 nm. This is in accordance with the results from our test. There were some problems with homing the EPPIRB from the bridge. Many times, we got signals in other directions then were the lifeboat was positioned. This might be caused by reflection from the mountains. The position of the test was in a fjord with large mountains on each side of the fjord. The crew on the bridge, including myself, were not experienced in using the equipment. We were often unsure if we used the equipment in the correct way or if it was reflection.

The homing frequency (121,5 MHz) is an aeronautical frequency and are primarily designed to be used for homing by aircrafts. When aircrafts are homing they might not have problems with reflection since they are above mountains. The crew on the rescue craft are more experienced in using homing equipment. But since we did not have any helicopter in this exercise we did not get any answer to if the reduced duty cycle on the homing frequency will cause any problems to how the helicopter crew or the equipment on board the helicopter. For the exercise with the AIS SART vs. Radar transponder we did not get any data which we can use. The most interesting with this test were that the rescue center at Faroe Island managed the receive signal from our AIS SART via AIS satellite. In Polar Regions and remote locations there is difficulties with communication. The AIS technology used together with AIS satellites can give a good alternative in the arctic.

CONCLUSION

It looks like there is now difference between the suggestions for new performance standard for EPIRB compared with the old. But this should be further tested with rescue aircrafts. For information it is planned to a test outside Stavanger with helicopters from 330 Squadron at SOLA in August/September 2017. If there are going to be an SAREX 3 there should be done some testing with AIS SART and radar transponders in ice to see if there are any difference in locating lifeboats in icy waters.

In my point of view the AIS SART should also be tested out to be an alerting system also to use the advantage of AIS satellites.

NAVIGATIONAL CHALLENGES IN THE SPITSBERGEN AREA

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Introduction

Maritime operations are common throughout the world, with operations ranging from cruise, shipping, fishing and aquaculture to maritime operations in the oil and gas industry. All such operations need to be conducted in a safe and effective manner, and the environment in which a maritime operation is conducted will determine its requirements. One of the most challenging regions in which maritime operations are conducted is the Arctic. This is due to multiple challenges associated with the harsh environment (Kjerstad et al., 2003).
Spitsbergen is one of the more visited regions for vessel traffic in the Arctic, with significant cruise activity in the region. The main season for the cruise ships in Spitsbergen is in the months from June to September with a few ships present in May and October. This traffic can be categorized in three segments (Multiconsult, 2014):
_ Overseas cruises
_ Expedition cruises
_ Day cruises

Overseas traffic is characterized by very large passenger cruise vessels taking up to 3600 passengers and crew. Svalbard is only one of many destinations on the sailing plan of these cruises, and they most frequently stop in Longyearbyen and occasionally New Aalesund. These vessels are considered to be very vulnerable to the environment as they have large bunker capacities (Multiconsult, 2014). Expedition cruises are smaller vessels taking from 12 to 300 passengers and specialized for coastal tourism in the Arctic. These ships visit the most remote and vulnerable parts of the Spitsbergen area and have the highest accident frequency. The consequences are however expected to be smaller than for the overseas segment (Det Norske Veritas, 2010). Day cruises are characterized by small ferry type ships up to 40 meters in length that take up to 90 passengers. Visits to various destinations in Isfjorden are common with both departure and arrival in Longyearbyen the same day.

Navigating in the Arctic and around the Spitsbergen area involves many challenges that impose a higher risk to personal life and the environment than in other maritime environments. As the number of maritime operations in the Arctic is increasing (Marchenko et al., 2015), it is of interest to investigate the primary challenges associated with navigation in Arctic waters. These include (Kjerstad et al. 2003):
_ Ice
_ Icing
_ Strong winds
_ Uncharted areas
_ Polar darkness

The most relevant navigational challenges for marine traffic in the Spitsbergen area are uncharted areas, the presence of floating ice and strong unpredictable winds.
Uncharted Areas

On the 1st of June, 2014, a small day cruise ship grounded on the reef at the inlet to Ymerbukta in Isfjorden. The hull was perforated in the forepeak, and extra pumps were supplied to stabilize the ship. 40 passengers, of all ages, were rescued by two helicopters and flown back to Longyearbyen. The rescue operation lasted approximately 3 hours (Dagbladet, 2004). The weather this day was perfect for a day-cruise; high-pressure and sunshine, light breeze wind and no waves. According to the Norwegian Maritime Administrations accident statistics database (Norwegian Maritime Authority, 2017), there were 14 registered accidents involving passenger vessels in the Spitsbergen area in the period from 1981 to 2014. Of these accidents, 12 were due to grounding.

For navigation in the polar waters around Svalbard, a major focus has been into the quality of the sea maps. Large areas are not surveyed or only with old methods not applicable for modern technology such as ECDIS. Glacier withdrawal results in new uncharted areas for the cruise ships every year. Additionally, the projection used for most maritime navigation charts, the Mercator projection, is not accurate at these altitudes. These unreliable factors are familiar to most polar navigators. As an accident can be considered the outcome of many unwanted events, one can say that the chart quality and reliability will only be one factor in an accident event chain.

Ice

Floating ice is often considered to be the primary hazard in Arctic maritime operations. Various maritime accidents can be attributed to collisions with ice, such as the collision with an iceberg and subsequent sinking of the RMS Titanic (Brown, 2000). Other incidents include the MS Maxim Gorkij and MS Explorer (Kvamstad et al., 2009). Extensive work has been done on minimizing the effect of floating ice on maritime operations, (see for instance Eik (2008) and Haugen et al. (2011)) as when operating in Arctic waters, avoiding hazardous ice features is generally considered to be of primary concern. Floating ice can have various forms ranging from consolidated pack ice, to open water with dispersed ice features.

Classification of Ice

Ice properties can have a significant impact on a vessel's navigational performance. Properties such as thickness and hardness are relevant for navigational purposes, as the collision with certain ice formations can under certain conditions result in the deformation or potential breach of the ship hull. Ice can also render a vessel un-maneuverable such that vessel is stuck in the ice. The origin of floating ice can be from frozen sea ice, as well as glaciers.

Sea Ice

Relevant types of sea ice include:

_ First-year ice

_ Multi-year ice

_ Ice ridges

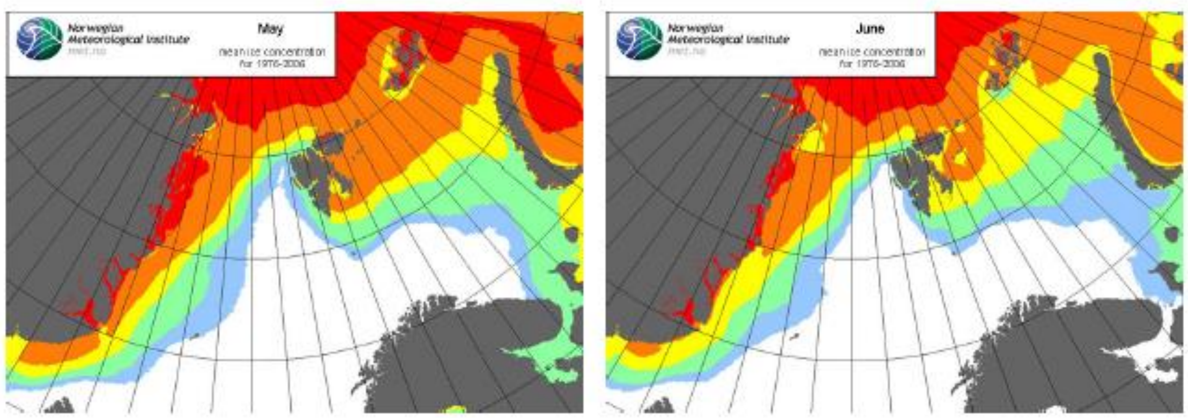
First-year and multi-year ice originate from frozen sea water, with first-year ice of a thickness anywhere between 30 cm - 2 m and multi-year ice up to 3 m. Multi-year ice is older, and by definition has survived at least two summers' melt (OCIMF, 2014). As a result, multi-year ice is much harder by nature, and poses a greater threat to ship navigation. Floating sea ice will begin to break up due to environmental effects, and drift about as drift ice in floes of various dimensions. Some of this drift ice can pack together with other floes, resulting in partially packed polar ice. Ice, or pressure ridges may also form in the pack ice, where the thickness can reach 10-15 m. The concentration of ice will provide a definition of the ice regime ranging from open water to packed polar ice (Kjerstad, 2011). The authors are will not go into further depth on classification of ice regimes, but the reader is referred to publications such as Kjerstad (2011) and OCIMF (2014) for further information.

Glacial Ice

Glacial ice is very hard and can cause considerable damage to a vessel if a collision were to occur. It is land based and categorized into one of the following categories:
_ Growlers
_ Bergy bits
_ Icebergs

Smaller pieces of ice that fall from the glacier into the sea are called growlers or bergy bits. Bergy bits are no more than 20 m long and show less than 5 m above sea-level, whilst growlers are normally less than 5 m long. Growlers are usually white, but can sometimes be transparent, blue-green or nearly black. Icebergs can have various shapes and sizes based on the environment the glacier it originates from is located in. An iceberg is a massive piece of ice that reaches more than 5 m above sea-level. (OCIMF, 2014)

The Presence of Ice around Spitsbergen
Ice is common throughout the year in the Spitsbergen region. As mentioned, the most relevant months for vessel traffic in the area are from May to October. The mean ice concentration over 30 years is presented in Figure 2. It is evident that sea ice can be found in all relevant months, but is more prevalent earlier in the year. Avoiding hazardous sea ice may therefore be necessary when navigating in the region.



May June

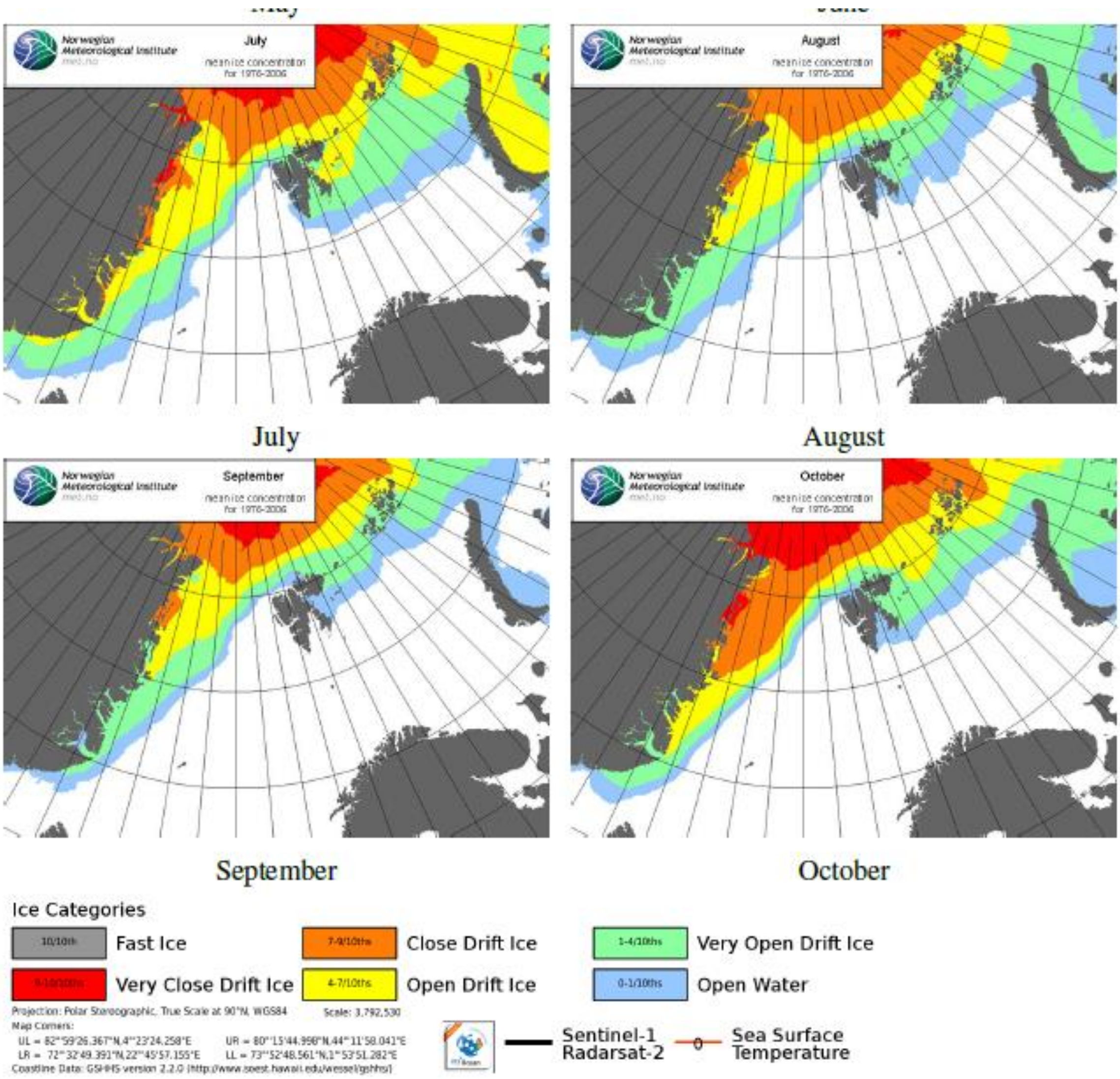


Fig. 2: Average (mean) ice concentration charts for each month of the year (30 years mean, 1976 - 2006).

Navigational Challenges in the Spitsbergen Area

Det Norske Veritas (2010) has found that the probability of collision with glacial ice in the form of icebergs and especially bergy bits and growlers to be high for marine traffic in the Spitsbergen region. The risk of collision is especially high in fjords where overseas and expedition cruise ships visit. Det Norske Veritas (2010) has identified that the risk is increased due to a number of factors. Det Norske Veritas (2010) outlines the fact that the areas where most glacial ice is found are popular tourist attractions, such as fjords near glacier fronts. Additionally, cruise activity is highest in the summer months, coinciding with the primary calving period for glaciers. Cruise vessels also have a tendency to go closer to glacial fonts than necessary, exposing them to increased risks from glacial calving. Det Norske Veritas (2010) also points out that it can at times be difficult to differentiate between harmless sea ice and glacial ice, giving rise to underestimation of the risks associated with ice collisions.

During the SARex 2 research cruise, multiple hazardous ice features were encountered.

Many of these ice features could pose a threat to a cruise vessel in the region, and would have to be avoided either by maneuvering around, or avoiding the areas which included hazardous ice features entirely. The Lilliehöök fjord is a prime example of an area where a cruise ship would be interested in visiting, as the Lilliehöök glacier is a popular tourist attraction. The fjord was littered with glacial ice that could pose a threat to a vessel. An example can be seen in Figure 3 which depicts a growler of an almost black color indicating its high density and hardness. At a high enough speed, a collision which such an ice feature could prove catastrophic. Growlers are however difficult to identify, increasing the risk associated with navigating in areas with glacial ice.

Fig. 3: Growler observed from KV Svalbard in the Lilliehöök fjord during SARex 2 (Photo: Brian Murray)

A less visited, but still popular region of Spitsbergen is the Sørgattet sound. KV Svalbard passed through the sound during SARex 2 on the 2nd of May. The ice chart shown in Figure 4 indicates open water for this date. However, upon arriving it was found that the sound was covered in ice as shown in Figure 5. After traveling further north, KV Svalbard returned through the sound on its way south later the same day.

Within a matter a matter of hours, the ice had drifted north out of the sound leaving it ice free. This gives an indication of how quickly the ice conditions can change in the Spitsbergen region, presenting a significant challenge to navigators.

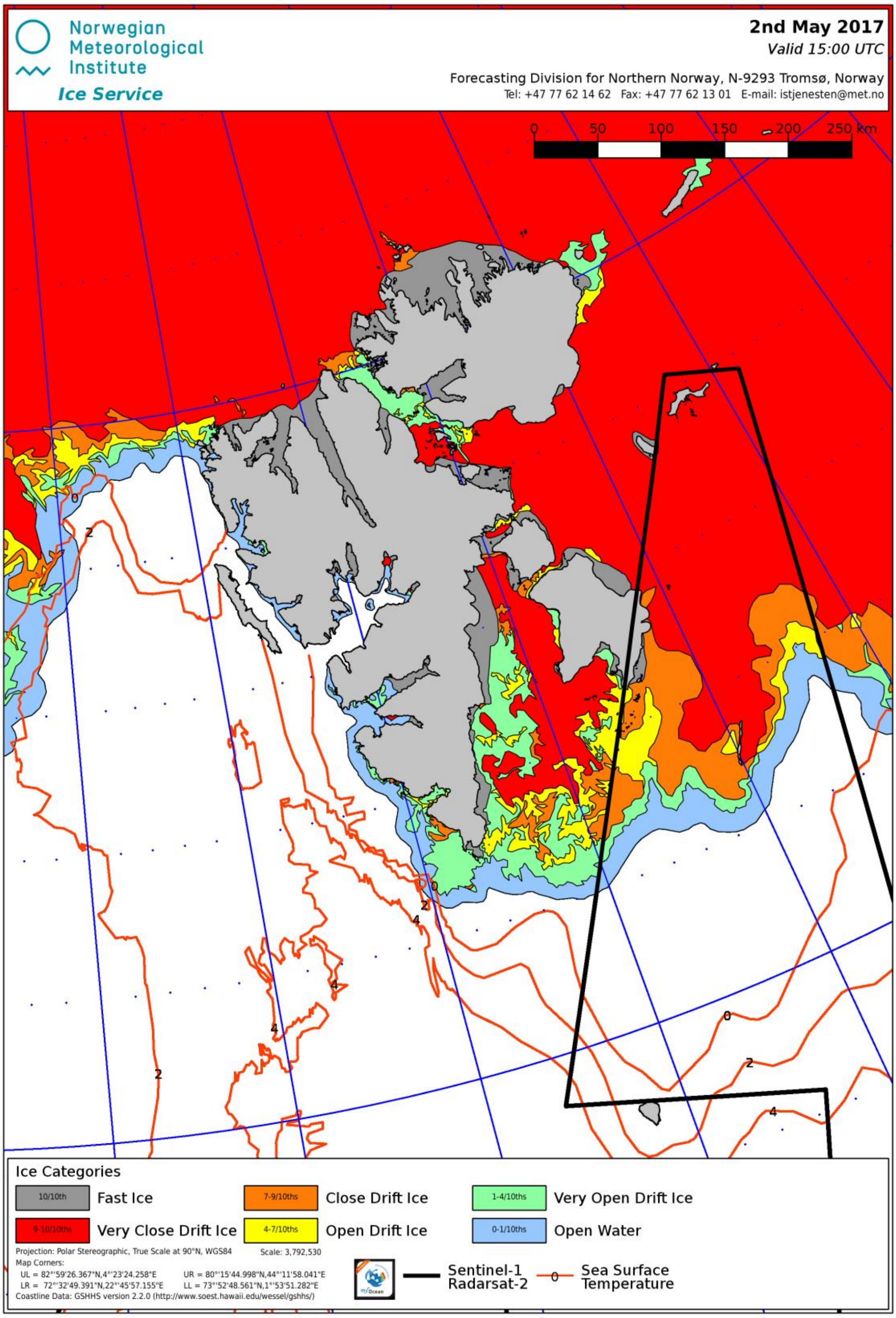


Fig. 4: Ice chart for Svalbard 02.05.2017 (Meteorologisk Institutt, 2017)

Fig. 5: Drift ice in Sørgattet (Photo: Brian Murray)

Wind

Various wind mechanisms and flow regimes can be expected in the Polar Regions and the responsible navigators on ships in these areas should be aware of these effects as they can arise without warning. Strong and unexpected winds can set an unprepared vessel into shallow water very quickly and the navigating vessel in these vulnerable areas should therefore be prepared to take immediate action if the vessel is exposed to such winds.

Svalbard consists of steep mountains, deep valleys and far inland reaching fjords. This complex topography interacts with the wind-flow passing the archipelago. Wind mechanisms due this interaction are downslope windstorms, valley flow or funneling winds and coastal jets and tip jets (Samuelsen, nd; Frantzen, 2016). A collective term for these wind mechanisms is mountain flow theory, and navigators on vessels in close proximity to complex topography should be aware of these mechanisms as they will occur when the upper flows interact with this topography.

Navigational Challenges in the Spitsbergen Area 9

Downslope Windstorms

Downslope windstorms or so-called fall winds can be observed on the lee side of the mountains. When the flow passes a mountain regime it will be subject to an adiabatic process. First the flow rises on the windward side due to the presence of mountains and cools down. Secondly, the flow sinks on the leeward side and heats up. This results in a pressure difference where the low pressure will be on the leeward side resulting in accelerated airflow (Samuelsen, nd).

Funneling Winds

Funneling winds or valley flow are related to the channeling effect given by the local topography. Channeling causes winds from any direction to flow along the valleys or the fjord's main direction or axis. Observations indicate that the strongest winds are where the funnel widens at the end and not the narrowest part. We can describe this effect as pressure driven channeling, where the flows in a funnel accelerate towards lower pressure and not in relation to the geostrophic flow (Samuelsen, nd).

Coastal Jets

Coastal jets are accelerated flows that result from topographic blocking. In cases where there are tall mountains, strong stability and the initial wind is weak, the geostrophic balance can be repealed and the flow will be accelerated towards lower pressure areas along the terrain. Coastal jets can be found in regions with tall mountains along the coast. According to Reeve and Kolstad (2011), tip jets also occur in locations where the airflow converges around obstacles such as islands and are in such cases the result of flow stagnation and flow splitting upstream of an obstacle. The generation of the tip jets are dependent on the stability of the air column, wind speed and direction upstream.

Polar Lows

Polar lows are another wind mechanism that a navigator in polar waters should be aware of. These small violent storms or mesoscale cyclones (diameter less than 1000 km), are frequently observed in the Atlantic sector of the Arctic. They occur most frequently during the winter when cold and stable air forms over the ice-covered areas in the Arctic. During certain synoptic weather patterns, cold-air outbreaks can arise and these air-masses become heated over the southerly warm ocean surface (Noer et al., 2011). This convection of air can form the polar lows which can be defined as active depressions (surface wind speed of 17 m/s or stronger), short lived (usually less than 24 hours) and occur over ice-free areas (Turner and Bracegirdle, 2007).

Catabatic Winds

Catabatic winds can form when a cooling effect occurs as high elevation air begins to descend beneath warmer and less dense air due to gravity. This dense air layer is created by intense surface cooling typically from glaciers (Esau and Repina, 2012). The glaciers down-sloping form towards the fjords contributes toward acceleration of this cold air together with channeling effect from the glacier-valleys. The catabatic winds also have a more contributing effect for the ice-navigators in polar waters as these winds accelerating down from the glaciers contribute toward removing sea ice from coastal areas thereby creating coastal polynyas. These polynyas in the coastal ice margin open leads in the sea ice where the ship can navigate (Müuller et al., 2009). The navigator in the polar environments should have proper knowledge how the local wind mechanisms work as they represent a considerable hazard for ships, aircraft and human activity. These mechanisms, particularly the tip-jets (Reeve and Kolstad, 2011) and polar lows are poorly resolved in the forecast models. Further the winds affect the pack ice concentration in the summer months as it grinds together or slackens depending on the wind variation.

Conclusion

The Spitsbergen area is riddled with navigational challenges. Cruise ships in the summer months are the most likely candidates to be susceptible to potential accidents. The contributing factors towards such an event range from the presence of ice, uncharted regions as well as complex wind phenomena. Only with a thorough understanding of the environmental challenges associated with the region can navigation be conducted in a safe and effective manner. Navigators therefore require a specialized skill set geared toward maritime operations in the Arctic.

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Implementation of results

SARINOR AND SAREX SPITZBERGEN

Lars Vollen, Maritimt Forum Nord and SARiNOR/SARiNOR2

First of all, on behalf of the SARiNOR projects and Maritimt Forum Nord SA, I would like to give credit to the SARex Spitzbergen project for the extensive work carried out and the very important and relevant knowledge coming out of the two exercises and reports. The extensive efforts and fruitful cooperation of the University of Stavanger and the Norwegian Coast Guard are very impressive.

- 1. Findings from the SARiNOR project

The following is a summary from the SARiNOR summary report "The Roadmap to Norway´s Arctic Policy", focusing on the main findings from the project:

1.1 MAIN FINDING 1: SURVIVAL AT THE ACCIDENT SITE

1.1.1 Avoiding hypothermia

Following an evacuation, the first prerequisite of survival is avoiding hypothermia and remaining in a position to look after oneself until rescued. If the body's core temperature begins to sink, one's capacity for self-care is reduced, and the negative development can escalate further. The surroundings and equipment for preventing hypothermia are therefore crucial to increasing the likelihood of survival. The preconditions for survival in the time leading up to rescue will be the life rafts/lifeboats being in a position to maintain a habitable environment that ensures survival over a longer period of time. The Polar Code sets out requirements for a "ventilated environment that will protect against hypothermia, as well as food and drink for a minimum of five days"."

1.1.2 Training and expertise affect results

Survivors' physical and psychological state, both before and after an accident, will also affect their ability to stay alive. The capability of the individuals concerned, together with their training and expertise, will affect how this phase is tackled. Crew members on a merchant vessel who know one another, are aware of the procedures and have carried out regular drills will have better prospects for coping in these situations than will cruise ship passengers. Evacuation onto land or even ice, as an alternative to remaining on a life raft/lifeboat, is a real option and is described in the Polar Code.

However, this requires extra equipment, and in cases where this is considered to be a probable scenario in advance, a list of suggested equipment in the form of packets of personal survival equipment and group survival equipment is described in the Polar Code. In the case of accidents in areas outside of helicopter range, the current P3 Orion aircraft has shown itself to be effective in searches, establishing communication between survivors and the Joint Rescue Coordination Centre, and dropping off extra equipment.

1.1.3 Staying dry is crucial

Dampness reduces the insulating characteristics of clothes. When combined with the cold, dampness reduces the body's ability to regain its normal temperature – something which is a prerequisite for survival over time. There is a likelihood of becoming wet during an evacuation from a ship in distress.

Dry evacuation improves the chance of survival. It is therefore important to have evacuation solutions that prevent direct contact with seawater. In addition, personal equipment should prevent people from becoming wet, with a good enough insulation ability to maintain body temperature. For those who do end up in the water, a prerequisite for survival is gaining quick access to a lifeboat/life raft, dry clothing and the essential heat. Today's lifeboats/life rafts are not particularly well-equipped for this type of rescue, and at this stage outside aid is not to be expected.

1.2 MAIN FINDING 2: RESCUE AND EMERGENCY PREPAREDNESS

1.2.1 Response time is crucial

After the evacuation itself, the time it takes for rescue resources to arrive on scene is crucial in determining how many people survive. In outlying Polar Regions, the time it takes to be rescued will be long – considerably longer than the introductory phases of alerting, search and notification. Experience from previous accidents has shown that during this time hypothermia is a real difficulty, especially given the cold climate. Any measure that can help to prevent hypothermia and reduce the time spent waiting for rescue will help more people to survive. The rescue response times are dependent on the presence of rescue resources in the region, particularly ships. This means that a deliberate positioning of rescue vessels in areas with marine activity – be it fishing, transport or the extraction of hydrocarbons – will help to reduce response times considerably. As the geographical areas involved are great, allocating rescue vessels across the entire region will require considerable resources. The resources should therefore be allocated to the areas with the most traffic.

1.2.2 Measures identified in the SARiNOR project:

Any factor that can cause delay and thereby increase the rescue time must be identified.

All measures identified must be evaluated and prioritised to make the rescue chain more efficient. Examples of the measures identified are:

- Improvements to infrastructure – including communications and broadband coverage.
- Advance storage, establishment of equipment depots that are suited to operational needs.
- Emergency medical preparedness, including the use of tele-medical equipment, must be improved.
- All categories of response personnel must be identified to ensure swift mobilisation, including the use of the Norwegian Armed Forces' Special Forces units (rostering systems will be evaluated).
- Establishment of a task force specially trained for demanding and "long-term" operations in cold climates.
- Evaluation of the setup for airdrops of rescue personnel and equipment in the case of major accidents.
- Improvements to R&D to make rescue operations more efficient, by putting new and modern equipment into use, including the use of drones, Arctic rescue equipment, improved search and monitoring, etc.

1.2.3 The next step will be to implement the findings and recommendations that have been raised:

- Future emergency preparedness must be efficient, risk based and truly proportionate to the actual activity taking place in the different geographic areas.
- A risk-based socio-economic evaluation of the different findings must be conducted to document how these are prioritised. The most socio-economically beneficial options should then be put into practice through a political will to implement the measures that will contribute to better safety in the High North.

The SARiNOR project highlights several different challenges regarding maritime emergencies in Arctic conditions; both on the vessel-side and the emergency response-side. The findings span from needs of new technology and practical solutions, to needs of large communication and infrastructure acquisitions to improve SAR in the High North.

The scope of SARiNOR2 to a large extent concerns salvage and pollution prevention, but also includes an extensive work package focusing on the implementation of the findings from both SARiNOR projects. The majority of the implementation work concerns developing findings from the projects into actions from the government side. This work is mainly focusing on improving the emergency response. Regarding issues pertaining to the implementation of the IMO Polar Code, SARiNOR has turned to the SARex-initiative. Representatives from the SARiNOR-projects have participated and contributed to both SARex-projects.

From a SARiNOR-perspective, the relevance of the SARex Spitzbergen project is evident; SARex Spitzbergen further investigates the IMO Polar Code regulation and highlights the practical challenges of surviving maritime casualties in the Arctic. This is a natural and important follow-up of the findings from SARiNOR.

3. SARex objectives and findings

The overall objective of the first SARex Spitzbergen exercise was to establish a baseline with regard to functionality of standard SOLAS lifesaving appliances in Arctic conditions. The exercise was a success, clearly demonstrating the additional challenges and clear limitations and shortages of such. The results from the practical demonstration has shown to be of great value; the presentation of the project to the IMO thoroughly underlining this.

The objectives of SARex 2 were a continuation of the objectives from 2016:

- Investigate the functional requirements as defined in the International Code for Ships Operating in Polar Waters (IMO Polar Code)
- Study the adequacy of modified lifeboats and life rafts for use cold climate conditions
- Study the adequacy of PPE for use in cold climate conditions
- Study the effectiveness of accessing and rescuing people from life boats and life rafts when in cold climate conditions
- Train Norwegian Coast Guard personnel on emergency procedures in cold climate conditions with particular reference to evacuation and rescue from cruise ships

The following is a summary of my observations as a participant in the exercise, and comments to the objectives and findings.

2.1 The adequacy of modified lifeboats and life rafts for use cold climate conditions

I was one of the participants in the life raft, and I was comfortable to stay until the end of the exercise. From my point of view, I would say that it should be possible to survive in a life raft under the given conditions, assuming it was equipped with the right kind of equipment (and not taking into account issues with sea ice). I should stress that the conditions were not severe during this exercise.

The inflated bottom of the life raft provided some isolation towards the sea, but it is my opinion that additional equipment would be necessary to provide for a habitable environment. Such could be personal equipment like improved suits/clothing and individual isolating devices. During the exercise, I was equipped with a personal inflated mattress, which proved surprisingly effective in providing isolation towards the cold bottom of the raft.

In my opinion, the life raft provided can be adequate for use in cold climate conditions. But the habitability of the life raft is largely dependent on additional equipment provided to the survivors. Equipped with the appropriate equipment, personal and group, it should be tested in more severe Arctic conditions to prove its adequacy. Also, the life raft needs to be tested in sea ice. I fear that this may not be an easy task for this type of survival craft.

2.2 The adequacy of PPE for use in cold climate conditions

As mentioned, the habitability of the environment inside the life raft during the exercise was largely dependent on the PPE. The ability to stay warm will of course depend on the isolating abilities of clothing, but also the potential for heat loss to the environment. It was very clear how the heat loss increased substantially when laying down on the cold life raft bottom. As mentioned, the individual inflated mattress proved very effective as additional isolation.

With the conditions inside the life raft during the exercise, more isolation would be necessary for survival. For myself, I was starting to get really cold at the time the exercise was stopped, and I would have had to make major changes to the situation to stop my body temperature from dropping further and going into a hypothermic state.

In my opinion, it is not possible to conclude whether the PPE provided is adequate for Arctic conditions or not, based on this exercise. What can be said is that requirements for PPE should be seen in connection with the type of survival craft provided. The requirement for PPE should be to enable the individual to keep warm under given conditions – be it with a canopy as the only shelter towards the Arctic climate or in a heated hard-top lifeboat. The same goes for the isolating abilities of the survival craft towards the sea. Requirements for the PPE and group equipment must be based on the abilities of the survival craft provided.

2.3 The effectiveness of accessing and rescuing people from life boats and life rafts when in cold climate conditions

One evacuation activity was carried out during SARex 2; helicopter evacuation from a life boat. My experience was that the evacuation exercise worked out well, and it was a very relevant show-case for how time-consuming and resource-intensive such an evacuation is. The most interesting observation was to see the extreme strain on the rescue diver. The build-up of ice-slush on the rescue diver from the water spray caused by the helicopter downwash, was severe. This additional strain caused by the Arctic conditions, must have a significant effect on the endurance of the helicopter rescue personnel.

The exercise also underlined the general limitations in capacity and range for helicopter evacuation operations.

2.4 Exercise limitations

It is important to take into account the limitations of the exercise activities and the effects of such when drawing the conclusions and applying the knowledge gained. The safety of the exercise participants is always the topmost priority, and together with ethical issues this will of course put limitations on how these exercises can be carried out.

In my opinion, one of the most important limitation to the life raft exercise was that the recurring opening of the canopy of the life raft. The reason for these events was for medical personnel to examine the participants inside the raft and for participants to enter the FRC to urinate. On each occasion, the heat loss from the life raft sheltered space was considerable. The second important factor was that the participants who went outside to urinate, suffered severe heat loss when exposed to the conditions outside the life raft. In my opinion, these factors have significant influence on the results. Adding to this, the fact that this is an exercise and not the real thing, make people uphold their intimate borders, i.e. refraining from sharing their body heat the way they would in a real situation.

Lastly, the functional and holistic nature of the IMO Polar Code addresses the adequacy of the whole system. It is therefore challenging to validate the adequacy of each component. Further work to suggest IMO Polar Code compliant LSA systems is needed.

4. Suggestions for further work

Based on the findings and experiences from both the SARiNOR- and SARex projects, the following is a short list of topics and thoughts that could be relevant for future SARex Spitzbergen exercises:

3.1 Further testing of survival craft adequacy

Life raft

The adequacy of this type of survival craft should be tested more extensively, focusing on issues that might disqualify it from operation in specific conditions, the most evident being operation in sea ice.

Lifeboat

Based on the experiences from SARex 2 it may be feasible to modify a standard SOLAS lifeboat for Arctic operation. A next step could be to do the same exercise for a typical passenger vessel lifeboat. How much capacity would be lost? Also, testing of life boats in more severe Arctic conditions would be of great interest.

3.2 Wet evacuation

With reference to the comments regarding the adequacy of PPE and survival crafts, another issue is the evacuation part. The SARiNOR findings stresses the importance of dry evacuation, and concludes that standard SOLAS equipment will not be able to support regaining heat after severe loss of body heat. The question is whether it is possible to exclude the risk of wet evacuation from the equation or not. If wet evacuation remains in the equation, means for survival of such in Arctic sea conditions must be taken into account.

The eventuality of wet evacuation is not mentioned explicitly in the IMO Polar Code. It is however stated that *"All life-saving appliances and associated equipment shall provide safe evacuation and be functional under the possible adverse environmental conditions during the maximum expected time of rescue"*.

The combined LSA provided, including PPE, survival crafts and additional survival kits, should also take the possibility of wet evacuation into account.

Is it possible to survive for 5 days after a wet evacuation in the Arctic? What would be required to recover from such? How rapidly will one become hypothermic? What is needed in terms of PPE to preserve body heat? Is it possible to regain body heat in a survival craft? If so, which equipment is needed?

3.3 Group Survival Kits

The application of Groups Survival Kits may be part of the solution in a Polar Code LSA setup. Testing of pick-up and use of different types of Group Survival Kits is therefore relevant. Can GSKs supplement be a way to fix the shortcomings of standard SOLAS LSA?

3.4 Survival of cruise ship passengers

Without having the statistics to support this statement, I dare assume that the general fitness and mobility of such differs considerably from that of the population participating in the SARex Spitzbergen exercises. The Operational Assessment of the IMO Polar Code for cruise vessels should take the level of physical fitness and mobility of their passengers into consideration. Is it possible to test or demonstrate the additional challenges originating from a less physically fit and mobile population?

3.5 Evacuation to ice

Another interesting topic is evacuation from a vessel onto ice or ice slush. Will it be possible to test such a scenario? How can different types of survival crafts be applied in such a scenario?

5. The future of SARex Spitzbergen EXERCISES

As of today, there is no organisation or finance in place for setting up and carrying out a new SARex Spitzbergen exercise next year. The University of Stavanger has given Maritimt Forum Nord SA (MFN) the task to bring the initiative forward, and MFN is currently working hard together with the University of Stavanger and other key resources, towards establishing a new foundation to enable a continuation of the initiative for the coming years.

On one side – as mentioned, the SARex Spitzbergen project has delivered substantial knowledge regarding relevant and critical challenges and questions. On the other side, the project has been run on a minimum-budget, driven forward by key personnel with strong ambitions. This is a vulnerable organisational model, which will be challenging in the longer run. It is the opinion of MFN that the time is right to establish a more robust and long-term organisational and financial model for the SARex Spitzbergen initiative.

Going forward, the preliminary objective is to establish an attractive and relevant arena for testing and development of critical equipment and training of personnel, in close cooperation with relevant users, regulators and competence centres.

The intention will be to test and verify that critical equipment to be used in incidents and accidents works as intended and according to national and international standards and requirements, such as the Polar Code.

MFN plan to establish a project that is intended to initially run for 3 years.

Lastly, I would like to encourage organisations and persons interested in contributing to the development of the SARex Spitzbergen initiative, to contact MFN or the University of Stavanger for further discussions.

Relevant parts of White Paper to the Norwegian Parliament. Innstilling 326 S (2016 – 2017) Innstilling fra justiskomiteen om Risiko i et trygt samfunn – Samfunnssikkerhet (In Norwegian)

Jorodd Asphjell, Member of Norwegian Parliament (Labour)

Chapter 15 of the White Paper

Kapittel 15: Internasjonalt arbeid
Sammendrag
Arbeidet med samfunnssikkerhet kan ikke betraktes i et avgrenset, nasjonalt perspektiv. Truslene og risikoene Norge står overfor er i stor grad knyttet til utviklingstrekk utenfor våre grenser. Det er nødvendig med et tett samarbeid med andre land for både å forebygge og håndtere utfordringene.

Regjeringen vil:
– fortsette det gode nordiske samarbeidet, spesielt innenfor Haga-samarbeidet
– være en aktiv deltaker i EUs samordningsmekanisme for sivil beredskap
– arbeide for en tverrsektoriell, norsk deltagelse innenfor det nye programområdet på katastrofe-forebygging innenfor rammen av EØS-midlene
– bidra til å revitalisere retningslinjer om humanitært-militært samvirke i regi av FN
– aktivt arbeide for internasjonale standarder innenfor samfunnssikkerhet

Komiteens merknader
Komiteen vil peke på viktigheten av at samfunnssikkerhet ikke kan betraktes i et avgrenset, nasjonalt perspektiv. De trusler og risikoer Norge står overfor, er i stor grad knyttet til utviklingstrekk utenfor våre grenser. Det er nødvendig med et tett samarbeid med andre land for både å forebygge og håndtere utfordringene. Grenseoverskridende utfordringer krever grenseoverskridende samarbeid. Det nordiske samarbeidet er viktig og har tradisjonelt vært godt.

Komiteen vil vise til Haga II-erklæringen fra 2013, hvor det ble fastsatt en ny plattform for det nordiske samarbeidet innenfor samfunnssikkerhet. Målet med denne erklæringen var et robust Norden gjennom forebygging, håndtering av og gjenoppretting etter alvorlige hendelser. Det å ha gode rednings- og beredskapsavtaler med våre naboland er viktig. Nordområdene kjennetegnes av lange avstander og spredte ressurser som gjør at samarbeid knyttet til redning, sikkerhet og beredskap mellom land i regionen er svært viktig.

Komiteen viser til at Norge har lange tradisjoner for skipsfart i nordområdene, og det er ønskelig å videreutvikle vår posisjon som en ledende og ansvarlig maritim aktør i nord. Over 80 prosent av skipstrafikken i Arktis foregår i norske havområder. Økende aktivitet i nordområdene generelt og vårt område spesielt, medfører økt risiko for større sjøulykker med fare for tap av menneskeliv og materiell, og med miljømessige konsekvenser.

Komiteen er kjent med at det de senere årene har blitt åpnet opp for kommersiell gjennomfart med gods- og varetransport mellom Europa og Asia gjennom Nordøstpassasjen. Det er grunn til å anta at denne trafikken vil øke i de kommende årene dersom klimaendringene fortsetter og Russland legger til rette for økt trafikk.
Komiteen er også kjent med at fiskeriaktivitetene øker i nordområdene som følge av økt biomasse og varmere hav, i tillegg kan det bli økt petroleumsaktivitet og skipsfart i området.

Komiteen viser til at nordområdene har en kraftig økning i turisme, og mye av aktiviteten foregår til havs. Antall cruiseskip som bl.a. besøker Svalbard er økende. Det samme er passasjermengden. I 2011 var det om lag 25 000 passasjerer, i 2016 var det økt til 41 000 passasjerer. Også mange av turistene som kommer til Svalbard med fly, deltar på ekspedisjonscruise rundt øygruppen. Komiteen viser for øvrig til Meld. St. 19 (2016–2017) Opplev Norge – unikt og eventyrlig. Komiteen viser til at Norge over lang tid har vært en pådriver for å få på plass globale kjøreregler og beredskap i polare farvann.

Komiteen vil i den forbindelse vise til vedtakene i IMO, Polarkoden for skip, som trådte i kraft 1. januar 2017. Komiteen er kjent med rapportene fra bl.a. SARiNOR, som dokumenterer at det er et betydelig gap mellom de minstekrav som aktørene i dag følger og de obligatoriske mål og krav som følger av vedtakene i Polarkoden. Komiteen vil peke på at norske myndigheter har et selvstendig ansvar for å sørge for at dette gapet lukkes. SARiNOR har i sine rapporter kommet med en rekke anbefalinger til tiltak som er nødvendige for å lukke dette gapet. Komiteen vil med utgangspunkt i utredningene og anbefalingene fra SARiNOR anmode om at regjeringen vurderer videre oppfølging av prosjektet i SARiNOR.

Komiteen viser for øvrig til Meld. St. 32 (2015–2016) Svalbard og Innst. 88 S (2016–2017) og de anbefalingene som der fremkommer for å styrke SAR-beredskapen. Komiteen mener at etablering (Innst. 326 S – 2016–2017 21) av værradar på Svalbard vil ha stor betydning for sikrere sjøtransport, samt ha stor beredskapsmessig betydning for lokalsamfunnet i Longyearbyen, som vil få en betydelig forbedring av forhåndsvarsling av snøforhold som vil kunne medføre snøras. Det samme gjelder selvsagt også på sommeren og ved varsling av store nedbørsmengder.

Komiteen vil understreke viktigheten av et sterkt og velfungerende internasjonalt redningssamarbeid. Kvaliteten er avhengig av nødvendig fokus og kunnskap om hvilke utfordringer aktivitet i nordområdene kan føre til. Komiteen mener at samarbeidet med Russland om søk og redning viser at selv i krevende tider internasjonalt finnes det områder hvor man likevel makter å holde det rette fokus. Komiteen vil også vise til Innst. 236 S (2011–2012), jf. Meld St. 7 (2011–2012) om Nordområdene. I denne innstillingen sier blant annet en samlet komité:

«Komiteen mener at etableringen av et ressurs- og kompetansesenter for sikkerhet og beredskap i nordområdene (RKSN) vil befeste Norge som verdensledende på SAR (Search and Rescue). RKSN vil være et logistikk- og utdanningssenter for sikkerhet, redning og beredskap i nordområdene.» Komiteen vil videre vise til Meld St. 32 (2015-2016) Svalbardmeldingen. Komiteen vil vise til at Nordområdenes særskilte utfordringer ble gjennomgått.

Komiteen vil henvise til følgende merknad:

«Komiteen mener også at regjeringen bør vurdere Longyearbyen som et nav for søk og redning i Arktis. Det vises til at Norge etter avtale med Canada, Danmark, Finland, Island, Russland, Sverige og USA har et betydelig ansvar for søk og redning i Arktis. Bakgrunnen for avtalen var en erkjennelse av økt aktivitet og trafikk i Arktis krever styrking av redningssamarbeidet.» og videre:

«Komiteen mener det blant annet er viktig å intensivere sjøkartleggingen av farvannene rundt Svalbard. Komiteen viser til at Maritimt Forum Nord SA har gjennomført en omfattende utredning om søk og redning i arktiske farvann som avdekker mangler ved beredskapen.»

Komiteen slutter seg til de tidligere komitémerknadene og støtter opp om de ambisjoner som der er beskrevet. Likedan understreker Komiteen alvorlighetsgraden som er beskrevet. Komiteen forventer derfor at regjeringen tar problemstillingen på største alvor og vurderer nødvendige tiltak fortløpende.

Komiteens medlemmer fra Arbeiderpartiet og Senterpartiet viser til meldingen som omtaler Norges omfattende redningssamarbeid med andre land i nord. Som følge av de lange avstandene, det røffe klimaet og de relativt få redningsressursene vil et styrket redningssamarbeid mellom de landene som har ansvar for søk og redning i arktiske farvann, være en forutsetning for å oppnå et akseptabelt nivå for SAR-beredskapen.

Disse medlemmer vil i den forbindelse vise til vedtakene i Arktisk Råd og IMO Polarkoden for skip, som trådte i kraft 1. januar 2017. Rapportene fra SARiNOR dokumenterer at det er et betydelig gap mellom de minstekrav som aktørene i dag følger, og de obligatoriske mål og krav som følger av vedtakene i Polarkoden.

Disse medlemmer vil peke på at norske myndigheter har et selvstendig ansvar for å sørge for at dette gapet lukkes. SARiNOR har i sine rapporter kommet med en lang rekke anbefalinger til tiltak som er nødvendige for å lukke dette gapet.

Disse medlemmer vil med utgangspunkt i utredningene og anbefalingene fra SARiNOR anmode om at regjeringen tar initiativ til at det utarbeides en handlingsplan med sikte på styrket SAR-beredskap.

Disse medlemmer vil peke på at selv om arbeidet med samfunnssikkerhet og beredskap på Svalbard er blitt styrket de senere år, har Svalbard særlige utfordringer knyttet til Svalbards geografiske plassering, store avstander og krevende klima.

Disse medlemmer har merket seg at meldingen viser til at den stedlige beredskapen ikke er dimensjonert for å håndtere større eller samtidige hendelser over lang tid.

Disse medlemmer vil samtidig fremheve at Svalbards geografiske plassering også har en annen dimensjon, nemlig Svalbards strategiske beliggenhet i forhold til de sterkt økende aktivitetene innen petroleum, skipsfart, fiskeri og ekspedisjonscruise.

Disse medlemmer vil i denne sammenheng vise til innstillingen til Meld. St. 32 (2015–2016) Svalbardmeldingen, fra Stortingets utenriks- og forsvarskomité, der denne komiteen ber regjeringen vurdere Longyearbyen som nav for søk og redning i Arktis.

Disse medlemmer støtter denne anmodningen og vil i den sammenheng også henvise til funnene i SARiNOR-rapporten, som dokumenterer at beredskapen i nordområdene må styrkes i takt med den økte aktiviteten. Sentralt i dette står et riktig dimensjonert beredskapslager i Longyearbyen som vil bidra til å redusere responstiden som følge av lange avstander i Arktis. Dette er et sentralt tema som bør utredes i tilknytning til en handlingsplan for å styrke SAR-beredskapen innenfor Norges ansvarsområde i Arktis.

Asphjell's comments re SARex 2 to the Parliament during his presentation

Jeg ser at internasjonalt samarbeid knyttet til samfunnssikkerhetsarbeidet i nordområdene og på Svalbard også er omtalt, hvor komiteen har en fellesmerknad om hvilke utfordringer vi ser er knyttet til den økende trafikken vi ser i nordområdene, knyttet til Polarkoden. Jeg var så heldig å kunne være med på SARex, Search and Rescue exercise, på Svalbard i mai. Der fikk vi oppleve og se – sammen med leverandører av utstyr som livbåter, redningsflåter, livredningsutstyr osv. – hvilke utfordringer som oppstår hvis et forlis skulle skje i disse områdene. Det er viktig at denne typen øvelser blir gjennomført flere ganger, og at det ikke bare er leverandører av utstyr, men ikke minst også de som trafikkerer i disse områdene, som får bruke utstyret, prøve det og kjenne på kroppen hvordan det er å ligge i en flåte, og hva sannsynligheten for å overleve er, og hvilke krav vi som land skal sette til dem som skal være i disse områdene, og hvilke ressurser vi som land skal bruke for å kunne redde folk ved alvorlige hendelser i disse områdene. Så det er også en viktig bit – at vi tar innover oss at vi har store områder og store farvann, og at vi har et viktig samfunnssikkerhets- og beredskapsarbeid knyttet til dette området. KV «Svalbard», som ferdes i dette området, gjør en viktig jobb sammen med mannskapet om bord i de båtene.

LEARNINGS FOR THE OIL AND GAS INDUSTRY AFTER SAREX I AND II

Jan Erik Jensen, Petroleum Safety Authority, Stavanger, Norway

Summary
The SAREX I[13] and II provided valuable insight to challenges in an emergency situation involving prolonged stay on lifeboats and -rafts. The venue was further north than today's exploration and production of oil and gas activities. However, there are several lessons learned relevant for where the oil and gas activities are situated today on the Norwegian Continental Shelf (NCS). The environment where the oil and gas industry are in some ways more harsh due to winter time activities (as oppose to cruises in the summer, which was the basis for the SAREX I and II scenarios), with an open ocean environment, darkness and more precipitation than north of Svalbard.

The key relevant learnings are especially related the need for proper equipment and competence to increase chances for survival in a prolonged (over a period of up to five days) stay in lifeboats and –rafts in Arctic or close to Arctic conditions. There is a considerable need to have competence related to cold climate survival including leadership in the lifeboats and rafts. In addition to specific requirements to evacuation equipment, survival clothing needs to be sufficient, worn correctly together with necessary activities to remain cognitive abilities to be able to handle and operate survival equipment.

Note that this article does not provide a full list of experiences from SAREX I and II, but rather highlighting those that are identified as particularly relevant for the NCS, as well as personal experiences.

Introduction
SAREX I and II considered evacuation and survival for maritime emergencies in Arctic waters. The scenario on both expeditions was an emergency on a cruise ship with evacuation. This section will look into learnings from SAREX I and II, which could be relevant for the oil and gas industry on the NCS.

Although the expedition was on higher latitudes than present oil and gas activities in the Norwegian sector, there were several learnings relevant for emergency preparedness in any cold harsh climate waters.

PSA[14] participated in both SAREX I and II, being an active part of the performed tests. The survival test participation in both SAREX I and II were done in the raft. Off course, the best learnings came from the direct participation, which were the raft survival tests, evacuation of lifeboat by K/V Svalbard personnel, helicopter evacuation from lifeboat with the SAR-rescue helicopter and use and testing of emergency equipment for maritime causalities in the Arctic. Also witnessing other tests such as lifeboat survival, use of different types PPE (Personal Protection Equipment), testing of AIS-SART and EPIRB, use of IR-camera to identify casualties and simply by being on a vessel exposed to low sea and air temperatures.

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[13] Solberg, K.E., Gudmestad, O.T.; Kvamme, B.O. (2016) SARex Spitzbergen: Search and rescue exercise conducted off North Spitzbergen: Exercise report. Report 58, University of Stavanger, 2016

[14] Petroleum Safety Authority

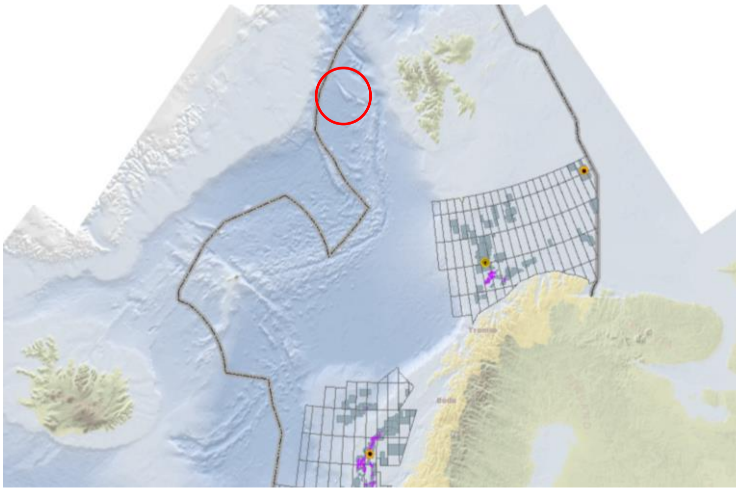


Figure 1 Red *circle indicates area for SAREX I and II activities. Rectangles indicate areas opened for oil and gas activities (source: www.npd.no).*

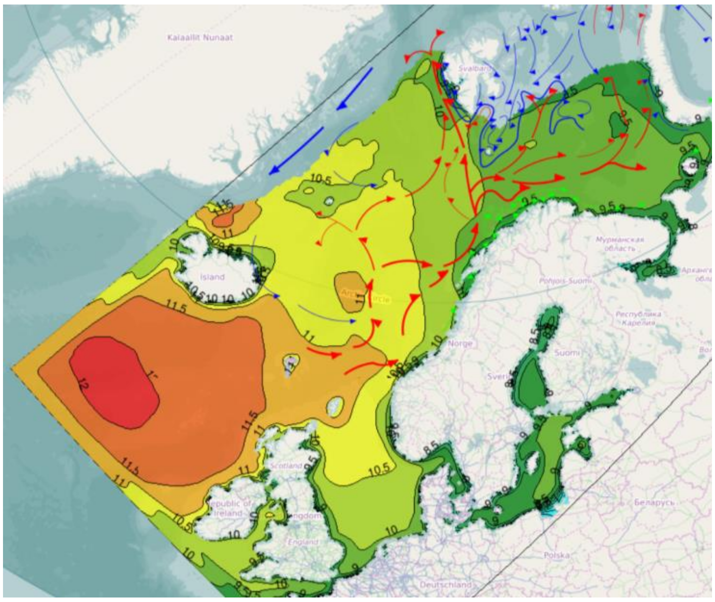


Figure 2 *Average water temperatures summer and winter for Barents Sea and Arctic Sea around Svalbard*

Climatic relevance

The sea temperatures during last year's SAREX I were -1 °C and this year's SAREX 2 about 1 °C. Air temperatures in 2016 were around -10 °C, whereas this year they were from above 0 °C to about – 5 °C. Winds were relatively calm to moderate in 2016 and wind varying up to strong gales this year. The SAREX 2 even experienced half a meter wind chop, even though the fetches were very limited inside the fjord that was the venue of the trials.

Although the sea temperatures during SAREX I and II were lower than in most areas of the NCS, the air temperatures and wind conditions are comparable to any part of the NCS during periods of the winter seasons. The open ocean temperatures on the NCS is typically never much less than 4 °C. However, in the far north and north east of the licensed area, there are occasionally sea temperatures close to 0°C.

The SAREX I performed tests related to solid sea ice, *e.g*. maneuvering and mooring of lifeboat, life raft transport on top of solid ice and test of emergency airdrop supplies. Those type of tests are not relevant for today's oil and gas industry in Norway and not part of this articles evaluation.

Relevance of technical, operational and organizational barriers
A simplified illustration of the different type of barriers used in the Norwegian oil and gas industry: **Who** (organizational) is doing **what** (operational) with what type of **equipment** (technical)?

Technical barriers
The equipment put to test for both SAREX I and II was for the most part, relevant for the offshore oil and gas industry, *i.e*.:

- Lifeboats
- Life rafts
- Survival equipment, survival suits and life vests
- Personal Protective Equipment (PPE), clothing underneath suits and life vests, hoods and gloves
- EPIRB and SART - detection equipment
- (Not part of SAREX but general experience) Heat tracing e.g. outside muster areas, helideck, water rations in life rafts and lifeboats

Although not part of the primary goals for this exercise, there were also several learnings from being on a ship in arctic climate, especially related to heat tracing.

Operational and organizational barriers
Several operational barriers were tested during both SAREX I and II:

- Leadership in survival exercise on-board life raft and lifeboat.
- Rescue of people from lifeboat to KV Svalbard with the use of MOB boat (SAREX I).
- Rescue of people from lifeboat to shore with the use of helicopter (SAREX 2).

Evaluation of relevance of the different parameters for the petroleum industry in Norway

There are very few descriptive and specific requirements in the HSE regulations[15] related to Arctic conditions. The exception is the NMA[16] regulations that has some requirements related to operations in areas with temperatures considerably lower than 0° C in the 856/87 Construction Regulations, Section 7. However, the HSE regulations are functional and the operator and rig owner must adapt both facilities and personnel to enable safe operations in the northern parts of the NCS. It is a requirement that the specific conditions at the location where an activity is performed, shall be taken into account and given due consideration.

In the following section there will be a review of the different barriers listed above, what the most relevant PSA or NMA regulations related to offshore oil and gas industry, and potentially learnings for the offshore industry. Note that other requirements may also apply. The list is aiming to show the main regulatory references. There are for instance general requirements in the HSE regulations. For example the Activity regulations Section 77 c) states that the operator or rig owner must ensure that "*personnel can be rescued during accident situations, cf. also Section 41 of the Facilities Regulations*," and in d) "*the personnel on the facility can be evacuated quickly and efficiently at all times, cf. also Section 44 of the Facilities Regulations*,". This in turn may imply that technical

[15] Regulations relating to Health, Safety and the Environment in the Petroleum Activities (HSE-Regulations)
[16] Norwegian Maritime Authorities

measures, not listed in the Facilities regulations, must be in place to obtain the requirements in the Activity regulations.

There are some key **differences** between the scenario of SAREX I and II (a large-scale mass evacuation scenario in northern part of Svalbard), and the accident scenarios possible in the petroleum industry:

Distance from shore based resources: Today's distances from shore based rescue resources to the offshore facilities, even in the furthest exploration areas, are considerably less than a potential cruise ship evacuation north of Svalbard. However, in the newly opened areas for exploration, distances are much greater than in the more developed areas of the NCS. One example is Korpfjell in block 7435, where exploration drilling started in August 2017.

Number of persons to be rescued: The number of personnel on-board an oil installation is considerably lower compared to number of passengers on a cruise ships (even though there are restrictions on how many passengers that are allowed on-board cruises in the most remote areas around Svalbard). However, there are also mobile offshore hotel (flotel) facilities that support projects on fixed installations. The flotels can host up to 450 guests in addition to the personnel on board the fixed installation. Normal manning levels on fixed and mobile offshore facilities are typically in the order of 50 – 120.

Threat of solid ice: There are no areas on the NCS with exploration drilling (or production) with an imminent threat of either sea- or glacial ice. There is year round presence of ice around Svalbard, except the parts of the west coast.

Other environmental differences: The areas chosen for the SAREX I and II were in an area with;

- limited fetch, *i.e.* well protected, as oppose to the offshore oil and gas industry present in open long fetch ocean areas. Hence a completely different environment with regards to waves and currents in particular.
- low average precipitation compared to areas of offshore oil and gas industry.
- lower sea water temperature, although in the areas furthest north for exploration there can be seasonal temperatures similar to what was the case in SAREX I and II.
- wildlife threats (polar bears and walruses).

Presence of daylight: The expeditions were performed in the spring, which in these latitudes means 24 hours of daylight. This is also typical for the cruise industry in these areas. The offshore industry will in many cases operate through the dark winter months, which together with higher likelihood of more wind, waves and precipitation making SAR operations far more difficult.

Availability of emergency preparedness resources: The offshore oil and gas industry is obliged by regulations to sustain emergency preparedness resources dedicated to each specific operation, whereas the cruise industry rely on public resources.

Emergency preparedness training: The offshore oil and gas industry provides emergency response training for all personnel travelling to an offshore installation (Basic Safety Course[17]) in addition to inter-active courses before travelling offshore, heliport safety brief and introductory safety briefs lasting for about an hour on-board each facility. The cruise passengers get a safety brief on-board most cruises as well as performing an emergency response exercise, but it is reasonable to believe that this training is not of the same standard as on an offshore installation.

[17] Basic Safety Course lasts for five days, and includes helicopter evacuation training in a pool. It's mandatory for all personnel travelling to an offshore installation

<u>Average health of cruise passengers vs. offshore workers</u>: All offshore workers need to have passed certain health requirements and received a certificate of proof to be fit to work offshore. Similar strict requirements are not common for cruise passengers.

There are also some key **similarities** between the scenarios and equipment used in SAREX I and II and what is relevant for the offshore oil and gas industry on the NCS:

<u>Means of evacuation</u>: Both cruise vessels and offshore oil and gas facilities use lifeboats and life rafts. The actual means were comparable in SAREX I, both the conventional lifeboat and rafts. NOTE: the modified lifeboat in SAREX 2 and improved specification life raft of SAREX 2 **are not used** in the offshore oil and gas industry.

<u>Emergency preparedness organization</u>: The dedicated emergency response personnel both on-board an offshore facility and on a cruise ship have certification and received training in their emergency response role.

<u>Survival suits and life vests</u>: The insulated survival suits used in SAREX I and II are assumed to have an insulation capacity reasonably comparable to the helicopter transport suits used on the NCS. However, the helicopter transport suits are available in several sizes and thereby functionality is increased. The insulated suits used in SAREX I and II are typically found in cabinets in the lifeboat muster areas. The life vests used in SAREX I are similar to those used on MODU's[18].

<u>Air and sea temperatures</u>: The air temperatures during the expedition where similar to what can be experienced during winter seasons in some parts of the NCS. Water temperatures in the north/north eastern part of the NCS can seasonally drop to temperatures experienced (at least in SAREX 2 where the sea temperature was 1,5° C).

<u>Crew taking part in the SAREX I and II</u>: Although the crew on-board K/V Svalbard and many of the participants on these expeditions where specialized in emergency response, on average, the composition of participant in survival tests were comparable to offshore crew. The need for communication and leadership would be similar in both a cruise and offshore industry evacuation.

Technical barriers

Lifeboats

<u>Regulations</u>

1. Facility regulations Section 44 (permanent production facilities), also with references to NORSOK S-001 and DNVGL-ST-E406
2. NMA 16/90 Lifesaving appliances regulations, several sections *e.g.* Sections 10 and 21 (mobile offshore units – MODUs)

<u>Lessons learned</u>

See also SAREX Spitzbergen Report April 2016, Chapter II.2.4 "*The lifeboat's capabilities and capacity during the Phase I exercise*" and similar chapter from SAREX 2.

1. **Ice formation in vents** in SAREX 1. The low pressure release valve that activates when engine is running (using air inside) clogged up with ice. The DNVGL-ST-E406 Chapter 3.6.1.2 says that ice formation shall be taken into account when designing a lifeboat. It also refers to DNVGL-OS-A101.

[18] Mobile Offshore Drilling Unit

2. **Ventilation** - an issue related to condensation and also low O_2 plus high CO_2-levels. Part of DNVGL-ST-E406 Chapter 8.3.3. There was a CO_2- meter that indicated the need for ventilation. This in turn, caused lowering of temperatures inside and condensation.
3. **Diesel heater** provided too warm temperatures for wearing survival suits. Use of diesel heater needs to be such that survival suits could be worn in cases of needs for quick evacuations. There is not enough room for storing of survival suits in a secure and proper manner. Part of DNVGL-ST-E406 Chapter 8.3.3.
4. Ability for lifeboat captain to **communicate** with passengers at the opposite/far end of vessel. The captain is often located at the helm which was a raised seat in the aft of the lifeboat. There was additional noise from engine, wind, wave motion etc. which made it difficult to make direct commands. A speaker system inside the lifeboat would be of great help. This subject is not covered by DNVGL-ST-E406.
5. **Evacuation** to helicopter from lifeboat roof top not realistic in open seas due to wave motion and risk of hooking into deluge system. Some sort of removable railing together with anti-skid cover would be a great asset for helping standing on lifeboat roof.
6. **Toilet facility** useful. Covered by DNVGL-ST-E406 Chapter 8.3.5.

The SAREX I and II had the same type of lifeboat, being a conventional lifeboat. The lifeboat used this year was an improved version of last year's, *e.g.* insulation on seats (styrofoam), toilet (type "porta potti") and diesel heater. Just these two improvements provided a huge impact on comfort and estimated survival rate on-board, respectively.

Life rafts

Regulations

1. Facility regulations Section 44 (permanent production facilities), also with references to NORSOK S-001
2. NMA 16/90 Lifesaving appliances regulations, several sections *e.g.* Sections 11 and 23 (mobile offshore units – MODUs)

Lessons learned

See also SAREX Spitzbergen Report April 2016, Chapter II.2.6 "*The life raft's capabilities and capacity during the Phase I exercise*" and similar chapter from SAREX 2.

1. The SAREX 2 life raft also had near standing height and a air filled beam to keep the tent in position which provided support to hold on to during times of wave motion and needs to move around the raft.
2. The SAREX 2 life raft with features such as double bottom and a double tent provide a major improvement in terms of insulation from the single bottom and tent version used in SAREX I.
3. The SAREX 2 life raft had welded double bottom where the welds itself created cold bridges.
4. The SAREX 2 life raft also had some leaks in seams that created a small but constant flow of sea water into the raft. This was removed by using sponges throughout the exercise.
5. Even though the raft was not filled to maximum certified capacity there was very little room to move. Similar experiences where made both in SAREX I and II. However, personnel was pulling out of the experiment at a far faster rate last year, leaving much more room to move. This room was used effectively last year to do exercise in order to produce heat. This was not possible to the same extent in SAREX 2, where almost all participants lasted the whole duration of the experiment.
6. The zipper on the outside of the tent froze when waves hit the raft's tent. Over a prolonged stay in a raft this could be an issue.
7. The radar reflector was not easily mounted on the raft ceiling outside. The reflector was also lost while the wind reached gale force.

8. The pontoons around the raft in SAREX 2 provided a good bench, removing the need to sit on the cold and at times wet raft bottom.
9. The ballast tanks underneath the raft bottom provided a lot of stability together with the very strong winds and short period wind-waves (chop) towards the end of the experiment. Nevertheless, there was a sincere concern when the winds reached more than 20 m/s that the wind could have toppled the raft. At this time the personnel on-board the raft were taken on-board K/V Svalbard. The situation showed at least the importance of stability measures in place, in particular in an open ocean situation.

Survival suits & life vests

Regulations

1. Facility regulations Section 45 (permanent production facilities)
2. NMA 16/90 Lifesaving appliances regulations, several sections *e.g.* Sections 13, 14, 25 and 26 with references to the LSA Code Chapter 2.2 and 2.3 with some exceptions (mobile offshore units – MODUs)

Lessons learned

See also SAREX Spitzbergen Report April 2016, Chapter II.2.7 "*The capabilities of personal protection equipment the Phase I exercise*" and similar chapter from SAREX 2.

1. Compared to last year's SAREX I, all participants in SAREX 2 wore full suits. Three participants in the survival test wore uninsulated suits, the rest fully insulated suits. Some of the insulated suits also had extra insulation/padding in areas that had contact with raft floor in sitting or lying positions. The insulated suits were comparable to the commonly used helicopter transport suits[19] used on the NCS. The expected time of rescue in the case of an oil and gas related incident on the NCS is about 24 hrs. Together with wool clothing, these suits would most likely provide enough insulation in a dry environment inside a double bottomed/double tent type raft sustain body temperature in an Arctic environment.
2. The "one size fits all" suits that was used in SAREX I and II does not have pockets that could be useful to keep safety equipment and food rations.
3. The personnel on board used suits differently. It was obvious that some basic competence related to routines to open the zipper to let steam out would have been useful. The suits are water and airtight. There is a buildup of moist inside the suits. The timing and length of unzipping suits seemed essential. In addition, the use of the hood had an effect on the experienced cold. Those persons without an integrated hood noticed cooling at an earlier stage than those with hoods.
4. The Velcro around the ankles and the waist strap was an essential feature for the smaller persons using the "one size fits all suits".
5. From SAREX I there was a learning related to the heating effectiveness of simple one sheet bags for those that only wore life vests.
6. There was a limit number of water proof torches on-board. In a winter situation with complete darkness it would be essential to have sufficient lighting to ensure all activities and operations necessary.
7. The use of clothing underneath the survival suits and life vests provided in SAREX I was not standardized. However, it clearly showed that typically that persons properly equipped with several layers of wool did better than those without. In SAREX 2 it was more or less standardized, with woolen underwear plus normal clothes underneath survival suits.
8. The ones with uninsulated survival suits without integrated hood, but separate hood were noticing a distinct cooling of neck area. The thin provided neoprene hood was in some cases

[19] Helly Hansen Sea Air or Barents survival suits

successfully replaced by wooly beanies or hoods that retained heat better. Better still are the suits with integrated hoods.
9. All suits had separate gloves or mittens. The types provided where either three-fingered type crab-claw neoprene mittens or five fingered thin (2 mm?) neoprene gloves. The crab-claw mittens are far warmer, but impossible to wear while performing the simplest tasks.
10. It is a requirement of the NMA to have life vests with light, which automatically starts in contact with water. Lights on life vests might not be sufficient to detect personnel in the sea in snow or fog (common over between ice in open ocean in Arctic areas). See below section about detection equipment. There were no lights either on the "one size fits all" type survival suits used in this experiment.

PPE[20]

Regulations:
Facilities regulation Section 75 with reference to PPE regulations.

Lessons learned:
1. There are no protective gloves with insulation for Arctic conditions that enables operating of valves or small items either in a normal work situation or in an emergency situation: operating VHF, zippers, fastening and mounting of radar reflector, emergency flare *etc*. The personell on K/V Svalbard used conventional Arctic clothing; however, this equipment did not provide protection against crush injuries.
2. The personnel on K/V Svalbard used balaclavas combined with googles to provide adequate protection in e.g. operating the MOB-boat with a considerable wind chill. They also used Gore-Tex waterproof working suits with neck seal.

Detection equipment

Regulations:
No specific requirements but relevant requirements are:
Facility regulations Section 41 about efficient rescue of personnel overboard, same regulation Section 45 about survival suits and life vests (no specific requirements here) and Activity Regulations Section 77 c) about rescuing personnel during accident situations.

Lessons learned:
AIS-SART and EPIRB provided excellent opportunities for detection of either individuals when attached on survival suits and EPIRB on lifeboats. The coverage of satellites at these high latitudes is rather poor and part of SAREX 2 did trials to identify weaknesses. This is covered in other sections of this report[21].

Visual aids (which it is a lot of in a SOLAS life raft – mirror reflectors, smoke and flame flares) can prove useless in the dark winter months and with snowfall on the northern NCS. It should therefore be elementary to look at other means to identify evacuated personnel.

Other technical barriers
Heat tracing was used on parts of K/V Svalbard. During SAREX I it was some precipitation combined with cold weather. This clearly showed limitations of heat tracing enabling efficient removal of snow and ice. The heat conducting characteristics of materials used varies, but in general heat tracing requires tremendous energy resources to enable sufficient heat tracing (pers.com. Trond Spande, Safe Yards AS).

[20] Personal Protection Equipment
[21] Trials done by Norwegian Maritime Authority and Memorial University of Newfoundland, St. John's

When performing the helicopter pick up the inflatable life vest[22] popped, as it should. It was not possible for the rescuer to thread the sling either from above or below. The blown up floatation device on the life vest had to be cut open by the rescuer using a knife.

Operational and Organizational Barriers

Leadership

Regulations:
1. Management regulation Section 11 about manning and competence
2. Activity regulation Section 21 about competence

Lessons learned:
See also SAREX Spitzbergen Report April 2016, Chapter II.2.8 "*Leadership on-board life raft during Phase I exercise"*, Chapter II.2.9 *Leadership on-board lifeboats during Phase I exercise"* for lifeboats and similar chapter from SAREX 2.

The participation in the life raft survival tests showed the necessity of having a good leadership on-board. Both for physical and mental aspects. The life raft leader both on SAREX I and II was one of the Navy's own officers. The ability to organize the evacuated personnel to ensure:
1. Activities to sustain heat/warmth.
2. Operating the life raft at sea, watch routines.
3. Organizing water and food rations.
4. Organizing various safety equipment on-board the raft.
5. Activities to sustain motivation to awareness, encouraging people to take responsible, come forward with good ideas and entertainment.

The life raft leader ensured that all passengers on-board:
1. Got responsibility for at least one or two pieces of equipment, making all persons on-board explain function and usage of the designated equipment.
2. Distributing other tasks, *e.g.* distribution of food rations, control of timing, taking turns on watch
3. Bonding and engaging activities within the group of people on-board, introduction of each individual, games *etc.*.

Competence and fitness

Regulations:

1. Management regulation Section 11 about manning and competence
2. Activity regulation Section 21 about competence

Lessons learned:

1. Based on the operation of the life raft, function of various equipment it proved important either have a competent life raft leader or competence amongst the evacuated passengers to operate the life raft and associated equipment. Knowledge on cold climate survival would also be an important asset in terms increasing survival chances. Activities to keep warmth, how to minimize exposure to cold surfaces (*e.g.* raft floor).

[22] Type of life vest with a salt tablet dissolving once in contact with sea releasing air into the life vest

REPORT FROM PARTICIPATION IN SAREX 2 ON BEHALF OF UNIS AND THE ARCTIC SAFETY CENTRE

Fred Skancke-Hansen, Director of Safety, UNIS, Longyearbyen, Norway

To:	Ole Tobias Gudmestad		
From:	Fred S. Hansen, UNIS and Arctic Safety Centre		
Copy for:	Ann Christin Auestad, project leader Arctic Safety Centre		
Archive:		**Longyearbyen**	29.08.17

Fred S. Hansen participated in SARex 2 on behalf of UNIS and the Arctic Safety Centre.

The following learning points and experiences from the project seems to be of special interest for both the University Centre on Svalbard (UNIS) and the Arctic Safety Centre;

- Networking. Getting in contact with safety and operational specialists is of vital importance.
- Cooperation with the Coast Guard as a professional actor in the high Arctic.
- "Hands on" experience from testing different life saving equipment and life rafts, especially in relation to practical limitations to the equipment.
- Discussions and experiences around individual endurance after an accident in high arctic waters.
- Discussions and practical tests on rescue techniques and the realistic time span in such operations in high Arctic conditions.
- Knowledge on how the Polar Code will be outlined and implemented.

The learning points above will be directly used to improve UNIS` operational procedures, practical safety training and safety equipment. The arctic Safety Centre will benefit from the participation by better design of the subjects (primarily courses on a master level) that are planned taught as part of the centre, and also in relation the scope of the centre and practical courses planned offered for commerce, industry and academic projects working in the high Arctic.

The Arctic Safety Centre (ASC)

ASC is a project led by UNIS and funded from the Norwegian Ministry of Foreign affairs. The project started in 2016 and will last until mid. 2019, when the ambition is to open the Arctic Safety Centre. The project is funded with about 7 MNOK from the ministry and an additional equal part from the partners, in total about 14 MNK.

The background for the Centre is a high Arctic natural environment in dramatic change in combination with a high interest for science exploration, economic and industrial development of the region as well as increasing geopolitical relevance. As a consequence, the need for increased competence and sharing of experience in how to operate in a safe and environmental manner in the high Arctic is acute and extremely relevant. Both the location of UNIS and years of experience related to Arctic safety make Svalbard an excellent location for an Arctic safety competence center. There is already a demand from several national and international partners for such competence.

The purpose is to contribute to as safe and sustainable human activity in the high Arctic as possible and the deliverables are as follows:

- A Master program in Arctic Safety
- Practical safety courses for industry, academia and residents of Longyearbyen

- New knowledge, theories, and models.

The academic content in the Centre builds on knowledge from these three areas;

- Natural sciences relevant for the high Arctic region.
- "Best practice" in terms of accomplishing challenging fieldwork and expeditions in the high Arctic.
- Risk and safety theory.

The different partners in the project will both contribute with their competence and knowledge into the center as well as use the future results and knowledge produced by the Centre. At present the Centre has got the following partners;

- The University Centre in Svalbard, UNIS (project leader Ann Christin Auestad)
- The Norwegian Polar institute
- UiT
- UiS
- NTNU
- Sintef
- Sysselmannen på Svalbard
- Visit Svalbard
- Pole Position Logistics (Svalbard)
- KSAT / Svalsat
- Longyearbyen Lokalstyre
- Lufttransport as (Svalbard)
- The University of the Arctic, UArctic
- Københavns Universitet
- INTERACT
- Forum of Arctic Research Operators, FARO

By the opening in 2019 the Centre is aiming at giving four different master level courses at 10 ECTS each. The preliminary topics are;

- Management of arctic safety
- Safe operations in Arctic Conditions
- Preparedness and response in an arctic context
- Risk assessment of Arctic natural hazards.

The course are currently being developed and will be open for all types of master students that needs competence in this field as part of their educational program.

In addition there is under construction several different practical courses and safety programs for the local population in Longyearbyen, for Arctic field stations and for industry working in the high arctic. The academic content in the courses listed above will also be an important element of these practical courses

Locally, the ASC`s ambition is to transfer Longyearbyen into a "high safety awareness society"

Fred S. Hansen

UNIS

INNOVATION IN ARCTIC SAFETY EQUIPMENT

Marit Karlsen Brandal, Innovation Norway, Longyearbyen

How can innovation in arctic safety equipment be done in a more innovative way than today, and how can Innovation Norway help to realize this?

Experience from SARex 2

Many ideas for improvement arose during our discussions on board K/V Svalbard. The following ideas for improvement are based on my notes made after the raft exercise where I remained for approximately 27 hours.

Survival Suit: Although I am used to putting on a survival suit, it is always a challenge to get the zipper all the way up. This is crucial to avoid water getting into the suit, and many people need help from others to secure it properly. In a stressful situation, there might not be anybody to help.

The gloves were very cold. Unfortunately, this was due to many of us not knowing how to use them properly. In an emergency, it could be crucial that everybody on board gets the necessary information.

Raft: How about adding some "windows" to the raft? These could be plastic windows, maybe on two sides. In addition to (maybe) having a psychological effect, this could also be important in case it is necessary to signal in order to get rescued.

Inside, there ought to be a few handles. After many hours of sitting still, handles are helpful if you want to stand up for a while. Standing up is impossible without holding on to something. These handles could be made of the same material as the raft itself and could be placed in the ceiling.

Some guidelines were printed on the structure. These were hard to read/understand and should therefore be expressed more clearly, if they are important.

Survival Equipment in Raft: We had leakage on the "floor" and used two very small sponges most of the time to get the water out. The sponges should have been much bigger, so that they could soak up the water more efficiently.

In the case of somebody falling into the water, there should be easy access to a lifeline already fastened to the raft and clearly marked.

It has become more common to have whole families on board a cruise ship, which means that small children or even babies could end up in a raft. The way it is currently equipped, there is nowhere to place a baby. A lightweight hammock in the survival equipment could solve this, and it could also be used for a sick person.

Wool caps, wool mittens and warm elements would have helped us to keep warm. These would not take up much room in the equipment box.

In the following, I offer some suggestions for increasing innovation, as well as information about how this may be realized through Innovation Norway.

Inventors

All industries have creative people from different backgrounds. A good exercise for increasing innovation is to let these creative people work across disciplines. In Stavanger, we have many examples of workshops/meetings like this resulting in new ideas/innovations for solving specific challenges.

One possibility could be to invite inventors from different disciplines and others and present them with some of the challenges SAR is facing. They could be further invited to come up with possible solutions. This could perhaps be arranged as a noncommittal competition. Innovation Norway could possibly support such a workshop.

The outcome could be many more or less feasible innovative ideas within SAR. Those companies with innovative and realistic ideas that have the potential for commercialization and growth will have a good chance of gaining support from Innovation Norway to develop their idea.

Startup grants are offered to startups with clear growth ambitions, whose business concept represents something new. The enterprise can apply for funding of activities linked to the clarification and testing of the actual business concept or to the further development of the design concept/solution.

Startup grants primarily target enterprises that have been registered in the Brønnøysund Register Center for less than three years.

Innovative development cooperation

It might be hard to take a product under development all the way to market. The company which owns the idea might need help on the way, since they do not have all the resources internally in their own organization.

Innovation Norway has a program called Innovation Contract. The Innovation Contract is entered between a demanding customer business in the private or public sector and one or more supplier companies.

The program prioritizes small and medium-sized companies with the knowledge, ability and capacity to develop a new product, solution or service that is not currently available in the market.

Regardless of sector, the pilot customer should be demanding. They should actively participate in the development project by helping to concretize specifications, acting as an important reference client and strengthening the marketing aspect, by either operating as a direct marketing channel or using their own network in another way. There should be a high level of innovation and international market potential.

The aim is to increase value creation in Norway, but the demanding customer can, of course, be international.

Business network

For companies facing the same challenges, working in a business network could be a solution. This will help to trigger specific innovation potential, based on cooperation. The cooperation should be strategic and founded on a strong, committed partnership and specific projects.

In a network, there must be a minimum of three businesses, both large and small companies. Business networks normally pass through three phases:

Feasibility study – approx. 3 months

Pilot project – approx. 6 months

Main project – approx. 3 years

In the above, I have mentioned some ways of going forward with innovative ideas. Within SARex 2, we experienced many areas for development. New projects within the SAR area, which has the potential for growth and value creation in Norway, will have a good chance of obtaining grants from Innovation Norway.

Marit Karlsen Brandal

Innovation Norway

Longyearbyen

EXPERIENCES AFTER SAREX 2, BY VIKING ICE CONSULTANCY

Andreas Kjøl, Viking Ice Consultancy/ Supply, Norway

Preamble

Over all personal experiences of the expedition is really good, writing this with background as Captain of Offshore and Icebreaking Vessels with long experience in Arctic Operations.

The day to day planning and decision making had to be taken under the continuous changes of the prevailing weather and ice situation. This could be as a very good example for operators to understand the unpredictable conditions of the Arctic.

The positive spirit from all involved, benefit to strengthen the smaller team's performance and overall expectations were easier to fulfil.

The marine operations were performed professional by the Coast Guard officers and crew together with the lead team of Sarex 2 with good and realistic testing of LSA (Life Saving Appliances) equipment.

Clearly the improvements from last year's expedition of raft (double bottom and double spray hood), Life Boat (Heating) and Survival suits (Extra Insulation and Gore-Tex fabric) were really important to be able to prolong survival period.

However, it was very interesting was to see how the individual human responses developed by time isolated in the survival craft and how those reactions in survival mode can really influence the ability to stay an extended period as the code requires.

After participating in the tests, it is very obvious the Polar Code requirement of 5 days Survival in remote and harsh environment is a really big challenge. To set the standards determining which equipment is suitable and how it will work together with operational procedures is really important and there is not easy for ship operators to do the selection at the moment to fulfil the code requirements in a good way.

As a part of ship-owner and ship operating company I will focus on how the Sarex 2 experiences and lessons learned can be implemented in the Polar Code work and the ISM continuous improvement system and will describe this for following processes:

1. Polar Water Operational risk assessments
2. ISM system (Lessons Learned system)
3. Polar Water Operation Manual (PWOM)
4. Training Modules supplementary to Cold Water Survival (IMO MSC.1/Circ.1185)

Risk assessment processes

To be able to make good strategic decisions before a voyage or operation a lot of information needs to be gathered and risk assessment needs to be done. Flowchart below explain the initial process from first inquiry for a voyage in Polar Waters

Only if all risks have well based and sound mitigations the voyage can be validated and the vessels allowed starting the voyage.

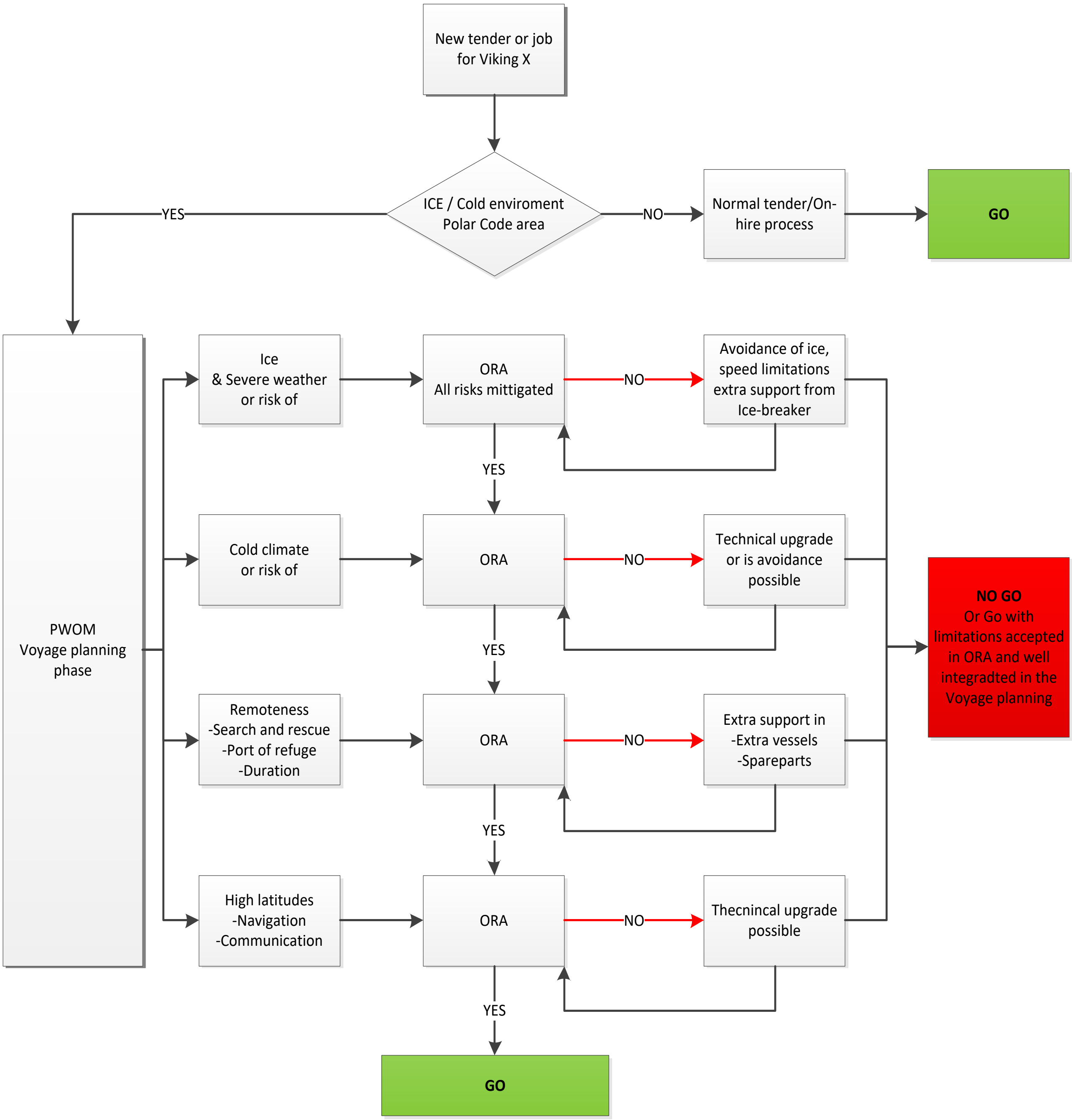


Fig 1. Flowchart describing the initial ORA (Operational Risk Assessment) process

General Operational Risk Assessment Principle

SEVERITY	DEFINITION
5 Major	**Personnel:** Multiple deaths, lung diseases, permanent debility or fatality. **Ship operation:** Major damage to equipment or vessel causing the operation to cease. **Environment:** Major pollution with long-term implication and very high restitution costs.
4 Serious	**Personnel:** Involving a single death or severe injury, poisoning, sensitisation or dangerous infection. **Ship operation:** Serious damage to equipment or vessel causing the operation to cease temporarily. **Environment:** Severe pollution with short-term localised Implications incurring significant restitution costs.
3 Moderate	**Personnel:** Event leading to a lost time incident or persistent dermatitis, acne or asthma. **Ship operation:** Localised damage to equipment requiring extensive repair, significant loss of function/production. **Environment:** moderate pollution incurring some restitution costs.
Minor	**Personnel:** Minor injury requiring first-aid treatment or headache, nausea, dizziness, mild rashes. **Ship operation:** Damage to equipment requiring minor remedial repair, loss of production. **Environment:** Minor impact to the environment.
1 Negligible	**Personnel:** Negligible injury or health implications, no absence from work. **Ship operation:** Negligible loss of function/production with no damage to equipment. **Environment:** No damage to the environment.

Risk Rating (R)	SEVERITY (S)				
LIKELIHOOD (L)	1 Negligible	2 Minor	3 Moderate	4 Serious	5 Major
1 Very Unlikely	1	2	3	4	5
2 Unlikely	2	4	6	8	10
3 Possible	3	6	9	12	15
4 Likely	4	8	12	16	20
5 Very Likely	5	10	15	20	25

LIKELIHOOD	DEFINITION
5 Very Likely	Almost inevitable.
4 Likely	Not certain to happen but an additional factor may result in an accident.
3 Possible	Could happen when additional factors are presented but otherwise unlikely to occur.
2 Unlikely	A rare combination of factors would be required for an incident to result.
1 Very Unlikely	A freak combination of factors would be required for an incident to result.

1-6 Low Risk	May be acceptable; however, review task to see if risk can be reduced further.
7-14 Medium Risk	Task should only proceed with appropriate authorisation. Where possible, the task should be redefined to take account of the hazards involved or the risk should be reduced further prior to task commencement.
15-25 High Risk	Task must not proceed. It should be redefined or further control measures put in place to reduce risk. The controls should be re-assessed for adequacy prior to task commencement.

Survival after disembarking assessments

The 3 below tables describes the following and is part of the overall Polar Waters Operational assessment used for Polar Code compliance.

1. Present risk mitigation used in Polar Waters Operational assessment
2. Elevated risks based on Sarex experiences with no operational or improvements/mitigations
3. Risk mitigation updated based on technical and operational improvements learned at SARex

2

Picture 1. 25-men Raft quite crowded with 19 persons on board. Limited space for activities to maintain good circulation and heat.

able 1. Present Risk mitigation in Operational Risk Assessment for Polar Water Operation.

No	Identified hazard	Initial risk			Mitigations	Controlled risk		
		L	S	R		L	S	R
16.	Abandon ship on to ice when normal use of Life rafts/Boats is difficult and in cold environment.				1. Procedure for abandon vessel on to ice. 1. (PWOM and Procedure)			
17.	Survival after disembarking in very cold environment	4	5	20	2. Increase crew knowledge about survival, by training and drills. When evacuate, additional to LSA use Personal and Group Survival Equipment (PWOM Part II Ch. 5)	2	2	4

Table 2. Risk elevated with learning's and experiences from SARex 2 and no further improvements

No	Identified hazard	Initial risk			Mitigations	Controlled risk		
		L	S	R		L	S	R
16.	Abandon ship on to ice when normal use of Life rafts/Boats is difficult and in cold environment.				3. Procedure for abandon vessel on to ice. 2. (PWOM and Procedure)			
17.	Survival after disembarking in very cold environment Personnel heat loss in raft	4	5	20	4. Increase crew knowledge about survival, by training and drills. When evacuate, additional to LSA use Personal and Group Survival Equipment (PWOM Part II Ch. 5)	2	4	8

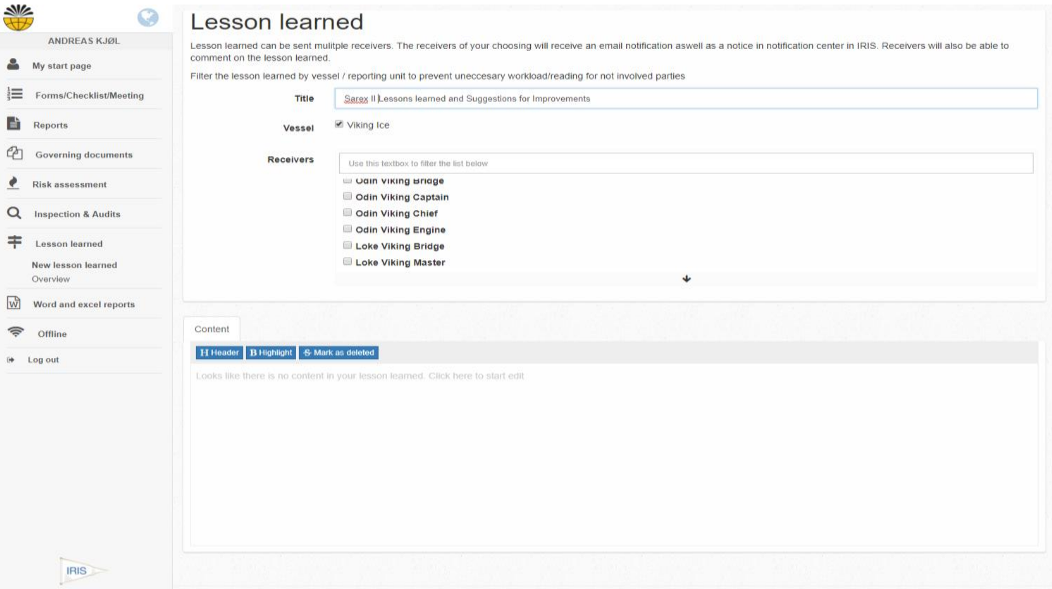
Table 3. Suggested Risk mitigation updated based on technical and operational improvements learned at SARex 2. Risk outcome acceptable.

No	Identified hazard	Initial risk			Mitigations	Controlled risk		
		L	S	R		L	S	R
16.	Abandon ship on to ice when normal use of Life rafts/Boats is difficult and in cold environment				1. Procedure for abandon vessel on to ice. 3. (PWOM and Procedure)			
17.	Survival after disembarking in very cold environment Personnel heat loss in raft	4	5	20	1. Increase crew knowledge about survival, by training and drills. Understand Guide to Cold Water Survival (IMO MSC.1 /Circ.1185) 2. When evacuate, additional to LSA use Personal and Group Survival Equipment (PWOM Part II Ch. 5) Proper clothing under survival suit is paramount for prolonged survival. 3. Use of Life Rafts with double bottom for insulation to sea. 4. Use of Life Raft with double spray hood to avoid moisture drip to personnel and avoid cooling evaporation. 5. If possible distribute personnel in the rafts to keep temperature, but also important with room for movement and	2	2	4

				activity to maintain core temperature (Approx. 60% of max personnel rating) Also room for Personal Survival Kit must be taken into account 6. Bring Gas meter during abandoning for monitoring CO2 and O2 to avoid unnecessary ventilation and heat loss. 7. Open Survival suit when in raft to evacuate moisture and keep dry. 8. Use insulating mattresses in Group survival kit to increase insulation to environment.			

Lessons Learned Process.

Report will be posted in Iris (Improvement Reporting and Information system) our incident reporting and Risk assessment system to all vessels in our fleet and shore support organization.



Picture 2. Screenshot from Iris Lessons learned Module

Suggestions to Updates in Polar Water Manual Part I Chapter 6, Survival.

Requirements for survival are minimum 5 days according to Code. To obtain this in Life Raft following should be done:

- As much Clothing and insulation as possible under the Survival Suit. Minimum as described in the Personal Survival kit.
- Use thermal insulation mattresses from group survival kit to cover raft floor to reduce heat loss.

- Bring Gas meter to monitor CO_2 and O_2 levels to avoid unnecessary ventilation and further cooling of rafts inside temperature.
- If possible reduce number of personnel to approx. 60% of total capacity, try to find balance between keeping inside highest possible temperature and sufficient room to do heat creating activities.
- If safe when in raft open survival suit to ventilate humid air and reduce heat loss by evaporation.
- Use Life rafts with double inflatable bottom to reduce heat loss.
- Use Lift rafts with double spray hood to avoid condensate water drip, keeping raft inside environment as dry as possible.
- Use Survival suits with Gore-Tex fabric keeping personnel dry and reduce heat loss by evaporation. This suits can also be fitted with additional insulation.

Suggestion for improvements to training Modules in Polar Water Course

Update learning salient points, same as above, show video and Pictures from SARex 2.

TRAINING AND CRISIS RESPONSE IN A COLD CLIMATE CONDITION – THE SAREX 2

Bjørn Ivar Kruke, Associate professor, University of Stavanger, Norway

- Introduction

The aim of this chapter is to discuss experiences from SARex 2 in relation to the requirements specified in the Polar Code regarding equipment, manning and training of personnel that may face a need to evacuate a ship in polar waters. The findings in this chapter are mainly based on my experiences as an exercise participant in a life raft during SARex 2. Some experiences from the lifeboat are also included, based on discussions with participants that stayed in the lifeboat during the exercise. The findings are also based on discussions with the captain and crew on board the Coast Guard Vessel (KV) Svalbard, and on exercise participants that also participated in SARex 1 in 2016.

1. Exercise location

The SARex 2 took place 3-4 May 2017 in Krossfjorden, a 28-km long fjord (inshore) on the west coast of Spitsbergen, Svalbard, just north of New Aalesund. The SARex 2 was part of a one-week expedition on board KV Svalbard for testing of equipment related to emergency evacuation of ships in polar waters.

2. Exercise scenario

One lifeboat and one life raft were launched by KV Svalbard in the Krossfjorden area. The boat and raft were then filled/manned by the civilian exercise staff and crew from KV Svalbard.

3. Exercise conditions

Exercise start 3. May 2017: -4 degrees Celsius air temperature and gale.

Exercise end 4. May 2017: -9 degrees Celsius air temperature and full gale (storm) 35-55 knots.

Sea temperature around one degree Celsius.

The waves were around 1-2 meters with short wavelengths, not like the big ocean wavelengths.

4. Exercise management

The overall management of the exercise was conducted by the captain and crew on board KV Svalbard. The scientific part of the exercise was managed by Professor Ove Tobias Gudmestad, University of Stavanger, Norway.

5. Exercise objectives:

- Investigate the functional requirements as defined in the INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS (IMO POLAR CODE)
- Study the adequacy of modified lifeboats and life rafts for use in cold climate conditions
- Study the adequacy of personal protective equipment (PPE) for use in cold climate conditions

- Study the effectiveness of accessing and rescuing people from life boats and life rafts when in cold climate conditions
- Train Norwegian Coast Guard personnel on emergency procedures in cold climate conditions with particular reference to evacuation and rescue from cruise ships.

- International code for ships operating in polar waters (IMO POLAR CODE)

6. Sources of hazards (Chapter 3)

The Polar Code considers hazards, which may lead to elevated levels of risk due to increased probability of occurrence, more severe consequences, or both:

- Ice, as it may affect hull structure, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks and malfunction of safety equipment and systems;
- low temperature, as it affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems;
- extended periods of darkness or daylight as it may affect navigation and human performance;
- high latitude, as it affects navigation systems, communication systems and the quality of ice imagery information;
- remoteness and possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential for groundings compounded by remoteness, limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response;
- potential lack of ship crew experience in polar operations, with potential for human error;
- potential lack of suitable emergency response equipment, with the potential for limiting the effectiveness of mitigation measures;
- rapidly changing and severe weather conditions, with the potential for escalation of incidents; and
- the environment with respect to sensitivity to harmful substances and other environmental impacts and its need for longer restoration.

7. Polar Service Temperature (para 1.4.3)

For ships operating in low air temperature, survival systems and equipment shall be fully operational at the polar service temperature (PST) during the maximum expected rescue time. The polar service temperature means a temperature specified for a ship which is intended to operate in low air temperature, which shall be set at least 10 degrees centigrade below the lowest Mean Daily Low Temperature (MDLT) for the intended area and season of operation in polar waters.

8. Manning and Training (Chapter 12)

Ships operating in polar waters are appropriately manned by adequately qualified, trained and experienced personnel.

9. Maximum expected time of rescue (para 1.2.7)

The maximum expected time of rescue is specified as "the time adopted for the design of equipment and system that provide survival support. It shall never be less than 5 days". In other words, this is the standard to which the equipment and rescue resources have to meet. This is also the dimensioning requirement for own survival after a shipwreck, that is to say, the period in which survival is down to the activities of the survivors themselves, prior to the arrival of rescue organisations.

10. Polar Code - Summing up

The particular polar waters hazards are dimensioning factors for survival equipment and preparedness activities for organisations operating in these waters. Cold climate, remoteness, huge distances, shifting weather conditions, less available rescue resources and capacities, and communication challenges are issues making preparedness and rescue operations particularly important and challenging. Maximum expected time of rescue of five days is a dimensioning factor for lifesaving equipment, but also for training and exercises, for ship crews, but also for passengers.

- The exercise

11. Exercise participants

- Officers (quartermasters) from KV Svalbard served as captains on board the lifeboat and the life raft. 16 civilians and two crew members from KV Svalbard formed the rest of the personnel to man the life raft. I do not have the details concerning the staffing of the lifeboat, but the ratio of KV Svalbard crew compared to civilians was bigger in the lifeboat than in the life raft.

12. Medical team

A team of medical doctors was to monitor the body temperature of exercise participants in regular intervals during the exercise. They also conducted other tests (cognitive and physical tests). They were given the authority to abort the exercise for participants with signs of hypothermia.

When leaving the exercise, exercise participants underwent medical tests, both initially in the hangar on board KV Svalbard, and in the infirmary on board KV Svalbard. They then went through the same cognitive and physical tests they had been exposed to during the exercise.

13. Startex

The exercise started with dressing in KV Svalbard's hangar. Participants came with their own "personal protective equipment":

- Two layers of underwear (preferably woollen)
- Some brought a hat/cap
- Some brought gloves or mittens

The participants were then provided with a survival suit of varying quality. After being dressed up, one of KV Svalbard's MOB-boats transported the participants to the lifeboat and the life raft. The actual exercise then started 3. May around 1515 hrs.

There were no pre-exercise specification of the personal protective equipment (PPE) to bring. This meant that the exercise participants came with a huge variety of PPE.

14. Organisation of activities

The command structure on board the life raft was the first to be organised. The captain of the raft, an officer from KV Svalbard, presented himself[23]. He then chose a second in command among the passengers. The second in command was chosen because of his participation on board the life raft during SARex 1 in 2016. This initial organisation was followed by the organisation of some core activities on board:

- The buddy system: two and two were paired by the captain as buddies. The buddies were tasked to look after and take care of each other. According to my observations, the buddy system was in place throughout the exercise, but functioned to a varying degree. I and my buddy had contact at regular intervals throughout the exercise.

- Duty rooster: a duty rooster was organised with shifts of three people on two-hour duty. The duty station was next to the main canvas opening. The tasks were related to:
    - Wipe up water from the floor. This was a nonstop activity since water came in several places, such as through the vacuum valves[24].
    - Lookout for ice, polar bear, walrus, rescue vessels/helicopters, other life rafts/-boats, etc.
    - Control of the ventilation and thereby the temperature level and the CO_2 concentration.
    - Radio communication[25] .

  The organisation of the duty rooster system was good. However, the crew on board the life raft did not fully respect and operate according to the rooster. Based on experiences from the exercise it is fair to say that an operational duty rooster system, and crew adhering to the system, is of the utmost importance in order to maintain good living conditions on board the raft.

- Medical responsible. One first-aid trained crew member from KV Svalbard was given the responsibility for medical issues on board. He distributed seasickness tablets every 12 hour. He also distributed paracetamol if that was required. The captain logged all medication that was distributed (time and the person receiving medication).
- Food and water responsibility. The captain maintained control of food and water distribution. An observation concerning food and water distribution is that the actual distribution worked fine. However, some exercise participants did not eat the biscuits and drink the water directly. Some participants ended up close to dehydration. This is mainly because of the low quantity of water in the rations[26], but also because they did not drink the water that was distributed.
- Garbage collection responsible. An important aspect of keeping up the morale in the life raft is a tidy raft. Therefore, one exercise participant was chosen as responsible for garbage collection. Much garbage were collected, but not all. It is a collective responsibility to collect all garbage to make and the living conditions inside the raft best possible.

[23] He was also officer in charge of the life raft during SARex 1 in 2016.
[24] Water also came in when the life raft was towed by the lifeboat, especially in "high speed" towing (more than 3-4 knots).
[25] The second in command acted as radio officer in the initial phase of the exercise. After that this function was handed over to the team on duty.
[26] The water ration is too small to be able to maintain the cognitive and physical strength to stay focused over a longer period of time.

15. Equipment familiarization

10 The life raft comes with two big sacks filled with standard equipment, food and water. After initial organisation of responsibilities and activities, the captain of the life raft distributed the raft equipment to the passengers on board, gave them a few minutes to get familiar with the equipment, and then asked everyone to present the item, what it is for, and how to use it. That gave us an opportunity to pay attention to and to familiarize ourselves with the equipment on board. This was later proved very valuable since we needed some of the equipment for various activities on board.

16. Familiarization with fellow passengers

A final part of the initial organisation and getting familiar process was the process of getting familiar with everyone on board.

The captain of the life raft asked everyone to present himself/herself and include knowledge they thought could be relevant for the situation in which we found ourselves. A second presentation of first names were conducted later in the exercise. During this presentation the passengers were asked to mention an animal with the same first letter as their name. This formed a lighter mood among the passengers and made it easier to remember the names.

The captain of the raft engaged the crew in various discussions and in quiz. This was very good and broke the monotony on board. Some of the exercise participants fell out of the discussions, and also from their duty team. I believe it is important to get all participants engaged in the activities, even though they are reluctant to do so.

17. Why this organizing and getting familiar activities?

There are many reasons for these activities. It is fair to say that utilising the knowledge, expertise and capacities among the passengers may be crucial for survival in a real shipwreck. It is also fair to say that drinking and eating the rations may be crucial for the passengers' cognitive and physical ability to take part in the various activities on board the life raft. To take part in the various activities on board may also be important to maintain the cognitive and physical capacity required for survival over a longer period of time.

There are also many reasons for getting familiar with who is on board. If one of the passengers is medical trained, this person could be appointed as chief for medical issues on board. I am a trained radio officer, very familiar with the Motorola VHF radios used by KV Svalbard. I could therefore be in charge of radio communication, or train the rest of the passengers in how to operate VHF radios and basic radio communication language. Other passengers could possess other important skills, e.g. related to diet, digestion, language skills, physical training, etc.

It may also be important that some information about passengers is made available, for instance if one passenger has a medical issue.

The presentation of names could have been done earlier in the exercise. It is a lot easier to communicate with each other if we use names. Communication was sometimes challenging on board the life raft, especially after the wind increased. The wind made a lot of noise in the raft.

18. The adequacy of modified lifeboats and life rafts for use cold climate conditions

This chapter is, as mentioned initially, mainly based in experiences from the life raft. I am, however, aware of some modifications conducted to both the lifeboat and the life raft based on experiences from SARex 1 in 2016.

Lifeboat

A heater has been installed in the lifeboat (Webasto). During SARex 2, the temperature in the lifeboat was relatively good. This meant that some passengers took off the survival suit while being in the lifeboat. A toilet was installed in one end of the lifeboat. Passengers therefore did not have to leave the lifeboat to go to the toilet.

The seating benches in the lifeboat were fitted with padding to make the seating arrangements more comfortable.

Life raft

The life raft in SARex 2 was of a different type than the life raft used in SARex 1 in 2016. However, some changes were made based on experiences from SARex 1. In SARex 1 the passengers on board the life raft sat directly on the floor with only a thin layer between themselves and the cold sea water. In SARex 2 the life raft was equipped with an inflatable floor. The exercise participants used pumps (of inferior quality) to inflate the floor. The passengers did therefor sit on a layer of air and were therefore not directly exposed to the cold seawater.

The life raft in 2017 did also have sidewalls it was possible to sit on. In 2016 the passengers could only sit directly on the floor. In 2017 the structure of the raft made it possible to vary between sitting on the floor and on the sidewalls. This changing in seating arrangements turned out to be good, both for varying seating position and for the possibility to conduct some physical training to gain some body temperature.

Some points worth mentioning:

- The raft came with two waterproof bags for the equipment. That was good. The waterproof bags made it possible to keep equipment and food dry. The bags could also be used to store other equipment brought by passengers.
- The raft did not have pockets for storing of equipment. Since most of the survival suits also did not have pockets, storage of equipment turned out to be difficult. Equipment could not be laid on the floor. 19 people were lying all over. Free space was not available. In addition, we had problems with water coming in making the floor wet. The only option except the waterproof bags was to put equipment inside the survival suit. That equipment could be difficult to find later on. It is recommended to fit the raft and the survival suits with some pockets for storage.
- The raft came with a valve to collect condense water and rainwater. The hose to be connected to the valve loosened all the time. The hose should come with a screw connection.
- The tent of the raft was held up by solid beams filled with air. Some handles fastened to the beams would have made it a lot easier to move around in the raft.

19. The adequacy of PPE for use in cold climate conditions

Every exercise participant was asked to bring his/her own personal protective equipment, such as underwear, socks, cap/hat, and gloves or mittens. The result was a variety of types, standards and quality of personal protective equipment:

- There was no registration of type of and number of underwear. We therefore do not know the extent to which the exercise participants wore decent quality underwear or if they actually did wear two sets of underwear.
- Some exercise participants brought gloves, others mittens, and some did not bring either gloves or mittens. We did not register the quality of gloves or mittens. Some brought woollen gloves or mittens, others brought gloves or mittens made of leather or Gore-Tex.
- The exercise participants were asked to bring two pairs of high quality woollen socks. Some participants did however bring only one pair of socks, or socks of inferior quality, such as cotton socks.
- Some exercise participants brought their own headwear, others did not. We did not register the quality of headwear. Some brought woollen headwear, others brought headwear made of cotton or Gore-Tex.

It is difficult to conclude with the impact of varying personal protective equipment on the exercise participant's wellbeing during the exercise or their ability to continue their stay in the live boat or life raft. Bearing in mind the harsh climate conditions during the exercise and that one important factor for being pulled out of the exercise by the medical doctors was low body temperature, it is likely, and fair to assume, that inadequate personal protective equipment would result in being pulled out earlier. It is also fair to expect that wearing high quality underwear, socks, mittens and hats would give an exercise participant a very good foundation for being able to stay in the life raft over a longer period of time with a fairly good body temperature. It was observed that all exercise participants remaining in the life raft until endex (6 exercise participants out of 19) wore a decent headwear.

Another issue is combination of personal protective equipment and survival suit. The different survival suits used by the exercise participants during the exercise is discussed in a separate chapter in this report. It is however important to see the personal protective equipment in relation to the type of survival suit we were handed out. Some survival suits came with padding in the seat, to protect against the cold of the seawater, others had suit and gloves in one piece, making it very difficult to use your hands without taking off the suit. The survival suits were fitted with hoods. Some exercise participants observed, especially if they were handed a survival suit that did not fit them, that they could not wear the hood due to strains on their neck muscles. If these exercise participants did have a proper headwear, they stopped using the hood when being in the life raft and used their PPE headwear.

Another observation was that many of the survival suits came without pockets. In a life raft, with some water on the floor, it is of the utmost importance to keep all clothes and equipment dry. Without pockets the only place to store gloves, headwear, food, etc., is to put the stuff inside the suit. Some stuff quickly ended up in the bottom of the suit. Collecting the stuff again turned out to be difficult, and involved either to strip down the suit, or to ask a good friend to search down your suit.

We were also handed out some seating pads. They protected us against the cold of the sea, but also against the wet floor of the life raft. They therefore made it possible to stay warmer, and also to avoid getting wet.

Technical equipment often require skills. This counts for radio equipment, medical equipment, pyro techniques[27], the actual life raft itself etc. Technical skills and knowledge is however also important for the proper use of survival suits. You could ask what the big issue is regarding how to use a survival suit. It is a standard suit, with "boots" and a hood, and gloves attached to it. However, I experienced during my 30 hours stay in a survival suit in a cold and wet life raft that there are some important issues that need attention:

- My survival suit was waterproof. That means that water is not supposed to penetrate the suit from outside and into the suit. The same is the case in the other direction. When staying in a suit for a longer period of time you will experience condensation on the inside. This condensation must be ventilated at regular intervals for the person to stay dry and warm.
- The survival suit is made for static positions. It is not made for walking around. It is one belt on each leg, just above the ankles, for tightening the suit to make it possible to walk relatively easy. These belts must be loosened when sitting in the raft for air to circulate around inside the suit. If you do not loosen the belts, you may end up freezing on your feet because warm air is not circulated freely inside the suit.
- The survival suit comes with neoprene gloves. These gloves are waterproof. They are constructed to keep you warm in cold weather conditions, just like how a dry suit works for divers. The gloves are not breathable, so you will sweat. That sweat is warmed to body temperature right away and helps keep the hands warm. This is good if you keep the hands in the gloves at all times. If your hands are cold in the first place, they will not get warm when putting on the cold and wet gloves. If your hands are cold, and you struggle to regain the heat, then the buddy system could be a good option: to warm your hands on the stomach of your buddy, or to borrow a pair of woollen gloves.

To sum up, there are a lot of issues to pay attention to regarding the use of the survival suits. Some instructions on these issues to follow the suit should therefore be in order!

20. Exercise participants

I will not go into details regarding exercise participants in this chapter. It is however some issues worth mentioning regarding the people taking part in the exercise.

First of all, all exercise participants knew in advance that they should participate in this exercise. They had therefore the possibility to prepare themselves mentally and physically, and to bring personal protective equipment of a good standard.

Second, the concentration of cold climate experience and naval experience was high among the exercise participants. It is less likely that these experiences would be available to the same degree among cruise passengers.

Third, the exercise participants' physical condition was fairly good and the average age was relatively low (between 30 and 40 years). It is likely that cruise passengers would have been older and in less robust physical condition.

[27] During the final stages of the exercise, we were asked, upon request, to test some of the pyro technical equipment on board. The equipment is labelled with the basic instructions on how to operate them. We did, however, experience some problems in their usage. One passenger tried to use one of the emergency rockets. It was specified that the red cap should be removed. The rocket had two red caps. This created some confusion on board. I learned after the exercise that a passenger on board the lifeboat experienced a small skin injury due to the use of pyro techniques. The instructions for use of pyro techniques must be clear, especially in life rafts. A misfire inside the raft could have devastating effects both on the passengers and on the life raft itself.

Fourth, the motivation among the exercise participants was fairly high. They looked forward to taking part in the exercise, even though some with a more careful enthusiasm.

Fifth, the moral of the exercise participants may have been under the influence of the presences of KV Svalbard. This is positive regarding the willingness to play along in the exercise, but may also have a negative impact. I will touch upon this later in the chapter.

Six, the exercise participants came from the crew on board KV Svalbard, and the scientific staff. It is fair to assume that management of the KV Svalbard crew may prove easier for the officers in charge of the lifeboat and life raft, than management of a loosely composed group of people (such as the scientific party taking part in the exercise or a group of tourists on board a cruise vessel).

Finally, even though SARex 2 is an international exercise, most of the participants were Norwegians. A more international and multicultural setting may have resulted in challenges that were not faced in this exercise.

21. Exercise artificialities

There will always be some artificialities in excises like SARex 2. These artificialities will impact the external validity of the exercise findings, i.e. the extent to which the findings from the exercise is transferable to other settings. The question is how relevant the findings from the exercise will be compared to the situation faced by people (tourists on board cruise vessels and others) after a real shipwreck in arctic cold climate conditions.

The exercise participants boarded the life raft from one of KV Svalbard’s MOB-boats. We were able to conduct a dry boarding, i.e. that no one of the exercise participants were wet following a rescue via the sea. It is likely in many shipwrecks that some people will be boarding the lifeboats and life rafts from the sea. In tempered waters, this may not be a big issue. In cold climate conditions, this could be a matter of life and death. We did not exercise rescuing people from the sea or reheating people that has been in the sea.

One major artificiality is KV Svalbard in close proximity to the lifeboat and life raft. It is relevant to assume that the existence of the region’s most well equipped and experienced SAR ship and crew will have an impact on the morale of the exercise participants. First of all, the exercise participants were allowed to either use the MOB-boat when in need to go to the toilet, or they were allowed on board KV Svalbard. In a real scenario, survivors on board a life raft would be required to make the best out of the facilities on board the raft when in need to "visit the rest room".

Another possible impact of the presence of KV Svalbard on the exercise was that the presence of a safe haven could mean that an option of aborting the exercise was nearby. The exercise participants were of course volunteers and had a free card to abort the exercise whenever they felt the need to do it. This option of an early retreat to KV Svalbard may have a cognitive impact of the will to engage in life maintaining activities on board the raft.

In SARex 2, medical doctors were visiting the life raft in regular intervals. They were testing cognitive and physical status of exercise participants. They were also supposed to measure the exercise participants’ body temperature. Unfortunately, the measurement of body temperatures turned out to be difficult for technical reasons. The result was that the participants’ body temperature were not measured in the last part of the exercise. The medical doctors then looked for others signs of hypothermia among the exercise participants. Even though the visits by the medical doctors were welcomed changes to the routine in the life raft, the visits were also an artificiality creating some disturbance on board the raft. The visits also meant opening one of the entrances to the raft, resulting in cooling down the temperature inside the raft.

22. Endex

The exercise ended after approximately 30 hours. The wind increased to gusts up to 50 knots and the temperature dropped to approximately minus 9 degrees Celsius.

The decommissioning of the exercise was determined by the captain and crew on board KV Svalbard. Being in the life raft gave us the opportunity to listen in on the radio (VHF) communication between the captain and officers in charge of the exercise and the officers in charge of the lifeboat and the life raft. The plan for decommissioning of the exercise was adjusted several times, due to changes in the weather conditions. In the final stages of the exercise, both of KV Svalbard's MOB-boats were involved in maintaining control of especially the life raft while exercise participants were transferred back to KV Svalbard.

To board the MOB-boat from the life raft upon endex turned out to be challenging, because of the waves, but in particular the strong wind. The MOB-boat came up alongside the raft several times unsuccessfully before it was possible to board the MOB-boat. It was my experience that moving between small vessels in cold climate conditions with wind and waves is very difficult. A successful transfer from life raft to MOB-boat is therefore dependent on both experienced MOB-boat crew, and that the passenger is in a physical condition making such a move possible. If passengers were ill, unconscious or lying on a stretcher, such a transfer would have been very difficult to conduct successfully.

- Conclusions

The main conclusion is that SARex 2 was a very important exercise to understand the challenges of sustaining a sort of livelihood on board a lifeboat or a life raft in arctic conditions.

The general impression I received from the exercise participants was that the Norwegian Coast Guard personnel on board KV Svalbard showed a professionalism of a high standard in cold climate operations and in emergency procedures in cold climate conditions. Thus, KV Svalbard was a very good platform for the exercise, and meant that it was possible to conduct the exercise in rough conditions, without putting exercise participants life at stake.

What did we get out of the exercise? SARex 2 gave a good opportunity to study the adequacy of the modified lifeboat and life raft in cold climate conditions. We were however not able to study the adequacy of personal protective equipment (PPE) for use in cold climate conditions in a structured way. We did not register, in a structured way, what kind of PPE the exercise participants brought with them. It is therefore recommended that a future SARex should study PPE in a more structured way, with a particular focus on the specifications of the PPE to be used.

Is it possible to survive five days in a life raft in arctic conditions? The experiences from a 30 hour stay in a life raft during SARex 2 is not adequate to fully answer this question. It is fair to say that staying in a life raft in trying conditions is difficult. Of the nineteen persons starting the exercise in the life raft, only six were left in the raft when the exercise ended. I am convinced that several of the exercise participants leaving earlier could have stayed longer. However, some of the exercise participants were pulled out due to low body temperature. This process of body heat loss would have continued. It is therefore likely that survival in a five-day period would have required a lot of effort by the life raft passengers, effort related to eating, drinking, physical and cognitive activities, caring for people in need for assistance, and to make sure people got regular sleep. Survival boils down to the micromanagement of the thousand details! With all these activities, some of the passengers in the life raft could have been able to survive the five-day period specified in the Polar Code.

LEARNINGS FROM SAREX RELATED TO NORWEGIAN FISHING VESSELS

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Disclaimer
The views expressed in this report are solely based on personal experience from SARex, and do not necessarily reflect the opinion of NMA.

SARex 2
I had a great experience during the exercise on board KV Svalbard. I want to thank the crew on KV Svalbard who was very helpful, skilled and friendly. The SARex participants was also a group of very friendly and competent people.

In my report I will write about my observation on what the exercise can teach us about life saving appliances on Norwegian fishing vessels.

Some of these vessels have operated in polar waters for decades. Vessel recently built are often well equipped and have class notifications for ice on hull and machinery. On many vessel owners order solutions and equipment that exceed requirement in our regulation. These owners are experienced and are aware on what conditions vessel is exposed to. They want a vessel that works, and are willing to invest to make the vessel resilient. However, lifesaving appliances has not always been a focus area for all owners. I believe that it is an important task for flag states to find the right requirement for life-saving appliances in polar waters.

Life-saving appliances on board Norwegian fishing vessels today.
A very fast and short introduction. I am only going to mention rafts and immersions suits because that is fishing vessels are carrying. Almost every Norwegian fishing vessels above 15 meters (My guess is 99% at least) have inflatable life rafts arranged to be dropped. The requirement is at least one unit on each side of the vessel with capacity to carry all of the crew. All vessels have wheel marked insulated immersion suits.

Norwegian regulation is based on the Torremolinos Convection, which is an IMO convention on safety of fishing vessels. Torremolinos is mandatory for EU states, and this applies to Norway through the EFTA agreement.

Life rafts tested in SARex 1 and 2017
This year we tested a self-righting 25 person's life raft. This raft has many advantages from last year's raft. Both of these rafts are wheel marked and are available on market today. In polar waters this year's raft proved to be better. These are the points that I think are most important:

- The raft is self-righting. In cold waters, nothing else should be allowed.
  The self-righting part is crucial.
- Large canopy. Better air quality, more space to move and possible to sit on the tube. This reduce heat loss and helps with blood circulation.
- Inflatable floor. The floor on this raft is installed between the two "main" tubes that goes around the raft. This is an improvement, but the main heat loss is still through the floor.
- The movement of the raft were surprisingly stable even when the wind picked up and the sea got rough.

Immersion suits and clothing

Last year people started to leave very early in the test due to poor clothing. This year people were able to stay on board much longer than last year. Many of us was wearing wheel marked brand new insulated immersion suits that are quite normal to find on a Norwegian fishing vessel. Some of these were test suits with extra insulation. These proved to work good. A few persons wore older suits without insulation. Most of those whit old suits left after 24 hours.

One of the challenges I see whit the wheel marked suits is that the marking is based on minimum criteria's. That means that you could have a suit, which are far better than the criteria, but the system today don't tell you that. Again, I guess it is very important to be thorough when buying equipment for vessels intended for polar waters

But one guy lasted till the far end of the exercise even though he wore a pore suit. I notice he had very thick wool underwear. Almost like he was wearing a sheep. And he had wool mittens and a cap. He was moving around quite a bit during the exercise. I guess that statement was exaggerated. It was way too crowded to move around. He did quite often stand up in the raft. I think that made a difference. Both the wool and the standing.

My point here is that small improvements in clothing can keep you warm longer and could make a difference. If this was a real situation, we would probably lose the first three people in old suits, but this person would probably survive.

Training
When we embarked the raft, I guess many of us behaved just as passengers on a cruise ship or whatever. Thinking most about ourselves and relaying heavily on the person in charge of the life raft. That worked fine, and the commander of the raft did an excellent job. We lasted as a group for 24 hours, but then we lost people due to hypothermia. I think we could have lasted longer if we acted more like a crew and less like cruise passengers.

I will try to be clearer. We were too relaxed. We were polite and a bit helpful, but not enough to save somebody from getting cold. Once you are too cold, it is too late. The right thing to do in my opinion is to be in survival mode right from the start. Force people to move and keep active for as long as possible. Do not save your strength and do not relax.

I think the right kind of behaviour would to be as active as possible right from the start. Do not wait until people are shivering. Move around and change position often. Even though we "only" were 19 people in a 25 persons raft, this proved to be a big challenge. My conclusion is that we did not quite succeed whit that part, and a ship crew would most likely do better than we would.

That is if the crew had the right understanding of the situation and the proper training to utilize equipment and knowledge.

Weather condition
Weather conditions in the artic changes fast. During our trip on KV Svalbard we experienced cold, clear whether with temperatures down to -16 degrees. Other times it was cloudy, wind and degrees above zero. When the survival part of the SARex started Wednesday, it was cloudy and around zero degrees. There was no wind at all. After 24 hours, the wind suddenly blew up to gale. It happens in like 15 minutes. From completely calm to full gale.

These winds and temperatures are representative for what we can expect on the Norwegian coast a big part of the year, and are completely normal for a fishing vessel to operate in. The big difference is the time the SAR service needs to response. If a vessel is in distress, someone would likely come to assistance in at least in a couple of hours most part of the coast. And of course, the sea temperature and sea ice.

The details make the difference

Where is the knife? How does the bailing valves work? Is there a pump somewhere? Where is the bailer? The valves are leaking and the water is ice cold.

This year we had a minor water leak through two bailing valves in the centre of the raft. There were two valves. We used sponges from the equipment bag to dry it into a bailer and then opened the canopy to empty the bailer. This was an ongoing for the first 24 hours. When people start to leave I noticed that there were black tubes in two of the corners that also could be used for bailing. Alternatively, to empty the bailer. In addition, right before the end of the exercise one person use it as a toilet. Worked perfect for that purposed also. So opening the canopy for emptying the bailer was unnecessary.

Part of why I did not see the tubes in the corners earlier was probably that the raft was packed. Or maybe it could be the fact that I finally read the fat instruction manual. It proves to be very informative. It was only fat because it was in like 25 different languages.

In a real scenario, opening the canopy can be a risk. Getting a big wave of seawater into the raft could cool someone down so much that they don’t recover. Then you need to know these details. A random introduction that all life raft has a bailing system is not enough, but you need to know what your raft has.

When the water is so cold, and the SAR service needs long time to reach you, margins are stretched thin. Doing the right things, a couple of hours more might save a life.

Important learnings

- Pay close attention to what equipment that your vessel has. To relay on the wheel mark alone is not enough.
- Crew needs to be very familiar with rafts and immersion suits that are on board their own vessels.
- Focus on how to survive once in the raft.
- What to wear under the immersion suit.

Conclusions

This was survival. Not an amusing experience. It was not a thrill like riding rollercoasters ore anything remotely fun at all. It was plain boring. Staying in a crowded life raft over time is really exhausting and uncomfortable. There are legs, arms, and people all over. Someone are sitting on your feet. Snorting in your ear. Freezing water are leaking into the raft. Sometimes you get a biscuit and a tiny portion of water. But if you do things right, you might have a chance to survive.

Conclusions

IMPLICATIONS CAUSED BY SAREX ON THE IMPLEMENTATION OF THE IMO POLAR CODE ON SURVIVAL AT SEA

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Abstract

The International Code for Ships Operating in Polar waters goes into effect on 01 January 2018 for all ships. This puts additional strain on vessel owners and operators as they will have to comply with an additional set of requirements. This includes the functional requirement of a minimum of 5 days survival time. The SARex exercise has elaborated on the issue of survival in close cooperation with the different stakeholders associated with the marine industry. Being an objective third party is important when organizing and executing these activities as all of the stakeholders has different agendas and priorities. Developing sustainable solutions is a balancing act, incorporating economic and political aspects as well as technology and requires a mutual common understanding of the mechanism involved.

Keywords

Cold Climate Marine Operation, International Maritime Organization (IMO), Polar Code, Risk, SARex, Stakeholders.

- ### The International Code for Ships Operating in Polar Waters - Regulatory rationale

The International Code for Ships Operating in Polar Waters is also known as the *International Maritime Organization Polar Code* [1]*,* and will go into effect on 01 January 2018 for all ships.

The International Code for Ships Operating in Polar Waters is a functional set of requirements, and utilizes a risk-based approach. It aims to mitigate the additional risks associated with marine activities in Polar waters. Having a risk-based approach induces additional strain on the chain involved in regulating, designing and conducing marine operations in a polar environment, as the risks are to be identified, assessed and mitigated through a holistic approach.

Functional requirements are utilized in the offshore oil and gas industry on the Norwegian shelf. The success experienced with in this field can be a result of a stable and close relationship between major oil operators, employees and authorities. Very few of the current marine regulations are based on a risk-based approach, with the exception of the ISM (International Safety Management) code. The process of assessing and mitigating the risk the identified in the IMO Polar Code requires in depth knowledge in relevant fields, and the outcome of the assessment is never any better than the knowledge available during the process.

The IMO Polar Code requires additional equipment to be carried, e.g. equipment that enables survival on ice/land and equipment that enables a minimum of 5 days survival time. This represents a challenge with regards to the capacity in the rescue craft, and downsizing, operating with a reduced number of passengers, can be a possible solution.

Currently there is no common understanding of the interpretation of the code. As a result, there are variations between flag states and classification societies on how to achieve compliance. For vessel operators/transportation providers the lack of consistency predictability and transparency represent not only a practical challenge. It also induces an economic risk as downsizing, can be a result of the implementation of the IMO Polar Code. Downsizing or operating with a reduced number of passengers will greatly affect the profit of a marine operation.

SARex

An increased activity within the field of expedition cruises is experienced in the Arctic. This increase is expected to persist in the coming years. The tourist industry in areas like Svalbard is already preparing to meet the expected increase in visitors to the area [2].

Much of the focus involves increasing the tourist activities and raising the revenue generated by the visitors. Few are question the safety and the risks involved in these types of activities.

Lack of understanding of the complex multi-discipline challenge of surviving in a rescue craft in a cold climate environment has troubled the marine industry since the first draft of the IMO Polar Code was released. Our goal has been to investigate and quantify survivability related to a major marine accident in the Arctic/Antarctic, and assess if our results are in line with the global societal expectations.

To increase the understanding related to the complex multi-discipline challenge of surviving in a rescue craft in an Arctic environment full scale experiments have been conducted. The project has been called SARex [3]and the objective has been to increase the level of maritime safety through quantification of survivability in relation to SOLAS (Safety of Lives At Sea) approved equipment. The full scale experiments have been conducted utilizing the Coast Guard vessel KV Svalbard in close cooperation with regulators (Norwegian Maritime Authority, Petroleum Safety Authority, ABS and DNV GL), equipment manufacturers (Norsafe and Viking-Life), in addition to experts within their respective fields (e.g. medical personnel and risk expert).

To fully grasp the concept of survival at sea, following an abandoning ship incident, there is a need for improved understanding of the mechanisms involved. An increased understanding of the mechanism involved, in combination with a functional based rule set, enables sub-suppliers to design their safety systems in a sustainable manner, incorporating not only the functionality required to supply adequate survival, but also at the same time take into account the economic demands enforced by the industry.

The results from our experiments have been communicated to the relevant major stakeholders in the global marine industry, including the Norwegian Government, maritime administrations, IMO, vessel operators/transportation providers and equipment suppliers.

The path of regulatory development

Much of the current regulatory regime enforced by IMO (International Maritime Organization [4]) has been developed as a result of a retroactive processes preceding a major accident, e.g. the Titanic accident triggered the development of the SOLAS convention.

It is however important to note that the implementation processes taking place in IMO requires extensive time and consensus among the member states. As almost every country in the world is a member state, and considerable divergence among cultures, financial situation and involvement is experienced. As a result, common consensus can be hard to obtain. It is at times experienced that political agendas overrule scientific facts in the voting processes.

As there are many stakeholders and agendas, regulatory development can be regarded as a process of causation, where the process focusses on predictable aspects of an uncertain future. The future is to be regarded as uncertain and most accidents “come as a surprise”. We humans have very little control of the future. Both the regulatory goal and the regulatory development path can be unclear, just like economic decision making and the process has strong analogies with the theories described in Saras D. Sarasvathy “*Causation and Effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency”* [5].

Traditionally full scale experiments or “reduced full scale” experiments, e.g. towing tank experiments has been utilized in the design process. A “black-box” approach has been utilized in many cases where the problem is complex and cross-disciplined, where all the individual mechanisms and interactions between the mechanisms have not been properly understood.

Scientific methods are utilized to improve the existing methodologies in the design of vessels and equipment. These methods involve everything from numerical models to full scale experiments. It is however important to note that much focus has been on cost efficient solutions. As a result, there has been a tradition of a heuristic approach. In the recent decades this has slowly changed and scientific method has slowly gained ground. This is much a result of better access to computers and a general increased understanding by the scientific community of the mechanisms involved in vessel and equipment design.

- Stakeholders

Working with regulatory development within the marine industry on an international level require an in-depth understanding of both the evident and at times hidden agendas of the different stakeholders. The main stakeholders affecting work related to marine safety can be summarized as follows:

- **IMO –** The International Maritime Organization is a special agency under the UN. It has currently 172 member states, usually represented by their maritime administration. IMO is organized through 5 committees, each with several sub-committees.
  The work associated with lifesaving appliances is anchored in the legal instrument, the SOLAS Convention, which is administered by the Maritime Safety Committee (MSC).
  Many of the decisions made in IMO are based on finding common denominators and reaching a consensus among the member states. This process is time consuming and often involves taking into account political and national interests.
- **National interests –** In Norway the marine industry is governed by “Fiskeri og Næringsdepartementet” and the national interests are administered by Norwegian Maritime Authority [6]. The Norwegian Maritime Authority (NMA) is not only administering and enforcing our national requirements, but is also administering our maritime registers (NIS/NOR registers). The vessels registered in our national registers are to comply with our maritime regulations. In most cases, the vessel owners are companies registered in Norway. Due to the income generated by the taxes imposed on the vessel owners, the individual nations strive to have commercially competitive regulations, both within the maritime regime and the taxation scheme.
- **Petroleum Safety Authority (PSA) –** The responsibility of the Petroleum Safety Authority (Petroleum Safety Authority, 2017) is to ensure an adequate safety level on offshore installations on the Norwegian Shelf. It is administered by “Olje og Energi Departementet”. PSA is only concerned with our national interest and no international consensus is required with regards to regulatory development/implementation. PSA has no formal legal connection to the maritime industry (ships/vessels registered under NIS/NOR or any other maritime administrations), unless they are drilling on the Norwegian Shelf. They will however enforce requirements on offshore drilling operators, including their sub-suppliers like offshore supply vessels. Traditionally the requirements enforced by the PSA have been more conservative than the ones enforced by the NMA, addressing weaknesses in maritime regulatory regime.
- **Classification societies –** Classification societies are interpreting the regulations defined by the costal administrations. In some cases, they act on behalf of the costal administrations. Other times they act as objective third parties. It is however important to note that having vessels registered in a classification society generates income for the society. This mechanism forces the societies to compete against each other in an aggressive marked. As a result, the societies have to balance the

need for conservative interpretation of the regulations with the cost implied on vessel owner/operator to keep a fleet registered under their rules.

- **Vessel owners/operators -** The vessel owners/operators have to cover the cost associated with the regulatory requirements. The owners/operators also have to pay insurance, which again is only valid if the vessel complies with the flag state requirements, typically enforced by class. In general, you are regarded as a responsible owner/operator if you operate in compliance with the flag/port state requirements.
- **Equipment producers –** the equipment producers provide the vessel owners/operators with equipment that enables them regulatory compliance. The safety equipment is usually evaluated on regulatory compliance, price, capacity, weight and volume, where regulatory compliance has to be in place, and where price is the key most important parameter determining the sales volume.
- **Ship officers/crew –** The training of the vessel crew is defined in the IMO STCW convention and their interest are safeguarded through unions, e.g. Norsk Sjømannsforbund (Norsk Sjømannsforbund, 2017). The unions enforce strong interest in the safety of the officers/crew, and have representatives present in IMO.
- **Passengers –** The safety of passengers is safeguarded by no individual organization. Usually their safety is the responsibility of the cruise operator/transportation provider. Their motivation of safeguarding their passengers is the risk of economic implications caused by an incident/accident. It is however important to note that the cruise operator/transportation provider main motivation is to generate a profit, which involves keeping the cost at a minimum level. To stay commercially competitive, they are often forced to keep the cost related to safety equipment at a minimum, but still within the levels defined by the regulatory regime.

Societal perspectives

In the marine industry the decision processes is seldom "black and white", and it involves many considerations that interact on the different stakeholders in different ways. This is influenced by culture, economic robustness, global politics and facts. As described in "Technologies of Humility" [7] science only offers part of the picture. It is important to keep this in mind when communicating our project results to the industry.

There are 3 main stakeholders affecting the design of safety equipment for the maritime industry, the IMO requirements (enforced through the flag state and class rules), the equipment suppliers and the vessel operators. Each party has their own agenda and much of the challenges are associated with finding the right compromise between cost and functionality. The different agendas can be summarized as follows:

- Regulators – ensuring a safety-level that is globally considered acceptable, within the frames defined in IMO and giving their flag state register no commercial dis-advantage.
- Equipment suppliers – supplying equipment that is fulfilling regulatory requirements and at the same time is commercially attractive.
- Vessel operators – providing the safety as required by the regulators at the lowest possible cost.

As defined in SCOT (Social Construction of Technology) [8] there is not just one way or one best way to design an artefact. Development of new technology and utilization of new combinations of existing technology could increase the safety levels considerably. This would reveal many unique opportunities with regards to development of commercial products. However, the marked will not purchase these products unless they are defined as a compulsory requirement in the governing regulations, or can be regarded as cost efficient solutions. A result of the above mechanisms is that increased maritime safety is mainly accomplished due to regulatory development, which later will be followed by development of new products.

"Proof" that the current situation is not in line with the global societal expectations typically initiates regulatory development. This "proof" can be obtained through a major accident, and traditionally the marine regulations are retroactive and major regulator changes has emerged in the wake of major accidents.

"Proof" can also emerge because of scientific documentation. Through the SARex exercises, we have investigated the survivability to be expected if a real accident occurred in an Arctic/Antarctic region. The survivability figures obtained does not meet the global societal expectations. This has been communicated to different maritime administrations. The maritime administrations have further brought our results into the IMO regime.

For the stakeholders represented as regulators, our results have to be incorporated in their organizations. The vessel operators/transportation providers are in general sceptical to our findings, as it will induce additional costs that is to be carried by them. On the contrary to what many expect, the equipment manufacturers have very few opinions on the issue, as they only provide equipment according to regulatory requirements and have no responsibility beyond that with regards to the functionality or survivability provided by their equipment.

The international maritime industry is a complex structure with many stakeholders. Michael Gibson addresses this type issue in "Science new social contract with society" (Gibson, 1999) where he states that the price for increased complexity in society is a pervasive uncertainty. The same can be the case in the marine industry where ownership and responsibility can be hard to identify [9].

- Responsible Research and Innovation Challenges

A Responsible Research and Innovation approach [10] continuously seeks to:

- Anticipate – evaluate the impacts induced by the research activity
- Reflect – reflect on the implications of the results from the research activity
- Engage – opening up for relevant discussions in a broader audience
- Act – utilizing the above processes to influence the direction of the research process

One way of fulfilling the above principles is that all societal actors are to cooperate and work together to align both expectations and results to societal needs. The SARex project has incorporated representatives from all major stakeholders within the maritime industry. This induces continuously discussions and dialog on the purpose, direction and implications of our findings.
The SARex project and its findings have also been present at several academic conferences, in addition to industry conferences. As the project has broad public interest, the results have also been communicated through media, in addition to several closed industry seminars.

Through our work on communication we have obtained dialog with multiple stakeholders that otherwise would have been difficult.

Among the maritime industry, in addition to all project participants, there is no disagreement on the importance of the issue of survivability on rescue crafts, and further knowledge is required. There is however conflict of interests among the different stakeholders. This is mainly due to the potential cost induced by our findings.

One of the main principles of the regulatory regime imposed by IMO is that there is to be no discrimination among the member states. From a vessel operator/transportation providers point of view this means that all competitors are to compete on “equal grounds”. Currently there are no common consensus with regards to interpretation of the IMO Polar Code. If SARex can contribute to help the global marine industry reach a consensus that would be beneficial for all parties involved, despite the fact that there will be a higher cost associated with the solution. IMO processes are essential to reach this consensus. This takes time and a closure cannot be expected for several years.

There are currently no indications that disruptive effects will reduce the need for cold climate marine activities in the future. However, there might be some unforeseen and unpredicted societal effects of our work. There are many examples where societal impacts and effects have not been adequately considered in the early phases of the project [11]. Unforeseen impacts of our work remain speculations but if it turns out that survival along the lines defined in the IMO Polar Code (a minimum of 5 days) is not achievable, a combination the following effects are to be expected:

- IMO will have to reverse the implementation of the Polar Code, which will take years
- Investment in the expedition cruise industry will be a high-risk venture
- The passengers on expedition cruises to the high Arctic will expose themselves to a high risk, resulting in reduced activity.
- The polar states will have to substantially increase their budgets set aside for Search & Rescue capacities to ensure a sustainable Arctic development.

The societal impacts and effects will most likely not reveal it selves until a major accident occurs, typically involving loss of life. Not only will the accident have to occur, but the accident will also have to be communicated to the public through the public media channels. Based on historical events it is a paradox that lives have to be lost before a major effort is put into regulatory development trying to safeguard lives.

Concluding remarks

Closure of the challenge related to survival in rescue crafts is achieved when the global marine industry reaches a consensus and perceives the problem as solved, along the lines defined in SCOT (Social Construction of Technology) [8]. This process will be influenced by not only the objective facts generated by academia, but also political and economic agendas. Science can only indicate that a potential disaster can occur and the effect of the different mechanisms at play, but not when and where it will occur. It is challenging for the policy makers and regulators to deal with this ignorance, and the best approach is through a robust humility approach also considering the ethnical aspects of their decisions [7].

As the global maritime industry is a complex and competitive industry where almost every party has an economic agenda it is highly important that we, as a scientific institution, stay clear of commercial economic opportunities related to this work. Our credibility within the maritime sector is dependent maintaining the status as an objective third-party. The moment we, as a scientific institution, contribute in driving a political process in a direction where our motivation can be linked to our own economic gain; industry, regulators, governments and the IMO will question our credibility. This will terminate our role as a leading knowledge provider for the maritime sector.

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PICTURES

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UiS-delegation with the captain on KV Svalbard. Left to right: associate professor Bjørn Ivar Kruke, PhD student Knut Espen Solberg, Captain Endre Barane, Professor Ove Tobias Gudmestad and MSc student Kontantinos Trantzas

Professor Gudmestad looking out from the lifeboat