D6.8 - Report on human factors aspects of e-Nav Services

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Contents

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Executive summary

This report suggests a new way of looking at ship bridge design based on resource demands in different phases of a ship's voyage as well as the stress and situational levels of the bridge operators. A series of simulations were conducted. Web based services, served as platforms to assess the advantage of strategic navigation and administrative services.Hollnagel's Contextual Control Model (COCOM) was used and the Strategic, Tactical, Opportunistic and Scrambled control levels identified as useful abstracts for different workload levels on the bridge. The four different control levels will require different types of information and HMI design and the work places are placed at different locations on the bridge, as suggested in Figure 1 below. Four papers/reports are appended to this report that tested elements of the proposed design model. These include additions entitled: Self-organizing emergency response and decision support for ice navigation (appendix 1); E-navigation from a human factors perspective: Investigation today's bridge systems and procedures, and assessing navigators' perception of a novel service website prototype in a ship bridge simulator (appendix 2); Development and analysis of evaluation algorithm for different cartographic systems (appendix 3) and Comparison of the EfficienSea2 project platform BalticWeb with a standard ECDIS (appendix 4).

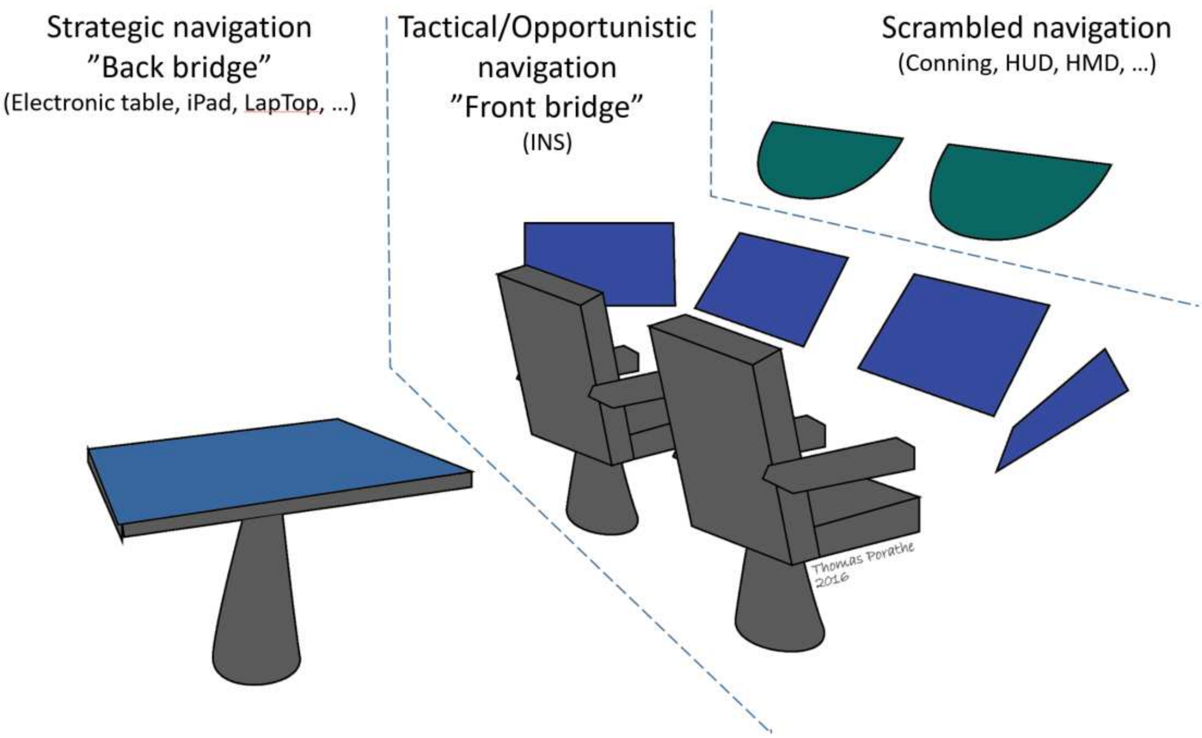

Fig. 1. The four different contextual control levels supported by different information displays and HMIs in different locations on the ship bridge (illustration Thomas Porathe).

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2 Introduction

2.1 Scope and purpose

The scope of this work was to use subject matter experts to assess the services, specifically the ArcticWeb and BalticWeb, through a series of experiments within the ship simulation suites located at Chalmers and the Latvian Maritime Academy. The purpose was to assess if safety and/or efficiency were improved through the use of these services.

2.2 Abbreviations

AIS – Automatic Identification System
ECDIS - the Electronic Chart and Display Information System
INS - Integrated Navigation System

3 Background

3.1 Two ship accidents

In 1999 the high speed craft ferry *Sleipner* crashed into a small island on the Norwegian coast and 16 of 85 passengers and crew drowned as the ferry subsequently sank. It was a dark November evening with strong wind and high waves. The ferry was underway in 35 knots over a stretch of open water. The captain and the first officer was seated in an airplane cockpit arrangement in the wheelhouse and navigating visually using the sector lights up along the coast. Due to the rolling of the vessel, the autopilot had been disengaged and the captain was steering using a knob on the armrest of his chair. During the final stretch of open water, both officers suddenly turned to their radar sets making adjustments and no one was for a number of seconds looking out the window for the white sector of the next beacon, which should be on the bow. After adjusting his set, the first officer looked up and saw the beacon's red sector on the starboard bow. He immediately realized that they were in danger of hitting the small island and called out a warning to the captain who turn on the floodlight of the vessels. The island appeared just ahead of

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Sleipner and the captain gave full port rudder and reversed the engines, but the manoeuvre had not time to take effect and the vessel crashed on to the island in almost full speed. One may in hindsight note that although the ferry had a fully functional, state of the art bridge, with an electronic chart system, the officers never managed to recover their situational awareness until it was too late. Although all information was available, there was simply not enough time to read all the necessary instruments and integrate them to a conclusive image of the situation (NOU, 2000).

A night in October 2011 the 225-meter long container vessel *Rena* grounded on the Astrolabe Reef off the North Island of New Zeeland. The vessel was severely damaged but remained on the reef for several months before she finally broke up causing environmental pollution. *Rena* was approaching the pilot pick-up station for Tauranga Port but needed to hurry because she was at the end of the tidal window allowing entry to the port. The captain decided to make a shortcut south of the planned track bringing the vessel within one nautical mile to the Astrolabe Reef. *Rena* did not have an electronic chart system but used paper charts placed in the chart room behind the bridge. The progress of the voyage was monitored by position plots marked by pencil on this paper chart. As the *Rena* approached Taruranga pilot station the captain joined the second officer and the lookout on the bridge. The captain noticed an intermittent echo on the radar screen about 2.6 nautical miles dead ahead of the vessel. He and the outlook tried to detect what it was causing the echo using binoculars both from the bridge and the bridge wing but without success. As the captain went for the chart room to plot his position on the chart *Rena* struck the reef in 17 knots. It is in hindsight interesting to note that part of the information needed to keep up the operators' situation awareness was stored on the nautical chart placed in the chart room behind the bridge while the only real-time information provided by the radar was available on the bridge. As the reef was submerged by water, the only indication on the radar was breaking waves every now and then (TAIC, 2014).

4 Human Factors aspects of bridge work

From an operator performance perspective the two accidents referred to above is very different. In the *Sleipner* case, the officers suddenly became aware of imminent danger and under influence of stress and time pressure, they were not able to recover their situation awareness. In the *Rena* case, the officers were unaware of the danger. However, in both cases, the presentation of information was suboptimal for the present circumstances. *Sleipner* had an electronic chart system showing both the danger and the position of the vessel relative to the danger, but the chart was located in an off-view position and presented in a format that did not support immediate action. On the bridge of *Rena* information was fragmented in two different locations and needed to be remembered ("carried in the head") between the chart room and the radar. It is interesting to reflect on the workload situation of the officers just prior to the accidents when recover would still have been possible.

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It is well known that stressors affect the efficiency of information processing generally by degrading performance (Driskell and Salas, 1996). Stress lowers the ability to take in and process information. Many of the effects are mediated by arousal. Physiological arousal can be objectively measures through indicators as hart rate, pupil diameter and hormonal chemistry (Wickens et al., 2014). The importance of physiological arousal is indicated by the inverted U function of performance, often referred to as the Yerkes-Dodson law (Yerkes and Dodson, 1908).

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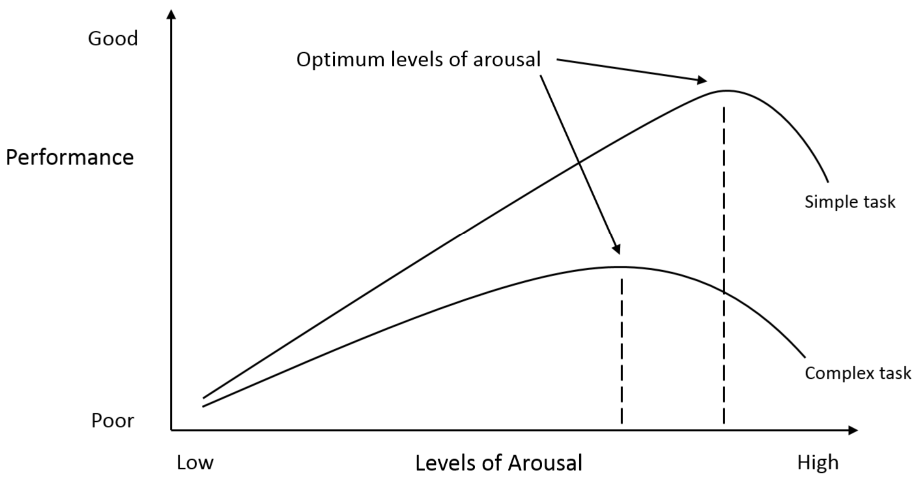

Fig. 2 The Yerkes-Dodson law showing the relation between levels of arousal (indicated by stress) and performance. The optimum level of arousal is higher for simple tasks (Wickens et al., 2014).

The figure shows that performance is generally low with low arousal then slowly increases towards an optimum level of arousal where also the performance is optimal, and then subsequently declines as stress induced arousal increases further. This is the reduced performance we can see under heavy stress. However, we can also see the difference

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between the two curves of complex and simple tasks. Simple tasks can still be performed under heavier stress that complex tasks. This might be due to less demand on cognitive resources. This suggests that information necessary for imminent decision-making should be presented in a less demanding form.

Before we return to *Sleipner* and *Rena* and our final goal to say something about human factors aspects and bridge design, we will need to take a short look at the work environment of a ship bridge.

5 Work environment of the ship bridge

Over 90 percent of the world's transports are carried on keel. Effective, safe and environmentally friendly shipping is important as we head into future unknown waters of changing climate with more extreme weather and higher demands on emission reductions. Shipping is an industry with longstanding traditions. Previously, information available on the deck of a sailing vessel or on a steam ship bridge was limited to a few course instruments often only rules of thumb, learned through experience. Today we have a plethora of information available. In addition, more is coming. In 2006, the International Maritime Organization (IMO) started working on a concept termed *e-Navigation* to "harmonize the collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment" (IMO, 2016).

It is little doubt that important environmental data available onboard in real-time will enhance the safety of shipping. Weather reports has already for decades been transmitted to ships within radio range of coastal stations, helped ships escape from bad weather compared to when only having barometers and general knowledge of the normal paths of weather systems in different parts of the world. e-Navigation will not only enhance knowledge onboard and increase safety and efficiency, but also support a sustainable future industry. However, one problem that must be taken seriously is where and how to display all this new information to support the operators on the bridge. Let us therefor briefly look at the working situation for bridge officers today.

5.1 Decision-making on the ship's bridge

Modern ocean going cargo ships of reasonable size usually have four bridge officers responsible for the navigation of the ship. The captain has the overall responsibility of the ship and is often not watch going under normal circumstances. The other three officers are watch going on a schedule, often 4 hours on watch and 8 hours off in ocean traffic. This gives each officer two 4-hour-watches per person per 24 hours. During the daylight watches, the officer is usually alone on the bridge in open sea conditions. The work consist of monitoring the surroundings looking out for other ships or dangers. This is done by binoculars and radar. With the roll-out of the mandatory ECDIS (the electronic chart and

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display information system) requirement completed in 2018 ships will not only see their own present position plotted on an electronic chart in real time, but also other ships equipped with an Automatic Identification System (AIS) transponder.

Normally only larger vessels are visualized through the AIS, smaller fishing vessels and leisure crafts will normally not carry AIS and will only be visible on the radar. There are of course a lot of other tasks but generally, during ocean passages, the workload can be very low. With no ships around and nothing on the radar screen for 24 nautical miles around the problem might instead be one of low arousal (boredom). During darkness, a seaman is added to the bridge as a lookout, both because the degraded visibility puts higher demands on vigilance, but also as a safeguard against someone falling asleep.

As the ship is approaching harbour and entering coastal waters the traffic intensity may increase, buoyage systems that needs to be detected and traffic separation adhered to. This puts higher demands on the resources on the bridge. More observations needs to be made and more decisions taken during a given time interval. The workload has now increased compared to the open ocean situation.

As the ship is approaching port, the workload increases even more. Radio contact needs to be taken with the pilot station and pilots picked up off the coast. During the approach through a complicated archipelago, great concern needs to be given the charts and other vessels in the area, communication may need to be made with various stakeholders in port to prepare for the arrival, and rigours time keeping in navigation exercised to arrive in time for tugboats and linesmen. Often this increased workload is mitigated by adding more persons to the bridge team, e.g. the maritime pilot and maybe an extra officer.

Finally, the ship arrives in port. The workload on the bridge now increases even more. The traffic in a busy port maybe heavy, a lot attention need to be put on manoeuvring with wind and current now affecting the slow moving vessel. Mooring lines needs to be prepared and a thousand tasks preformed. The workload is very high and the captain is also added to the bridge team often doing the final manoeuvring to berth.

But, just as in the *Sleipner* case, the workload might also peak at any time due to unforeseen circumstances.

The diagram in Figure 3 describes schematically workload of a bridge officer as the quota between available resources (both cognitive) on the y-axis and resource demand on the x-axis. To the left in the figure we can see that the resources demanded during an ocean passage are generally low and then increases as the ship enters coastal waters and finally the confined waters of the archipelago and the port.

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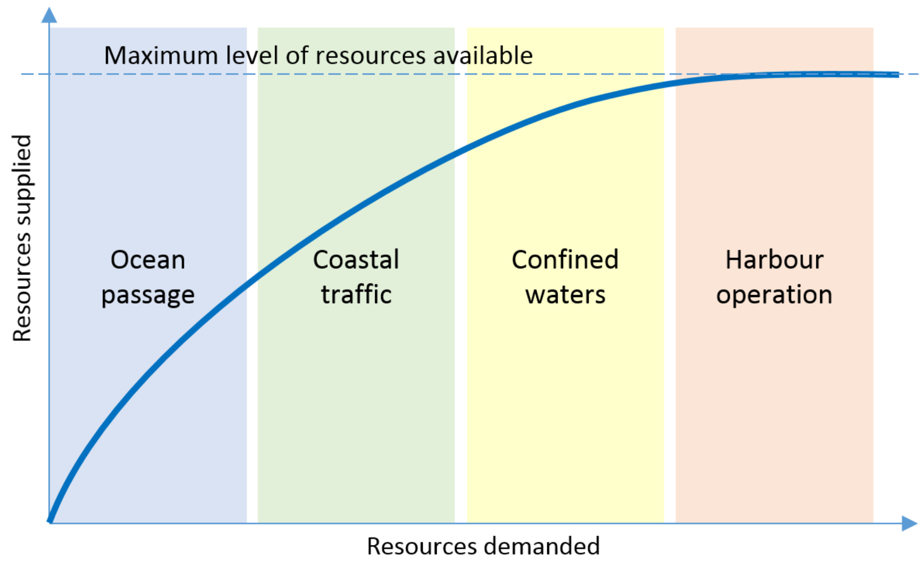

Fig. 3. The diagram shows the relationship between resource demand and supply during typical phases of a ship's voyage. Resources are here both cognitive and physical and can be supplied by higher arousal (up to a certain limit), by automation or by adding another operator. (Adapted after Wickens et al., 2012)

In the model above, we can see the resource demand on the bridge change during different phases of a prototypical voyage. Changing demands on workload can be dealt with on an individual level by increased or decreased arousal of the watch officer, but also, as in the typical port approach above, by adding more personal to the bridge team. However, in abnormal circumstances the situation will have to be dealt with the resources available at the bridge at the time of the incident. Changing demands might also be dealt with through information design. We now need to take a closer look at how the human operator can cope with these different demand.

6 The Contextual Control model

The Danish psychologist Erik Hollnagel in 1998 developed a model of human resilience and coping, later termed the Contextual Control Model (COCOM). The model consists of four levels describing the orderliness or regularity of performance and each such "control mode" can be associated with a characteristic type of performance: The four control modes are: Scrambled, Opportunistic, Tactical and Strategic. Hollnagel writes that they should be considered as regions on a continuum, which ranges from no control at all to completely deterministic performance. Hollnagel describes the control levels as this:

- The **scrambled** control mode. For humans there is little, if any, reflection or cognition involved but rather a blind trial-and-error type of performance. This is typically the case when situation assessment is deficient or paralysed and there accordingly is little or no

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correspondence between the situation and the actions. The scrambled control mode includes the extreme situation of zero control.

- The **opportunistic** control mode, the salient features of the current context determine the next action. Planning or anticipation are limited, perhaps because the context is not clearly understood or because there is limited time available. Opportunistic control is a heuristic that is applied when the constructs are inadequate, either due to lack of competence, an unusual state of the environment, or detrimental working conditions. The resulting choice of actions is often inefficient, leading to many useless attempts being made.
- The **tactical** control mode corresponds to situations where performance more or less follows a known procedure or rule. The joint system's time horizon goes beyond the dominant needs of the present, but planning is of limited scope or range and the needs taken into account may sometimes be ad hoc.
- Finally, in the **strategic** control mode, the joint system has a wider time horizon and can look ahead at higher-level goals. The dominant features of the situation or the interface therefore have less influence on the choice of action. At the strategic level, the functional dependencies between task steps and the interaction between multiple goals will also be taken into account in planning. (Hollnagel, 2016)

In the perspective of the work situation of the officers on the ship bridge, Hollnagel's control model can be used to structure the information environment so that it might fit different control levels of the operators, different resource demands, time constraints and stress levels. This might help information designers on where to display all new e-navigation information due in the coming years.

6.1 Contextual Control Levels on the Ship Bridge

6.1.1 Strategic control level

Modern bridge procedures and bridge design often well support the Strategic level of control. A pre-voyage "voyage planning" phase is here added to the procedures of the prototypical process. Voyage planning is done ahead of departure in the relative calm of the chart room or chart table on the back end of the bridge. Here is where you will find tables and literature needed for careful planning. Several alternative route chooses can be compared without time stress. On the modern bridge, an ECDIS planning station might be placed and a computer able to go online and receive updates from costal administrations and port authorities. This is also the place where strategic planning can be conducted during long ocean passages. This is where the bulk of the new e-Navigation information is envisioned to go. Available time also lessens the demands on information design. If information is not understood, there is always the possibility to read or look again, or ask for advice. In the model in Figure 4 the Strategic control level is typically placed to the left, during the voyage planning and ocean phases, with low resource demands.

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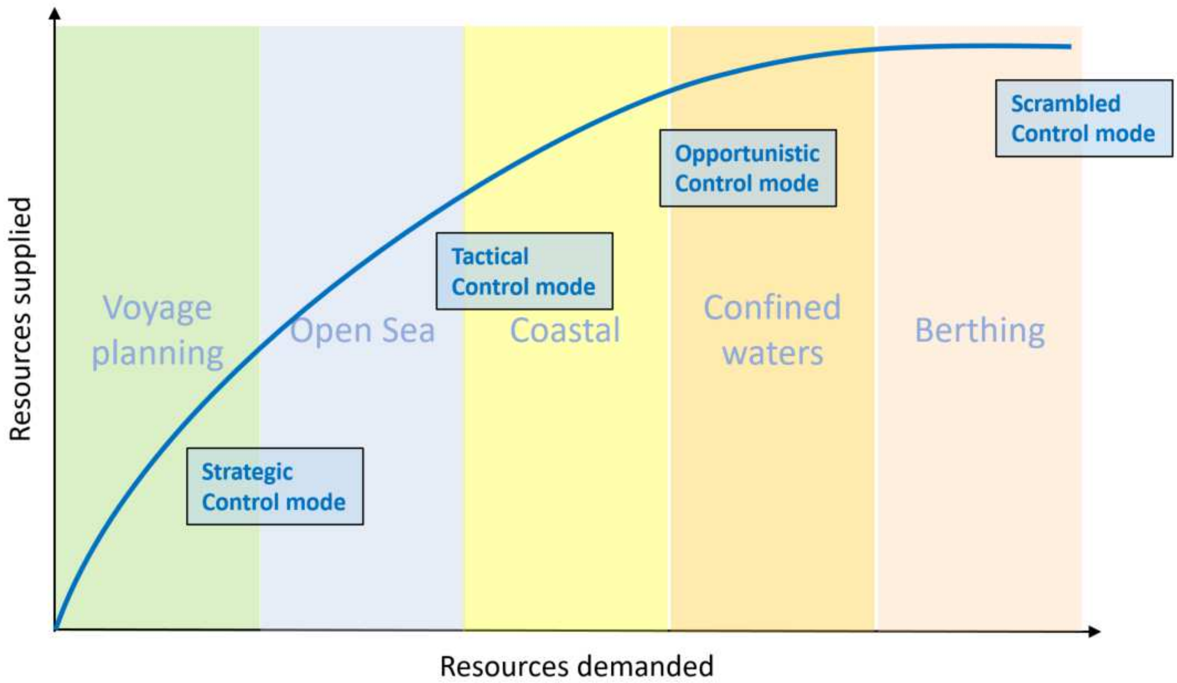

Fig. 4. The same diagram as in Figure 3, but with Hollnagel's four contextual control levels overlaid on the different phases of the voyage.

6.2 Tactical control level

On the front of a modern ship bridge, you will find an Integrated Navigation System (INS) with several screens on which ECDIS, radar and conning information are displayed as well as other possible services. If the bridge has a pilot, co-pilot setup you will find two chairs for the watch officer and a co-officer. Although there are several problems with the interaction and information design of radar and ECDIS equipment, they all fairly well support the navigators on the tactical control level, typically illustrated in Figure 4 by the coastal and confined water phases of a voyage. Bridge officers here work with a just-enough-time constraint and needs decision support to be clear and unambiguous. The problem in the *Rena* case related in the beginning was that information about the submerged reef was not available on the front bridge radar of *Rena*, which was not equipped with an ECDIS.

In Figure 5 a schematic drawing of a bridge is shown where the "Back of bridge" and "Front of bridge" fairly well corresponds to a design found on many modern ships. In this image, the back bridge is equipped with an electronic chart table, which is still in coming, but for the future will be an excellent format for nautical information joining the space and overview of the old paper charts, together with the layering and dynamics of information found in modern electronic systems. Complemented by the mobility of tablets and smartphones.

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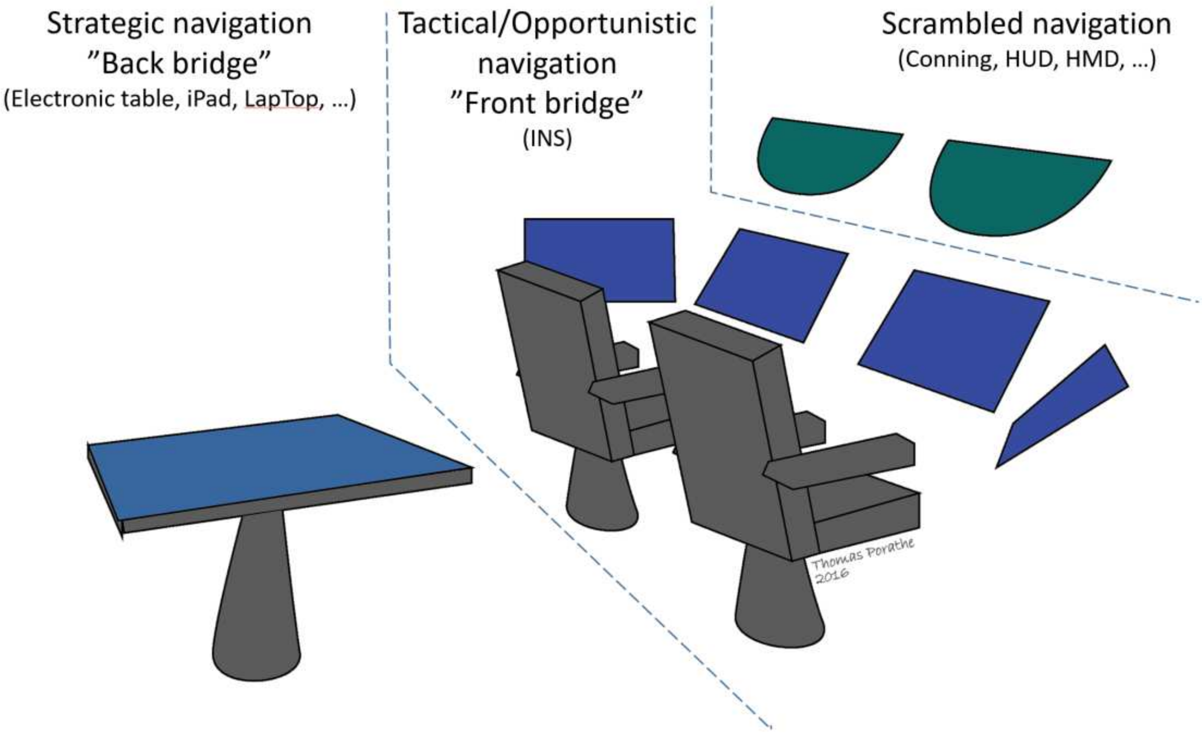

Fig. 5. The three different contextual control levels supported by different information displays and HMIs in different locations on the ship bridge (illustration by the author).

6.3 Opportunistic control level

The traditional bridge setup is using a separate screen for radar and another for ECDIS. The theoretical explanation is that the radar will provide an uncluttered presentation mode for the collision avoidance task (given that you are on open water and no land echoes clutter the display), and the ECDIS is used for the anti-grounding task.

However, modern radar and ECDIS equipment allows chart and radar picture to be merged. Radar echoes can be overlaid on the chart information on the ECDIS display, and chart information can be underlayed the radar image on the radar display. Thus removing the need for the navigator to look at two screens simultaneously, and "carry the information in the head" between the two screens. We remember the problem from the *Rena* accident where chart information about the Astrolabe reef had to be carried in the head from the chart room to the radar screen on the front bridge. Something that faulted.

Although not recommended as standard bridge procedure personal communication with instructors at navigation colleges show that modern procedure often involve using such a merged display, e.g. ECDIS with radar overlay. From a human factors point of view this makes great sense sins it offers cognitive off-loading for the navigator that can see information already integrated on the screen.

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6.4 Scrambled control level

In the *Sleipner* accident related in the beginning of this report, the two bridge officers suddenly found themselves in a situation where they had temporarily lost their orientation. They know that they were heading for danger but did not know if the danger was to the left, to the right or straight ahead. Nor did they have the time to investigate their position relative to the danger using the ECDIS. In this Scrambled situation, we may conclude that none of the available information displayed managed to supply them with the necessary decision support.

Research done on wayfinding and chart systems that show cognitive off-loading, removing the need for mental rotations by presenting the chart view in an egocentric 3D view (e.g. Porathe, 2006). Such a view could be shown on a display close to the windscreen or overlaid on the widescreen as in airplane Head-Up Displays (HUD). Several research projects are presently underway using Augmented Reality glasses or visors for maritime use (e.g. Pecota, 2012; Grabowski, 2015). In figure 5 the Scrambled control mode is represented by two HUD displays in the windscreen in front of the two operator chairs.

7 Conclusion

This report has suggested a new way of looking at ship bridge design based on resource demands in different phases of a ship's voyage as well as the stress level of the bridge operators. Hollnagel's Contextual Control Model was used and the Strategic, Tactical, Opportunistic and Scrambled control levels identified as useful abstracts for different workload levels on the bridge. The four different control levels will require different types of information and HMI design and the work places are placed at different locations on the bridge.

Future research will determine if a test method or methods can be developed to ensure that information and HMI design is compatible with different stress levels and time constraints.

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D6.8 Appendix 1
Self-organizing emergency response and decision support for ice navigation

Project no. 636329
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EFFICIENSEA2 – efficient, safe and sustainable traffic at sea

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Abbreviations

IACS – International Association of Classification Society

SAR – Search and Rescue

OSC – On Scene Coordinator

SRU – Search and Rescue Unit

LKP – Last Know Position

AIS – Automatic Identification System

EPIRB - Emergency Position Indicating Radio Beacons

VHF – Very High Frequency

JRCC – Joint Rescue Coordination Centre

PLB – Personal Location Beacon

SART – Search and Rescue Radar Transponder

COSPAS – SARSAT – Satellite network with global coverage for distress alerts

GEOSAR – Geostationary earth orbit satellite

LEOSAR – A polar low-altitude earth orbit satellite

MEOSAR – Medium altitude earth orbit satellite

GPS – Global Positioning System

HF – High Frequency, 3-30 MHz

MF – Medium Frequency, 300 kHz – 3 MHz

IMO – International Maritime Organization

SOLAS – International convention for the Safety of Life at Sea

MARPOL – International convention for the Prevention of Pollution from Ships

DSC – Digital Selective Calling

GMDSS – Global Maritime Distress and Safety System

IAMSAR – International Aeronautical and Maritime Search and Rescue Manual

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Scope

The scope of this document is to demonstrate the activities and the progress made as a part of the EfficienSea 2 project, work package 6.3. The objective with this task is to develop different services with the aim of improving maritime safety in the Arctic. The current platform ArcticWeb will be used as the baseline. One of the main targets is to develop means for self-organizing emergency response capabilities. This functionality will build on several elements including the route exchange capabilities developed in task 6.1, results from the MICE project and the VOCT (Vessel Operations Coordination Tool) prototype developed in the ACCSEAS project.

The main focus has evaluation of different capabilities and functionalities of the ArcticWeb, like:

- Position-sharing of AIS data
- Weather and ice information
- Route optimization
- SAR Management

Problem description

To limit the research problem and to pinpoint what we want to focus on, our emergency scenario is as follows.

We are in an arctic environment and have only a few vessels available, the vessels have limited connection to shore based emergency units; either through MF/HF radio land based AIS stations or via satellite connections.

Furthermore, co-operation with air resources like SAR helicopters, or emergency situations where emergency beacons becomes active and sends signals to national Joint Rescue Coordination Centres (JRCC) via the Cospas-Sarsat satellite system, will not be available in this exercise. Although not typical, it does reflect a worse-case scenario and will challenge the services within the ArcticWeb.

The report consists of a background which address maritime activates in the Arctic, communication, position-sharing and maritime safety and SAR in these regions. The second part focus on the practical tests and the methodology used during the evaluation. The third part highlights the results from the simulator study. Fourth part consists of discussion on todays practice and the result and finally the main conclusions.

Delimitation

The report is limited to mainly cover aspects and activities in the Arctic and addressing SAR management

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1 Background

In order to explore this scenario and provide the necessary background for the practical tests, we will start by looking at the current situation in Arctic with regard to traffic density development, different relevant types of accidents, current communication solutions, the Polar Code and how SAR is managed today. Thereafter we will look at the organisational aspect of a self-organized emergency operation and learnings from previous SAR exercises.

1.1 Maritime activities in the Arctic and expected growth

Due to climate changes and increased global temperatures, the polar ice caps are reducing. According to some studies the area around the north pole could be open in 2050 during the summer season (Smith & Stephenson, 2013). This development will create new possibilities for maritime activities in the arctic regions with for instance new and shorter trade routes between Europe and Asia and in addition increased cruise traffic (Nese & Dalsland, 2016).

According to numbers from the Norwegian Defence Research Establishment (FFI, 2015) the traffic density in Arctic is steadily increasing. Figure 1 show how the traffic has been growing in the period from 2010 to 2015. In addition, the recent boost in the Oil & Gas exploration in Arctic is expected to contribute significantly to the traffic growth in the years to come.

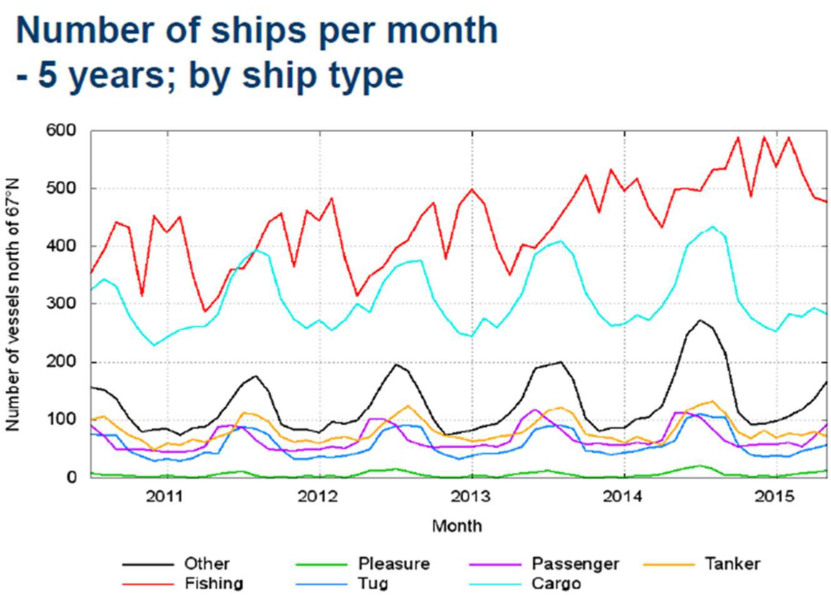

Figure 1. (Source: FFI)

As shown in Figure 1, many of the vessels sailing in the Arctic seawaters are smaller vessels with fishing vessels as the dominant type.

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According to Professor Borch at Nord University (2017) the following changes are hallmarking the activity in the high north:

- Fisheries - farther out at sea and towards the ice ridge searching for migrating fishing resources.
- Oil and gas - into challenging waters with longer distance to mainland and infrastructure
- Cruise - further North and East/West – explorer cruise close to ice
- Transport - more internal – dangerous goods transport to/from oil and gas filed, inter-continental transit
- Government (research, military) – complex operations
- Offshore mineral mining – new industry of sea bed exploitation in exposed, deep sea areas.

Figure 2 below shows more in detail where within the Arctic region the different activities are expected to take place towards year 2030.

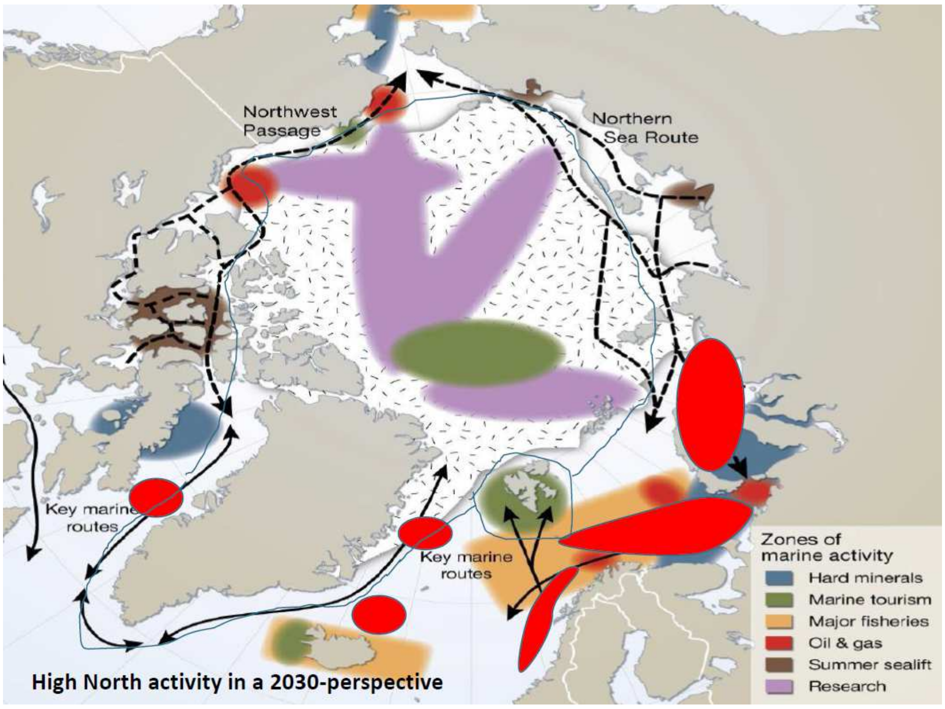

Figure 2. (Source: Nord University)

It is reasonable to believe that a higher activity level will imply that the risk for incidents will gradually increase accordingly, and therefore it becomes more and more important to be well prepared for what is regarded as relevant incident situations.

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When it comes to tourism different attractions such as remoteness and extreme environments are key aspects in the experience, which creates a type of paradox when these characteristics are central in emergency preparedness. If an accident would appear in polar regions, the consequences could be far worse compared to an accident in lower latitudes as polar waters are considered as dangerous due to its climate and geographical area.

There are many other factors that influence the safety of maritime activities in polar regions like; poor communication and abilities to determine position for safe navigation, different kinds of ice types, the impact of cold on life saving appliances and on human performance, poor infrastructure and long response time in SAR situations.

With increased activities in polar regions the risk of an accident is also increasing, in recent years there have been more focus on increasing safety of ships operating in these remote, vulnerable and potentially harsh environments.

Different kinds of guidelines have been implemented and the cooperation between involved countries in these regions have increased. The focus has culminated in, the IMO adopting the international code for ships operating in polar waters, the Polar Code (Nese & Dalsland, 2016).

1.1.1 Relevant emergency incidents

Statistics from the Joint Rescue Coordination Centres (JRCC) in Bodø (JRCC, 2017) covering the area above 65 degrees north on the Norwegian side, shows the increase in sea rescue operations in the period from 2014 to 2016.

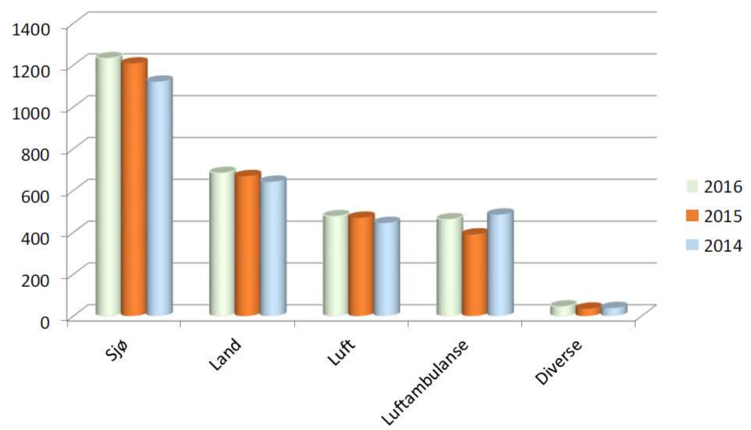

Figure 3. (Source: JRCC Norway)

To further illustrate today's situation, Figure 4 below illustrates the spread and density for the JRCC sea rescue operations carried out in the period from 2011 to 2016.

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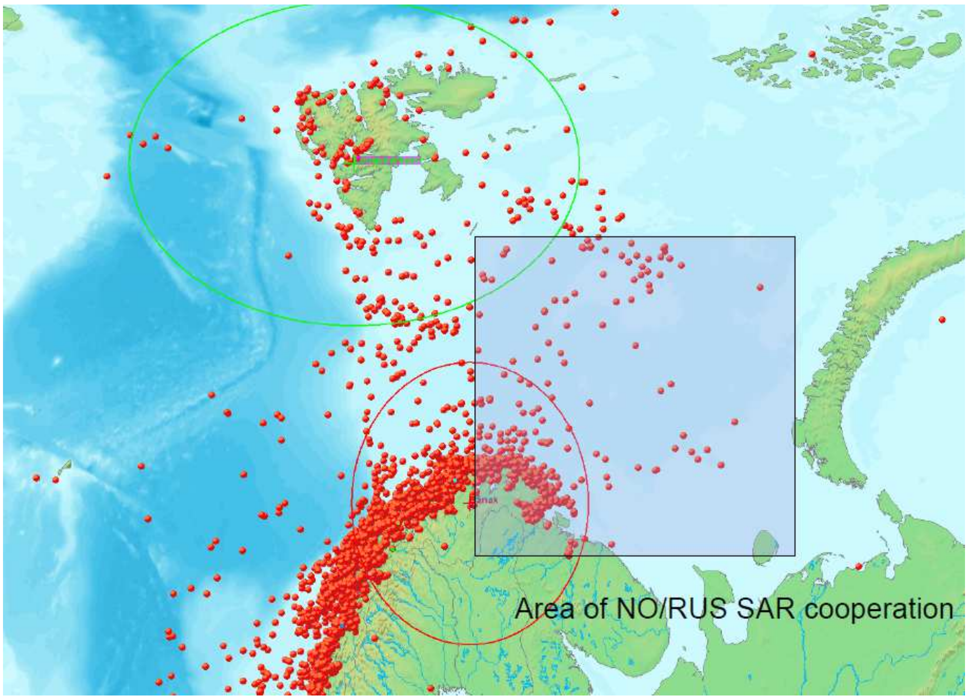

Figure 4. (Source: JRCC Norway)

Obviously, there are many different types of incidents can that take place in the Arctic areas, and some relevant examples are:

- Illness on board
- Grounding
- Collisions
- Fire
- Pollution
- Terror
- Man overboard (MOB)

The types and magnitude of incidents could naturally vary from smaller incidents to more "worst case" scenarios. For instance, in the Cruise industry, a worst-case scenario would be collisions with ice or grounding resulting in a situation with lifeboats spread over a huge area.

This would trigger the need for mass evacuation which must be executed within a short time period to avoid causalities due to low temperatures. Within the oil industry, incidents related to operation of offshore installations and helicopter transport of personnel is very relevant.

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1.2. Communication solutions for emergencies available in the Arctic

This section will provide an overview over what communication solution currently are available in Arctic and how these are used today.

1.2.1 Radio

All passenger and cargo vessels over 300 tons engaged on international voyages have to carry different kinds of radio and satellite communications equipment the meet the requirements of the GMDSS structure. Vessel approved for Arctic must carry GMDSS equipment for area A4 to ensure that a distress alert could be broadcasted to a JRCC, which could be a HF DSC radio equipment and/or a Cospas-Sarsat EPIRB (Waugh, 2007).

VHF radio is still the main tool used for communication at sea between vessels and between vessel and shore. This is due to the advantages of VHF communication which include minimal radio interference, good sound quality, and the portability of the antenna. But the range of VHF is limited to "line of sight" and it can only be used for voice communication. MF/HF radio is also used, but more for long-range digital and voice communications since a MF/HF radio has a longer range than a VHF radio.

Digital VHF, mobile phone systems and other types of wireless technology offer enough digital capacity for many maritime applications, but only to ships within sight of shore-based stations, and these means of communication are therefore not generally available in arctic waters.

A new radio solution on the market, which could have relevance for Arctic areas, is the Maritime Broadband Radio (MBR), developed by Kongsberg. Based on MBR equipment mounted on vessels, a local radio network for inter-vessel communication can be established for voice communication and data transfer. The range of the network could be up to 50 km.

The main challenges with the MBR solution are that that special MBR equipment is needed on-board, and in addition the solution seems to be quite expensive. So far, not many vessels have this equipment on-board and the solution is probably more suited for larger vessels as for instance special offshore vessels dealing with e.g. more complex oil and gas operations. It is maybe not realistic to believe that e.g. smaller fishing vessels will invest in such equipment

1.2.2 Internet and Mobile

In addition to traditional radio, the coverage of mobile telecommunications technologies as 2G to 4G+ has increased significantly in the recent year. And close to the coast, the coverage from land based stations is currently quite good. For oil installations that are not too far out, there has also recently been developed special solutions that provide these with 4G coverage from land based stations. It is also more and more common to establish local 4G network on-board large vessels as cruise vessel.

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Such coverage makes it possible to send emails, use internet etc. using common PCs. However, when these vessels are out of range from land based base stations they are dependent upon satellite connection. To send such data by the use of satellites is more costly and it could be limitations with regard to data transfer capacity.

1.2.3 Inmarsat

The Inmarsat system is a part of the GMDSS structure(telex/data) however the solutions from Inmarsat has a more limited coverage in Arctic since the satellites used are orbiting equator. Therefore, the coverage is very limited above 70 degrees north, although sometimes, dependent on variations in the satellites' orbits, the coverage could sometime reach as far as 80 degrees north. Similar to the Iridium solution, it is possible to transfer data like emails and so on via Inmarsat. Inmarsat is by many regarded as the preferred S-AIS solution

1.2.4 Iridium

Iridium is a basically a phone satellite constellation network consisting of more than 66 satellites. This system offers high accuracy, near-real-time transmitting and can also be used to transmit lower amount of data (like emails) in both directions. However, a current challenge is that data and voice cannot be transmitted at the same time; you need to choose either voice or data. This makes it a bit cumbersome to use. This solution also requires that vessels have special AIS transceivers on-board that can send and receive Iridium data and voice.

The S-AIS service providers that make use of the Iridium solution, claims that it has full coverage in the Arctic and that there is no time delay on the data transmission (offer e.g. real-time positions of vessels). Conversation with captains participating in the simulation exercise at Chalmers revealed that they had experienced a lot of disturbances and poor voice quality when using Iridium communication. Another challenge is that the cost for transmitting data is very high. Due to these reasons, the ones we talked with claimed that the Iridium solution on-board usually is used as a back-up solution.

1.2.5 Emergency positioning indicating beacons

There are in general three main types of emergency beacons. One type is beacons that transmit distress alerts via satellites to national rescue forces (JRCC), while the other type is beacons that transmit distress alerts via AIS to nearby vessels. The third, and newest type, use both approaches.

1.2.5.1Satellite based beacons

The most common system is the EPIRB, which also is a part of the GMDSS system. The other solution is the PLB's which are becoming more popular. A JRCC gets distress alerts from EPIRBs and PLBs that transmit distress alert via the COSPAS-SARSAT satellite network. As a part of the distress alert, they will get information about the identity and initial location of a vessel or person in imminent danger.

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The rescue canter will then attempt to contact the PLB's registered user (and/or the person's emergency contacts) while also dispatching a rescue team.

The COSPAS – SARSAT solution, which is on its way to be upgraded by including the MEOSAR satellite network, will when the upgrade is finished, consist of a large network of GPS satellites (LEOSAR, GEOSAR and MEOSAR) that is able to detect signals from different types of satellite based emergency beacons, and transfer the signals (with a quite accurate position) to a JRCC in real-time or close to real-time. In certain weather conditions, there could be a delay of up to 4 hours for the signal to be picked up by an orbiting satellite. At the moment, they also are working on improving this solution so that also a confirmation signal can be returned to the sender from the rescue force receiving the signal.

The performance of the system is somewhat dependent upon the age / technology used in the emergency beacons itself. And not all beacons have a built-in GPS capacity, something which expands the search area and consequently the time it takes to find the person or vessel.

1.2.5.2 AIS based beacons

Since around 2011, AIS emergency beacons have been on the market. They use the VHF/AIS system to transmit and have a range similar to the VHF. These beacons are designed primarily as a man-overboard(MOB) locator and do not transmit to satellites. They are mainly directed for localized traffic, meaning that the signals can be received by anyone in range who has an AIS receiver. The idea behind these beacons is to make it easier to be detected and rescued by your own vessel or other vessels in the vicinity.

There are also available beacons using the AIS SART principle transmitting a coded signal with GPS location to all AIS receivers within range. When the beacon's signal is first detected by an AIS receiver, the vessel's AIS system immediately displays an on-screen message advising that it's "MOB active." Once the beacon acquires its GPS position, it broadcasts it to all nearby AIS-enabled vessels.

1.2.5.3 Combined Satellite & AIS beacons

Recently beacons that have both the features of satellite based beacons and AIS beacons have become available. An example of this is the Smartfind 510 offered by McMurdo (McMurdo, 2017). This beacon does not only broadcast signals to rescue forces, but also broadcasts the distress message to all nearby AIS-equipped vessels in the area.

Vessel that operates in Arctic could potentially be equipped any of these types of personal emergency beacons.

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1.3 Position sharing in Arctic regions - AIS

Most vessels operating in Arctic are equipped with AIS transceivers. The AIS transceivers automatically broadcast information such as the vessel's position, speed, and navigational status, at regular intervals.

These signals can be picked up by nearby vessels or land based AIS station. The main part of the AIS infrastructure along for example the Norwegian coastline is the land based network of approximately 50 AIS stations that provides VHF and AIS coverage up to 40-50 nm from the coast. The AIS signals are broadcasted via a VHF transmitter built into the transceiver. AIS signals are transmitted on two reserved channels in the marine VHF allocation (87B and 88B). The system coverage range is similar to other VHF applications, essentially depending on the height of the antenna (distance in nautical miles is approximately equal to 2,5 x square root out of antenna height in meter).

There are two classes of AIS; Class A, the type mandatory for commercial vessels, and Class B for leisure and small craft. Class A is more sophisticated than Class B sending more detailed data out at a faster rate than Class B and will have transmit priority at all times. Class A is also much more powerful - transmitting at 12.5 watts whereas Class B is only transmitting at 2 watts.

Signals from commercial vessels equipped with Class A AIS can be picked up by other vessels many miles away - 20 miles and even more in ideal conditions (line of site between vessels), but Class B signals will be picked up only when fairly close up, typically 5 to 7 miles away, again, ideal conditions. However, this will also depend on the age of the equipment on-board the vessels. A Class B transmitter built with the latest technology will perform better than older types.

Some providers of AIS equipment has recently started to promote the advantages of High Fidelity-AIS. The claimed advantage of this solution is that it has a better capacity to decode transmissions and that it therefore is particularly beneficial in busy areas where the volume of AIS transmissions can cause processing errors and lost data in transceivers without HF-AIS. One of the providers of such solutions, SRT (SRT, 2017a and 2017b) claims that the solution is proven to see 30 % more targets in areas with high volume AIS transmission.

According to MarineTraffic (2017), the information contained in each AIS-data packet (or message) can be divided into the following two main categories: Dynamic AIS information and Static & Voyage related information.

<u>Dynamic AIS information</u> is automatically transmitted every 2 to 10 seconds depending on the vessel's speed and course while underway, and every 6 minutes while anchored from vessels equipped with Class A transponders:

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- Maritime Mobile Service Identity number (MMSI) - a unique identification number for each vessel station (the vessel's flag can also be deducted from it)
- AIS Navigational Status (read more on the subject)
- Rate of Turn - right or left (0 to 720 degrees per minute)
- Speed over Ground - 0 to 102 knots (0.1-knot resolution)
- Position Coordinates (latitude/longitude - up to 0.0001 minutes accuracy)
- Course over Ground - up to 0.1° relative to true north
- Heading - 0 to 359 degrees
- Bearing at own position - 0 to 359 degrees
- UTC seconds - the seconds field of the UTC time when the subject data-packet was generated.

Static & Voyage related Information is provided by the subject vessel's crew and is transmitted every 6 minutes regardless of the vessel's movement status:

- International Maritime Organization number (IMO) - note that this number remains the same upon transfer of the subject vessel's registration to another country (flag)
- Call Sign - international radio call sign assigned to the vessel by her country of registry
- Name - up to 20 characters
- Type (or cargo type) - the AIS ID of the subject vessel's ship type
- Dimensions - approximated to the nearest metre (based on the position of the AIS Station on the vessel)
- Location of the positioning system's antenna on board the vessel
- Type of positioning system (GPS, DGPS, Loran-C)
- Draught - 0.1 to 25.5 metres
- Destination - up to 20 characters
- ETA (estimated time of arrival) - UTC month/date hours: minutes

Class B transponders transmit a reduced set of data compared to Class A (IMO number, Draught, Destination, ETA, Rate of Turn, Navigational Status are not included). The reporting intervals from Class B transponders are also scarcer compared to those of Class A transponders (30 seconds minimum).

The information transmitted originates from the ship's navigational sensors, typically its global navigation satellite system (GNSS) receiver and gyrocompass. Other information, such as the vessel name and VHF call sign, is programmed when installing the equipment.

If breaking down Figure 1 presented earlier in this document into showing the AIS class of the vessels that have been operating in Arctic in the period 2011 to 2015 (see Figure 5 below), we can see that around 75 % of these vessels were equipped with Class A equipment, while around 25 % of the vessels only are equipped with Class B equipment.

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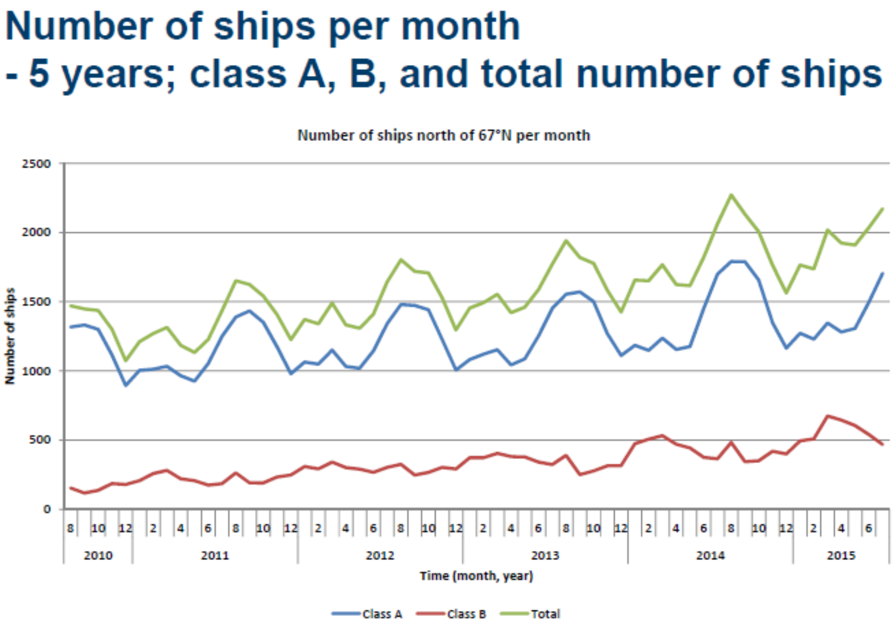

Figure 5. (Source: FFI)

In the category of vessels equipped with Class B AIS, we find e.g. smaller fishing vessels which are not covered by the IMO's International Convention for the Safety of Life at Sea (IMO, 2017a) which requires Class A AIS to be fitted aboard international voyaging ships with 300 or more gross tonnage (GT), and all passenger ships regardless of size. More recently, within the European Union, this has been extended to include fishing vessels over a certain length which at the moment stands at vessels over 15 metres.

It is worth noticing that the new Polar Code (IMO, 2017b) does not add any additional requirements to this regulation.

From these numbers, we can assume that many of the vessels involved in a collaborative rescue-operations in Arctic are likely to be smaller vessels equipped with Class B AIS equipment.

1.3.1 Satellite AIS (S-AIS)

When vessels are outside the range of on-shore receivers or outside line of sight from each other, Satellite-based AIS (S-AIS) takes over. There are several providers of S-AIS solutions, and the table below in Figure 6 (Birkeland, 2014) shows some of the systems available.

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System	Freq.band	Capacity	Con't coverage	Arctic
Gonets	UHF	2.4 - 64 kbps	planned	yes
OrbComm	VHF	low	no	some
Iridium	L	2.4 kpbs	yes	yes
Globalstar	L	9.6 kbps	yes	no
Inmarsat	L	20 kpbs	yes	no

Figure 6. (Source: Birkeland, 2014)

Currently and in general, the available S-AIS solutions have weaknesses, but the development goes fast and the improvement trends are aiming towards improving the following:

- Improve coverage
- Reduce signal delay
- Improve the ability to pick up weak signals (e.g. from AIS Class B receivers)
- Improve the ability to transfer gradually larger amount of data
- Reduced impact of weather and atmospherically related noise

For Arctic, there are in particular two S-AIS solutions that are relevant for Arctic communication; Iridium and Inmarsat.

1.4 Maritime safety in polar regions

1.4.1 The Polar Code

Before the implementation of the mandatory Polar Code, mainly guidelines (GUIDELINES FOR SHIPS OPERATING IN POLAR WATERS, adopted in 2009) and IACS ice class rules have been used to for marine operations in polar waters. In November 2014, the IMO adopted the International Code for Ships Operating in Polar Waters (Polar Code), and made

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it mandatory as a part of the International Convention for the Safety of Life at Sea (SOLAS) (IMO-Polar Code, 2014). The code entered into force, January 2017. The Code will apply to new ships constructed after that date and old ships from January 2018.

The Code will affect the full range of design, construction, equipment, operational, training, search and rescue and environmental protection; matters relevant to ships operating in the remote waters surrounding the two poles.

The Code would require ships intending to operate in the defined waters of the Antarctic and Arctic to apply for a Polar Ship Certificate, these would be classified as:

- Category A ships – ships designed for operation in polar waters at least in medium first-year ice, which may include old ice inclusions (IACS polar class 1-5)
- Category B ships – a ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions (IACS polar class 6-7)
- Category C ships – a ship designed to operate in open water or in ice conditions less severe than those included in Categories A and B. (Including Baltic Ice class Rules) (IMO-Polar Code, 2014)

Figure 7 below is demonstrating with geographical limitations in the Arctic, a 60-degree north boundary with exceptions of ice free areas.

Figure 7. Polar Code geographical boundaries Arctic (IMO-Polar Code, 2014)

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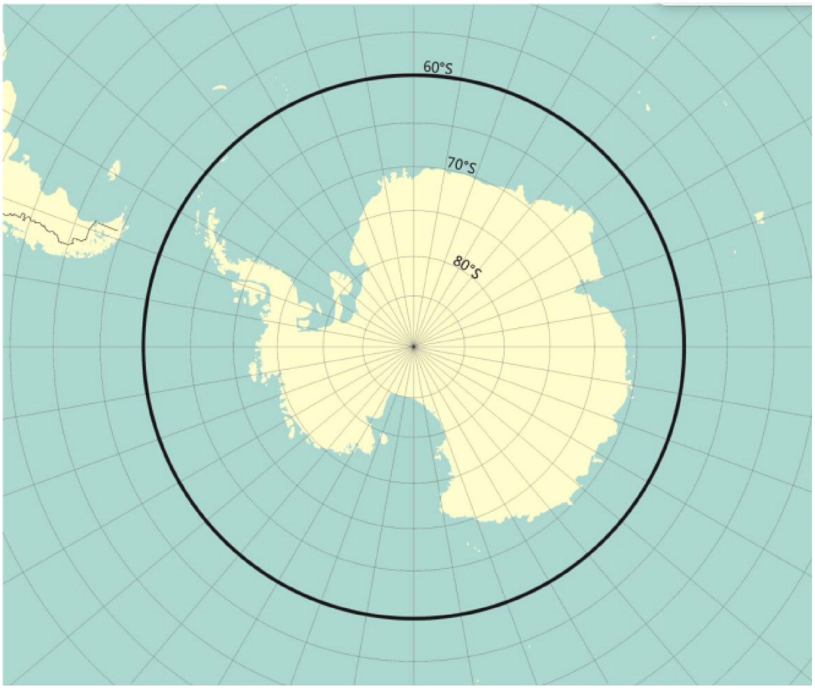

Figure 8. Polar Code geographical boundaries Antarctica (IMO-Polar Code, 2014)

Figure 8 is representing the Antarctica with 60 degrees south all the way around Antarctica.

The Polar Code will apply on both Antarctica and the Arctic. The code also has a risk based approach in reducing identified risks. The goal of the code is to:

"*provide for safe ship operation and the protection of the polar environment by addressing risks present in polar waters and not adequately mitigated by other instruments of the Organization"* (IMO-Polar Code, 2014).

The code identifies different Hazards. (All text in italic in this chapter is extracted from the Polar code (IMO-Polar Code, 2014).

3 Sources of hazards

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

- *.1 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;*
- *.2 experiencing topside icing, with potential reduction of stability and equipment functionality;*
- *.3 low temperature, as it affects the working environment and human performance,*

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maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems;

- *.4 extended periods of darkness or daylight as it may affect navigation and human performance;*
- *.5 high latitude, as it affects navigation systems, communication systems and the quality of ice imagery information;*
- *.6 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;*
- *.7 potential lack of ship crew experience in polar operations, with potential for human error;*
- *.8 potential lack of suitable emergency response equipment, with the potential for limiting the effectiveness of mitigation measures;*
- *.9 rapidly changing and severe weather conditions, with the potential for escalation of incidents; and*
- *.10 the environment with respect to sensitivity to harmful substances and other environmental impacts and its need for longer restoration.*

PART I-A SAFETY MEASURES CHAPTER 1 – GENERAL

1.2 Definitions

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 5 days.

1.5 Operational assessment

In order to establish procedures or operational limitations, an assessment of the ship and its equipment shall be carried out, taking into consideration the following:

- *.1 the anticipated range of operating and environmental conditions, such as:*
  - *.1 operation in low air temperature;*
  - *.2 operation in ice;*
  - *.3 operation in high latitude; and*
  - *.4 potential for abandonment onto ice or land;*
- *.2 hazards, as listed in section 3 of the Introduction, as applicable; and*
- *.3 additional hazards, if identified.*

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The major setup of the Polar code looks as follows:

Part I:

- Part I-A: Mandatory provisions on safety measures in accordance with the relevant SOLAS chapter
- Part I-B: Recommendations on safety

Part II:

- Part II-A: Mandatory provisions on pollution prevention in accordance with relevant MARPOL Annexes
- Part II-B: Recommendations on pollution prevention
  (IMO-Polar Code, 2014)

Chapter 10 Safety of Navigation

The content of chapter 10 is to provide requirements on appropriate nautical information and navigational equipment functionality for safe navigation

- Nautical information - Ships shall be equipped to receive up-to-date information including ice information for safe navigation.
- Navigational equipment functionality - The navigational equipment and systems shall retain their functionality under the expected environmental conditions in the area of operation (windows, antennas, search lights etc.).

Chapter 12 Voyage Planning

The contents of chapter 12 address voyage planning to ensure that the company, master and crew are provided with sufficient information to ensure safe operation of the ship and persons on board. The voyage plan should be strongly risk based and shall take into account the potential hazards of the intended voyage.

According to the Code the master shall plan the route through polar waters including:

- Procedures required by PWOM (Polar Water Operation Manual)
- Any limitations related to hydrographic information
- Iceberg information along the route
- Statistical met-ocean data including ice and temperatures from former years
- Places of safe refuge
- Possible presence of marine mammals
- Possible protected areas
- Available SAR resources (IMO Polar Code, 2014)

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1.4.2 Search and Rescue in the Arctic and Remote Areas

Rescue services at sea and air are mostly based upon international cooperation regulated by conventions and agreements. Mainly IMO and ICAO (Civil Aviation Organization) regulate rescue service worldwide through the international SAR Convention, SOLAS and the convention of International Civil Aviation (IMO, 2017). In general, this regulate that, no matter where the accident occurs, the rescue of person(s) in danger or distress at sea will be coordinated by a SAR organization and if required in cooperation between SAR organizations. The obligation of ships to assist other vessels in danger or distress rest on traditions and international treaties (IMO, 2017).

In order to interpret the obligations regarding rescue services at sea IMO has together with ICAO produced the IAMSAR manual (*International Aeronautical and Maritime Search and Rescue Manual*).

The manual contains three volumes and provides guidelines for a common aviation and maritime approach to organize and provide SAR services (IMO, 2010):

- Volume 1 – Organisation and Management
- Volume 2 – Mission Co-ordination
- Volume 3 – Mobile Facilities

From an arctic perspective, SAR is managed as a part of the IAMSAR guidelines and in addition the agreements made by the Arctic Council. The Arctic Council is an intergovernmental forum promoting cooperation, coordination and interaction among the Arctic governments and the indigenous people of the Arctic on common arctic issues. In particular in areas of sustainable development and environmental protection in the arctic (Arctic Council, 2013).

The primarily work carried out by the Council is managed through six working groups and one of these, the Emergency Prevention, Preparedness and Response Working Group (EPPR) works to protect the Arctic environments from pollution and accidents which also includes Search and Rescue.

In 2011, an agreement was made between the Arctic countries about cooperation on aeronautical and maritime search and rescue in the Arctic. The objective was to strengthen the cooperation and coordination regarding search and rescue in the Arctic (Arctic Council, 2011). One part of the agreement concerns SAR regions, which are seen below in Figure 3.

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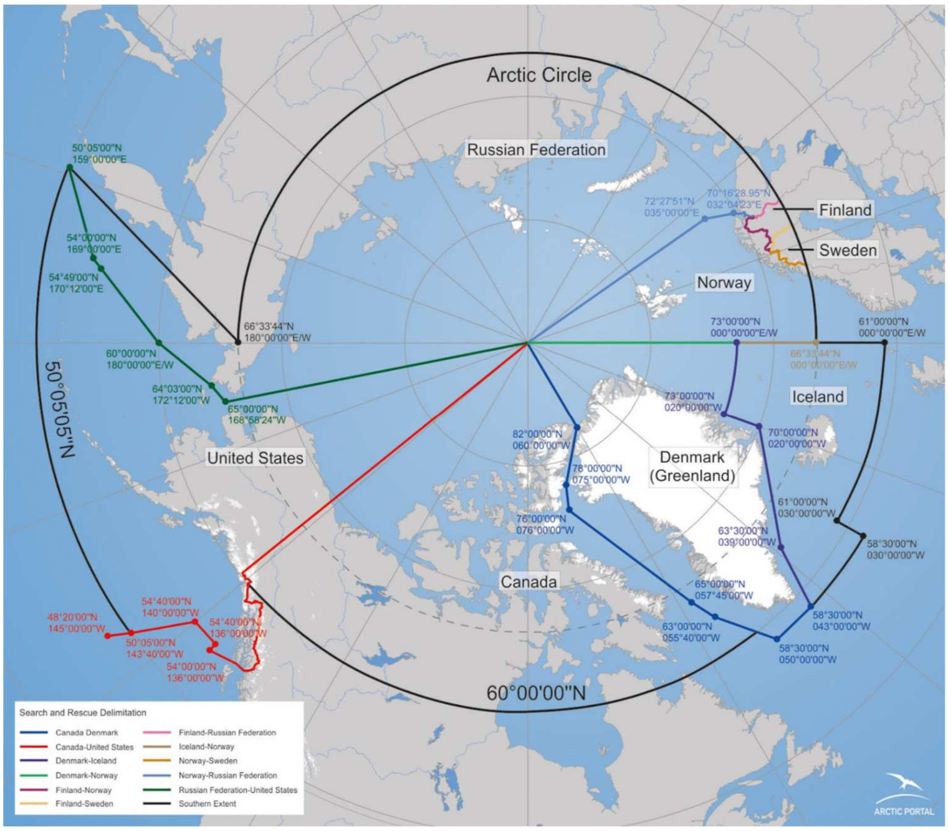

Figure 9. Arctic Portal Library, 2011

According to the Arctic Council homepage regarding EPPR; "*Harsh conditions and the sparse and limited amount of infrastructure in much of the Arctic increase risks and impacts and hinder response activities. Actions for prevention, preparedness and response must be carefully pre-planned and adapted to the conditions and remoteness of the Arctic to maximize the use of available resources. Accordingly, international co-operation in this area is of major importance.*

(Arctic Council, 2015)

Search and rescue in especially remote areas is a special challenge, especially in reviewing an arctic environment. Increased maritime activity in remote areas have created a push for new guidelines as a part of IAMSAR. Currently that process is ongoing and will most likely be implemented in an updated version of IAMSAR in 2019 (Laursen, 2015).

The new guidance will be based upon the requirements from the Polar Code. In remote areas SAR facilities, access to rescue units and communication infrastructure are limited and could even be none existing. Currently the IAMSAR volumes do not address situations where it takes a couple of days to move search and rescue units (SRU's) to a specific distress position (Laursen, 2015).

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The Polar code address important matters such ship safety, personal protection, risks associated with polar operations and so on. According to the code, the maximum expected time of rescue is five days which will put additional strain on existing lifesaving appliances (Nese & Dalsland, 2016).

The code also require that operators should produce risk-based procedures for contacts with SAR organizations regarding salvage, search and rescue and oil spill response (IMO, 2014). In chapter 10 (Communication) the code requires that vessels that operate in polar waters shall have the capacity to communicate two-ways in voice and data, ship to ship and ship to shore. This also concerns SAR coordination communication (IMO, 2014).

The IMO guideline "Guidelines on voyage planning for passenger ships operating in remote areas" from 2007 address the matters from a general remote area perspective but certain contents refers to Arctic or Antarctic waters. The guideline address that the voyage plans should contain limitations on SAR resources. It also highlights that contingency plans for emergencies in the event of limited support being available for assistance in remote areas (IMO, 2007)

This create requirements on especially the voyage plan to incorporate aspects as safe areas and no-go areas, surveyed marine corridors and if available; contingency plans for emergencies in the event of limited support being available for assistance in areas remote from SAR facilities.

In addition, the detailed voyage and passage plan for ships operating in Arctic or Antarctic areas should focus on: conditions when it is not safe to enter areas containing ice or icebergs because of darkness, swell, fog and pressure ice; safe distance to icebergs; and presence of ice and icebergs, and safe speed in such areas.

These features have been seen as important aspects when creating requirements for voyage planning under the polar code (IMO, 2014)

1.4.2.1 SAR management in the Arctic

The JRCC centers have the overall operational responsibility for emergency situations at sea, and also in Arctic. And if an incident occurs, they will take the command and handle the situation using the communication tool they have at disposal. We will now look at what kind of communication tools JRCC has available, focusing on how they can handle situations outside the range of the AIS land stations and VHF.

Communications in a SAR situation

In an emergency situation located in an A4 area outside of range for land based AIS and VHF stations, a distress message could be transferred through:

- By MF/HF Radio or DSC
- By satellite (Iridium or Inmarsat)
- By EPIRB (PLB)

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- By a distress relay from another vessel in the area

The initial procedure will be to acknowledge the distress message but the main priority for a JRCC will be to establish contact with the vessel in distress and nearby rescue resources by the use of satellite communication or with MF/HF radio. Depending on the circumstances and the area, hopefully there is at least one of the vessels that will respond, who can further reach other relevant vessels by the use of radio (VHF or MF/HF).
Since there are so many different vessel types with different communication set-ups, Arctic is such a huge area with varying level of satellite coverage, and the positions of relevant rescue resources will vary a lot, all rescue scenarios will be different. Therefore, what will be the most suitable communication solution to handle the situation at hand in the best way, will be very situation dependent. Information about what communication solutions that is on-board each individual vessel, is information that JRCC has access to through a special search engine that search across different ship registers (at least for commercial vessels).

The best scenario is of course when a JRCC has direct satellite contact with all vessels involved since this render possible direct voice communication with and across all vessels in the area. If the vessels in addition have Iridium equipment on-board, also some data can be transferred if necessary. A maybe more realistic scenario is that JRCC has direct satellite communication with, and S-AIS tracking of, one or a few of the vessels involved, and that this/these vessel can reach other nearby vessels by the use of radio.

The worst scenario is when it is not possible to communicate with any of the vessels via satellite or with MF/HF. In such case, the vessels are one their own. They then need to organize the rescue operations themselves. Since not many vessels have a MBR solution on-board, they will then have to rely on voice and local AIS-feeds as main tools for executing the rescue operation.

Position sharing and the use of Satellite AIS
When vessels are outside the range of land based AIS, the only way to determine the position of the vessel in distress and nearby rescue vessels, is the use of S-AIS. If satellite based solutions are not available, the operating picture for the JRCC will have limitations and this will influence the ability to organize an effective rescue operation.
From a Norwegian perspective, the JRCC gets their main S-AIS data from the Norwegian Coastal Administration, which primarily uses the satellites AISSat-1 and AISSat-2. These satellites pass over sea areas near Norway and receive AIS information from ship traffic every 90 minutes. The signal delay could sometimes be up 3-4 hours. Now and then contacts with the satellites are disturbed by weather or atmospherically conditions. JRCC's current S-AIS solution is a one-way solution where JRCC only can receive AIS positions; it is not possible to send data or voice in return. It is a bit unclear how well JRCC succeeds in picking up absolutely all Class B AIS signals.

As mentioned earlier, there are other service providers of S-AIS services using other satellites network than the one JRCC use, and JRCC (and IMO), is continuously looking for

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ways to improve their current solutions. An example of this is the recent evaluation that has been done of the Iridium solution, which claims to offer full coverage in Arctic. We do not have access to the concrete result of this evaluation, but so far neither JRCC nor IMO has signalized that they will switch to the Iridium solution.

What is important to notice is that even though JRCC use the satellite solution from the Norwegian Coastal administration as main system, in an emergency situation, they would use (buy) services from e.g. Iridium if necessary. In such cases, he Iridium services are primarily used as means for voice communication, but they could also be used for transmitting data. JRCC's experience is that Iridium has very limited band with for transmitting data, while Inmarsat has a much better band width, though the latter has as mentioned earlier, a very limited coverage above 75 degrees north. A special position sharing setup that JRCC can use when needed is to utilize the rescue helicopters positioned at Svalbard as AIS relay station, and by that be able to forward AIS data picked up by the helicopter, through Inmarsat or Iridium to JRCC in Bodø.

JRSS also have access to S-AIS data collected by the Norwegian Directorate of Fisheries' "Fisheries Monitoring Centre".

According to Norwegian law, all Norwegian vessels involved in fishing operations (fishing, harvesting seaweed, transport etc.) with a length of 15 meters and above are required to comply with position reporting. The vessels are required to be equipped with a transmitter programmed to send data about the vessel's position, course and speed to the fishery authorities at least once every hour.

It is also an absolute requirement that the S-AIS solution used by the fishing vessels should have coverage in the area where the fishing is done. So, for fishing further north than around 70 degrees, it is necessary to use a tracker from the solution provider Iridium, since this solution is the only one in the market today that guarantees satisfying coverage that far north. Therefore, indirectly the JRCC has access to quite a lot of vessel positions determined by Iridium satellites which in fact should be of better quality due to less signal delay. To summarize, with regard to use of S-AIS, the JRCC has the following options:

- Use AIS data from the Norwegian Coastal Administration (which could have a significant time delay) to determine vessel positions
- If it is a fishing vessel, use S-AIS data from the Fisheries Monitoring Centre to determine positions (which probably will be data coming from Iridium, Inmarsat or other providers) (gives real-time position without significant delays)
- Use data directly from providers like Iridium or Inmarsat or other providers (gives real-time position without significant delays) to determine positions, to communicate via voice and for sending small amounts of data.

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NB! To find a vessel's position by picking up AIS signals presupposes that the vessel has its AIS sender turned on. Sometimes vessels to not want to be tracked and turn the AIS off and then become invisible for JRCC. In such cases, a rescue vessel's radar is very important to detect vessels not sending out AIS signals.

1.4.2.2 Self-Organizing emergency response in the Arctic

In an emergency situation, a vessel in distress will send out a request for help to all surrounding vessels and rescue centers ashore, and these vessels will try to assist as soon as possible. However, due to the low traffic density in the Arctic, what type of vessel that first will be able to assist, what communication equipment they have on-board, and how long time it will take before help arrives, will vary a lot. So, if a vessel picks up a mayday form another vessel, the first natural response will be to:

- Get as much information as possible from the vessel in distress
- Relay a distress message to the closest JRCC
- Start to sail as fast as possible towards the position of the vessel in distress
- Contact other surrounding vessels and the JRCC for further assistance

On its way to the vessel in distress and if not appointed by the JRCC, the vessels involved in the emergency operation will decide upon which vessel that should take the OSC role. This decision will be taken based on factors like:

- What vessel will first reach the vessel in distress
- The experience of the Captain / crew of the vessels involved
- What type of vessels that are involved; emergency capabilities, relevant emergency resources on-board etc.

Sometimes it will also be relevant to hand over the OSC role from one vessel to another during the rescue operation as more, and maybe more suited vessels for the OSC role, arrives the emergency scene. It is also natural that the vessels that arrives to the emergency scene will do that at different times. So, a typical scenario could be that a small fishing vessel is the first that arrives and start to search for survivors in the sea, and then some hours later, a larger vessel arrives and so on. Due the characteristics of the Arctic and the traffic in the area, there could be numerous such different scenarios.

Also, what is obvious is that a good collaboration between the vessels involved in the emergency operation is critical to optimize the operational efficiency of the emergency operation and in order to avoid misunderstandings. The question is then how to achieve a good collaboration between the different resources involved in an emergency operation? There are many answers to this question, but one crucial premise to achieve good collaboration is to at all times during the emergency operation, is to have a good common operating picture. In practice, this means that all vessels should have the same understanding of the situation at all times. This means that all vessels should have the same information about:

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- All the other involved vessels' positions, route, speed and ETA at the emergency scene
- The Emergency operation (SAR) plan:
- What tasks / responsibilities are allocated and to what vessels
- What has already been done by which vessel, like e.g. sharing of areas that already has been searched

Relevant information which must be shared, related to the Emergency Operation (SAR) Plan, could for instance be:

- Calculated drift patterns
- Calculated search areas and suitable search patterns
- Pictures / Videos
- Maps
- Information about persons picked up from the sea

A common operating picture is based on the same situational awareness; the same knowledge about what has been done and what should be done. By ensuring that all vessels involved in the operation have this information, the ground for carrying out an efficient SAR operation is established. This will again optimize the probability for saving human lives and material assets.

So as an example, in an emergency scenario where a cruise vessel goes down, and leaves many life rafts in the sea, typically the first vessel that will arrive to the relevant search area, will take the lead in the emergency response and start to search. Thereafter many more vessels will arrive gradually at different times, potentially the SAR OSC role could by hand over several times. In addition, the duration of such an operation could stretch over many days. The challenge is then to ensure an optimal level of collaboration between the rescue resources throughout the whole operation, enabled by supporting technologies and procedures that provides all with a common operating picture

1.4.3 Findings from previous SAR table top exercises (TTX)

1.4.3.1 Arctic Zephyr

Arctic Zephyr was held in Anchorage, Alaska in October 2015. This was a multinational Arctic SAR exercise focus on command, control and communications in a rescue operation. The scenario involved a cruise ship which due an explosion in the main switch board needed to evacuate all passengers and crew to life boats and rafts.

The analysis of the result highlighted the challenges of a mass rescue operation in the arctic but the most extreme challenges were communications, situational awareness and logistical support. Some of the main findings are mentioned below:

- Communications were unreliable above 70 degrees North Latitude

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- No common operating picture exists with poor data sharing capabilities
- Infrastructure ashore regarding capacity handle survivors is extremely limited.

(NORAD and USNORTHCOM, 2015)

1.4.3.2 Arctic SAR workshop and table top exercise

This was a large scale joint SAR exercise including a workshop and TTX conducted in Reykjavik, April 2016. The scenario for the TTX involved a passenger vessel which sustained an engine room fire, then drifting and eventually grounding in danger of capsizing on the rocky of remote Jan Mayen. This challenged the aspect of the ship being the best life boat.

Half of the persons on-board abandon the stricken vessel into a lifeboat prior the grounding. Which later on, capsized in heavy seas while attempting to land a shore. The sum of all events triggered a mass rescue operation.

Regarding lesson learnt many issues from different perspectives where addressed in the final report, some is mentioned below:

- Available information about SAR resources and SAR contacts in the Arctic was in some instances to be inadequate.
- In the Arctic, depending on the position, it may take hours, sometimes days to get assistance
- Vessel of opportunity is likely the first one on scene and could perhaps be the only rescue facility available.
- JRCC coordination, the vessel of opportunity may be the best option in responding to a mayday. It could also be the case that the vessel will be on scene before the RCC can manage to organize a response by designated rescue facilities.

(AECO, 2016)

1.5 Route exchange in Arctic waters

MICE (MONALISA in Ice), was a feasibility study conducted in cooperation between the Swedish Maritime Administration (SMA) and the Chalmers University of Technology (Chalmers). MICE aimed at capitalizing on the more wide-ranging MONALISA and MONALISA 2.0 projects, which both are led by SMA, defining the Sea Traffic Management (STM) concept. The objectives were to improve situational awareness in the Arctic region. Ships' voyage plans are exchanged with the shore-based service centre in a hand-shaking procedure. Changes can be suggested based on the latest information about weather, ice conditions or marine wildlife.

The concept of exchanging voyage's plans in an Arctic context could support both the strategic and tactical phases in ice navigation using route exchange as a technical enabler supporting, i.e.:

- route optimization of the ice route;
- enhanced monitoring from shore center of ship traffic; and

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- remote assistance.

Ships' voyage plans could be exchanged with the shore-based service provider or an icebreaker in a hand-shaking procedure. This would give shore-based operator or the icebreaker a comprehensive situational awareness enabling them to verify that routes are followed, provide early warnings to ships and stakeholders, and to identify elevated risk situations to be used for improvement of operation. Route recommendations can be suggested based on latest information regarding; weather, ice, wildlife, etc. in combination with other decision support information.

Further, route exchange can support SAR or prolusion response operations conducted in ice infested waters exchanging search patterns. This will be described further in this report.

2 The ArcticWeb

The ArcticWeb is an effort to improve safety of navigation and maritime operations in the Arctic. The platform is intended for use by:

- Ships
- Shipping companies operating vessels in the area
- Arctic Command
- Other shore authorities

2.1 Description of the ArcticWeb

The development of the ArcticWeb was initiated by the Danish Maritime Authority in 2012 as an internal E-navigational project with the aim to develop the presentation of different E-navigational services through a web-based platform. Through its development it gained support from Danish Ministry of Defense in 2014 and from 2015-2017, the Nordic Council of Ministers supported the project and the development of web-based platform to be operated as a support to maritime safety in polar regions. This involved focus on:

- Support for risk management in maritime operations in arctic environments
- Development of a SAR- tool, as based upon IAMSAR protocols
- Implementation of an Arctic Voyage Planning Guide, supported by IHO-Arctic Regional Hydrographic commission (Denmark (Greenland) Canada, USA, Russia and Norway)
- Development of standardized Ship Reporting

The Arctic-web also became a part of the EU project EfficienSea 2 for further support and development. This also included usability analysis and practical tests of the platform in a simulated environment, which especially focused on the SAR-tool and the possibility to self-organize a response in a SAR situation. With the EfficienSea 2 support more focus were made to develop:

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- Route Optimization in Ice
- New Method for Ice and Weather Calculations
- Crowd Sourcing of Ice
- Space Weather Forecast

The main aim is that anybody can log on and get information provided by the platform and at the same time use its different services and tools. This will support an increased situational awareness and information exchange while operating in polar waters.

The technical set up aims to reduce the satellite communication which is a limitation in higher latitudes.

As the infrastructure and support for data communication is limited in polar waters, the format of ice charts for example have been reduced from 2 MB to 100 kB to support users to for improved downloading capacity.

Today the ArcticWeb is used by 120 ships (mainly cruise ships), around 30 pilots and in addition 120 on shore users. In its development phase, it has also gained support from the Cruise Lines International Association, CLIA the Association of Arctic Expedition Cruise Operators (AECO) and the Greenland Pilot Service.

2.2 ArcticWeb Capabilities

- Display AIS data collected by national and commercial satellites and base stations in the Arctic region.
- Facilitate GREENPOS and COASTAL CONTROL reporting.
- Mange coordination of voyages through the sharing of routes and schedules.
- Sharing of routes and schedules with Arctic Command.
- Display Ice charts from Danish Meteorological Institute (DMI).
- Display Inshore ice reports from Danish Meteorological Institute.
- Display satellite images from NASA provided by Danish Meteorological Institute.
- Mange navigational warnings and notices to mariners from Arctic Command and Danish Maritime Authority.
- Display weather forecasts from Danish Meteorological Institute including weather forecasts for a planned route.
- Operate forecasts for ice, current and waves provided by DMI and Defense Centre for Operational Oceanography (FCOO).
- Facilitate a SAR response including the ability to calculate search areas and patterns based on standards and as coordinator assign search and rescue units to tasks during the SAR response. Which means for example to send search pattern to vessels.
- Conduct voyage Risk Management to evaluate risk before and during a voyage.

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3 Methodology

3.1 Purpose

The purpose with the practical test of the ArcticWeb was to evaluate the usability and user needs, different functionalities and also if the ArcticWeb could provide a platform or tool to self-organize a response in a search and rescue situation in the Arctic.

3.2 Structure and organization

The practical tests were conducted in full-mission bridge simulators, at Chalmers University of Technology, Gothenburg Sweden between August 14th to 17th 2017. Between eight and ten participants where used and all having experience from ice navigation. In addition, a majority of the participants have been navigating in polar areas and some several times. The experience factor is vital in these type of studies as it provides conditions for a high validity. The practical tests were conducted over four days which had the following structure:

- **First Day**: Baseline SAR conducted without ArcticWeb and with a JRCC coordinating a SAR response (See Appendix A for description)
- **Second Day**: Three exercises were conducted focusing on learning the ArcticWeb. The exercises involved evaluation of capabilities, functionalities and information services including focus group discussions (see Appendix B for description) with the following content:
    1. General layout, usability, information provided, ice information, weather etc.
    2. Route and Schedule handling
    3. SAR – the SAR tool, creation of search areas, generation of search patterns etc.
- **Third Day**: SAR exercise with the ArcticWeb as main platform, involving a self-organizing of a SAR response with no or limited involvement of MRCC. (See Appendix C for description)
- **Fourth Day**: SAR exercise with the Arcticweb, containing a more advanced scenario with the focus on self-organizing. No or limited involvement of MRCC with special focus on the OSC, On Scene Coordinator. (See Appendix C for description)

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Even though the SAR functionalities were in focus, the most important aspect was to evaluate if the ArcticWeb could provide a tool for self-organizing in a SAR situation. With that background, it was important to conduct a “baseline” scenario as a normal response lead by MRCC staff, in order to identify differences, difficulties or challenges compared to the scenarios where the participants performed a self-organize by the use of the ArcticWeb.

The second day focused more on the ArcticWeb as a platform, where the participants through a set of questions and small exercises evaluated different functionalities, usability, information ex-change. That time was also used for familiarization with the ArcticWeb and its different tools. The last two days were used for running SAR scenarios, where the participants faced the challenge to self-organize a response in a SAR situation with different levels of complexity.

In these exercises, the ArcticWeb was used as a platform for achieving situational awareness, calculation of last know position (LKP), management of search areas and patterns, facilitate communication and assignment of SRU (search and rescue units). The role of the OSC was especially in focus; a role which was rotating between the bridges and crews.

3.3 Scenarios

The exercises where conducted in waters west of Greenland, west to southwest of Disko bay (see figure 4). This area was chosen due to its high presence of marine activity and it’s also an area where cruise vessels often visits. In addition, this area also contains a lot of icebergs which also was present in the exercises for a more sense of realism. The weather was based upon actual weather present in the area, as the ArcticWeb contains a function with actual weather forecasts. During the time of the exercises the mean weather was in general light to moderate winds, cloudy and risk of fog with different adjustments in visibility, from good to poor.

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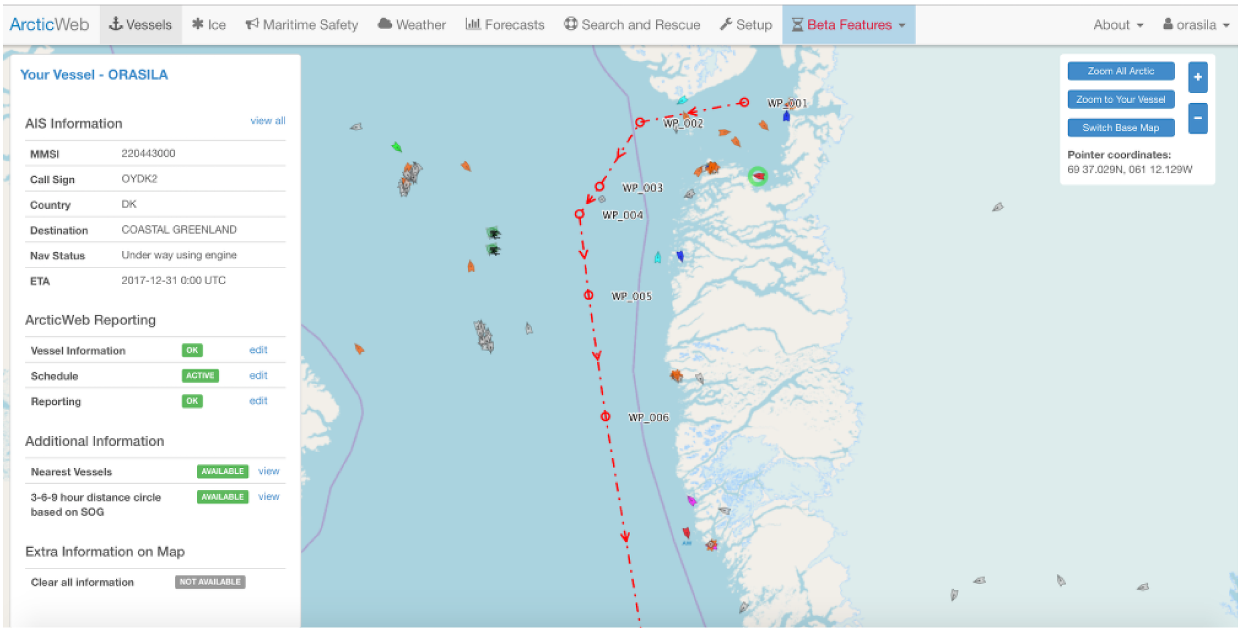

Figure 10. ArcticWeb main chart

Four different vessels where used in the simulator and prepared in the ArcticWeb Platform:

- A cruise vessel
- A general cargo vessel
- A tanker vessel
- An offshore vessel

All scenarios involved at least three vessels at the same time, which meant that the available vessels rotated between crews and simulator bridges. The content of the scenarios was:

- **Baseline SAR scenario (normal response)**: A *Fishing vessel collides with a growler, ingress of water which developed to abandonment by the use of the vessel's life rafts. MRCC coordinated a response using the three vessels available.*
- **Three self-organizing scenarios with the ArcticWeb**: OSC leading/organizing response:
  - *Vessel collides with growler,*
  - *Man-overboard situation from a fishing vessel*
  - *Sailing yacht not under command, drifting with an unclear LKP*

The scenarios where to some extent simplified as the focus was SAR and Self-organizing, see Figure 5 with an example from the ArcticWeb**.** With regards to data transferring capabilites it was assumed full access to AIS data and no disturbances in data traffic.The structure of the simulations was the following:

1. Brief by instructor(s) – 20 minutes
2. Preparations by the participants on each bridge – 30 to 40 minutes

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3. Exercise time – 2 to 4 hours
4. De-brief and joint discussions – 60 minutes

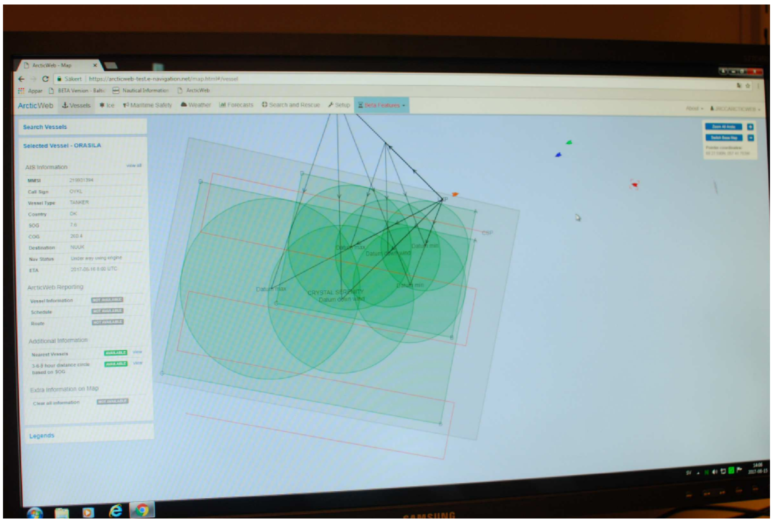

Figure 11. ArcticWeb, displaying search areas and including search patterns

4 Results from the practical tests

4.1 Results from the baseline scenario

In this scenario, the MRCC responded in a traditional way, after the emergency had arisen and the necessary required communication was established between the vessel in distress and MRCC. The MRCC made the necessary calculation of possible drift and based upon that a search area was established. In this scenario, the vessels responded in a timely manner according to GMDSS standards and protocols. According to the MRCC staff, lack of a clear overview of the area and available vessel(s) of opportunity were apparent. It was also notated that due to limited communication, there were some difficulties to transfer coordinates for search areas and to assess an appropriate OSC due to limited vessel information and available positions.

When all available vessels had responded and was heading against the search area, the role of the OSC became more important. Initially the required communication between MRCC and the OSC was high due not having reached a common operating picture yet. The high amount of communication was also seen between the SRU's and the OSC for the same reasons but also due to the difficulties to organize an appropriate search pattern and start points for the SRU's.

The OSC had to rely on the IAMSAR manuals to decide upon the appropriate search pattern and drift information for life rafts, which created some stress on OSC bridge. The ECDIS

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system provided support here as it contains a functionality to set up search areas (some systems also include functions to provide different types search patterns)

Eventually when the vessels arrived on scene, the search started and at the time the visibility was moderate and slowly reducing and the sea state was light. At that point, the only common operating picture was the ECDIS and radar screens as they provided AIS or radar inputs but with no ability to transfer data or information between the SRU's and the OSC. Therefore, mainly voice communication through the VHF was used to organize the search.

Due to the fact that the simulator's life raft target was clear on the screen (not necessarily in the reality), and the use of SART (Search and Rescue Transponder), the vessels managed to find the rafts quite fast.

However, the response time was long, which is an important factor when addressing SAR in cold environments. The stress and physical affection of persons in a raft in these areas is out most challenging and measures that could improve the response time could be significant importance for the exposed survivors´ ability to survive.

It was mentioned afterwards by the participants that it was difficult to organize search patterns and efficient coordination of the vessels. The experiences and knowledges on the OSC bridge were much in focus to be able to handle the situation and the support from the IAMSAR manual was also to some aid.

4.2 Results from the evaluation of functionality and usability

4.2.1 Functionality

4.2.1.1 User interface, layout, information, weather and ice services

Regarding user interface and layout, the participants agreed that in general the layout is satisfactory however it needs to be updated with maritime related terminology and standard maritime navigational tool such as Electronic Range Marker (VRM) and Electronic Bearing Line (EBL). In the ArcticWeb most activity take place in the "open street map" which is the only feature besides a standard map. The participants asked for a simple navigational map or chart to be used instead as it will assist user better in for example navigational planning. The information displayed regarding "your own" vessel was adequate and also available AIS information regarding other surrounding vessels. Other available services with for example the feature "3-6-9 hour" distance circle was a clear improvement however as mentioned by some of the participants, it's difficult to see how old the AIS information is. Despite this, the users found that as an important information in for example distress situations.

The service that provided the ice charts with different color coding's was acceptable however for the users it's important to see how old the information is, as this will provide an important understanding in doing the right interpretation of an "historic" ice situation. Again, the users asked for better information about when the analysis where made and what they are based

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upon. The weather services were on a acceptable level with for example access to local prognosis for specific areas. The graphic presentation was acceptable even if the uses would like a more simplified presentation.

In general, the participants felt that the information services provided by the ArcticWeb supported an increased situational awareness even though some modifications are needed to fully meet the users' needs. The participants were asked if they could provide examples of other type of information that could be broadcasted as a part of an AIS signal and be displayed on for example the ArcticWeb, and the following were suggested; ice breaking capability, doctor on-board and helicopter on-board.

According to the participants the information provided through the AIS system, with the capability to identify nearby vessel and ice and weather services were the most important.

4.2.1.2 Schedule and routes

These functions were relevant even if they required more support for usage. Some of the users found these difficult but despite that they could clearly see benefits with the functionality. According to the users it would have been better if they could provide more information along the route, with for example the presence of ice concentrations above 6/10 at some places along the route. In addition, the ability to share routes is according to the participants very important when transiting an ice field especially if other vessels are expected to transit in the same area in an acceptable time frame. Many of the participants have experience from ice management in the Baltic when working on the Swedish icebreakers and the benefits are several if previous routes can be used. By adding the capability to share historic tracks would provide an important improvement in achieving a full route optimization ability in a specific area.

4.2.1.3 Search and Rescue (this evaluation was conducted before the self-organizing simulation)

According to the participants the idea and functionality is very good, but they found that it was difficult to work with as this was the first time using it and more training was required. There are many abbreviations used and as the right settings in for example a SAR scenario are very important; a quick guide would be of great help for the OSC.

For a better implementation, the user wanted a function with the ability to transfer search areas/patterns in to the ECDIS, as the ArcticWeb is not a primary navigational tool. Despite that, the users could clearly see decision support benefits for an OSC with, visualization of search areas/pattern and the ability to communicate more efficient without VHF. These would potentially reduce time for a response, improve conditions to initiate a SAR response without the involvement of an MRCC and get a better overview of situation.

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4.2.2 Usability

Regarding the usability, the participants found the system a bit difficult to use as different functions and terminologies within the Arcticweb was hard to understand. It would have been beneficial with some quick guides and some text explaining within the system.

An Usability Questionaire was completed by each participant (n=8) at the end of testing period. It included the following questions:

1. Overall, I agree with how easy it is to use this system
2. It was simple to use this system
3. I could effectively complete the tasks and scenarios using this system
4. I was able to complete the tasks and scenarios quickly using the system
5. I was able to efficiently complete the tasks and scenarios using this system
6. I felt comfortable using this system
7. It was easy to learn to use this system
8. I believe I could become productive quickly using this system
9. The system gave error messages that clearly told me how to fix problems
10. Whenever I made a mistake using the system, I could recover easily and quickly
11. The information provided with this system was clear
12. It was easy to find the information I needed
13. The information provided for the system was easy to understand
14. The information was effective in helping me complete the tasks and scenarios
15. The organization of information on the system screens was clear
16. The interface of this system was pleasant
17. I liked using the interface of this system
18. This system has all the functions and capabilities I expect it to have
19. Overall, I am satisfied with this system

Each question was rated between 1 (Strongly Agree) and 7 (Strongly Disagree). The results are summarized in the following table:

Question	Mean	SD	Max	Min
1	4,4	1,1	6	3
2	4,0	1,6	6	1
3	4,3	0,9	5	3
4	5,0	1,1	6	3
5	4,5	0,9	5	3
6	4,1	1,3	6	2
7	4,2	1,3	6	2
8	3,4	1,2	5	2
9	4,7	1,4	6	2
10	5,1	0,6	6	4

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11	4,3	1,3	5	2
12	4,3	1,2	6	3
13	3,6	1,4	5	1
14	4,3	1,3	6	2
15	3,6	1,3	5	2
16	3,4	1,5	6	2
17	3,8	1,5	6	2
18	4,1	1,2	6	2
19	4,3	0,9	5	3

4.3 Results from Self-organizing SAR scenarios

In the other scenarios, the Arcticweb was used as a platform to organize a response to a SAR situation and the aim was to use the MRCC as little as possible. The main finding was that the ArcticWeb provided a tool to self-organize a SAR response. With training and good familiarization, you can as an OSC organize search areas and designate SRU's with specific search pattern.

Another important factor was that the platform provided a common operating picture or shared situational awareness between SRUs and even with a MRCC, which reduced open communication. This made the response more effective and structured for those involved.

According to the participants based upon their experiences the platform provides important instruments and information services that are very important for safe operations in polar areas.

The ArcticWeb also demonstrated an improved information exchange between SRU's, which also reduced the needed volume of open communication. A designated OSC could command and control multiple SRU's at the same time through this platform. On the other hand, this lead to an increased workload for the OSC, which was mentioned by the participants when they were acting as OSC's. Regarding different kinds of scenarios, a SAR situation involving a known LKP (Last know position), the ArcticWeb facilitated the necessary tools to organize a good response.

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When the scenario contained an uncertain LKP (last scenario) with a more complex situation, it was more difficult to self-organize. This would probably require assistance from a MRCC for more expertise and experiences to assess and analyze a relevant search area and at the same time guide SRUs to different starting points.

Another thing that was mentioned several times, especially in a SAR situation when the OSC had established a search pattern, the search operation would be more efficient if there is a functionality to transfer these areas into the ECDIS, preferably as a "layer" on top of the ECDIS screen. The functionality with creating search areas is good within ArcticWeb however its more difficult to follow as the AW "screen" is not the primary navigational display and due to the slow update rate of AIS. Can you create a layer with the search area/pattern as baseline and then extract that into the ECDIS then you would have better possibilities to overlook the progress in a search.

5 Discussion - Shortcomings in today's practice and possible solutions

This chapter will discuss shortcomings in today's practice of conducting emergency response and SAR management, and elaborate around what would be a desired way of organizing such operations. As a part of the latter, we will take a closer look at a concrete suggestion for what could be done to better support the concept of self-organized emergency operations.

The main issues are to identify what is needed to obtain a full situational awareness and a true common operating picture. The main objective for such activity is that all vessels involved in a rescue operation can talk to each other and share all relevant data (in real-time). As described in the previous chapters, all current communication / data transfer solutions have different kinds of shortcomings. We will now take a closer look at what could be done to improve the situation.

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5.1 Communication

Besides the functional GMDSS requirements for vessel that operates in arctic waters and their ability to transfer a distress message to JRCC. Direct inter-vessel communication between vessels that collaborate in a joint rescue operation will always be very important. Today, in many scenarios, this is the most important communication tool, and sometimes also the only one.

The problem with radio communication is that is has some weakness. One challenge is the limited range, another challenge could be noise or different kinds of disturbances and in addition poor voice quality could affect. Another general challenge with voice communication is the potential for misunderstandings. In particular, in situations with many resources involved, and when the operation goes on for many days, to manage and organize such operation only by voice communication is very difficult. The most promising, radio related, initiative is maybe the MBR concept that recently was launched by Kongsberg (described in Section 1.2.1).

If for instance all vessels in Artic were equipped with such equipment, it is easy to see that this would have been a huge advantage in emergency situations. Then rapidly, all involved vessels could melt into a shared data and voice network as they gradually arrives to the emergency scene. This would at least contribute to achieving a good local common operating picture within an emergency scene However, no vessel can be further away from another vessel than approx. 27 nm.

Whether or not this is approach is the best solution to solve the current challenges is probably very much a price question.

A solution that requires special equipment on-board all vessels must be affordable, and / or the governments must decide that this is something a vessel must have to be able to sail in the Artic; something which probably not will be done if the cost for the ship owners will be regarded as too high.

5.2 Position sharing

Almost all vessels sailing in the artic has already AIS equipment on-board. AIS transceivers do not fully have the same range as the MBR solution. And the range is also related to whether or not it is a Class B which typically has a range up to 8 nm or a Class A which typically has a range up to 20 nm. A pertinent question is if this solution could in some cheap and simple way be extended so that it could be used to transmit more data. Today already some amounts of data are transmitted like for instance a vessel's position. If the system had the ability to send a set of positions, containing for instance a SAR-pattern, this wouldn't require so much more transfer capacity.

Another question is that with today's solution, a vessel is only sending its own position. Not the position of other nearby vessels. The current solution can be characterized as a dyadic

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solution, where two vessels, equipped with the same equipment, can see each other within the range of the AIS. The common operating AIS picture in this case is defined by the overlapping circles in figure defining the area where both vessels can see the same. If there are other vessels, or a person with an AIS personal beacon in the water outside this area, the whereabouts of these must be communicated from one vessel to another by the use of radio.

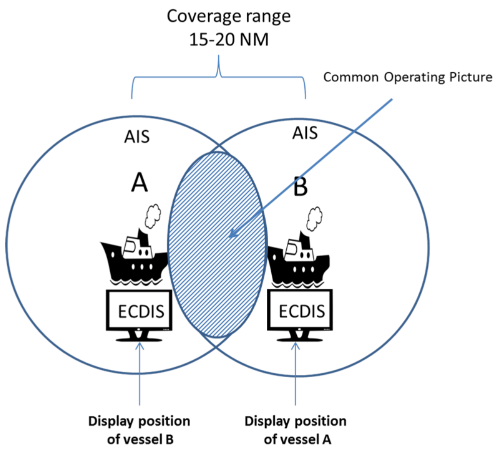

Figure 12. (Source: VISSIM, 2017)

It is possible to imagine that AIS could be used in the same way as the MBR solution; by also using the vessels as modems to forward data to other vessels.

And by this render a possible network with each vessel as a node, something that would significantly expand the common operating picture.

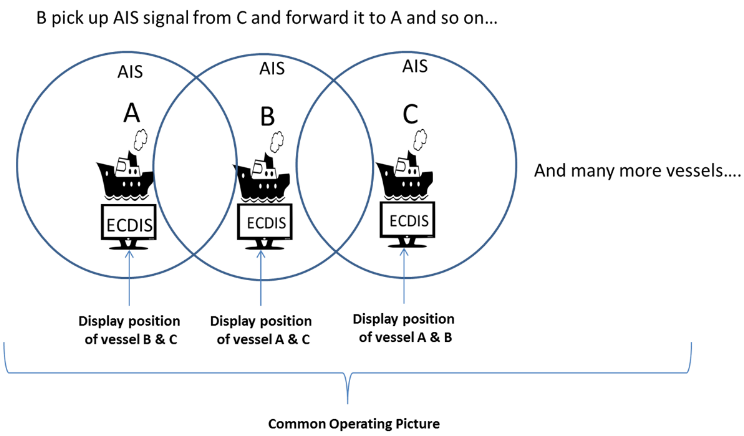

Figure 13. (Source VISSIM 2017)

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It is reasonable to believe that the capability to pass on other vessel's position in such a way will represent a significant improvement in creating an improved shared common operating picture. So, to explore this possibility this could be a natural first step. Thereafter as a next step, to increase the data transfer capacity within the network would help even more. As for the MBR concept, to have the possibility to link together vessels in a network like this over larger distances also increases the probabilities that one of the vessels /nodes in the network will have good SAT connection, and can function as a gate to / from the network to operational rescue units as JRCC.

The AIS network features described could also have other more commercial uses in areas with poor SAT coverage. If existing AIS equipment could relatively simply be modified / upgraded to function as described, this could be a significantly cheaper approached compared with the MBR solution, and therefore maybe easier to introduce e.g. as a Polar Code requirement.

5.2.1 ARCDIS (Arctic Display Information System)

One can imagine the introduction of an Arctic Information Display onboard vessels operating in the arctic environment. We can refer to it as ARCDIS- Arctic Display Information System. The functionality should then be governed in the same manner as IMO is governing the ECDIS standard. This way, the market can be populated by low-cost and type-approved units.

The AIS standard does not allow for repeating of positions from other vessels. The AIS standard does however include options for sending binary messages. Usage of binary messaging should be limited to messages related to maritime safety, so any usage improving safety of arctic operations should be inside the limits.

Cost

To keep a low-cost solution, we can build it on the AIS structure. All vessels have AIS and we avoid any expensive satellite based solutions. A satellite based solution will of course be better, but will perhaps be difficult to enforce due to cost. The ARCDIS will probably be a ruggedized PC with the type-approved software, connected to the already on-board AIS transponder.

Increasing coverage

Using binary messages to retransmit messages from regular AIS, vessels A and D would be able to see each other on the ARCDIS displays. Furthermore, the ARCDIS can also predict the vessels for some time, after loss of coverage, to keep a larger overview of vessels in the area. Retransmission of messages must be based on a standard set of rules, how many times it can be retransmitted, for example 10 times, and a maximum range from originating position, for example 100nm.

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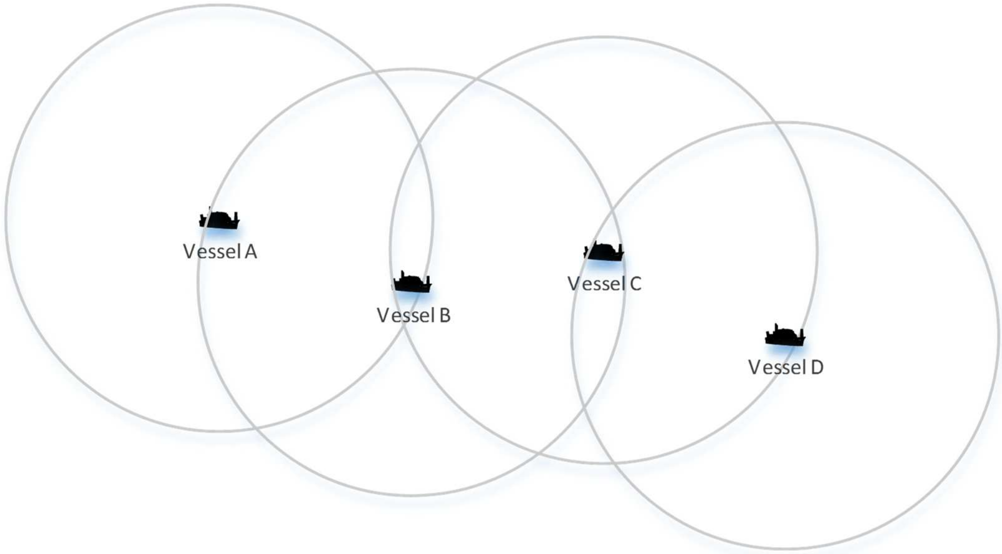

Figure 14. (Source: VISSIM 2017)

5.2.1.1 Self-organizing Emergency Response using ARCDIS

In a scenario, where for example Vessel F is in distress, the extended coverage is including 5 ARCDIS equipped vessels. The distress may come as a DSC distress message, or verbally via VHF.

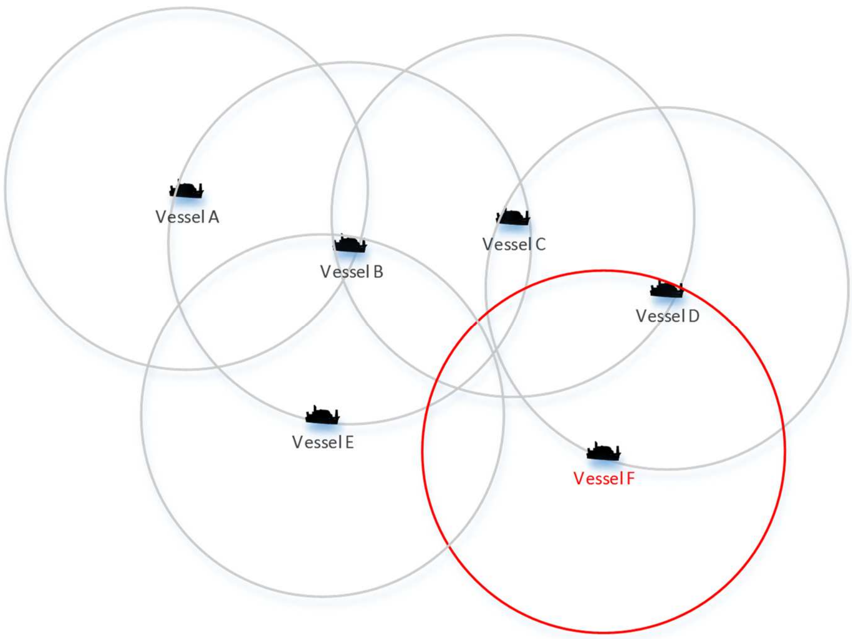

Figure 15. (Source: VISSIM, 2017)

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Even if the 5 ARCDIS displays are from different manufacturers, they will have to agree on how to organize the rescue operation, based on a common rule set. It has to be simple with minimal interaction from the crew, to support optimal performance by the vessels. One of the ARCDIS displays have to take charge, a rule may be that it is the nearest one to the distress. This display may then generate search patterns and distribute to the other participating vessels via AIS binary messages. This chapter is simply meant to illustrate how to utilize existing technology to create a self-organizing network. The rule sets for the imaginary ARCDIS, will of course have to be detailed for different scenarios.

5.2.2 SAT-AIS

The development of SAT coverage in Artic has increased significantly in the recent years, and it is reasonable to expect that this positive development will increase in pace with increased activity / more customers in the area. But as described earlier, today's SAT solution has weaknesses and at the moment, there are only one main sat data provider; Iridium. So ,in the short run, it seems too risky to relay on SAT-solution based tools as the only way to create and distribute a "common operating picture" in an emergency situation.

In fact, when it comes to solutions that are critical in emergency situations, it is common to have several solutions available to ensure robustness.

5.2.3 ECDIS

ECDIS is a very important tool for all larger vessels, and the ability to combine charts, AIS and radar information in one display is of outmost value for achieve a good understanding and managing the situation at hand. And ideally, all ships should also have had the possibility to display information coming via SAT-AIS, MBR or any other desirable solution providing relevant information, on the ECDIS screen.

As mentioned, only the most modern ECDIS solutions have integrated SAT functionality so that SAT based AIS or other SAT received data can be displayed directly on the ECDIS monitor. This means that almost none of the vessels in Artic have direct "ECDIS to ECDIS" communication.

In an emergency situation, the consequence of this is that important SAT received "common operating picture" relevant information cannot be seamlessly integrated in the ECDIS display.

To improve the situation, there are at least two possible ways. One is of course to hope that all vessels in the future gradually will get the most modern ECDIS solutions with integrated SAT connection, and that that it at all times will be satisfying SAT coverage, enough data transfer capacity and reasonable pricing of these services. Another possible way is to go in the direction described in Section 7.1.2. exploring the possibilities for introducing an "ARCDIS" solution.

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5.2.5 ArcticWeb

The ArcticWeb have been in focus as a part of the report and is today fully operational. It's SAT-based E-navigation solution and the main idea behind the service is to render possible a better intra-vessel sharing of SAR-patterns via internet, and by that obtaining an improved common operating picture.

Vissim participated in this simulation exercise as observer, and based upon the background section of handling of emergency situations in Artic as described in this document, the following observations and reflection were done:

Advantages

- To be able to share a SAR patterns between vessels is a huge advantage in order to be able to organize and manage a SAR operation in an efficient way. This was clearly stated by all the nine captains participating in the SAR simulation exercise.
- The route and schedule sharing abilities
- Developed capabilities to manage the risk awareness in voyage planning and in ice navigation with for example online weather and wave forecasts and ice information
- The platform meets some of the requirements address in the polar code concerning Navigation
- A tool like ArcticWeb could potentially substitute or at least complement today's ways of sharing info about SAR-patterns
- Explain the SAR-pattern using radio / voice
- Take a photo of ECDIS monitor and send via Iridium mail
- The solution does not require more than a PC with internet connection on-board the vessel. So it is an inexpensive and simple solution.
- The technical set-up have been adjusted to fit limited capability to transfer data with for example weather and ice information.
- The graphic and the functionalities available seems to be very good compared to other comparative tools on the market.

Improvement potentials

- The solution is SAT dependent. This means that without Internet / SAT connection, the service is not available.
- The solution is not integrated to ECDIS. So the crew, needs to relate to two different monitors. A direct integration possibility to ECDIS so that everything could be viewed on one single monitor would have been beneficial.
- The SAT-data used by ArcticWeb comes from the Norwegian Coastal Administration, which means that the AIS data received could be several hours delayed. Something which again means that there could be discrepancies in vessel positions received in

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ECDIS and ArcticWeb. The delay of data could also lead to wrong calculated ETAs at the SAR area for vessels /rescue resources.

- The user interface; how to operate the tool in an intuitive way, could still be improved significantly.
- So far there is not any direct integration between the SAR tolls and live weather forecast. Weather parameters must be added and updated manually to be able to make good search and / or drifting patterns. This is cumbersome and requires that adequate updating processes are implemented. This is particulate important in situations with shifting weather conditions.
- Functionality to calculate SAR *areas.* Today only SAR *patterns* are calculated based on input from JRCC.
- Functionality to illustrate on map with colors what search areas that already has been covered would be useful.
- Functionality that automatically calculate when the involved vessels /rescue resources will arrive the search area (with continues and automatic updating) would have been useful.
- Functionality / SAR algorithms that takes into account when / the ETA for when vessels / recue resources will arrive search area.

7 Conclusions

The main conclusions from this report are:

- There exists a need in arctic regions to self-organize for a more effective and improved emergency response to a SAR situation
- The report demonstrates that different technical solutions and concepts exists that could support and facilitate a self-organizing capability
- Such solutions, the ArcticWeb was evaluated and tested in a self-orgnizing situation with a positive result even if there is need for some improvements

Despite that, SAR and maritime safety in polar regions are complicated due to the extreme weather, sensitive environment, limited communication possibilities, long distances, lack marine traffic and poor SAR infrastructure. With that background, there exist a need for a platform, where vessels, other maritime units/organization and even local communities could monitor, plan and facilitate different kinds of maritime activities with a relevant level of support for an improved awareness and preparedness. If platform could target SAR situations as well, that would provide an optimal solution for safe operations in polar regions.

The GMDSS requirements demands that vessel that operates in the Arctic (A4) should be able to transfer a distress message either through a MF/HF DSC solution or by the use of a

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EPIRB. In addition, the polar code requires that vessels could communicate in two-ways in voice and data ship to ship and ship to shore. This clearly indicates that the GMDSS A4 requirements or on a minimal level and additional solutions are needed for SOLAS classed vessels, in this case the Iridium system would provide a relevant complement for that need.

The ArcticWeb services and tools meets some of the requirements as stated by the Polar code regarding in for example voyage planning and safety of navigation. Despite some improvement potentials for the platform identified during the practical evaluations, the services were considered as acceptable by most of the test participants

The polar code also addresses other important matters with regards so safe maritime operations in polar regions but the main focus is the capabilities of the vessel itself. The above-mentioned factors make emergency response difficult in polar regions and the chances of long-time survival in harsh conditions are low without the proper lifesaving appliances. The matter was clearly addressed in the master thesis *"Identification of Challenges and Hazards associated with Cruise Traffic and Evacuation in the Arctic"* by Nese & Dalsand (2016), where they identified several gaps between the performance of existing SOLAS-approved lifesaving appliances and the level of safety that the Polar Code tries to ensure. This highlights that the response times and an efficient assistance in a search and rescue operation in the arctic is most vital and could perhaps be even more important if the equipment isn't functional in cold environments.

For a vessel in distress, it's top priority to establish connection with a JRCC in order to get assistance as fast as possible. As provided in this report different solutions exist that could facilitate such communication. However, the second part involves the organization of an effective response, in the arctic this could provide a challenge depending on the area and available resources. The worst-case scenario would involve a mass evacuation from a cruise ship and adding communication disturbances and/or poor SAT-AIS update would increase the challenging level to a very complicated situation. It has been proven in previous SAR TTX exercises that limited communication, lack of situational awareness, information about available SAR resources and lack of infrastructure reduce the ability of an effective response.

A success in any SAR response is dependent available SRU's, their response times and their ability to organize an effective response on scene and in maintaining a common operating picture. In considering the arctic where the JRCC could be several hundred miles from the location, it could be difficult to get a complete overview of the circumstances, conditions and the progress. The required situational awareness is of outmost importance in order to manage the development of the SAR situation and predict future events. This highlight the need for self-organizing by local maritime units, however this will require means of sharing a common operating picture in order for the response to be effective and it will also assist an OSC in organizing such an activity. A common operating picture could be provided by the

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ArcticWeb and also other concepts have been addressed in this report like the MBR solution or AIS crowd-sourcing.

The main objective is to improve maritime safety in the arctic, the possibility to self-organize is an interesting concept that could involve new response methodologies in responding to an emergency in the arctic. However, it's up to relevant stakeholders to collaborate on more specific solutions and performance requirements.

5.1 Suggestions for further research

Based upon the result and conclusions in this section, following suggestions for research were made:

- Addressing search and rescue in remote areas, especially in polar regions are important. E-navigation services could provide tools to assist a more effective response, further research should be made in this area.
- Another area addresses the concept of "Self-organizing" to a SAR event in remote areas, additional analysis is needed here.
- Can the ArcticWeb be connected to the Polar Code

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Appendix A

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<table>
<tr><td>No.1</td><td colspan="3">Exercise description for participants</td><td>E2AW-Baseline</td></tr>
<tr><td>Exercise Title</td><td colspan="4">E2 ArcticWeb – Search and Rescue – Baseline</td></tr>
<tr><td>Exercise No.</td><td colspan="4">1</td></tr>
<tr><td>Equipment to be used for planning</td><td colspan="4">N/A</td></tr>
<tr><td>Exercise time</td><td></td><td>Paper charts</td><td colspan="2">DK</td></tr>
<tr><td colspan="5">Vessel data</td></tr>
<tr><td>OS Vessel</td><td colspan="4">Bridge 1 - Cruise ship: CRYSTAL SERENITY/C6SY3 – Further information see pilot card
Destination NUUK ETA 16-08-17 18:00 from Ilulissat ETD 15-08-17 06:00 – Route in ECDIS called ”Crystal Serenity D1”

Bridge 2 – Cargo ship: EILBEK/5BSB4 - Further information see pilot card
Destination Ilulissat ETA 15-08-17 20:00 from Holsteinborg ETD 15-08-17 04:00 – Route in ECDIS Called ”Eilbek D1”

Bridge 3 – Tanker: ORASILA/OYDK2 – Further information see pilot card
Destination Nuuk ETA 16-08-17 22:00 from Disko Bay ETD 14-08-17 23:30 – Route in ECDIS called ”Orasila D1”

Some other vessels are also available in the area</td></tr>
<tr><td>Area</td><td colspan="4">West – Southwest of Disko bay. (for further information see ECDIS or paper charts)</td></tr>
<tr><td colspan="5">Purpose: Evaluate capabilities and response to SAR situation in polar areas from a management/vessel perspective</td></tr>
<tr><td colspan="5">Available publications</td></tr>
<tr><td colspan="5">IAMSAR Vol III
DMI weather forecast
Access to internet at will</td></tr>
</table>

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Task

Your vessel is enroute to a specific destination, along the way SAR situation will arise which you have to respond to.

SAR Situation

At 1200 UTC the Fishing Vessel Claudia, in position N 68°28,17´.0 /E 057°64,3, alerts MRCC Greenland through telephone informing that she has collided with an iceberg and requesting assistance.

Communication

- VHF for short range traffic – Available on designated "VHF"
- MF/HF Voice and DSC – available on designated "VHF"
- Iridium telephone available
- On-board telephone available

Point of Contact

- SAR Greenland – MRCC Gronnedal
- Telephone 85005
- MF Voice 2182 kHz, DSC 2185,5 kHz (needs to be simulated as VHF DSC)
- Bridge 1 – Telephone 85003
- Bridge 2 – Telephone 85004
- Bridge 3 – Simulated Telephone as "UHF"

Environment/Weather:

Ice – no ice
Ice bergs – Many in eastern parts. Otherwise some ice bergs and growlers
Wind: N'ly 4-5 Bf
Sea: 1-2 Hs
Current: NW – 0,5kn
Weather: Cloudy, occasional fog

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Preparation and Briefing of the Bridge Teams before the Simulation

Prior to the start of the simulation exercise the Local Simulator Instructor is to prepare the following on each bridge:

- Start all available equipment, i.e. radars, logs etc. as applicable

Briefing of the bridge team prior to the simulation exercise needs to consist of the following:

- Load the route for the simulation in the ECDIS and set it to “Monitoring” status.
- Type of vessel, size, draft etc. and its maneuvering characteristics
- Actual position at the start of the exercise
- Voyage plan i.e. route, destination (no full route is required)
- Draft restrictions if applicable
- Reporting points if applicable
- Weather, visibility and wind conditions including forecast
- Sea and current conditions
- Traffic nearby
- Speed and engine settings
- MSI/Navtext information if applicable
- Status on equipment (ECDIS, radar, logs etc.)

De-brief

For each participating vessel:

- Three things that we did good.
- Three things that we could do better/different
- We found the instructions and order from the OSC as……..
- We found the information and instructions from the JRCC as……..
- SAR in remote areas are….
- What is required for an effective response?

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1	Exercise Plan for instructor	E2AW-Baseline

Exercise Title	**E2 ArcticWeb – Search and Rescue – Baseline**		
Exercise No.	**1**		
Sea Area	**West Greenland**		
Exercise time	Maximum 3 hours	**Paper chart**	
Duration			
Bridge Team			
Participants	3-4 Persons per "Bridge"		

Exercise storyboard

Time	**Instructor`s actions & messages**	**Participants expected actions**
-30	Preparation of work space Preparation of publications and internet access	
	Check working of AW, possibly feed AW with simulated traffic, connect to simulator	
	Verify weather from DMI and add that into the simulator	
	Upload exercise "Day 1 – Baseline" Assign vessels and assign Arcticweb to "Lantronixewa"	
	Prepare computers with AW, check settings	
	Prepare JRCC, access to AW, communication etc	
	Verify settings on the bridge, radar, ECDIS etc	
00	**Briefing**	
	Brief part. of purpose/content/description etc	Listening
	Part. Prepare bridge for departure, verify settings, establish start position.	When ready for dep, call in
00:30	Start Exercise check visibility,	Check roles
00:40	Claudia have collided with an ice berg and called MRCC Gronnedal for assistance, Make a Mayday announcement of the MF/HF - May Day… - Fishing Vessel Claudia call sign… - Position N 68°28,17´.0 /E 057°64,3 - Cullieded with an iceberg - Ingress of water - 10 POB - Any vessel in the vicinity contact MRCC Gronnedal Verify vessels in the area that could assist and contact if they could. MF/HF or phone Assign one OSC according to capabilities	Should respond positive and provide positions and ETA Claudia

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1:00	Claudia informs MRCC of ingress of water and needs to abandon ship Position from the instructor (LKP) 10 persons onboard 2 liferafts SART and portable VHF All has survival suits, life wests and in good health Instructor place out 2 rafts at LKP, verify drifting	Communication between MRCC and Claudia
1:10	Assign vessel to proceed to LKP and provide an update of ETA to LKP MF/HF	Vessel respond individually
1:20	Establish contact with OSC by phone and provide instructions Plans, search etc Communications Sit-reports Etc..	Between MRCC and OSC
1:30	Vessels are proceeding start to calculate search areas, sub areas and assign suitable search pattern	Verify on the AW Make calculations on the AW and manually on paper charts
2:00	Inform OSC of the plans	
2:10	OSC informs the other vessels	Should start making preparations, assign look out, search pattern in ECDIS ?
2:20	Vessel proceeds: Instructor move vessels abit ahead or 5 times speed, inform bridges of the new position – close to search areas.	Vessels should verify their new positions
2:30	Vessels arrive on location and starts searching according to their search pattern Monitor progress of search OSC to inform when search starts	Vessel should starts with their search pattern, OSC is leading VHF communications OSC communication with MRCC
3:00??	When they have noticed the life rafts, start SART on liferafts	Should communicate with other vessel, OSC to inform MRCC
3:00 ??	When in sight of liferafts call vessel on portable VHF, voice reduced by extreme cold	Vessel proceed and intercept life rafts
3:00??	When vessels arrive on scene – terminate the exercise Ask participants to do a debrief For each participating vessel: 1. Three things that we did good. 2. Three things that we could do better/different 3. We found the instructions and order from the OSC as…….. 4. We found the information and instructions from the JRCC as…….. 5. SAR in remote areas are…. 6. What is required for an effective response? Instructors do the same	All bridges and part. Takes part in the discussions

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Appendix B

EFFICIENSEA

CHALMERS UNIVERSITY OF TECHNOLOGY

No.2	Exercise description for participants			E2AW-Func/Usa
Exercise Title	**E2 ArcticWeb – Functionality and usability evaluation**			
Exercise No.	**2**			
Equipment to be used for planning	N/A			
Exercise time		**Paper charts**	D	
Vessel data				
OS Vessel	**Bridge 1** - Cruise ship: CRYSTAL SERENITY/C6SY3 – Further information see pilot card Destination NUUK ETA 16-08-17 18:00 from Ilulissat ETD 15-08-17 06:00 – Route in ECDIS called" Crystal Serenity D1" **Bridge 2** – Cargo ship: EILBEK/5BSB4 - Further information see pilot card Destination Ilulissat ETA 15-08-17 20:00 from Holsteinborg ETD 15-08-17 04:00 – Route in ECDIS called "Eilbek D1" **Bridge 3** – Tanker: ORASILA/OYDK2 – Further information see pilot card Destination Nuuk ETA 16-08-17 22:00 from Disko Bay ETD 14-08-17 23:30 – Route in ECDIS called" Orasila D1" Some other vessels are also available in the area			
Area	West – Southwest of Disko bay. (for further information see ECDIS or paper charts)			
Purpose: Evaluate capabilities, functionalities, usability and for familiarization				
Available publications				

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Task

1. Start the Arcticweb and login
2. Main chart page, zoom in and zoom out, switch map to open street map. Usable?
3. Find you vessel, can you easily see information about you vessel ?
4. Other vessel around you, what type of vessels exist? Information provided relevant? (use legend description in user manual)
5. Test the 3-6-9 hour distance circle from your vessel, in which point could this be useful?
6. Which is the nearest vessel from you?
7. Ice charts,

   load latest ice charts, that covers Greenland.

   Where is the ice limit?

   Color coding's provides the correct information or other solutions better? Usable for ice navigation or would you prefer to have the information provided differently, in what kind?

   Ice charts

Color	Ice Concentration	Definition
(grey)	10/10	Fast Ice
(red)	9/10-10/10	Very Close Drift Ice
(orange)	7/10-8/10	Close Drift Ice
(yellow)	4/10-6/10	Open Drift Ice
(green)	1/10-3/10	Very Open Drift Ice
(light blue)	<1/10	Open Water

   Iceberg tool and selected ice observation nor available, look in the instructor manual to find example of this type of information, relevant?

   Load Satellite images, compare to your experience with these, is relevant information provided

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Select satellite image by area link - click this link and then choose the desired region on the map. Functional?

8. Ice information provided to you as users, in the way it's presented and displayed does that provided a usable tool for executing strategic voyage planning and actual ice navigation?

9. Weather
   - Go to the weather functions menu
   - What is the present weather for area "Attu"?
   - Any warnings present?
   - Any other comments on the weather function?

10. Forecast
    - Go to the forecast menu
    - Type of forecast available?
    - Work your way through the different forecasts
    - How much time ahead can you see
    - The ice forecasts, what type of development can you see in NE Greenland, ice concentration, ice thickness, etc? In what navigational situations is this useful?
    - For the area of "Attu" what's the current and sea forecasts?

11. In creating a good common operating picture or establish a good situational awareness is the information provided and the usability relevant for operation in polar areas?

12. The update rate of AIS data, how could this affect the situational awareness of surrounding vessels?

13. Explore the possibility to provide more information to your vessel through – Vessel information, type of data in what scenarios could this be relevant? Any other info you would like to see from a vessel ?

14. With regards to usability, what's your general impression?
    - Information provided relevant?
    - Easy access and clear presented?
    - Is some information not relevant?
    - Which is the most useful data?

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Schedule and routes

1. Explore the schedule and route functionalities
   - Is there any acive schedules for you vessel?

2. Based upon the data provided above for your vessel create a schedule for the intended voyage

3. When the schedule is complete, import a route from a usb stick into the system and upload? (it's possible to import route from

   - Can you see the route on the arcticweb?
   - Other vessels, type of color of their routes
4. Try to edit the route, this could have several reasons for ex ice present, many icebergs etc, working?

5. What's your opinion with regards to the route option?

6. With the function to share routes, could this tool and working with historic tracks be useful in for example demonstrating navigational areas through an ice field, any functions missing? Comments?

Search and Rescue (for support use the IAMSAR manual)

1. Open the SAR menu, different SAR operations are active (these are user specific and only the designated user can delete a SAR operation)
2. Press create a new SAR operation, explore the different types, which are available?
   - We will mainly use "Rapid response" and "datum point" what's the difference?
   - Select rapid response and fill in the data
     LKP: select one of your choice in the area
     Position error 0,1
     Estimate 2h response time, start of search
     Variables for surface drift, select this from the arctic web weather and forecast data
     Other variables 0,1 /1
     Object raft 4-6 persons, without drift anchor
     Press next, what is displayed?
     Press Finished, what happens?
     Review the information, what is provided for your specific operation?
     Press the mange effort allocation button
     Add a SRU, Bridge 1 enters Balder Viking, Bridge 2 enters oratank and Bridge 3 enters JRCCarcticweb and fill in the information and save

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Press calculate subarea for that unit and fill in the relevant information and calculate sub-area

Share the area with the unit, what happens? With regards to colors etc, try also to move the search area, by pressing on the area with your cursor, what happens?

Then press on new search pattern, and select an expanding search and assign to the candidate, what happens?

Press messages, write a message..

Try with different settings to change the sub-area and search pattern

Any comments on the procedures or the information that needs to be provided, any problems?

- Establish a search area in another position, select "datum point" instead and expand response time to 6h.
  Any difficulties

3. What's your impression of the search and rescue tool?

4. Discussion within the group a SAR scenario, how should this tool be used? (polar areas)

5. How can it support the OSC?

6. In a scenario with a self-organizing perspective (polar areas), how should you manage this tool with surrounding vessels?

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Appendix C

EFFICIENSEA 2.0 GETTING CONNECTED — CHALMERS UNIVERSITY OF TECHNOLOGY

<table>
<tr><td>No.3</td><td colspan="3">Exercise description for participants</td><td>E2AW-Self org 3</td></tr>
<tr><td>Exercise Title</td><td colspan="4">E2 ArcticWeb – Search and Rescue – Self-organizing</td></tr>
<tr><td>Exercise No.</td><td colspan="4">5</td></tr>
<tr><td>Equipment to be used for planning</td><td colspan="4">N/A</td></tr>
<tr><td>Exercise time</td><td>3h</td><td>Paper charts</td><td colspan="2">DK</td></tr>
<tr><td colspan="5">Vessel data</td></tr>
<tr><td>OS Vessel</td><td colspan="4">Bridge 1 - Cruise ship: CRYSTAL SERENITY/C6SY3
Destination Disko Bay (Ilulissat) ETA 17-08-17 23:00 from Nuuk ETD 16-08-17 09:00 – Route in ECDIS Called ”crystal serenity D3”

Bridge 2 – Cargo ship: EILBEK/5BSB4
Destination Aasiat ETA 17-08-17 18:00 from Nuuk ETD 16-08-17 16:00 – Route in ECDIS called “Eilbek D3”

Bridge 3 – Offshore Support Vessel: Balder Viking/SLKA
Destination Nuuk ETA 19-08-17 08:00 from Thule Air base (Pituffik) ETD 15-08-17 10:00 – Route in ECDIS called “Balder Viking D3”

Some other vessels are also available in the area</td></tr>
<tr><td>Area</td><td colspan="4">Disko bay. (for further information see ECDIS or paper charts)</td></tr>
<tr><td colspan="5">Purpose: Evaluate capabilities and response to SAR situation in polar areas from a self-organizing perspective</td></tr>
<tr><td colspan="5">Available publications</td></tr>
<tr><td colspan="5">IAMSAR Vol III
ArcticWeb user manual</td></tr>
</table>

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Task
The exercise commences at 12:00 UTC 17.08.17. Your vessel is enroute to a specific destination, along the way a SAR situation will arise which you have to respond to. You need at first to create a schedule in the AW and load up a route. **Communication** • VHF for short range traffic – Available on designated "VHF" • MF/HF Voice and DSC – available on designated "VHF" • Iridium telephone available • On-board telephone available **Point of Contact** • SAR Greenland – MRCC Gronnedal • Telephone 85005 • MF Voice 2182 kHz, DSC 2185,5 kHz (needs to be simulated as VHF DSC) • Bridge 1 – Telephone 85003 • Bridge 2 – Telephone 85004 • Bridge 3 – Simulated Telephone as "UHF" **Environment/Weather:** Ice – no ice Ice bergs – Many in eastern parts. Otherwise some ice bergs and growlers Wind: NW 2-7 m/2 Sea: Hs 1,5m Swell 1m Current: 0,5kn / WSW direction Weather: Partly cloudy Visibility: Good to poor visibility

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Preparation and Briefing of the Bridge Teams before the Simulation

Prior to the start of the simulation exercise the Local Simulator Instructor is to prepare the following on each bridge:

- Start all available equipment, i.e. radars, logs etc. as applicable

Briefing of the bridge team prior to the simulation exercise needs to consist of the following:

- Load the route for the simulation in the ECDIS and set it to "Monitoring" status.
- Type of vessel, size, draft etc. and its maneuvering characteristics
- Actual position at the start of the exercise
- Voyage plan i.e. route, destination (no full route is required)
- Draft restrictions if applicable
- Reporting points if applicable
- Weather, visibility and wind conditions including forecast
- Sea and current conditions
- Traffic nearby
- Speed and engine settings
- MSI/Navtext information if applicable
- Status on equipment (ECDIS, radar, logs etc.)

De-brief

For each participating vessel:
For each participating vessel:

- Three things that we did good.
- Three things that we could do better/different
- We found the work with the AW as…
- We found the information and instructions from the OSC as……..
- SAR in remote areas are….
- Success in a self –organizing scenario is dependent on..

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3	Exercise Plan for instructor	E2AW-Self org 3

Exercise Title	**E2 ArcticWeb – Search and Rescue –Self-organizing**		
Exercise No.	**3**		
Sea Area	**West Greenland**		
Exercise time	Maximum 3 hours	**Paper chart**	
Duration			

Bridge Team

Participants	3-4 Persons per "Bridge"

Exercise storyboard

Time	Instructor`s actions & messages	Participants expected actions
-00:60	Preparation of work space Preparation of publications and internet access	
	Check working of AW, possibly feed AW with simulated traffic, connect to simulator	
	Verify weather from DMI and add that into the simulator	
	Upload exercise "Day 3 – Baseline" Assign vessels and assign Arcticweb to "Lantronixewa" and instructors for VHF	
	Prepare computers with AW, check settings	
	Prepare JRCC, access to AW, communication etc	
	Verify settings on the bridge, radar, ECDIS etc	
00:30	**Briefing**	
	Brief part. of purpose/content/description etc	Listening
	Part. Prepare bridge for departure, verify settings, establish start position. Prepare AW.	When ready for dep, call in
00:00	Start Exercise check visibility, place out **PIW**	Check roles
00:10	Fishing vessel Polar Nataarnaq/OYCB announce mayday man overboard on VHF ch 16 My position… Speed 5kn Course 085 deg Last seen working aft, equipped with survival suit and life west at 07:00 Position N68 46,490´ W054 35.928´ LKP but we don't know when he fell over board Vessel have kept a ENE course for last 5 hours with 4,5 knots The person is in good health Due to VHF antenna breakdown ashore – no response from JRCC Instructor: If no vessel call in, Le Boreal contact Polar N	Should respond positive and provide positions and update of ETA to Polar N

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0:20	Depending on the outcome, if some vessels ask to be OSC or take the role – await the outcome otherwise trigger some involvement from JRCC JRCC involvement due to communication issues on sight, with poor coverage JRCC assign crystal serenity as OSC by phone and ask them to update them regularly Instructor: call in for vessel Le boreal/ RV Atlantis to assist no AW Await OSC reaction	MRCC Gronnedal contacts Crystal serenity by phone and instruct the to be OSC
0:30	OSC should start to calculate on search areas and instruct the other two vessel to proceed with speed against the LKP – Note that this scenario may require that the OSC consider datum line SA, if wrongly placed SA guide them in the right direction through conversation with JRCC or attending on the bridge Polar N informs OSC that she is going back in her own assumed track, back track Instructor/JRCC: be logged in as JRCC arcticweb to follow the calculations JRCC to make manual calculations	OSC to make SA/PA calculations Vessel to be instructed by the OSC
0:40	OSC to contact vessel an instruct them for SA/SP Follow up on the calculations made in AW, verify that the vessels are assigned to a SA/SP Follow up if they use the chat function Might improve the visibility temporary Follow up on drift for PIW	Between OSC and vessel
1:00	Vessels are to arrive on site and start searching in designated SA If Le Boreal is assigned in some way Instructor to control them Update with Polar N	Verify on the AW Communication between vessels
1:10	While in the search follow the outcome adjust the PIW accordingly and perhaps move some icebergs, the intention is that the search areas are filled with icebergs OSC should monitor the progress of all the vessels	Communication between vessels
1:20	Let them play the role that they search for 45 min to one hour, then move the PIW if needed MRCC to be in contact with OSC to ask them for sit-report	Vessel should be on high alert, the crew's active on the bridge. OSC leading/communication in between

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1:50	If they are not closing in consider to move the PIW closer	
2:20	Consider to move or not the PIW very close to one vessel..	Verify lookout activity
2:30	Stop the scenario , When stopped MRCC to make a calculation of search area, we need to have a correct area for the discussions	
2:30	Ask participants to do a debrief For each participating vessel: 1. Three things that we did good. 2. Three things that we could do better/different 3. We found the work with the AW as… 4. We found the information and instructions from the OSC as…….. 5. SAR in remote areas are…. 6. Success in a self –organizing scenario is dependent on Instructors do the same	All bridges and part. Takes part in the discussions

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Appendix <enter number here>. Review procedure

No°	Reviewer Initials	Reference in document (General or Paragraph, Figure …)	Type (editorial, structural, formulation, error)	Reviewer's Comments, Question and Proposals	Editor’s action on review comment.

E-navigation from a human factors perspective:
Investigating today's bridge systems and procedures, and assessing navigators' perceptions of a novel maritime service website prototype in a ship bridge simulator

Nicole A. Costa *, Scott N. MacKinnon *, Jeanette J. Jakobsen **

1. Introduction

We find ourselves in a fast-changing era of global and exponential propagation of automation, intelligent computerized systems, and information digitalization. In this historic and revolutionary context, the international shipping industry is no exception to the rule, even if deployment and regulatory changes can be generally slow. Shipping, responsible for approximately 90% of all world trade (International Chamber of Shipping, 2015; Stopford, 2009), is a self-organizing network where each ship is its own principal decision-maker and responsible for maintaining own safe operations. Whereas in general terms the domain is a loosely coupled (Orton & Weick, 1990) sociotechnical system with distributed control (Hollnagel, Woods, & Leveson, 2006; Praetorius, 2014), safe navigation and manoeuvring of large vessels within VTS areas is an activity that requires coordination between the bridge officers of the ship, the VTS (Praetorius, 2014), and often the coastal pilots (de Vries, 2015). Here, decision-making for anti-collision and anti-grounding strategies is based on communication between ships and shore operators, and on local information integration for preparation and prediction (de Vries, 2015). The stakeholders, who are mostly not co-located (Bruno & Lützhöft, 2010), are linked and aided by information technology devices (e.g., Electronic Chart Display and Information System (ECDIS), Automatic Identification System (AIS), Very High Frequency (VHF) radio, Navigational Telex (*Navtex*)). And currently, the domain is suffering the demands and challenges for emission reduction and for more interconnectivity between ships and shore.

1.1. E-navigation

One of the domain's ongoing engagements is the E-Navigation programme by the International Maritime Organization (IMO), who recently approved an e-navigation implementation strategy to be accomplished by 2019 (IMO, 2014a). The main objective of this programme is to digitalize and harmonize nautical information across ships and shore to optimize the safety and efficiency of navigation and promote environmental protection. A living predecessor of this has been the Electronic Chart Display and Information Systems (ECDIS) which made possible carrying the nautical charts and publications for planning and displaying a voyage on screens with real-time information. Although it had been gaining force since the 1990s, the ECDIS was made mandatory by the IMO for new ships built from 2011 (IMO, 2017). It not only arrived at bridge operations but also shore operations, such as the Vessel Traffic Services (VTS) who utilize ECDIS to display nautical charts and monitor the traffic in their area. In support of the e-navigation programme, the European commission project EfficienSea2 [http://efficiensea2.org/], within which this study was conducted, aims to identify, develop, test, standardize and release innovative and smart e-navigation solutions that will help further improve connectivity and information obtainability, reducing communication limitations and therefore the risk of accidents (Billesø, 2016; Danish Maritime Authority, 2016; Juhl et al., 2016). Within this context, a testbed – the BalticWeb – was developed consisting of a website prototype of navigational and administrative services intended to assist navigators and shore operators (bridge officers, pilots and VTS operators) with administrative duties, navigational information and decision-making during route planning and monitoring for the Baltic region. The services implemented and tested here for the Baltic context are imagined for future deployment at a global scale.

* Maritime Human Factors Unit, Division of Maritime Studies, Department of Mechanics and Maritime Sciences, Chalmers University of Technology, Sweden
** Department of Applied Psychology, FORCE Technology, Denmark

1.2. Developing BalticWeb testbed and maritime services

The test scenario was planned for the strait between Helsingborg Sweden and Helsingør Denmark, passing through the Sound VTS area. Although this testbed was limited in this way, it is a proof of concept for web-based services on a unique platform. These services would be made available by international certified service providers and could be accessed by all registered maritime stakeholders. This was intended to increase the opportunities for standardization across the shipping industry.

A number of service prototypes was developed and implemented into the BalticWeb (see Figure 1) and then tested in this study (presented in Table 1). A number of other services was planned within the EfficienSea2 project but could not be implemented in time, and hence did not get assessed in this occasion.

Due to existing regulatory restrictions, the web-based platform would not be possible to overlay on the existing ECDIS. Thus, the developers decided to present it on a thirteen-inch 360-degree laptop (convertible into a tablet) that could be moved around the bridge for both route planning and navigation. This study was limited to testing the BalticWeb and its services with bridge officers due to the nature and maturity of the website and services at the time of testing.

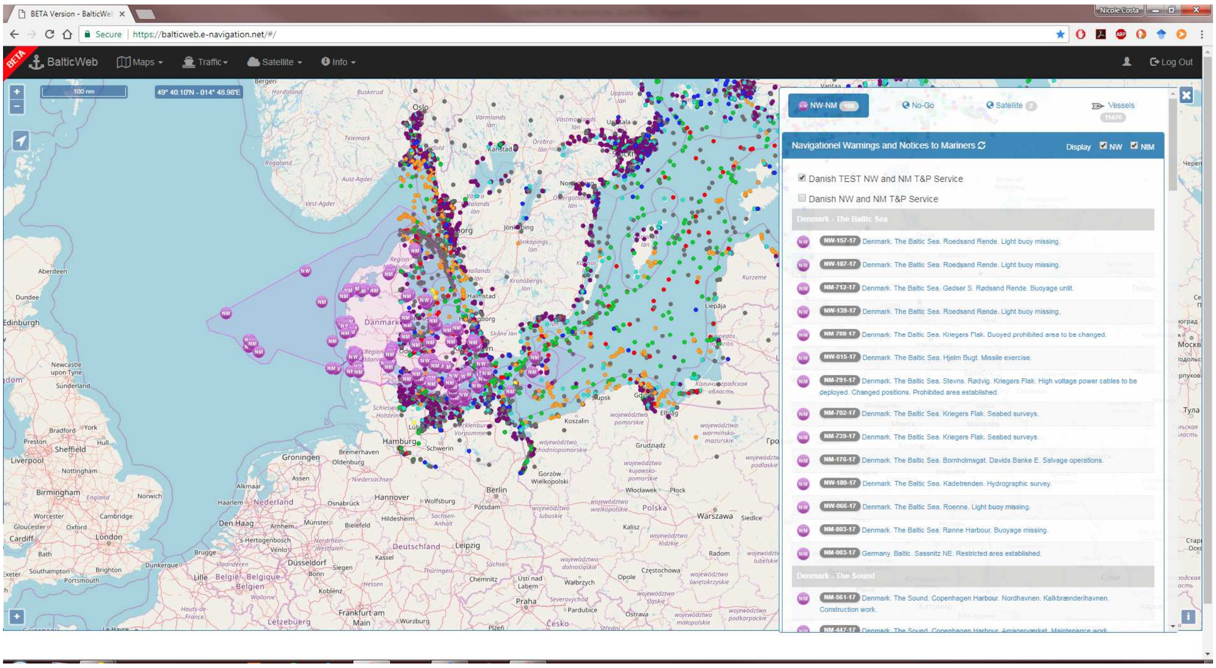

Figure 1. BalticWeb homepage.

Table 1. Services embedded in the BalticWeb prototype assessed in this study (Danish Maritime Authority, 2017).

	Service	Description	Current operations
Navigational Services	**Maritime Safety Information (MSI): Notices to Mariners (NM) and Navigational Warnings (NW)**	All MSIs (both NMs and NWs) are treated as one service. This is a standardized service for real-time promulgation and update, and for graphical portrayal of MSIs on electronic chart displays. A symbol is directly presented on the charts, indicating the geographical location of the event. This is intended for route planning and navigation.	NMs and NWs are provided separately today: NMs are commonly known already during voyage planning (through booklet PDFs) and NWs occur during navigation (transmitted via *Navtex* or VHF radio). In rare cases, some NWs may already be found within the route planning software used by the mariners, depending on the software brand and version. MSIs are also not published immediately as occurred or reported. This information will go first through the designated

			authorities who may take up to 2 hours processing and publishing this information to ships.
	No-Go Areas (under-keel clearance)	This service allows for the merger of a variety of data, such as draught, bathymetry and tidal levels, into simpler information indicating the waters where a vessel can safely navigate. The safety contours are then draught-specific as defined by the user but dynamic based on better bathymetric data with higher resolution. The contours should automatically change depending on meteorological and oceanographic forecast changes. This is intended mainly for route planning.	Shallow waters and safety contours are set by the mariner on the ECDIS depending on the vessel's draught (e.g., 12m). This is set with a margin for the state of the sea, squat effect etc. depending on the area (e.g., 14m). Once this is set, the contours are automatically marked with a distinguishable colour on the charts and are static.
	Route Optimization	Standardized and easily accessible service for acquiring a fuel-optimized route for a vessel. As of this moment, the route optimization algorithms require the navigators to lay out a route with waypoints before requesting an optimization. The algorithms will then take into account origin and destination, water resistance, fuel consumption according to length of voyage, draught of the ship and shallow waters. The algorithms do not account for COLREGs or traffic separation schemes, traffic density, local norms, weather (hydrographical and meteorological), distances to other ships, or maritime safety information. This is to be used during route planning.	The mariners themselves may optimize their route plan according to own specifications or those of their shipping company, e.g., optimizing for fuel consumption or for weather using a calculation, a specific software for the purpose, or a purchased service from an external provider.
Administrative Service	**Automated Vessel Traffic Service (VTS) Reporting/Ship Reporting System (SRS)**	This service proposes a way to standardize VTS reporting procedures for ships and delivery for VTS centres, making it possible to report to different VTS centres via a single platform, where standardized online forms for each VTS centre are to be filled out and submitted directly on the BalticWeb, generating an automated and standardized email that is received by the VTS. This is to be used mainly during route planning.	There is no standardized manner or platform to report to VTS centres across the globe. For each VTS, ships have to consult how to report (via email, online form, VHF radio), when to report, as well as what to report and VHF radio channels to use.

1.3. Usability assessment

The e-navigation programme promotes a human-centred approach to design and development (IMO, 2014b), and one of the ultimate goals is to make "maritime navigation and communications more reliable and user friendly" (IMO, 2014b) (p.1). Usability, or *user-friendliness*, is defined as the extent with which a product, service or system can be used by a targeted user group in their particular context to achieve its desired goals with effectiveness, efficiency and satisfaction (ISO, 2002, 2010). Effectiveness refers to the extent to which a desired effect is produced, a task completed or a goal achieved. Efficiency refers to the amount of effort, errors, expenses or time required to finally accomplish a goal effectively. Lastly, satisfaction is about the level of comfort, contentment and acceptance using a product to achieve specified goals. If effectiveness, efficiency and satisfaction are attained when using a given product, one can say the product is usable. In the end, the efforts of making a product usable can avoid use problems and safety risks (Jordan, 1998). It can promote increased productivity when users are able to concentrate on the task rather than on the complexity and ambiguity of the tool; reduce propensity for errors when dealing with well-designed interfaces (Maguire, 2001); reduce training and support needs and costs by improved learnability while using the product (ISO, 2002; Maguire, 2001; Norman, 2013). Social and economic benefits for the stakeholders can also be achieved (Maguire, 2001). For example, human well-being, accessibility and sustainability can be improved, reducing discomfort and stress (Maguire, 2001), and neutralizing possible hazards of use on human health, safety and performance (ISO, 2010); heightening the reputation, competitiveness and commercial success of the organization in the marketplace (Jordan, 1998; Maguire, 2001).

When assessing the usability of a product, its effectiveness, efficiency and satisfaction can be measured at different points in time and within a spectrum of tasks. For example, the lower the struggle in trying a new product for the first time, the higher the *guessability* (Jordan, 1998); the faster a user becomes competent at performing a task using the new product after the first try, the higher the learnability (Jordan, 1998; Nielsen, 1993); the quicker a user can get back on track using a system after a long period of disuse, the higher the *memorability* (Nielsen, 1993) and re-*usability* (Jordan, 1998). The implementation of usability evaluation methods is about having subject-matter experts examine the usability-related aspects of a design/user interface (Hornbæk, 2006; Jordan, 1998; Lewis, 2014; Nielsen & Mack, 1994), fostering a human-centred design process (Holden et al., 2013; Jordan, 1998; Maguire, 2001). A lack of user involvement might implicate the risk that the new tool or interface does not entirely fit the user, the purpose and context of use in actual practice, and that user acceptance drops. This can be avoided by applying a series of usability methods that call for the active participation of users in the iterative design process, the thorough analysis of user and context requirements, the appropriate distribution of functions between technology and user, and the input of multiple experts (ISO, 2002; Maguire, 2001). Usability tests can resort to a number of methods for quantitative and qualitative data collection directly with the users to support the human-centred process. Other methods that do not require the users to be directly involved but that complement active user involvement can also be useful (ISO, 2002). Methods can range from observations, performance-related measurements, critical-incident analyses, questionnaires, interviews, thinking aloud, model-based approaches and expert evaluations (ISO, 2002). There is not one optimal participant sample size that fits all usability tests, but in some cases the first five participants will already identify 85% of the usability issues (Lewis, 2014). It is essential that human factors specialists are involved in this process (ISO, 2002; Man, Costa, MacKinnon, & Lundh, 2018) along with the developers and users.

1.4. Proof of concept/Perceived usefulness

Now, usability and usefulness may be seen as different concepts. A product may be usable and help a user achieve his/her intended goals in an effective, efficient and satisfactory manner, but perhaps this does not necessarily mean that it enhances his/her performance compared to other existing tools. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989) (p.320). Usefulness has also been described as "the degree to which a specific information item will serve the information needs of the user. Usefulness may be determined by: (a) inherent attributes of the resource, as semantic entity and as an object; (b) its applicability to specific information seeking contexts and work tasks" (Tsakonas & Papatheodorou, 2006).

1.5. Aim of this study

The BalticWeb website prototype and its four services were tested in this study for a given route planning and navigation exercise and scenario, in a simulated environment at the premises of Chalmers University of Technology. This study assessed proof of concept of the prototype and services and explored how they were perceived by experienced mariners using a mixed-methods framework. As the website and services were meant as an aid to existing bridge systems, it was important to have a good understanding of baseline operations and systems, without the intervention of new prototype as well. Hence, this study involved a control/baseline and an experimental/intervention condition. It is important to note that this research was not intended as an evaluation of the different voyage plans or navigation performances of the participants.

2. Methods

2.1. Study design

This study had a quasi-experimental design (Shaughnessy & Zechmeister, 1994) consisting of five days of control/baseline condition and four days of experimental/intervention condition. The first condition ran the test scenario utilizing solely existing bridge equipment for voyage planning and navigation. The second condition had the same equipment complemented with the BalticWeb prototype presented on a 360-degree laptop/tablet through voyage planning and navigation. Before the study with test participants, a two-day pilot study with two in-house project members of a navigational background (39 and 40 years of age) was performed as preparation (Lewis, 2014). However, for the pilot study only three of the BalticWeb services were ready to be tested (the maritime safety information service and the no-go areas service were ready, and the route optimization service could be simulated for this occasion).

2.2. Sample

The initial plan was to recruit twenty participants; ten for the control condition and another ten for the experimental condition. The twenty participants would be divided into pairs and each pair would perform the test exercises during a full day, making up a total of five days per condition. The sample size and amount of days were limited by the monetary resources within the project. The recruitment process, however, rendered only a total of eighteen participants; ten for the control condition and eight for the experimental condition, dependant on the participants' own availability to participate.

The participants were recruited from an existing database within the university, through announcement on social media networks, and with the help of project partners and their contacts. They were not selected at random. The purposeful sampling (Creswell & Clark, 2011) consisted of a recruitment and triage process to make sure participants with the relevant background and experience were selected and distributed into the control and experimental conditions to balance out the groups and not pair up co-workers. Each applicant filled out in advance an individual informed consent form and a demographics form electronically.

There were no repeated measures (a between-subjects design was used). On each day, two participants played the roles of bridge captain and officer of the watch for the voyage planning and navigation sessions. In-house bridge simulator instructors/managers played the role of other vessels as needed, and a local VTS operator was invited for the role of VTS during the simulations. When not available, the bridge simulator manager would also play the role of VTS operator.

The eighteen test participants were of Swedish nationality, between 25 and 58 years of age (with a mean of 38 years old). Among the participants, 13 were ship bridge personnel, 2 were pilots, 1 a VTS operator, 1 an in-house simulator instructor (not otherwise involved in the project) and 1 a nautical editor of notices to mariners. Of the participants, 1 had less than a year of seagoing experience and of navigational experience, otherwise they ranged from 1 to 28 or more years of navigational experience (with a mean range of 7-9 years). Regarding ranks, there were 6 captains, 6 first mates, 5 second mates, and 1 cadet. Of the eighteen participants, 83,3% reported to have had prior experience passing through the Sound VTS area, although none of them claimed to be extremely familiar with the area.

2.3. Test Scenario

The simulated ship type and characteristics, as well as the simulated day, traffic and weather conditions, are described in Table 2.

Table 2. Description of simulated vessel type and characteristics, day and weather conditions.

Simulated vessel	• Ro-Ro passenger ferry with 182.6 meters of length, 25.5 meters of breadth (displacement 21104,0 tons) • Draught of 7 meters even keel • Maximum speed of 21 knots
Simulated travel day	• April 21st, 2017 (day time navigation scenario) • Medium dense traffic • Normal weather conditions for the area (good weather, no tides)

2.3.1. Briefing and familiarization sessions

For both test conditions, a short briefing was held every morning explaining to the pair of participants the project, the characteristics of the voyage and vessel that were going to be simulated, and the data collection equipment. The participants and project members involved also had a chance to introduce themselves and their professional backgrounds. For the experimental condition in particular, a familiarization session for the BalticWeb and each available service was also held following the generic morning briefing, usually by one of the BalticWeb developers. After this BalticWeb introduction, the participants were given a chance to have a more hands-on familiarization and become acquainted with the tool following a number of short predefined exercises to try out the services (Stanton et al., 2013). For this, a different geographical location (the Great Belt) was focused on the BalticWeb chart to keep it as separate as possible from the actual test scenario (the Sound VTS area). During the first half of the experimental week, a BalticWeb developer was present for the whole duration of the study days to provide technical support as needed.

2.3.2. Voyage planning exercise

In the voyage planning session, for both the control and experimental conditions, the participants were instructed to plan a route from anchoring area Charlie/Bravo outside Gothenburg Sweden to berth Basen IV of Gdynia Poland (see Figure 2), with estimated time of departure 21st of April of 2017 at 08:30/45 UTC, and estimated time of arrival 22nd of April of 2017 at 08:00 UTC. How to proceed with the voyage, taking west or east, north or south channels was up to the participants based on their knowledge and on the information available and used.

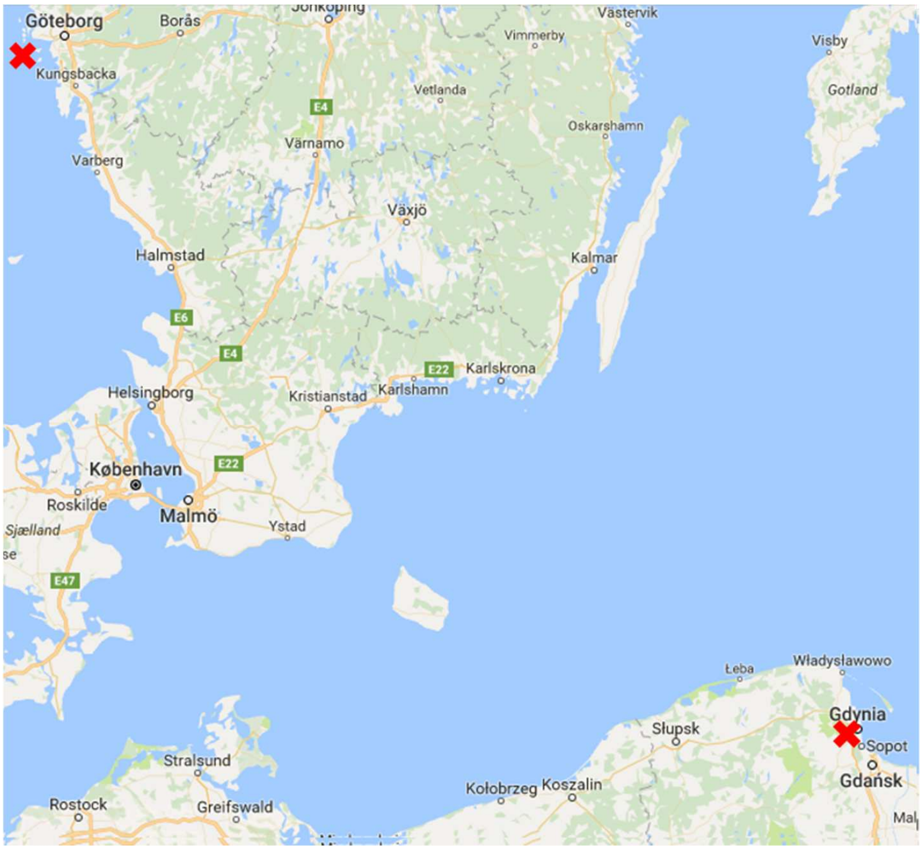

Figure 2. Complete route Gothenburg-Gdynia, going through the strait between Sweden and Denmark, for both control and experimental conditions.

The participants were also instructed to place more attention and effort onto the section of the voyage before entering the Sound VTS area and navigating through the strait between Sweden and Denmark, which was the excerpt that was going to be simulated for navigation. These instructions were specified in a printed document and also presented on a stationary slide on one of the screens in the route planning station so that they could be consulted at any time. The voyage planning session was given approximately two hours. The control and experimental groups used the available route planning software on one desktop computer, the TRANSAS Marine Navi-Planner Software, otherwise used at the university for student and professional training. Since it could not be taken for granted that the participants were used to this particular software, the bridge simulator manager accompanied them through the route planning exercise to provide hands-on support with regards to the technicalities of the software as needed. This did not include any advice on decision-making that could affect the results. The participants had also access to printed resources such as the Pilot Card, Wheel House Poster, applicable Admiralty Sailing Directions, Tide Tables, List of Lights, Radio Stations, Pilots, VTS and Ports, VTS Sound pdf, the weather forecast for the particular simulated day, notices to mariners from Sweden and Denmark, *Navtex* (both printed and on the ECDIS on a separate screen) that included cable work west of the island of Ven, and Danish guidelines for navigation in their area. Paper and pencil were also provided to the participants, and they were given internet access at will. On top of this, the experimental groups had the additional device (a 360∘laptop/tablet) with the BalticWeb (see Figure 3). In this case, the participants were requested to test the route optimization service on the BalticWeb by uploading their original route onto the BalticWeb and requesting the optimization. After receiving the optimized version of their route (a pre-arranged default optimized route was used to mimic the real process) after approximately five minutes, the participants were asked which one they preferred and would proceed with – the original or optimized version. They were also requested to test the VTS reporting service when they wanted to do the reporting activity. The MSI and no-go areas services could be used at will.

Figure 3. A group of participants of the experimental condition doing the voyage planning exercise. In front of them is the voyage planning software where participants planned their voyages, and next to it – on the round desk – is the laptop with the BalticWeb. The printed resources are seen in the bottom pictures (by the window), and an additional screen with the Navtex integrated in the ECDIS was also available in the back of the room (not included in this figure). The desks for briefing, familiarization, and debriefings are also seen in the bottom right picture. A desk with the eye-tracking equipment was placed in the same room (not included in this picture).

2.3.3. Voyage execution exercise

For the navigation exercise, the participants were taken to a stand-alone full-mission bridge simulator with an electronic vessel conning station, a 180 degree/back-of-the-ship visual view, and two Radar/ARPA and ECDIS/AIS units (see Figure 4). Running the full planned voyage was naturally not possible due to time constraints. Seeing this, only an excerpt of this voyage was chosen to be executed in the navigation session with the duration of approximately two hours. With the start of the simulator exercise at 13:15 UTC simulator time, the vessel was expected to enter the Sound VTS area at 13:30 and report. Figure 5 specifies the approximate VTS reporting location as well as MSIs created for the test scenario to see how the participants would work with this information and to test if the participants of the experimental group would find use in the MSI service of the BalticWeb.

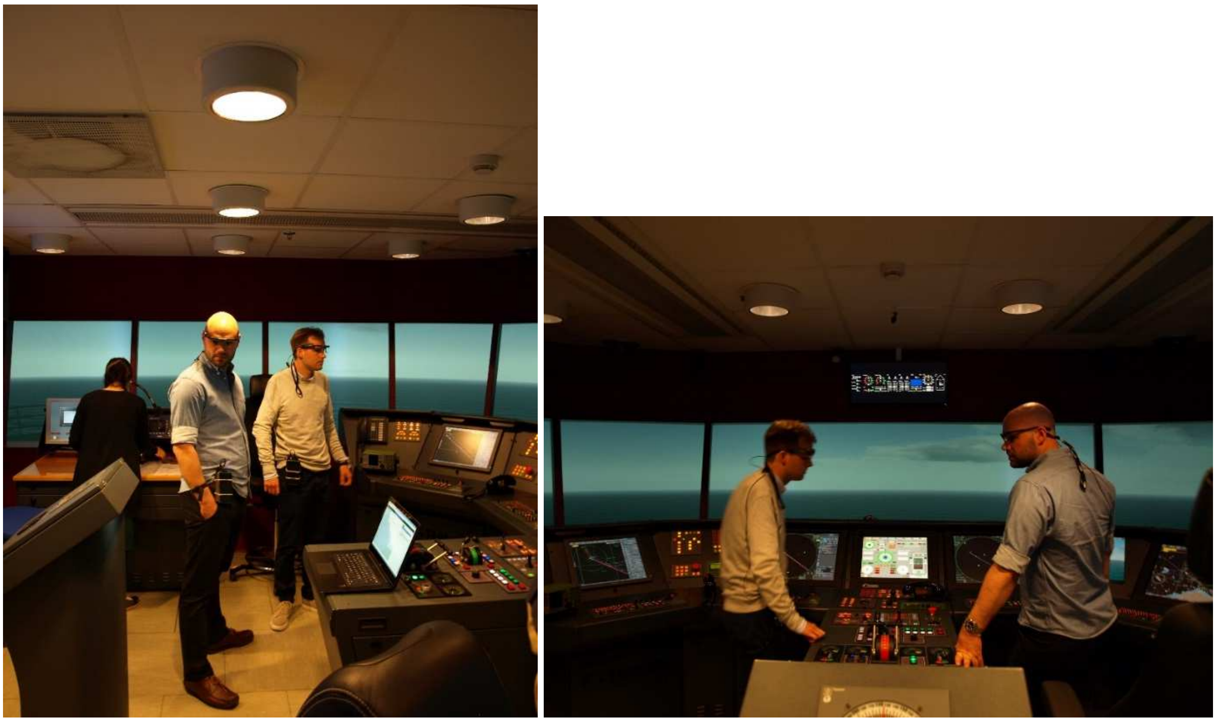

Figure 4. A group of participants of the experimental condition during the navigation exercise. They each had their own conning stations and there was one BalticWeb laptop as can be seen in the left picture.

1) **VTS reporting:** Entering the Sound VTS area. Regardless of reporting method used during voyage planning (email, online report), a VHF radio call is mandatory.

2) **MSIs**
   a) Missing buoy warning coming in as printed Navtex during navigation;
   b) Cable work notice at island Ven (already known at voyage planning stage);
   c) Drifting container warning coming in from the Sound VTS through VHF radio during navigation.

Figure 5. Navigation scenario with VTS reporting and MSIs' approximate locations. The MSIs were created for this scenario to test how the participants would work with the information available and if the experimental group would find use in the BalticWeb's MSI solution.

The control and experimental groups could bring whatever printed or written papers into the simulator for the navigation exercise as desired. The experimental group was still given access to the BalticWeb laptop during navigation. In this occasion, the VTS operator also had with him another 360-degree laptop/tablet with the BalticWeb in the control room as the purpose of the EfficienSea2 project is to provide all relevant stakeholders access to the same information (although data was not collected in this study from the perspective of the VTS operator).

Regardless of the VTS reporting method used during voyage planning (e-mail, online report), a VHF radio call was still mandatory when entering the Sound VTS area, hence this was performed by the participants as per Figure 5. Of the MSIs created for this study (cable work, missing buoy and drifting container) (see Figure 5), the navigation exercise only allowed time for the participants to pass the missing buoy location, and see the cable work and vessel coming ahead on the ECDIS depending on speed. Nevertheless, the intention with the cable work and drifting container was that they would still need to plan ahead and integrate them in their voyage.

2.4. Evaluation protocol and data collection

A mixed-methods research approach to data collection and analysis (Creswell, 2014; Creswell & Clark, 2011) was chosen, where qualitative and quantitative data complemented each other. More specifically, an embedded convergent parallel mixed-methods design (Creswell, 2014; Creswell & Clark, 2011) where the qualitative and quantitative data complemented each other and were both collected during the same occasion. The evaluation protocol of the control condition was divided into four main stages: the voyage planning exercise and posteriorly a collective interview session, the navigation exercise and a final collective interview session. For the experimental condition, there was the additional familiarization session starting off the day, before proceeding with the same stages.

2.4.1. Direct observation

The full extent of the simulator trials was observed (Patton, 2002) by two human factors researchers, and hand-written notes were taken (Patton, 2002). The think-aloud technique was encouraged throughout the sessions to get the participants' verbal descriptions of their tasks and decisions but without impacting their operations (Lewis, 2014; Patton, 2002; Stanton et al., 2013), and the observers could intervene to ask clarification questions with minimal impact to the exercises (Patton, 2002).

2.4.1. Visual data

The familiarization, route planning and navigation sessions were captured through screen-capturing software tools for the planning software and BalticWeb (with audio), the radars and ECDISs (no audio). During navigation, a surveillance camera in the simulator room was also used (no audio).

2.4.1. Eye-tracking

During voyage planning and navigation, the eye-tracking equipment Tobii Pro Glasses 2 was used on both participants to capture how the systems were utilized and time was divided among them, and how quickly certain services and functions could be found and used (with audio). The glasses were connected to software Imotions 6.4 for rendering and analyses.

2.4.1. Collective interviews

The collective debriefings (Patton, 2002) after each exercise departed from a set of semi-structured questions regarding the advantages and disadvantages of existing systems, and of the website and the services and how the participants experienced their usefulness during the two exercises. The questions also included discussing common procedure, what was missing and how the new tool could or could not support that.

2.5. Data analysis

The data collection methods produced visual data (Silverman, 2014), audio-recordings (Patton, 2002), and numerical data. As the audio-visual material resulted in numerous and extensive files, they could not be transcribed *verbatim*, but detailed notes were taken and participant statements highlighted, taken into simultaneous consideration with the visual images and the observers' hand-written notes. The notes and statements were then clustered into themes to describe what the participants experienced and how they experienced and perceived it in a phenomenological analysis (Creswell & Poth, 2018; Patton, 2002). The analysis of eye-tracking data was performed with the appropriate software and merged/consolidated with the qualitative data to be able to make more complete meta-inferences (Creswell & Clark, 2011).

3. Results

After an initial data analysis, practical user input on the usability of the BalticWeb interface and its tested services was reported to the BalticWeb and service developers within the EfficienSea2 project so as to make design improvements. The user input included:

a) BalticWeb platform and interface issues (e.g., size of the text on the screen; website updating speed; being automatically logged out after idle period and losing uploaded route);
b) what each service was providing or not proving (e.g., route optimization did not account for TSS nor was it possible to request an optimized route by just providing origin and destination; there was no chance to compare the original and optimized routes in relation to no-go areas and MSIs; there was no opportunity to save pre-filled information for future VTS reporting);
c) how the information was being displayed (e.g., service description disappeared from the screen once the optimized route button was pressed; difficulty visually comparing the routes in the route optimization page; problems finding the VTS reporting function on the homepage; issues with the MSI side list in relation to the MSI symbols on the chart; no differentiation between NWs and NMs, old and new, seen and unseen MSI symbols);
d) how the navigators were required to interact with the interface (e.g., users needed to scroll down the route optimization page to discover that the service offered a more detailed report about the optimization rather than just the waypoints; no clear indications existed on how to fill in the VTS reporting template, and red error boxes did not elaborate on what was wrongly filled in or how it should be corrected).

Beyond this initial analysis and feedback, general gaps and opportunities were identified regarding today's bridge systems and procedures, and regarding the potential future for BalticWeb-like solutions (presented in the following subheadings), and these are of relevance to the wider e-navigation community. This section of the paper will focus on such aspects from the empirical data on how planning and navigation were done with typical equipment and procedures and with the BalticWeb.

3.1. Voyage planning and navigation operations

This data collection was done in pairs of participants for the route planning and execution exercises to play the roles of bridge captain and officer of the watch as per regulation. However, it was reported that commonly one navigator only will make the route plan which will then need to be approved by the captain before departure, and one officer of the watch will commonly be alone navigating the ship during channel passage.

Route planning is a strategic activity for anti-grounding, anti-collision, communication procedures with shore-based stakeholders, and scheduling and fuel efficiency in some cases. This requires the consideration of static parameters when drawing the route and the planning for some dynamic parameters such as the weather. The route planning process typically involved the following steps, not necessarily in this order:

- Marking waypoints from point of origin of the vessel to point of destination. These waypoints are set within the navigable waters according to the ship's draught and typically within the COLREGs'[2] Traffic Separation Schemes (TSS)
- Following local traffic patterns and recommendations, such as what channel to take for a southbound route or a northbound route; what is the expected traffic (e.g., ferries, fishing boats, and what is the density)
- Integrating speed limits if any, with the vessel's draught, shallow waters and squat effect

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[2] COLREGs refer to anti-collision regulations (IMO, 1972). This works similarly to road driving regulations in marking the waterways where ships are recommended to navigate. Ships going in opposite directions will then be separated by a line marked on the sea charts.

- Following a schedule and/or fuel optimization policies if applicable, and readjusting the speed or waypoints
- Considering weather, water current, tide forecasts
- Integrating notices to mariners and restricted areas, possibly needing to readjust waypoints
- Planning for reporting tasks, such as VTS reporting points and information, pilot pick-up points and information if taking a pilot is mandatory, recommended or preferred
- Running the route planning software's route check function to identify any unnoticed dangers in the delineated route and possibly fine-tuning details.

A pilot who participated reported pilots may make a contingency voyage plan to be able to choose during navigation depending on circumstances (also see Costa et al., 2018).

Voyage execution is a tactical activity that relates back to the voyage plan, but where new dynamic information is integrated: "*You must constantly evaluate how you proceed. It could be a traffic jam with a lot of vessels (…)*". I.e., the navigators follow the planned route and planned procedures while processing new information such as the traffic they can observe outside the window, the radar, the ECDIS and AIS, VHF radio communications between ships and between ships and shore, incoming *Navtex* messages, and alarms. While processing this new information, the navigators will "*think ahead*" by playing out different scenarios in their heads and trying to predict the next ship movements and manoeuvres that they and others will make. With this, certain measures may be required to be taken, such as contacting other vessels to understand intentions. Things that were planned in the original route may need to be adapted during navigation (e.g., taking another channel due to a new *Navtex* message; changing speed to meet a specific vessel). Route deviations occur as needed and the objective is to get back on route as soon as possible.

3.1.1. Information dispersity and inaccessibility

Route planning is an activity that requires the consideration of numerous variables (local geographical and institutional information, weather forecasts, etc.) and information sources (planning software's and ECDIS' functions; paper or electronic admiralty books; official websites or documents about the VTS, ports and local recommendations on how to navigate the area; weather websites, smartphone applications and service packages for purchase; paper or electronic *Navtex*, notices to mariners; web-browsing) to help plan for and mitigate potential risks in navigation. In this activity, it is easy to forget or miss certain variables, to need to consult many sources to find certain details, or even to not have easy access to relevant information when planning a route from the start, especially to a destination the crew has never navigated before (also see Costa et al., 2018). During the two-week trials, participants forgot to account for air draught, MSIs and weather/water currents, even at times where they did eventually notice the resources provided, according to the eye-tracking data; and could not find details about pilots and Gdynia port information.

To cope with the issue of numerous variables, a participant mentioned having onboard checklists for voyage planning, reminding them of certain steps to take. Interestingly, they also commented on the fact that one must not become over-reliant on checklists and forget to take other potentially important parameters into account that are not included in the checklist but that a new destination may require, such as different ways or information to report to a VTS centre: "*I think it's easy to get complacent when you have a checklist*". Another participant mentioned they will for example trust the VTS to contact them if a) they miss an important reporting detail, and b) if they miss an important MSI. So, some mariners will not overdo it when planning a voyage when they know that the VTS will alert them or ask questions if they are doing something wrong. Especially for cruise liners that do the same voyage all the time, they may not need to be so strict with MSIs compared to tankers for example, that are strictly vetted and need to be meticulous with these aspects in voyage planning.

VTS area information. Although the charts have overlays with reporting lines, this was not always easily noticeable. The reporting line to the Sound VTS was searched on the planning software, on the VTS printed information or electronic information, or on the BalticWeb (during experimental condition). There was one occasion where finding the reporting line on the planning software ECDIS took longer than on the BalticWeb because overlays were not active on the ECDIS. At another occasion, a participant group missed the reporting line on the ECDIS during navigation and reported a bit later than intended. Participants also tried to find information of whether this was an area where the VTS would order to wait or if it had a "*first in first out*" policy, but because one of the participants was familiar with the area, she knew the VTS here did not coordinate the traffic that way.

Participants also wanted to see the schedule of the ferries in the area – those participants who already knew that it would be an issue not to overlook. Participants could not find the phone number to the air traffic controller regarding the air draught, but assumed the VTS would take care of this.

Pilot information. Participants took time to find pilot boarding coordinates. In one case, this could not be found at all and so the participants assumed a random location and planned to get into VHF radio contact during navigation. Hence, it seemed useful to have integrated on the ECDIS pilot boarding points and information. The same information was deemed useful on the BalticWeb besides integrated weather and lighthouses.

Depth information. Seeing certain depth information on the charts for the Drogden channel for example seemed difficult. It was mentioned that this is a question commonly received by the Sound VTS, and finally the reason behind this was suddenly understood as soon as the participant who is a Sound VTSO experienced these charts himself. The VTSO noticed that the chart on the planning software did not have easily available depth of 8 meters indicated for the Drogden and Flinttännan channels: "*Mariners always call us to ask the depth in this channel and looking at this ECDIS I sort of understand why!*". He noticed later it was available but he needed to actively look for it and it showed below on the interface in the additional information of the chart. Some of these additional information notes though were perceived by him to have a lot of "*jumbled information that I have absolutely no use for*" beyond the actual useful information that he needed.

The Swedish Maritime Authority website was also used by other participants to look for depth information and this was eventually found on the Sound VTS website. Other participants found the depths on the paper admiralty books instead.

Participants tried as well to find speed restrictions and could not find any. It was not clear for navigators unfamiliar with the area that they could not find this information simply because there were no speed restrictions for the area.

Foreign ports information. Finding ports, reporting points and regulatory areas for Gdynia was not straightforward. The paper Admiralty books and Polish websites on Google were consulted. In one occasion, a participant used Google Maps to see the ports of Gdynia because he could not find them elsewhere at the time or see them on the electronic charts in the planning software: "*Where do I find those? Internet? Probably google it*". This could have possibly been solved with a chart update in the system, which did not have all approved ENC charts.

Weather information. Participants wanted to find weather and water information for the Sound VTS area and used the ViVa app on a smartphone. They could not find it at the time and could not find if there was a ViVa station for that area on the Swedish Maritime Authority website ("*Strange we can't see it here*"), so they tried to Google it some other way, but could not find it either. They eventually gave it up because they expected the weather to be "*negligible in this area*". In the meantime, a participant found the printed water currents that we made available for them and confirmed it was negligible.

3.1.2. Geographical familiarity

Prior experience sailing a particular route or prior knowledge of national procedures plays a role in how fast a route planning process can be. Information gathering for a route from A to B is faster if the navigators already know a) where to look for the information, or b) what that information is and can skip looking. Being that the participants were Swedish and that the test scenario was for the most part taking place along Swedish coast, the majority of them had an idea of the regulations and specificities of the area. One example was of participants choosing to navigate west of the island Ven based on familiarity that north-bound vessels would go east and south-bound would go west, like a roundabout ("*I want to go around here. I expect other traffic to expect us to go that way*"). Another example was of the knowledge that there were ferries coming out at a certain time from a given direction, or that there was high density of fishing boats ("*It is advisable to follow the TSS since there is a lot of fishing vessels*"). This was relevant to know during planning so that they could adjust waypoints to have more or less space in the fairway. This was, however, local knowledge that was not explicitly written.

There was a printed resource on how to navigate on Danish waters. A participant checked this to find out if they needed to take a pilot, but his co-participant knew due to experience that this was not mandatory in the area. Participants tried to find out whether reporting to the VTS when leaving Gothenburg was also necessary. This information was often not found, and someone would be acquainted enough with the area that they knew it was not needed. One participant had been to Poland before so he knew how to find reporting information for Poland and skipped searching for it. Otherwise, in most cases, this was something the participants took time looking for in the admiralty books or trying to google it.

However, prior knowledge can at times lead to complacency, assuming that things are in a certain way without checking official sources to confirm that they were right and that things have not changed in the meantime. One example of this was to choose to go through the Drodgen or the Flinttrännen channels depending on their prior knowledge of the water depth. Participants with previous knowledge of the area assumed one channel was deeper than the other, which indeed used to be the case but no longer is. Another example was that the Sound VTS required an e-mail to be sent in advance with reporting information. Although this was not incorrect, this kept some from noticing that the VTS had implemented an online reporting format as well.

For those more unfamiliar with the geographical location, the BalticWeb was used to learn about traffic and density in the area to decide which channels to take. When most south-bound traffic was going west of the island Ven, for example, the participants would follow.

3.1.3. Incorporation into existing ECDIS

One aspect repeatedly pointed out by all participants was the advantage that the electronic admiralty books present over the paper ones these days, and the comparative simplicity of finding needed information in them. One can zoom in and out on the maps and search for the information one needs for a specific location. One buys a license and gets them updated automatically. Although mostly not integrated into the route planning software (also see Costa et al., 2018), the electronic admiralty books still represent a step into digitalization that has facilitated route planning.

It was suggested that – especially when less familiar with a geographical area – having integrated information in one place would be the most convenient option: "*Integration and standardization is always better*"; "*We would prefer that there were only one system – the ECDIS – with everything. So we'd do the planning and everything on ECDIS and we'd get all the information there. That would have been the perfect scenario. But like you said before, ECDIS has a lot of regulation and you have to fulfil the formal standards of the ECDIS, so to implement new functions – that takes a lot of time*"; "*You can't have that many sources*". In this sense, one participant openly stated about the BalticWeb that – although he said that had the BalticWeb been approved and available onboard his ship he would probably make use of it – "*it will maybe be even one more source to find the information. There is actually a risk today that you have the information in too many ways. For example, the Navtex – you got it printed out, you got it inside the ECDIS, and now we got it here [on the BalticWeb]. It's the same information but it can be too much to check all those three or four places all the time. We don't have just that simple time onboard. It's too much other administrative things to do*".

3.1.3.1. Cognitive overload and clutter

Participants mentioned information overload and repetition in more than one place, and in this case of information that was deemed unnecessary, such as repetition of engine information on screens, which was deemed "*information* *overload*" and unnecessary from the point of view of navigation: "*For example, one information overload could be engine information. As a navigator, you're not interested to know exactly what's happening in the engine, because you have engineers in the engine room. What you're interested in [is] – what do I need to do? Because on the old ships, often you had like two lights as in slow down and stop. So, if the engine needs to be slowed down, then ok, I slow down, or do I need to stop. I don't need a screen that says 'oh, the boiler temperature is this much and we have so much fuel and we have this and that. Yeah, sometimes it's over fancy engine room computer, it's not important.*". It was suggested this information could be moved to back bridge if needed but not to conning position as it is today.

In the same sense, it was suggested that a route planning station remains separate from the conning station, as they are two different activities and require different functionalities. Nonetheless, integration of bridge systems and importing and exporting is essential.

Already today there is unnecessary information available, there is clutter on the ECDIS screens ("*This is the problem with the ECDIS. It's just a lot of information*"), and hence incorporating more functionalities could worsen it. Clutter versus simplicity was an aspect of concern for the participants. So, although integration seemed important for the participants, there seemed to be a complicated compromise between integration and not having too much clutter on the screen. Participants suggested having the possibility to turn overlays on and off as a solution, as is already possible today for many functions. When more and more information is gathered on one screen, the more this needs to be done in a smart way: "*For me, it's nice to have as little information as possible. I'm not interested in all the light lines, you know, it makes the screen blurry. But of course, necessary information, it would be really nice to have it – I think – on one screen, everything. But of course, it cannot be too much because then you don't see anything… it's a tough puzzle to solve*".

3.1.3.2. ECDIS standardization

Although the basics of the ECDIS are standardized, manufacturers will come up with own alternatives of the same product for competitive advantage: "*The user interface is different. The functionalities are the same, but the GUI is different.*" The 'different GUI' sometimes includes well-liked innovative functions that not all manufacturers offer because they are not standardized, and hence are underexploited in the sector and should potentially be implemented in a more standardized manner worldwide. However, this is not only limiting in terms of timeline, as standardizing something is usually a long process, as well as it is limiting from a manufacturer's innovative and competitive advantage perspective. So, besides the ECDIS itself already setting up mariners to disparities, a lack of training was also identified (also see Costa et al., 2018).

S-mode was discussed during baseline week. This refers to standardization of bridge systems onboard. It is important for users that systems are standard, instead of different manufacturers making different solutions. But from the perspective of the manufacturers this may be limiting, so there is a limit to what is standardized so that manufacturers can innovate and compete with each other: "*I think the standardization is an issue. I heard that they were in the IMO conference on ECDIS standards but all ECDIS developers want to go their own way to set functions and to get market shares and so on, so they're not so keen on setting some kind of standards, but I think that's a drawback for the safety of navigation, for the users. I may be talking about education-type-specific. Think you would have that with cars – you can borrow my Volvo. – Sorry, I don't have a Volvo-type-specific education. This is just a stupid thing. So I think radars is still fairly easy. You know what you're looking for. Base functions is always on top of the screen in the four corners. And I think that's fairly easy to find all the important functions." (…) "Going from radar to radar, I think that's easy, but going from ECDIS to ECDIS, that's really difficult. You know what you want to do, but to find the functions is really difficult in the ECDIS systems, I think. I think it's still after 10 years, they haven't improved that to help the users (…) You can understand that they want to develop functions, but that's been the talk of the S-mode, of some sort of standardized start-up screen so you can get the baseline correct and then you could get up, as you said, a more clear picture because I could agree that it's too much if you put on all pictures, and then you almost drown in information*".

3.1.3.3. Complexity and training needs

Participants seemed to have different information or knowledge about ECDIS functions. This points again at the complexity of this system and having to relearn it when changing manufacturers or versions, but also indicated the lack of training for known functions. Participants would not know how to use certain functions even though they knew of their existence or did not know they existed altogether (e.g., the planning software could have an overlay with the *Navtex* but this was not known by all participants so in some cases things like a missing buoy would be manually added to the plan if found on the BalticWeb or printed *Navtex*). Participants reported they could get a week of intensive training for ECDIS or receive a new ECDIS version and have to learn it on the job.

In a new ECDIS system it may be harder for mariners to fully know what to expect or what they can find in the system. This may partially explain how certain participants did not notice the *Navtex* functions on the ECDIS even when working with the same *Navtex* information. These symbols were not noticed probably because the mariners did not expect them to be there, as one who noticed was surprised it was there. They will not find what they do not look for when their expectation would mainly be to find the *Navtex* in the traditional way instead. Another speculation is related to ECDIS clutter, as other information in the charts may have made the MSI symbols less conspicuous.

With more technological availability, the ECDIS can run the risk of becoming more and more varied in terms of available functions across manufacturers. This means that without them being intuitive, the complexity of the system is increasing. More intuitive systems and appropriated training is needed to cope with a developing and growingly automated system: "*Make it as simple as possible. If your grandma can understand, then I guess you can reach anybody*"" – said one participant referring to the VTS reporting system.

It was suggested that e-navigation may be taking it too far with complexity, as it was suggested that highlighting a *Navtex* on the ECDIS is possible today but it is too complicated to do this manually while navigating. In this sense, a participant said that they used a whiteboard onboard to write *Navtex* and that "*it doesn't have to be that complicated (…) For me, that's good enough*". However, another participant interjected in a humorous tone "*that's not e-navigation [laughter]*". Indeed, the ECDIS should offer friendlier ways to process and work with the dynamic information during navigation, especially considering those navigators travelling through unfamiliar waters.

3.1.4. Ship type specificities

It was noted that different ship types will have different requirements with regards to what to prioritize during route planning and navigation. For example, participants who were serving on passenger ferries, pilot boats, and tankers for the offshore sector talked about their procedures: passenger ferries, which go back and forth along the same route do not need to plan the same voyage from scratch every time. They do, however, need to consider schedule, and fuel consumption is an emphasized aspect of their operations. For tankers there are no strict schedules to follow and fuel consumption is not as much of a concern. As they have a wider range of destinations, planning a new voyage from scratch is routine. Considering the cargo type, tankers can have very strict vetting of their voyage plans, of taking the recommended lanes, of their attention to navigational warnings and notices to mariners, and be more concerned with avoiding traffic-dense areas and close CPAs, and with following an optimized speed for their vessel and cargo type.

3.1.5. Good seamanship

Regarding how ships respond to each other and how action is taken, they can usually predict movements based on COLREGs. It is also based on experience and the "*gut feeling*" that is developed through time. For instance, why vessel A should overtake vessel B now or later based on the traffic situation depends on what "*just feels better*". When in doubt, navigators will commonly use the VHF radio to contact other ships and ask what their intentions are. This way, they can negotiate how to bypass each other.

Local waters may have specific regulations or recommendations on how to navigate their waters, and navigation in VTS areas may be coordinated by the VTS. When such local rules or external coordination do not exist, following basic navigation rules like the COLREGs was seen as common sense and good seamanship. This is something taken for granted as a shared view of navigation among mariners. For example, it is seen as good seamanship to leave as much space as possible in the fairway for other vessels to feel comfortable and pass safely. However, this good seamanship is not always encountered, and as was reported this can cause sour attitudes, misunderstandings in radio communication, and unsafe behaviour.

Common sense was perceived as a result of experience and cultural aspects as well: “My decisions were within the COLREG, but I mean, it is common sense. But the common sense is built on experience”; “Sometimes when you see some traffic, you wonder how is he doing and why is he thinking like that, and what is the reason he’s turned the ship some way I’d never want to do. This is compared with experience and cultural awareness, how you react in different situations. So, I don’t say we have better navigators in some country or some other country, but it’s different ways to handle different situations”.

Part of the experience that this common sense is based on is about learning how to give space to the other vessels to act: “Some people will be on the radio to establish contact and I understand why, but I find that typically if you just stick to the rules and just show the other vessel what you intend to do, that things tend to sort themselves out”; “You just get a feeling to – how would I be driving the ship if I were that guy? And so you sort of expect he will probably want to come here and then he will probably turn down here. And as soon as they deviate on that, you sort of like start wondering – why – what is he trying to do now? And sometimes it will be someone who just does something that you consider inappropriate or dumb”; “I would have done something else if I were him [the other vessel], but then it turned out that he had a plan (…) so it all made sense”, “You go to a point where you sort of assume that the other ship should be doing something, and then you reach the point where – ok, it seems they will be not doing it. So then I take action. It’s always about having a little margin for your options. And we had that margin at all times [during the navigation exercise]”.

3.1.6. Experience levels

There was an indication that the experience of the senior versus the young officers will cause a difference in reaction time to a certain imminent danger: *“I think I will be a little bit more laissez-faire. If there seems to be somewhat of a danger coming up ahead, my experience tells me it’s usually just best to do nothing until it becomes an issue. Whereas younger officers will be more inclined to maybe take action in a way that maybe sometimes is good, maybe sometimes not necessary”; “For a young officer this would be a problem because they would feel a need to avoid these ships [fishing vessels]. I would just go! If they come too close, I would honk the horn, make the move, until it became…Of course it can still arise dangerous situations, but my experience tells me it’s more likely that I put myself into a dangerous situation by actively trying to take their [fishing vessels’] manoeuvres into account than it is for me to end up in a dangerous situation because they failed to do something”*. This was reported as potentially being linked to them being *“young, eager, less experienced (…) a need to prove themselves. Whereas if you’re older, you don’t really have the need to prove yourself and you don’t really see the same issues as a problem”*. In other words, less experienced mariners are more alert but also more stressed and rushed into acting. Experienced mariners, on the other hand, remain calmer because they have learned not to intervene when not necessary. They also have more information and local knowledge, and hence do not need to put as much energy into it, although it can mean they take something for granted.

3.1.7. Use of paper charts, printed documents and hand-written notes

The subsections in Results are assuming that the mariners are using computer solutions, although it was called to our attention that some ships may still prefer to make plans on paper charts or at least partially have reporting information, etc. printed out on paper as well. During planning, although the participants would use waypoint notes/to-do lists/checklist functions in the planning software charts to emphasize reporting lines and marking what VHF radio channels to report into when entering the VTS area, for the details to report (e.g., draught, air draught) they often took hand-written notes that they would later bring to the conning station in the bridge simulator (they normally chose to bring vessel information, VTS reporting list, and a notebook into the simulator). MSIs that affect the voyage and VTS reporting information were usually manually typed directly into the charts of the planning software with a note/*infotex* on a route’s waypoint marking the position of the event, or by using a similar function, in order to have a reminder during navigation (“*It’s a requirement*” (for example for tankers); “*It’s very helpful for navigation*”).

Participants also reported that onboard they would normally print out certain information instead of hand-writing it, and then they would highlight some of it with a marker, and keep a dossier or folder with all the information for a given voyage, including printed charts of the planned route, VTS reporting information, etc.

Paper charts can also still offer an easily accessible overview, even if updating them manually takes time. Pilot charts from the UKHO have depths that are more trusted by the mariners than the ECDIS charts for a region where they never sailed before. Pilot preferred paper charts because it's a lot less to consider "*because I like paper charts more. I think they are faster. Much faster! (…) Most probably because I'm used to it. And I found them very reliable and easy to use. They're always working, paper charts. What can go wrong?*". She would then print out all the voyage plans with notes throughout to have a better overview of the geographical area during navigation. Screens are too small for this. Though, other younger seafarers that need to be the ones doing the voyage planning and paper chart updates think that "*Paper charts take too long time and the human error is big. I like the ECDIS, but I would still like to have 2 separate systems that cross-check each other*". During navigation, the mariners would have known the voyage by heart, but they would have also had everything on paper.

During navigation, in most cases, the participants would also run for a piece of paper and a pen once they received the VHF radio call from the VTS to inform about the drifting container during the navigation exercise. It was common to take notes of VHF radio communications of coordinates for certain events in the water. Either this or the replay button option on the console would be used on the VHF radio to re-listen to the coordinates. This technology is available but not available to all. The alternative was to contact the VTS again and ask them to repeat coordinates. The replay option was available during the trials but the participants were not acquainted with it enough to know it and most of the times assumed it was not available here.

In one instance, the participant typed in the coordinates directly into the ECDIS and hence did not need to write them down. But the information could be mistakenly written on the paper. And this was a task that often needed to contact the VTS again for repetition of coordinates because they had had no time to write down the coordinates. After this, they would insert this into the ECDIS manually when they found time. However, sometimes they would still leave a paper note at the screen or some form of message on a white board on the bridge for the next officer of the watch.

3.2. Potential of the BalticWeb services

According to the eye-tracking data, the four experimental participant pairs spent an average of 32,03 minutes using the BalticWeb during planning against 2,74 minutes during navigation. Without exception, the pairs seemed sceptical in the beginning of the navigation exercise when it came to taking the BalticWeb laptop into the bridge, as they did not foresee great value in it for this purpose, as well as they expected that they would be too consumed with navigation to use the BalticWeb. However, the MSI service was used during navigation, and there was also interest in seeing traffic density and patterns ahead of time. In both cases, there was admission from the participants that they felt pressured into giving the BalticWeb a chance during navigation: "*I was in my mind trying to find a use for it [during navigation]*"; "*For a planning stage, it's all right*"; "*It's more a planning tool*".

Overall, some participants perceived that the tool was immature for testing, although the MSI and VTS reporting services were the most appreciated: "*This programme was not ready for testing (…) it didn't add anything*". Integrated MSIs on chart already exists in some ECDIS although not in real-time which was considered good for safety reasons during navigation. The route optimization service was incomplete and similar tools already exist as well from other manufacturers. VTS reporting was considered a good idea to have it all in one platform for all VTS centres around the world and standardized, which does not yet seem to exist. But the online form itself is already being implemented in few parts of the world including the Malmö area simulated here. The no-go areas were just like the safety contours on an ECDIS and the weather on route function was not ready for testing. Also, some weather services already seem to offer weather-optimized route alternatives. The traffic visualization on the BalticWeb was also relevant but already existed on marinetraffic.com as well.

3.2.1. Vessel and traffic information: AIS, marinetraffic.com and BalticWeb

The BalticWeb was compared to marinetraffic.com. The BalticWeb provided AIS information about vessels, as well as the direct link to marinetraffic.com. Participants mentioned marinetraffic.com for getting more information about a vessel – commonly when the vessel name is missing from the AIS due to poor connection, or destination and ETA of a vessel not having been updated on AIS, or to get a list of targets (although that is also possible on the existing onboard systems). This website was mentioned by some of our participants and seemed to be common knowledge in the field, although this is a tool not approved by the IMO either. This supposedly presents more information about a vessel than the approved AIS information. marinetraffic.com will show the picture of a vessel for example, so that the mariner knows what a vessel looks like. Onboard ships today, marinetraffic.com can be consulted on a separate computer even if sometimes not physically at hand on the front bridge.

The traffic seen on the BalticWeb "*is basically what you would see on marinetraffic as well.*". The same information could be seen on the ECDIS with AIS information, but they were already plotting some vessels' vectors, and once you plot even more, you start to see "*spaghetti on the screen*".

The BalticWeb was also used with the intent of seeing traffic patterns in an area, just to get a feel for it, both during planning and navigation. There is a difference between traffic patterns and current traffic. Current traffic is what the BalticWeb shows for a specific time and place. The BalticWeb did not show traffic patterns; only current traffic. When planning a voyage, traffic can be predicted in the following ways: you know where the TSSs are, and you may be familiar with the area and know when a ferry is coming out etc. If you are not familiar with the area, there's still a possibility to check online the times for departures but you can only know this for those vessels that are going on a route, not for those that are more opportunistic vessels.

A participant also wanted to know how many ships pass the sound per day. He found this on Google eventually, but this was a newspaper article. The simulator manager was equally curious and found another statistic on Google. The numbers were referring to different statistics (36.000 in 2012 alone, but average 100/day. Simulator manager found 55.000 in 2012 instead).

During navigation, participants contacted a ship to see if the information from the transponder was true or not in terms of destination. This is manually updated by the crew and sometimes they forget, so "*you should never assume (…) always double check*"; "*if you look at the transponder and just go with that, you have just made an assumption*". The same thing happens with static draught (not dependent on bathymetry but dependent on cargo load) – this one is also manually updated and they may also forget to do this. But some navigators have a problem talking on the radio to double check this AIS information, so they only follow AIS. Pilots check marinetraffic.com for draughts but 1 out of 5 is not correct.

VTSO who participated mentioned that there are regulations/authorities that regulate ships updating their AIS to the right destination: "*It's actually a regulation. We [the VTS] chase vessels regularly regarding this, that they should have (…) all causal states will require you to have a proper destination (…)*" – "*Require, but it's not a must?*" – "*I don't know where it's actually based this, but naval controls around the world frequently go after vessels that have the wrong destination*".

3.2.2. Approval and reliability

The issue of reliability is at stake for institutional reasons: would a platform like the BalticWeb and its services be approved by the IMO before implementation? If not, this cannot be used as a stand-alone decision-support system due to the roles and responsibilities of ship captains and officers of the watch to have to rely on official systems to make their decisions: "*Will it be some kind of certified system? Are we actually allowed and can use this one? Because they sometimes can be very picky about where we find our sources. (…) I show them certificate after certificate where I'm finding my information*"; "*You can use this [the BalticWeb] as help but if they can prove that you only used this you can end up in jail*"; "*You have to check official sources*"; "*Not approved is a limitation to use it as a decision making tool – it can only be a help*".

3.2.3. Applicability of web-based platforms onboard (Internet connectivity)

Internet is required for the BalticWeb to function, and this is the reason why real-time push messages are possible. This was perceived, however, as problematic in various ways, one of which being the most immediate: internet connectivity limitations onboard. For a website like the BalticWeb to be functional and reliable, internet connection onboard would have to be improved first. Navigators mentioned experiencing problems with the internet connection at least once every week as it is today. Not being able to have push MSI messages via the internet would require another medium for this information to reach the ships in real time and this could potentially imply higher costs.

3.2.4. Placement of screen and system

Whatever the best solution may be, the majority of participants considered that unification with the ECDIS is always the best solution compared to adding more screens and devices: "*As much into the ECDIS as possible*". It was however called to our attention that too much clutter is not helpful either and could represent a safety concern: "*For me it's always do I need it for navigation or for planning?*"; "*Should be functions that would be able to click off/on if inserted as an overlay in ECDIS*" – referring to MSIs; "*We used it more like a Navtex almost*"; "*Usually less is more and more is too much*" – said one participant suggesting there should be a base map option for when the ECDIS starts to look too cluttered (as the S-mode option). On another note, a participant mentioned it was good to have the BalticWeb on a separate screen during planning, since the planning software under use in this exercise was "*not always easy to use*". Hence, ease of use seemed to be a factor that encouraged or discouraged how much information should be integrated at the same time.

As all of the participants identified the benefits of the BalticWeb as mainly a planning aid ("Personally I think the BalticWeb will not be used during navigation that much at all actually, no"; "If there is a navigational warning, you will get that information from the vessel traffic - from the VTS"; "It will be too much to go to the computer and check that from time to time also. I think personally I wouldn't use it when I'm navigating, no. But for a planning purpose, yes."), this would make more sense back bridge and it was also a matter of space ("Back desk because there is space for it").

However, there were a couple of potential uses for the BalticWeb during navigation although attention to give to this is very limited with the other competing and already approved systems. In this case, being back bridge would make it highly unlikely for the system to be consulted during navigation, as all attention needs to be put on the front bridge consoles and out the window. As a portable device, this would not be a problem, but there is limited space on the front bridge to position a portable device. Along these lines, a participant said that if the BalticWeb was to necessarily become an extra screen and useful for navigation, then this should be a fixed screen placed under their eyes since there is no space on the console for portable devices. If it were to only be for planning, then placing it in the planning station would be appropriate.

From planning to navigation, the participants would take information papers about the vessel and VTS reporting information with them. Unless written on a small piece of paper, there wasn't space at the station for papers either. Hence, the ship information papers were usually placed at the back desk which sit just behind the navigation station.

For example, during navigation, when receiving the paper *Navtex*, the participants would almost always look the coordinates up on the ECDIS rather than going to the BalticWeb to find it, because it is more reachable and more familiar, as well as they need to stay at the front bridge. Sometimes the BalticWeb would be consulted afterwards as a confirmation tool: "*You want to have as much into the system ahead of you. You don't want to have like 10 different systems. That would be too much to go around and monitor and check. As much input into the ECDIS is actually the best way, I think*".

Looking at the conning display above their heads was minimal compared to other screens. This may reveal something about the relevance of contents and/or bridge workload. Adding another screen to the whole set-up may not be viable.

3.2.5. Simultaneous use by different stakeholders

A platform like the BalticWeb was discussed as a platform that would need to be used by different stakeholders at the same time, such as the mariners and the VTSOs to be able to share information or create an awareness together of the information shown on the platform. Not just this, but also to take full advantage the technology offers the domain: for example, if the MSI function can be automated from the authorities, ships do not have to worry about typing anything manually into the ECDIS when in high traffic, or manually editing/removing old messages. The redundancy of having the *Navtex* overlay plus a typed-in note with the exact same information would also be avoided.

3.2.6. Service – Real-time MSIs and chart incorporation

This service was liked for being a real-time overlay on the BalticWeb charts. As it works today in route planning, MSIs will be received as paper Notices to Mariners, paper *Navtex*, or *Navtex* received in the ECDIS system. Participants would look at the lists of MSIs and try to identify which ones were of relevance for their voyage, and integrate them into their decision-making of where to set waypoints. Notes were made in the voyage plan to remind of the MSI. There was one occasion where the participants forgot to take MSIs into account altogether (control); one occasion using the printed lists of MSIs where a participant took for granted that the given coordinates for the cable work were referring to a different location where a similar MSI had recently occurred in real-life (control) ("*I should have checked the position (…) it is good to see on the screen!*"); one occasion where one of the participants noticed the cable work on the BalticWeb but failed to communicate this to his co-participant, who only accidentally noticed the cable work later at the start of the navigation exercise directly on the ECDIS (experimental); and one occasion where MSIs were partially considered but the cable work was still unnoticed until the navigation exercise (experimental).

As it works today in navigation, MSIs will be received as paper *Navtex*, *Navtex* received in the ECDIS system, or by VHF radio call from a VTS centre. The ECDIS system solution may only appear as text, which can be highlighted in a bright colour for the next OOW to notice, or can appear directly as geographically located MSI symbols on the map in some ECDIS cases like the service on the BalticWeb. Be as it may, *Navtex* are not released in real-time even on ECDIS brands that include *Navtex* functions. *Navtex* will still have to go through the designated official authorities before it can reach the individual ships, which may take a minimum of 2 hours. The way the sector deals with this is to have VTS centres inform over the VHF radio important new MSIs to ships in their VTS area. This way, the ships do not miss out on essential local MSIs that are not yet published on their *Navtex*. But the difference is that the mariners on the bridge that receive a VTS call about a new *Navtex* (or a new paper *Navtex*) need to take the coordinates down on paper and write a hand-written note for the next OOW, or input a note into the ECDIS while doing other competing activities on the bridge during close-quarter navigation. This was perceived as dangerous and hence sometimes information received on the paper *Navtex* or VHF radio needed to be ignored and returned to at a later point with less traffic density. When receiving the VHF radio call about the drifting container, two pairs asked for repetition as they did not manage to quickly find pen and paper and/or write the coordinates fast enough or keep them in their memory. In one case, a participant inserted the coordinates straight into the ECDIS as they were being transmitted, and one other participant wrote them on the phone since paper was not available. Generally, identifying the position was a time-consuming task and the eye-tracking recordings showed that the participants were continuously interrupted by other tasks while trying to identify the MSIs, requiring a shift of attention between tasks. Even when receiving the paper *Navtex* of a missing buoy, one group confused it with another MSI of an unlit buoy. The same group tried to identify the drifting container on the BalticWeb but could not find it although it was there. The BalticWeb required the users to zoom in and out or move the mouse for new MSIs to appear. For this reason, it would be assumed that there were no MSIs.

It was reported by the participants who served onboard tankers that vetting in this context is much more thorough and strict than for ferries, for instance. When receiving a *Navtex* on paper or VHF radio call, the OOW is required to confirm whether this will be relevant to the voyage, and make a note directly on the ECDIS for the next OOW to be informed: "*For me – I'm navigating officer – those paper strips come out and when they come out – because you can hear it – the officer of the watch go read it and then they compare to the ECDIS. If it's applicable, then they have to make a mark so the next officer of the watch can see that 'Ah, this buoy is missing and we will pass it by soon'*". A reported downside of having *Navtex* texts or symbols on the ECDIS, though, was that these needed to be manually eliminated when no longer valid: "*It's too time-consuming to edit everything that comes into the Navtex and you can only have one guy sit and do that*". A participant claimed he spent at least half an hour for every eight hours just to update MSIs into the ECDIS system onboard his vessel. This amount of time will depend on whether the MSI list is referring to single-coordinate MSIs or larger polygon MSIs. However, another participant said it was possible in some systems to set a timer to his/her own MSI note, for automatic removal.

For the ECDIS brand and version available in this simulator study, the *Navtex* function on the ECDIS was available both as text beneath the chart, as well as as an orange MSI symbol on the chart itself, indicating the position. These options did not always seem, however, to be noticed by the participants, even after manually inserting the coordinates for the MSI that was already integrated. Even for those who noticed that the *Navtex* was there as text, the MSI symbol was still not necessarily seen ("*Navtex message is received within the ECDIS (…) So this is convenient as well, it works (…)*"). In situations where the MSI symbol was in fact noticed, it caused some intrigue as to how it had gotten there if they had not manually inserted it. In one case as well, the participant asked what the abbreviation 'MSI' stood for, being more used to refer to such messages as 'Navtex'. MSIs on the ECDIS were also reported difficult to see and that having a different screen for this was a good option.

The MSI service on the BalticWeb was mostly used to double-check MSI information found elsewhere in the resources provided, although in one case the participants used the MSI service on the BalticWeb as a stand-alone tool to see MSIs (although still missed the cable work due to interface issues); and in one other case a participant read the printed list of MSIs and consulted the BalticWeb at the same time to help confirm the coordinates for a specific MSI and confirm its impact on the voyage: "*It's always good to see it on a map, the navigational warnings. Then you can forget a lot of them because you know you will not go there anyway*". Although coordinates can be found on the ECDIS too, seeing the symbol immediately on the chart was considered a benefit regarding "*Time!*". As said, this is a function available on some ECDIS systems, but hence not available or known to everyone: "*Where you can see the map with the warnings is an incredible option… I'd never seen anything like this!*". Besides MSI symbols, it was equally important to see MSI polygons marked directly on the map, and this seemed to be a different functionality that not all mariners knew of or had available on their ECDIS systems onboard. The BalticWeb, having the NW and NM symbols, polygons and lines on the chart, was helpful to confirm the exact position of the MSI both during voyage planning and navigation, but this did not keep the participants from wanting/having to integrate the same information into their voyage. The participants could see on the BalticWeb that there were many MSI symbols on the chart and hence wondered if they should insert it all into their planning software to see the interaction with their route ("*There's much to write into the chart*"). It was, however, explained to them that this was not necessary because the voyage could be uploaded to the BalticWeb to directly see the impacting MSIs.

There were issues in the way the symbols were portrayed in the BalticWeb interface that were not immediately grasped by the participants and led them to the assumption of certain MSIs simply not existing, such as certain MSIs only appearing depending on the zoom-in level of the screen or requiring moving the cursor along the route for the MSI list to be updated.

During navigation, in the control week, every group identified the light buoy missing on the chart not using the BalticWeb as a starting point, whereas in the experimental week, one of the groups did not identify it as they confused it with a different MSI of an unlit buoy. Regarding the floating container, the control condition succeeded for all groups at identifying the coordinates, and the experimental condition did too, not using the BalticWeb as a starting point. In some cases the identification was interrupted by other tasks but resumed at a later point. In some cases, the BalticWeb was used for double-checking. During navigation, new MSIs were always first seen on the ECDIS before checking the BalticWeb if at all (the BalticWeb was used to double-check in 3 out of 8 cases). New MSIs dropping into the BalticWeb went unnoticed as there was no screen warning or alarm or sound associated with it. For example, during the trials, the floating container showed up on the BalticWeb even before the call from the VTS, but this was not noticed, since it required the participant to be actively looking at MSIs on the interface.

3.2.6.1. Navtex, navigational warnings, notices to mariners and maritime safety information

On top of the confusion with the *no-go area* term, four names are officially used for similar information. The maritime safety information is actually an authority that vets navigational warnings and notices to mariners and then transmits these via a solution named *Navtex*. Nonetheless, the nomenclature was often used interchangeably, and there was one participant that did not directly understand the acronym MSI for maritime safety information when presented as a chart symbol on the ECDIS screen. An opportunity here for clarification too?

However, participants emphasized the importance of distinguishing navigational warnings from notices to mariners in the symbolism used on the BalticWeb.

3.2.7. Service – Route optimization services

The route optimization service on the BalticWeb was tested by the four groups of the experimental condition. It was perceived as important to know the source of the route optimization service, and generally of all information and services. This plays a role in the mariners' trust with regards to the information upon which decisions are being based: "*It's the same with weather report or anything. You quickly find out who you can count on or not. It's not necessarily the one who has the highest fee*". Besides the source, knowing the parameters that are being used for calculation was a requirement. This is not something the mariners can be left to wonder ("*You have to have some knowledge of what the automatic thing's doing*"), and this determines the posterior work tasks they will need to focus on to be able to plan a voyage and later be able to take responsibility for it if something were to go wrong.

The suggested optimized route that the participants received was only adopted by one of the groups, partly used by two other groups, and rejected by one group. However, this service had the major flaw of not accounting for the TSS parameter and hence even the group that adopted the optimized route needed to tweak it to be within the TSS. This flaw was also the reason why the other three groups chose not to adopt the optimized route. However, two of those groups still took advice from the optimized route keeping their originally planned route but adjusting it only to adopt a couple of waypoints or choice of channel. For example, a group not so familiar with the geographical location chose to change from taking the Flintrännen channel to taking the Drogden channel according to the optimized route. Although this may or may not have been the most advisable choice in terms of traffic (as the algorithms do not account for traffic), this choice was still relevant in reducing mileage (saved six nautical miles).

Another thing that did not promote adoption was the fact that this service worked with an algorithm based on an original planned route. This means that waypoints needed to be delineated by the mariners first for the algorithm to calculate the shortest distance for that voyage. The mariners felt that this tested service should be possible as a *route-maker* with just inserting origin and destination, and a couple of ship characteristics, and that this should be enough for an optimal route to be suggested and spare the mariners the need to manually designate the waypoints themselves only for them to be modified by the algorithms afterwards. This calculation must include parameters that mariners are used to considering such as TSS, traffic patterns, shallow waters. Other parameters can also be thrown into the mix, but this is a situation where rules, regulations, recommendations and traffic patterns are prioritized for safety reasons. For not including TSS and traffic parameters, the service tested in the BalticWeb was not perceived as useful enough: "*This can't be*"; "*Practically, it's not usable*"; "*My captain would never allow us to go here on Bornholm*"; "*We like to have safety margins, more water, in case something happens, like a blackout. We'd be very nervous on the bridge if the optimized route was taking shortcuts*"; "*This needs to be more intelligent*"; "*You don't wanna end up like costa Concordia*"; "*They don't even use the lane, they go outside the lane, and that's…you should never do that!*"; "*You have to follow the TSS*".

There is indubitably already a market for this. It was reported that some route planning software today already include an option for auto-routing, where crude waypoints are provided by inserting some parameters, which was reported as useful for long voyages, but may or may not consider fuel consumption, and this was not known by all participants. It was also reported that some weather service providers offer the service of optimizing a voyage according to weather forecast for navigation and manoeuvring performance. Also, some shipping companies (e.g., mostly ferries which repeat the same voyage regularly) may have their own optimization solutions for fuel efficiency, considering important ship and navigation parameters, including regulations.

It was suggested as a downside, however, that receiving a suggested route may signify that the mariner gets less of a chance to get acquainted with the route and with the geographical location that the route is for: "*I don't think I would trust a system like that! Maybe it's just me being old school, but I feel that's like a little bit too much. Liability – if I have checked a route myself, I have made a route myself, I will be the one responsible for it anyhow. If I just received it from someone else, since I am still the one liable for it, I will have to check it anyway, so there's no savings the way I see it… Maybe it's just me being conservative about it*". Nonetheless, as the route still needs to be approved and signed by the ship captain, this should signify that the officer of the watch will double check the voyage they received for all the important parameters.

3.2.7.1. Route sharing

Route sharing is a service that was planned for the BalticWeb but was not implemented. Uploading a voyage to send for optimization could as well be used to demonstrate the route on the BalticWeb for other users to see, including shore-based users (also see Costa et al., 2018). During the navigation exercise, there was much VHF radio communication with other ships to negotiate how to meet and overtake each other. There was potential for a route exchange service for more accurate predictions and decision making. Participants asked if this was a possible function of the BalticWeb and some mentioned a previous EU project they had participated on – MonaLisa. This project suggested a solution of sharing between ships a portion of the route in order to better foresee the movements of surrounding ships. The BalticWeb had been planned for a service that allowed for vessels' routes to be displayed and this could be seen by other registered ships, but this service was not ready to be tested.

Sharing full routes was mostly seen as irrelevant and as a liability in ship security. But sharing a couple of waypoints back and 5-10 waypoints ahead for a ship with which ship X is about to meet was seen as very pertinent. The narrower the fairway, the more waypoints ahead they would like to see. This is in some way already used on the ECDIS with ship vectors and the AIS information. The problem is that sometimes these vectors will suggest that a certain vessel is taking a certain heading when actually this turns out to be outdated AIS information. For this reason, the mariners always find the radar more reliable than the AIS.

Participants also mentioned that route sharing is already possible among ships that use bridge systems of a particular manufacturing brand. A route can be requested from ship X to Y.

Participants thought if one is to have access to everyone's routes, it should be an on/off option, since this is not always relevant to have on the screen. Having such a possibility could perhaps minimize the need to report certain information to the VTS, as some of it would already be contained in sharing a voyage plan. However, a participant alerted for the fact that VHF radio communications serve more purpose than just reporting to the VTS: *"I would still like to hear them on the VHF, because that gives me a quick picture of who they are, if they speak English, if they can understand me later on. (…) Get a feeling for who is this person, is this going to be a problem or not? Because that is what we evaluate all the time. (…) Because I want to know if I can understand them, if they can understand me. The level of competence. How to express… because you do have regulations. If everybody were following regulations, there would never be any collisions, but there are. So after a couple of years working with this, you do get some experience about different people and you do see if it's going to be a problem or not. Of course you can always get the wrong impression. Could be that someone that cannot express themselves in English is still very flexible and move, as they should be, but you don't know. So it's just a way of evaluating the situation, because it's not only radar, ECDIS and the vessel, it's the crew that is handling all these systems in the end in the background. So depending on the crew that is behind all this technology, it´s depending how the situation will arise because he's the one making the decision really, so that is why it's nice to get something"* – says pilot. How well they speak the language is important, *"and also how they respond to VTS for example. Because it's standard questions. What's your draught, for example. And if they're gonna answer "say again please", then they don't even know the question 'what is your draught' which is a standard question, then you know"*. The participant referred that they deal with these situations by avoiding contacting these vessels for fear of misinterpretation. Route exchange could also have use in VTS reporting, such as the Norwegian single window reporting system example (see The Norwegian Coastal Administration, 2011). Allegedly, they can share a planned route and that includes all reporting details.

3.2.8. Service – VTS reporting pool and standardization

When it comes to reporting to the Sound Traffic VTS, they had at the time of the study indicated on their website that "a mandatory SOUNDREP report must be communicated to Sound VTS online or by VHF, e-mail or telephone" (Swedish Maritime Administration & Admiral Danish Fleet, n.i.) before entering the reporting line. This does not specify exactly how much time in advance to do this. Using email or online report does not keep them from having to contact the VTS via VHF radio when entering the area, and some of the information already provided before must still be repeated in voice communication for confirmation, but it shortens the radio communications to the bare minimum (e.g., draught, air draught, dangerous cargo, flaws). What this brochure does not mention is that the centre created templates for the email and online reporting, and it does not include the links that lead to those templates, existent on their website. Moreover, the website does have those templates but they are found on different subpages. This will promote that mariners do not realize that there are such templates and they may instead create their own email template, as was observed with our participants, which complicates the reception of information for the VTSOs (also see Costa et al., 2018).

When it came to VTS reporting to the Sound VTS, there was no full agreement on this among participants, as this was fuzzy and no standard existed. Participants reckoned sending an email after voyage planning was validated and 24h before departure, some talked about reporting any time before departure (usually during voyage planning), or right after departure, or before entering the reporting line, some mentioned a couple of hours before entering the line would be enough ("*A lot of agencies they want 2-4 hours before, it's ok to send. 2-4 hours before arrival. (…) You put a mark "at this hour you send an email". And you do it! No problem!*"). This seemed to depend on preferences of the VTS centre as well as convenience for the ship. Then, they would call the VTS via VHF radio when entering the reporting line during navigation. Only a minority of participants was acquainted with the new online report format launched by the VTS. In the experimental condition all groups used this report via BalticWeb, and one group in the control condition (1 group out of 5) knew of this online report and wanted to use it via the Sound VTS website, as they did not have access to the BalticWeb.

On average, it took the control condition groups 17,63 minutes to complete reporting activities during the route planning exercise (this does not include time used to identify reporting line, and does not include the group in which the participant who is a VTS operator at the Sound VTS took part, and does not include one other group who was not certain whether it was mandatory to report to the Sound VTS and hence decided to use the VHF radio later during navigation and say they had submitted a report which they did not). It is important to refer to the fact that the 2 groups taken into this calculation who did not use the new online report but used the email instead, did not in fact use email. As the trials were not prepared to mimic this, we assumed that the emails had been written, sent and received. Had this really been done as in a real-life situation, this may have taken even longer time. It is also important to stress that the one group who used the new online reporting format used less time than the other 2 groups (8,42 minutes). During navigation, the VHF radio communications for reporting took the whole control condition an average of 1,15 minutes.

In the experimental condition, they were all requested to use this online report format via the BalticWeb interface[3], to test the solution. On average, during route planning, it took the experimental condition groups 9,00 minutes to complete reporting activities (excluding time used on identifying reporting line). During navigation, they took 0,43 minutes on average to do the VHF radio reporting.

VTS reporting information is something that is commonly found outside the route planning software, using other sources such as the admiralty books, Swedish Maritime Authority website or Sound Traffic website. The participants were also provided with printed resources in this matter, taken from the Sound VTS website. As previously indicated, finding the reporting line on the map was not always straightforward, and the participants would always make a note on the map indicating the reporting point, and what VHF radio channels to call on. With regards to what to report, however, they commonly preferred to write it down on paper, although some participants reported that in a real-life case they would have printed out this list and highlight the main reporting details. In this sense, some participants decided to take the available printed Sound VTS information into the navigation simulator to have all of the necessary information when reporting. This information was repeated on the paper admiralty books, on the printed VTS pdf (which exists on the official website), on the VTS website that some participants still chose to visit, but it was not necessarily consistent or updated everywhere.

Even after making a note on the voyage plan, confusion remained during navigation as to what radio channel to use, as different parts of the VTS area required a switch, and the VTS needed to call and request a change of channel (3 instances where the VTS called the vessel to inform to change channels), and reporting details forgotten, such as air draught, which the VTS needed to actively request. There was even ambivalence about how to refer to the VTS over the radio – *Sound VTS* or *Sound Traffic* ("*Some people don't have the information in front of you,*

[3] The online form in use by the Sound VTS on their website and the BalticWeb online form for the Sound VTS were received in the same way by the Sound VTS operators, but the content of the forms was not exactly a copy of each other.

so they're like "oh, please stand by" and they go check the information… You're still occupying the channel. So this way, by sending the report, you solve all the problem").

The VTS pdf also said one should report whether they were planning to go east or west of Disken. Participants did not know what Disken was, so they tried to google it and to find it on the planning software, but they could not find anything. Only with the help of the simulator manager did they realize this was on the same pdf (on the printed map), and then they could also see it on the planning software. Once again, this comes down to familiarity. Those not familiar with the area will have more difficulty collecting information that is obvious to those familiar with it. The information made available may need to include not only what the mariners need to consider and what they may not. Participants tried to find out whether reporting to the VTS when leaving Gothenburg was also necessary. This information was often not found, and someone would be acquainted enough with the area that they knew it wasn't needed. Some also wondered if they needed to report when exiting the VTS area. Most of them assumed from experience that it wasn't needed. Only one group actually mentioned a symbol on the charts of the route planning software that meant that reporting when exiting was not necessary. This did not seem to be noticed or understood by the other participants. Finding speed restrictions was the same situation – this could not be found and in some cases the participants knew there were no actual speed restrictions for the area in question.

Two participants mentioned the voluntary reporting to Amber US coast guard for rescue purposes. This is not mandatory and especially considering there is already a VTS in the area to help with issues if anything is to occur. But this is another reporting process mentioned that increases the stack of reports one needs to send on top of VTS, ports, pilots, SAFESEANET when transporting dangerous cargo (dangerous cargo must also be reported to the VTS, who will report it to SAFESEANET yet again), Microsoft Single Window for dangerous cargo and crew onboard.

A participant (pilot) liked the Sound VTS website: "*They did something good here!*". Information on reporting can take 20 minutes if you know where to find this information – estimated the participants. They missed reporting line during planning – and didn't send email or online form. And only during navigation realized there was a lot of information the VTS required. They only reported through the VHF radio and VTSO said they had received the email, which they did not. In reality, they would have sent email and then short VHF call. They didn't notice the online form existed.

A participant (pilot) said reporting everything via VHF radio has the advantage that everyone can be informed and get an overview of the traffic situation. Destination and draught is good to know. Regardless, VHF radio communications should be minimized: "*Usually when you enter these areas, it's dense traffic. And you're gonna call up and answer all these questions, you lose the sight of the navigation, and that's a very dangerous time, you know, if you're talking on the radio, navigating and you're supposed to take decisions. A lot of accidents happen because of this! So I think they should move all that kind of questions, because you're occupying the navigator*".

The participants also tried to find information if this was an area where the VTS would order to wait or if it was a "*first in first out*" policy. Because the pilot was familiar with the area, she knew the VTS here did not coordinate traffic that way. But the participant said that the VTS Oslo Norway is good at telling people what to do "*you wait here, this one passes first…*". This was appreciated by the participant since the VTS is coordinating things and this was considered more comfortable for ships' bridge teams.

Having a reporting template spares the mariners to go and look elsewhere for what is supposed to be reported (websites, admiralty books, etc.), since the template already has everything the VTS centre wants to know. In this case they would only need to focus on what channel to report in, what to report when entering the area (which requires fewer details) and when to do so. Having a template with which to report before departure was helpful in the sense of not forgetting any reporting details (be it an online template or an email template).

VTS reporting was discussed for its potential in standardizing: "If you could get one system for all, that would be fantastic!"; "The thing is it's different systems all over the world. Most ports you have to send in a lot of email reports before you go there, and some VTS areas as well: you send emails. And then you go to another system and they have an online-based system, so you log into the webpage, like the whole Norway you have to upload your route and everything before you go into coastal navigation in Norway. The problem is there is no standard. Every place has their own system. And when a new system is coming they just add it (...) you end up sending like ten emails (...) They're just stacking up. It doesn't get any easier". Not only was the potential of having all worldwide VTS reporting templates be as standardized as possible and presented on the same platform mentioned, but also of having pre-filled ship information on that platform to reduce the workload and redundancy of having to type in the same information for different reports and different VTS centres (although this service did not offer pre-filling option at this stage). If a pre-filling functionality were available, this should be for static information, which is not changing for every voyage, "Because it's very unnecessary to enter those figures all the time". Otherwise, there should be a reminder for mariners to update the pre-filled information in case it changes and they forget to update it, not to be sending obsolete information to the VTS. Another thing is that such templates already have the receiver's address pre-programmed, and if there is a change in this it should be automatically updated and the mariners do not need to search for this information themselves. Not all VTS centres require receiving the same information, but a participant suggested that perhaps "if they get too much, I think that would not be a problem". This participant group suggested that MSIs and reporting forms should all be incorporated into the ECDIS but that be as it may, it was already beneficial to come as far as having a standardized template for VTS reporting compared to having to email. Emailing was perceived as more cumbersome unless one already had an email template as well, but online report is done and integrated, so the mariners don't need to worry about that themselves. They mentioned as well that if internet connection is lost for a short period, it is important that they don't need to restart the whole filling-in process. "Make it as simple as possible. If your grandma can understand, then I guess you can reach anybody" – referring to VTS reporting system.

During navigation, a group of participants needed to consult again information about the simulated vessel and their voyage plans when reporting to VTS via VHF radio, because they couldn't remember anymore how they were passing the Disken buoy. The ECDIS doesn't normally show the overview of the voyage, so this is where paper charts might still come in handy. The same participants also said they don't always need a screen with route overview all the time. They can use one of the screens to zoom out on the voyage if they want to. But a full time screen with the route overview is unnecessary when most of the time they are only looking ahead at the 10 upcoming objects in the next half hour; it's very short-term.

In real life some participants mentioned having the onboard procedure of creating a folder where they document every detail of a voyage on paper, so they would have had all information before calling the VTS. In such a folder, the information reported by email or online form would have been printed out or written down just in case the VTS asks for it again. Hence, it might have been a good function on the BalticWeb to go back and see a record of information sent out to the VTS. They did say there's less and less paper onboard because they are experiencing the transition towards the digital age, so it would be good to see on a screen what had been sent out to the VTS ("*(…) you can just read off the screen or something, you don't have to keep any papers anymore. Because I guess that's where we're all kind of transiting from right now, because we're trying to get less and less paperwork involved in the bridge (…) everything is moving to a digital format.*").

They also mentioned that VTS-required information is similar to AIS information, which is already being shared. It would be hence more helpful if the VTS template profiles could be filled in automatically with AIS information and the rest be filled in manually and be possible to save. Indeed they suggested that if AIS information could include the planned routes, the VTS would receive this and wouldn't need reporting forms. And neither would mariners need to fill in reporting forms.

3.2.8.1. Air draught calculations

Air draught refers to the ship's maximum height above water surface. Although this definition exists, there was some confusion as to how to calculate air draught to then be able to report it to the VTS. The VTS website provided the definition of it on one of their pages, but did not specify how this was meant to be calculated on the template. This seems to be necessary to eliminate subjectivity of terms used in the domain.

3.2.9. Service – No-go area service and weather on route

This was a service supposed to be available to test on the BalticWeb. The no-go area service was developed to be able to see dynamic changes to the safety contours based on weather changes. Although this was not ready in time, the service provided an animation to exemplify this. This was both liked and disliked and, after the familiarization session, only one group in the experimental condition actually decided to give it a go and test it. If we are referring to a location with tides, currents, winds or bad visibility for instance, this service was deemed interesting as long as the sources of weather/bathymetric information were accurate. It was exemplified that some locations will have completely different weather three days after the planning, so planning in advance for such areas may be difficult. Having weather on route could be a potentially relevant use for these situations, such as the example of the Kiel lighthouse mentioned by a participant. But at the same time, having static shallow waters is considered more secure and it was what is approved on the ECDIS. Dynamic safety contours were then considered more novelty than a relevant need, because they don't talk in terms of high or low pressure since it is too small a difference and it shouldn't have an impact on decision making. Safety contours that change with the weather were not deemed trustworthy because planning today with a weather forecast that tomorrow will rain and then tomorrow it doesn't come true, means they would have relied on the wrong information. There was mention that tides are accurate but other data not as much, hence there is a need for more reliable weather and hydrographical data, improved satellites and weather forecasts ("*I wouldn't use it [the no-go area service on the BalticWeb] for that [for navigation] (…) because the ECDIS is the approved system*"; "*(…) taking into account changes in water depth due to high and low pressure is on the edge of not really professional. Because if you do that, you are on the margin. Usually if you make a route plan, open waters should have under-keel clearance on the draught plus 30%, and then a 10 cm-change due to high or low pressure, I wouldn't like to sail on that because your margin of error is too small, and you don't really know – did the wind take all the water out in this bay or not? (…) I have to be able to trust my plan whether or not it's windy or not, or high or low pressure*"). Regardless, today, shipping companies can purchase weather forecast services that may include similar alternatives such as "*weather routing*" where mariners can see weather along their route or even get waypoints suggested to them according to weather forecasts. However, this is still a separate and internet-based service. Participants mentioned learning that a manufacturer may be working on integrating this into the ECDIS. Yet another participant mentioned an existing tool for a similar purpose (passageweather.com) that is used onboard his ship to type in a date and time a vessel will pass an area, and the system shows the expected weather for that area on that date and time.

Safety contours may be uncertain in some cases and make the navigators choose to take a different path. Perhaps this could be a use of the dynamic no-go areas: *"(…) this feels better, so I don't have to worry about shallow waters here (…) Even if I check this very carefully, here is the risk that I might miss something. I don't know what the weather conditions are here, even though it said – I think the lowest point was like 10 m here inside somewhere. And that should be no problem, but I don't know what are the wave heights here (…) so if I stick here, I know I'm safe; I don't have to worry about it".*

During navigation, it was relevant to look up winds, water currents and visibility.

3.2.9.1. Ambiguity of the widespread term No-go areas/zones

The nomenclature used for one of the tested services "No-go Areas" was discussed during the trials. Participants were familiar with this expression, used widely in the maritime domain (see for example The Nautical Institute, 2017). However, different participants interpreted the term *no-go areas/zones* somewhat differently, reflecting a need to rethink the name for this particular service and even perhaps clarifying it in the whole maritime domain.

Some participants referred to no-go areas as non-navigable waters considering draught and safety depth, which was the immediate expectation of one participant when first introduced to the no-go area service on the BalticWeb on the second day of BalticWeb trials. Whereas other participants mentioned MSIs or restricted areas as temporary no-go areas, such as exercise areas, regattas, environmentally protected SECA areas. They don't need to be dangerous areas, just areas to avoid, like oil rigs, *Navtex* areas, windfarm construction.

Participants referred to no-go areas as manually highlighted areas on the ECDIS screen by the officer of the watch him/herself. Marking such an area would make chart information below it invisible, so the participants said they tried always making no-go areas small on the screen. The participant suggested no-go areas to be renamed into "(un)safe waters".

There was an understanding of static no-go areas as those that remain the same for a particular ship with a particular draught, and dynamic no-go areas as those that may change over time and hence need to be checked and updated into the system for every single voyage and during navigation. In no case was weather/bathymetric data referred to in relation to the expression *no-go areas*, but it was indeed perceived as linked to navigable waters depending on tides, currents or known areas of moving seafloors. This could hence contribute to dynamic no-go areas.

3.3. Automatic Identification System Information

It has been identified that AIS information can often not be relied upon, as it requires manual input from the bridge personnel and hence it is not always updated or there at all. This causes operators to have to contact the crew directly to confirm basic information such as the vessel's draught. This causes repetitions and, more VHF radio communications (also see Costa et al., 2018; de Vries, 2017). In the discussion of e-navigation as more connectivity and information sharing, it would make sense to take better advantage of underused systems such as the AIS. Participants suggested that draughts could be updated automatically, and this could also be assembled automatically to report to VTS centres, for instance, and redundancy and separate systems could be eliminated and more automation could make sure that information is taken advantage of for all that is needed for all stakeholders.

3.4. Safety contours and draught

Participants suggested that draught should be connected to safety contours, "*A ship's draught should be connected automatically to that setting*" because if a mariner sets the figures wrong on the computer, this is a safety hazard for grounding the ship. This has been suggested in previous work as well (also see Costa et al., 2018). But it should still be flexible enough that the mariner can go in manually and tweak the safety contours if wanted, "*So it's a thin line*". Others didn't agree that safety contours should be manually modifiable at all, because this is at the risk that the participant feeds wrong information into the ECDIS and removes a whole shallow water layer by mistake.

4. Discussion

Information was compartmentalized and local information difficult to access. There was information repetition from different sources and it was not always updated. The unification of sources and better use of real-time updated information across the shipping industry may be a strategy to provide a baseline to geographically distributed stakeholders. Information access problems, the uncertainty of repeated and contradictive information, and occupying the VHF radio and adding to the workload could potentially be minimized. In a previous study by Costa et al. (2018), the low interconnection of information technologies was evident, as they were not necessarily aligned with the devices of other stakeholders and therefore caused gaps of information, of perception of the other operator's perspective, and of trust. Basic local navigational information was dispersed, sometimes conflicting or inaccessible, increasing uncertainty and complicating decision-making for ship- and shore-based stakeholders.

Quotes like "*Integration and standardization is always better*" indicated that having all relevant information on one single platform was perceived to potentially facilitate the work of mariners. This wish for integration indicated the perceived usefulness of a) collecting all important information from the same place and what this could mean for diminished voyage planning workload, and b) having the important information all integrated on the route for facilitating navigation and memory aid later on. The latter included, for example, having a warning just before or as one reaches a reporting line with all reporting information needed and VHF radio channel to use.

The integration of the platform with an existing ECDIS was discussed but not feasible due to existing regulations. However, Porathe, de Vries, and Prison (2014) proposed having a more advanced ECDIS and not add yet another display to the bridge. However, a minority of participants suggested that having separate screens for information to avoid too much clutter on the ECDIS was a potential solution for the clutter problem which they complain about already today. Nonetheless, the majority seemed to be bothered by the vast number of sources of information and screens as it is. The array of information actually triggered repetition, uncertainty (Costa et al., 2018; de Vries, 2017) and forgetfulness to account for so many parameters. A participant also commented on how they have different needs when planning and when navigating, hence the systems should continue to be separate and suitable for the specific activity. It seemed also that in terms of editing, the computer-based solutions were much easier and less time-consuming that the paper-based charts and documents. However, the paper charts offered the chance for the mariners to get a much easier overview of the entire voyage and geographical area than the smaller computer screens with a more zoomed-out map to get the same overview. For complex systems like an ECDIS, the size of the screen could also possibly decrease the concentration of clutter but still be able to present a large amount of options and information all in one place.

Regarding the solutions tested in the BalticWeb, these seemed possible to integrate into a route planning software. In many cases, similar solutions to those of the BalticWeb already exist. It would just perhaps take fine-tuning the design, or integrating some new functions. As to integrating more functions, the more complex the system becomes, the more cleverly it needs to be designed, not to clutter the screen so much or not to hide available functionality in hidden menus.

Regarding the functions of the BalticWeb that were more useful during navigation (MSIs and traffic density and patters), this seems to also be possible to integrate into existing systems, as for example for the MSIs whose solution already exists for ECDIS. For traffic density and patterns, perhaps again a bigger screen for a wider perspective, a shared screen table (Maritime HumanFactors, 2013) could be considered. Just because the ECDIS is IMO-approved and the mariners are now used to this system and like it – and from a regulatory and economic perspective it is likely easier to reform an existing system than to change the bridge design paradigm altogether – it may still be necessary to change the paradigm in the future to accommodate more complex but uncluttered systems, paperless operations, enhanced communication and information exchange. A new more intuitive and information-exchange-oriented system could look different than it does today. To answer the existing challenges, the existing systems could be replaced by innovative systems altogether as long as the regulatory and standardization bodies can approve.

The experimental condition was planned to, for example, release the missing buoy *Navtex* paper and the same MSI on the BalticWeb, or launch the drifting container MSI on the BalticWeb and announce it on the VHF radio as well, to mimic what would be a real-life case but with the BalticWeb add-on. This may be seen as what in reality would be a transition phase into the full adoption of the technology, because if the MSIs are already being launched on the platform in real-time, there would be no need to release a *Navtex* printout or to announce it on the VHF radio. In this sense, new technology is challenging standard procedures such as these, implying that it is important to rethink procedure together with the further development and implementation of new e-navigation technology.

A developed model/pattern of information exchange such as that the programme of e-navigation is meant to seek (IMO, 2014a) may actually imply more changes to the maritime network as a whole than what is being considered. For example, the way that ship and shore operators work and communicate today will certainly be modified (Costa, Lundh, & MacKinnon, 2017; Costa et al., 2018; de Vries, 2017). But it may also mean that certain roles may be changed to adapt to new technological capability. It may mean that the VTS gains capability or instead becomes more redundant to assist and coordinate ships from ashore, for instance, render navigators more and more independent from shore-based assistance services (Costa et al., 2018; van Westrenen & Praetorius, 2012).

The MSI service was considered the most useful by the participants in comparison to the other services tested. It is not so farfetched to think that for the e-navigation objectives to be reached, information needs to be highly reliable and fast-moving. The existing centralized bureaucracy today before publishing an MSI will supposedly guarantee its veracity and accuracy when finally published, hence guarantee that it is reliable information. On the other hand, receiving or exchanging the right information immediately as it occurs is important for informed decisions to be made.

With improved internet coverage or sensors onboard ships, connectivity between ship and shore can be made sharper. However, for MSIs to be published in real time, one must consider the structure and functions of the sector. Would a vessel or a VTS centre still need to contact the MSI agency first before the information can be spread out? Or would they be able to themselves feed new MSIs into the system that can automatically be caught by every ship? The system would then need to be built against publishing repeated records of the same information by different publishers, and always follow a standardized format to be more easily recognizable.

The purpose of the first work package in the EfficienSea2 project was intended for dissemination of a human-centred design approach to the project partners, prior to development. This was, yet, not successful, as not all partners were at the same level with regards to this approach, and therefore it fell short. Those developing the e-navigation solutions within the project, though, had some prior knowledge of human factors studies and user needs, stemming from previous similar E.U. projects from which EfficienSea2 emerged (e.g., EfficienSea, MonaLisa, Accseas), and this knowledge helped them gain insight into user needs and the new services. Although the present study was proof of concept, it suggested human factors should have been applied from an even earlier stage in the process so as to capture user needs and avoid the participants' perception that the BalticWeb and its services *"(...) didn't add anything*".

Information Technology (IT) service providers may naturally perceive that digitalization brings value to the maritime domain. Yet, it does not necessarily advance safety, especially if it continues to perpetuate the technology-driven mind-set that has been reported to dominate IT applications in the sector (Man et al., 2018). Safety enhancement may undoubtedly take advantage of cutting-edge technologies, but should not be used as an excuse to develop and deploy new technology for the sake of mere novelty and modernization, without the fundamental acknowledgement of the human element, especially in safety-critical work environments where the workers are not generally offered alternatives to the available systems (Jordan, 1998).

The main criticisms towards the BalticWeb were:

1) Not IMO approved cannot be relied upon as stand-alone information for decision making (although this presents an opportunity to create independent sources of information that can be used as aids even if not IMO approved, which would be a very long process)
2) Web-based tools are good for development of independent services and provision of updated information, but this takes for granted that vessels have proper internet connectivity. This should then be the first step towards more development in the programme of e-navigation. Ships may still be at a more elementary level of development before they can become more application-based
3) This is yet one more information source when mariners already feel overwhelmed with the sources they have today
4) During navigation, if it is not integrated in the existing systems or console, the navigators will not go back-bridge for it, or will not have time to look at it during high-density traffic or close-quarter navigation
5) Integration as ECDIS overlay is preferred, but this needs to be done in a way that does not clutter the ECDIS and navigators can choose what functions to turn on or off
6) Standardization is leaving much to be desired. Although navigation equipment and systems are standardized, the functions and overlays available are not in every case. The navigators will get used to the systems and versions they have onboard, and working with different brands or versions is not straightforward without practice, since manufacturers will produce systems in their way for market competitiveness
7) Training of complex systems like the ECDIS and all of the available functions and how to take full advantage of them
8) The BalticWeb did not necessarily facilitate identifying relevant MSIs. It was also observed that the MSIs were not necessarily communicated between officers, and thereby there was no clear indication that the BalticWeb helped to enhance situational awareness. As there was one screen with the planning software for both participants, and one BalticWeb laptop for both participants, there is a change that they will be looking at different parts of the voyage, and they miss to communicate everything with each other, hence accidentally skipping something that should be incorporated into the voyage. Had the BalticWeb information been in the planning software already, this would have not been kept out of the voyage plan.

It was also seen that there is a risk that new MSIs are confused with prior knowledge and the consequence is flawed situational awareness. This was, however, both demonstrated both with and without the BalticWeb. Had the MSIs been already an overlay on the voyage plan, the misinterpretation of one mariner might not have affected the following OOWs.

Nonetheless, there are clear opportunities to:

1) Overlay MSIs on the ECDIS in real-time
    a. MSIs are dynamic (tactical planning)
        i. So there is an opportunity for the BW tool to be of use in both planning and navigation for static and dynamic information. But this would be better suited not as an add-on on the back-bridge and front-bridge, but as an improvement – an update – of the existing ENC charts and ECDIS software (incorporated)
2) Overlay weather on safety contours if desired (this should be depending on the choice of the navigators)
3) Share routes or parts of routes (2 or 3 waypoints behind and 5 or 6 waypoints ahead) with VTS and other ships to facilitate communication and prediction
4) Standardize VTS reporting procedures and formats globally and have this as an ECDIS option in the route planning software
5) Integrate options for route optimization in the ECDIS in the route planning software for distance, weather, etc.
6) Use historical data to provide decision-support solutions
    a. Traffic patterns
    b. Current and wind history (weather and hydrographical data that is sometimes restricted to mariners) could be further developed by weather forecast services
7) Develop more accurate weather forecasts to improve weather routing services
8) Integrate information in ENC charts, and subsequently these should be the same charts used by all stakeholders, in planning and in navigation, monitoring and maritime information broadcast
    a. Of navigational warnings and notices to mariners
    b. Restricted areas
    c. Shallow waters and safety contours (perhaps dynamic to weather and draught)

Stakeholders like the Maritime Safety Information authority and/or the Vessel Traffic Services should be able to broadcast new information such as navigational warnings directly into the ENC charts via push message (together with an alarm warning) for those navigating through the area and who may be affected by it, as one does with online calendar invitations. This would potentially minimize VHF radio communications in circumstances where the mariners are experiencing a stress peak and must keep an eye on traffic and have no possibility to write down navigational warning coordinates or search for them on the ECDIS.

    d. VTS and pilot reporting lines and all necessary information about channels, details to report and how (via VHF radio, email or online form – and provide all the links, forms and email templates for this to happen). This is as simple as integrating digital admiralty books into the ENC charts
9) Redefine the term no-go areas/zones (e.g. into everything that does not involve navigable waters, and present them in red colour)
10) Standardize available functions and the way information is presented on the display among manufacturers, as per the s-mode programme.
11) Improve AIS information and reliability
    a. Draught being updated automatically measured by sensors onboard
    b. Safety contours can be automatically set with AIS draught information
    c. Providing extended information about ships (maybe even a link to the vessel on marinetraffic.com) and route sharing as mentioned above
12) Develop route planning/optimization services making rough waypoints based on:
    a. Origin and destination
    b. Schedule
    c. Draught
    d. Maximum depths and shallow waters
    e. COLREGs TSS'
    f. Traffic patterns

g. Weather forecasts
h. Fuel consumption
i. No-go areas

If the service provider didn't have for example access to TSS, traffic patterns and no-go areas, this is something the mariners should be able to adjust themselves based solely on their ENC chart information after received the suggested voyage.

13) Use bigger screens for better overview
    a. During planning a bigger surface and/or touch screen could perhaps be used to more easily make voyages
    b. During navigation, a bigger screen to have an overview of the whole voyage when VTS calls and asks for destination and directions, for example
14) Apply human factors to develop the ECDIS further and deal with existing challenges of overload of information and visual clutter
15) Augment education and professional training of complex systems

A sister platform to the BalticWeb, the ArcticWeb, which is the same but it includes additional services for navigation and rescue in icy waters, is already operational onboard ships around Greenland. There has been interested from Ghana Africa and Australia to develop the same platform for their waters. The purpose within the EfficienSea2 project is to obtain interest from different parties in the adoption of this tool and eventually merge the different websites into a global website, and eventually develop its services into ECDIS solutions. As this is a website, the bridge team can choose on what screen to present it, stationary or mobile, and this is how the ArcticWeb is being utilized. In the Arctic, VTS reporting is done every half hour, to increase safety in dangerous and tricky waters. Hence, the route upload and display on the ArcticWeb is very useful and shorter reports are sent every half hour after the complete VTS report has been submitted when entering the reporting line. The full route is uploaded and displayed.

With the user feedback provided to the developers of the BalticWeb, this tool is currently under further improvement. Whatever is improved here will be so on the ArcticWeb, GhanaWeb, etc., as one of the main purposes is to standardize the solutions.

Nonetheless, even if this concept becomes successful and useful, it becomes yet another source of information for the mariners. According to empirical data in this study, this is not the ideal path of e-navigation. Even so, perhaps this serves as an incentive/endorsement to push for innovation without the lengthy bureaucracy of the official organizations, to have a chance to develop according to open feedback, and to cause influence on the manufacturers of existing ship systems. However, a question may be if we want to endorse this sort of 'experiment' to take place onboard ships affecting decision making and safety, because it may increase the mariners' workload along with the approved systems.

4.1. Methods Discussion

The general conclusions taken here resulted from empirical evidence that is indicative of the mechanisms of overall bridge procedures and information use during route planning and navigation, and offers direction on how to develop e-navigation solutions further. The baseline condition was for creating a picture of how today's systems are used for information gathering and decision making during route planning and navigation, but it was clear that systems, procedures and experiences were somewhat different for everyone. The trials required the participants to use the available systems which they might or might not have been used to for both planning and navigating the given simulated voyage (in this case the Transas Naviplanner software for planning and Transas navigation equipment in the bridge simulator). This meant that some participants who were more acquainted with the available systems may have had an advantage over the others, but more importantly this is relevant because additional time for familiarization with the 'typical' systems may have made a difference: "*I cannot to 100% say that I am happy with that route but for the intents and purposes today, I mean, it's ok…I don't really know that system that well; I* *would have wanted to learn more about how it presents data, check the route more in depth, where are shallow waters etc etc…had I used the ECDIS I'm used to, it would have been easier for me to do that process*"; "*It took way longer today than it would have otherwise*". The Transas NaviPlanner received criticism for not being very intuitive, but other participants also liked this tool. The hardware in the simulator was liked for being "*old-school, minimal*", but this pointed out the potential major differences between the simulator and the actual ships the participants were used to. Some procedures may have differed had they known how to use the systems better, like making checklists on the route planning software, or using the MSIs on the ECDIS or the replay button during navigation. Having more familiarization time may have been valuable for this sort of function, but the project was restricted by both time and budget for the trials that already took a full day for each pair of participants. For the same reasons, the planning exercise was designed to fit within a certain timeframe.

The planning needed to be done within two and a half hours, which was calculated with the simulator managers even prior to the pre-study to be able to fit in all basic tasks of planning a short voyage. Nonetheless, all participants referred to this schedule as too short to make a detailed plan from the start, even considering that this was not a long voyage. They mentioned that between 3 to 6 hours would have been more realistic and perhaps 45 minutes just to check dynamic information in case the route had already been done before. For a longer foreign voyage, it was suggested that it could take between one or two days, and this is if the mariner knows where to find the relevant information. In this case though, the simulated voyage was short (it did not even require planning from berth to berth – instead they were given the chance to just plan from a pilot boarding point to a port) and the participants were specifically asked not to spend much time on correcting the voyage based on the automated route-check function of the planning software. The participants were asked to focus on the voyage to reach the destination within the given schedule, accounting for all safety information. Moreover, they were already provided with information sources which should have saved some time.

The presentation of printed information papers already signified a bias for the participants that they should look at that particular information. In a real-life case, they would have needed to search for all those papers themselves, and might have wanted similar or different information from different sources than those made available here. Even with the printed papers at hand, some of them were forgotten or ignored. One participant even said: "*All this paperwork is just going to confuse us*".

The BalticWeb was only available for Danish waters and this was commented on, this was a hinder for testing the BalticWeb. Regarding the assessment of the new platform and its services, it was pondered if they should be tested in an isolated manner (each service isolated from the others, and the platform isolated from the existing bridge systems) not to affect construct validity (ensuring that we were measuring what we intended to measure and not nuisance variables). However, it needed to be taken into consideration that the platform was meant as an aid to other systems, so in order to ensure ecological validity (setting up the scenarios as close to a real-life setting as possible), it was only realistic to test it in a scenario where all systems were complementing each other.

The simulator scenario was considered realistic for the area in terms of weather, whereas traffic and the amount of ferries crossing the channels were perhaps not characteristic of April, but were not unrealistic. Also, it is not common that northbound ships go west of the island Ven; and after the TSS, ships should have appeared less organized.

5. Conclusions

This study tested in a controlled and simulated environment the BalticWeb website prototype and its four services for use during route planning and navigation with experienced navigators – three navigational services (MSIs, No-go areas, Route optimization for fuel consumption) and one administrative service (VTS reporting). This study was intended as proof of concept and usefulness. At this stage, the user feedback demonstrated that the tool was not significantly novel compared to other existing and implemented solutions in the domain, but it also definitely demonstrated (a) their potential for further improvement, adoption and standardization by all manufacturers, and (b) their incorporation into the existing ECDIS system. Some of the challenges with this transition into digitalized planning and navigation, however, refer to the increased complexity of the ECDIS not just in terms of functionality, information and cognitive overload, but also in terms of visual clutter. This suggests that future bridge systems that involve more and more digitalization and availability of maritime services need to be cleverly designed to overcome these challenges and be user-friendly for efficiency and safety.

It is of relevance for future studies to include pilots and VTSOs as well, as the purpose of the BalticWeb and services is to harmonize information across the domain to all relevant stakeholders, and be used by all relevant stakeholders which should help take better advantage of this e-navigation technology. The intent would not only be to capture how useful these services may or may not be for these stakeholders, but also capture how the dynamics of interaction and communication between them and bridge teams are affected by the tool.

A control/baseline condition was also evaluated to gain a deeper understanding of baseline operations and systems, without the intervention of the new prototype. This stressed the effect of numerous information sources needing to be consulted for voyage planning and how this signified information repetitions and sometimes even contradictions. There is opportunity to integrate sources (e.g., AIS information), simplify and maintain information more updated in real-time, so long the connectivity between ships and shore is also improved within the e-navigation programme. The benefits would be less information overload and workload for the operators, and more reliability of information.

Further developments need to consider not only the technological designs but the ways in which operations are being affected. Procedures, regulations and more may need to be rethought together with new technological availability and possibility in the shipping industry. From a human-centred perspective promoted in the e-navigation programme, adapting everything else *a posteriori* around the technology may lead us into a path where humans have to adapt to technology rather than having technology adapted to fit human needs.

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Development and analysis of evaluation algorithm for different cartographic systems (ECS, ECDIS, BalticWeb).

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Project acronym:	EfficienSea2
	EFFICIENSEA2 – efficient, safe and sustainable traffic at sea
Funding scheme:	Innovation Action (IA)
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Abstract

The paper examines the definition and concept of Electronic navigation (e-navigation), Electronic Chart Systems (ECS) and Electronic Chart and Display Information System (ECDIS); research STCW convention's Manila Amendments requirements about seaman education for operation with ECDIS and develop evaluation algorithm for electronic chart systems; also provides examples of evaluations and compare positive and negative aspects as for officially realized ECDIS, as for new e-navigation system BalticWeb designed in project "EfficienSea 2".

In addition, the paper provides evaluation algorithms' testing methods and implementation process for all types' electronic chart navigation systems.

Paper is intended to familiarize wide range of specialists with positive and negative sides for last developed ECDIS, ECS and e-navigation systems and demonstrate subsequent possible ways of development for those systems.

Introduction

First Electronic Chart Systems were developed when no international standards for electronic charts displayed information; functions, information accuracy, correction and updating of the information were approved. Now electronic charts and Electronic Chart Systems are designed according to requirements from the International Maritime Organization, the International Hydrographic Organization and the International Electrotechnical Organization. However, there are various Electronic Chart Systems from different manufacturers, which differ from each other even following the detailed requirements.

For example, presently in Europe is developed new navigation system – "EfficienSea 1/2", provided for shipping in the Arctic and the Baltic Sea. This is a new type of navigation system that has been developed in accordance with all the requirements for Electronic Chart Systems, which aims to develop and bring in innovation in order to improve maritime safety and effectiveness of expanding the information available for the navigation in certain areas of the ship managers.

Objective of this work was, using new requirements from the STCW Convention, develop the electronic chart system evaluation algorithm based on focus group exercises and check practical application of the usefulness, evaluating '' EfficienSea 1/2'' software, '' Navi-Sailor 4000 '',"'Navi-Fisher " and special navigational chart system for pilots. In order to develop evaluation algorithm are discussed the STCW Convention requirements in relation to seafarers' education and the ability to use individual Electronic Chart Display Information System functions. To check the scoring utility of algorithm is designed focus group, which executes certain tasks in accordance with the scoring system. The results are analyzed on the basis of the evaluation marks.

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Definitions

Electronic Chart and Display Information System (ECDIS) is a computerized navigational system meeting the requirements of the International Maritime Organization that can be applied as an alternative to paper navigational charts. Obtaining information on-line, it continuously updates ship's position in respect of the coastline, conspicuous objects, navigational marks and invisible objects [1], [2]. An ECDIS that does not comply or follow the relevant performance standards is classed as an Electronic Chart System (ECS).

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E-navigation is defined as "the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment." [3]

The e-navigation not only as physical installation, nor merely as provision of a service but as a strategic framework for the development of current and future technological infrastructure on board and ashore. Thus, the term "e-navigation" currently includes systems and services, but the e-navigation user requirements have evolved and it is intended that the term also include an increased focus on more material elements. It should be noted that in the absence of e-navigation, systems and equipment diversity would continue to evolve provided with various degrees effectiveness. E-navigation development and elaboration is a way to optimize this development and to ensure attention to the further development of a holistic approach to safe navigation [3].

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BalticWeb

The developed system, called "BalticWeb" at this moment exist in Beta version (shown on Figure 1), was introduced in the project "EfficienSea2". It looks and works like conventional Electronic Charts Display and Information System (ECDIS), but not all ECDIS functions are implemented, as system is going to be a maritime map-centric portal. The site will aggregate relevant maritime data and information

- Notices to Mariners and Navigational Warnings
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For a closer look on the BalticWeb; functionality, data and display, please follow below link:

https://balticweb.e-navigation.net/

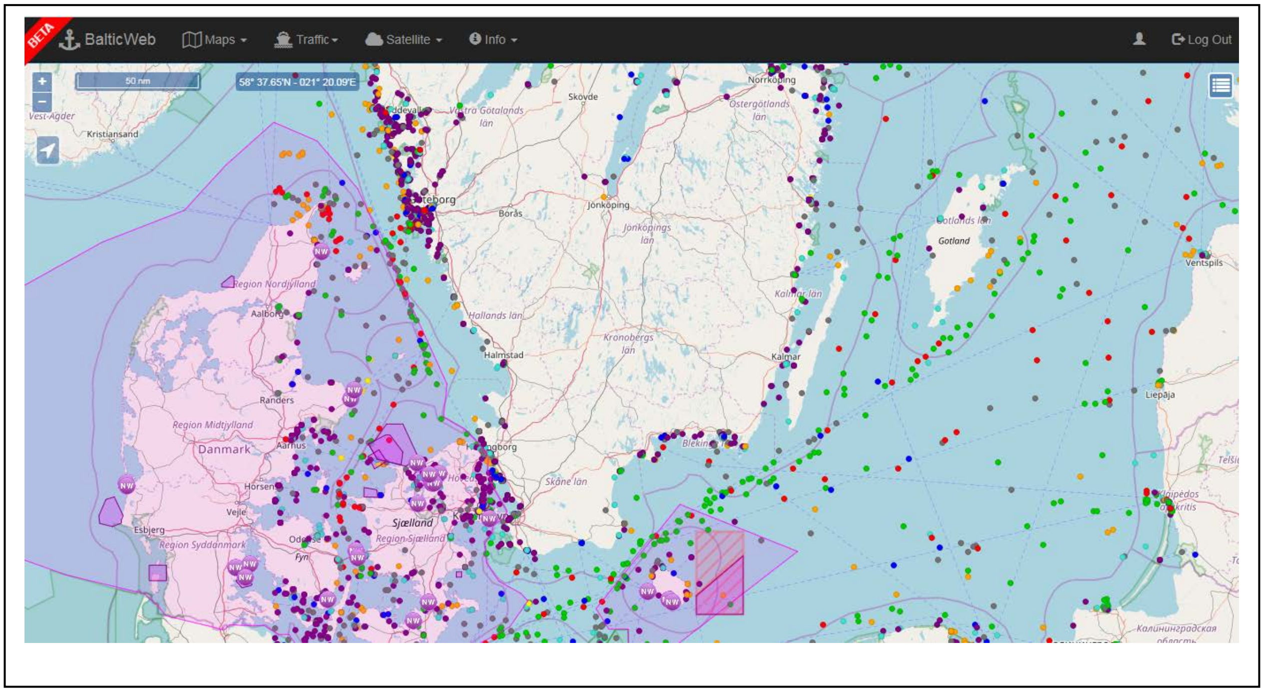

Figure 1. BalticWeb

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Development of testing algorithm

Because of adopting at 2012 requirements for ECDIS mandatory use at certain types of vessels, IMO guidelines aimed at facilitating the transition from paper charts to Electronic Chart Systems was developed as for shipping companies, as well as for vessel's command. It is called "Transitioning from paper chart to ECDIS navigation.

Usage of ECDIS as the primary means for navigation, in general, is different process, comparing with using paper charts. Important on-bridge work processes have changed especially route and route planning control. These processes need special attention. [4]

The electronic chart system evaluation algorithm is based on the use of the STCW Convention, the 2010 Manila amendments, which describe requirements for seafarers in respect of ECDIS education use. The amendments cover full range of possible actions, which must be able to carry out ECDIS operator. [5]

Requirements for training of seafarers were revised for generating electronic chart system's evaluation criteria. Evaluation criteria summarize individual chapters in relation to their application. Rating scale is designed individually, so that it can be universally applied to all evaluation criteria and for calculating total mark. To test usefulness of the evaluation, algorithm was used to compare the "BalticWeb" e-navigation systems, ECDIS systems "Navi-Sailor 4000" and ECS systems "Navi-Fisher" and "iSailor".

The aim was to develop a universal evaluation algorithm, which may be used for evaluation of any electronic chart systems and examine this algorithm's effectiveness during testing of various Electronic Chart Systems s. The testing being done on the basis of developed evaluation algorithm, it is compile structured set of tasks to be met by using an Electronic Chart Systems.

In order to maximize objectivity and accuracy of results, in addition to officially approved by IMO and IHO ECDIS, were evaluated " Navi-Fisher " and " iSailor " systems. They were selected to examine the evaluation algorithm as for certified systems as well as for non-certified or partly certified systems, it is necessary to clarify the evaluation algorithm usefulness. For testing purposes was created focus group consisting of fifty persons. In group was included as 4th course Latvian Maritime academy student as well as Captains with work experience more than ten years. For every person was issued the same scoring algorithm.

During development procedure of algorithm was gathered data from 2010 Manila amendments for the STCW Convention: requirements of the training of seafarers working with Electronic Chart Systems s. Data was processed to obtain full list of requirements for electronic chart functions and features. Requirements were used to draw up the criteria for the evaluation algorithm. Since the evaluation algorithm does not provide tasks, task list was drawn up individually for each inspection; in evaluation algorithm is added position, where tester must write the description of tasks in order for future possibility to restore testing process.

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Evaluation criteria were compiled and distributed to the individual functions by type:

- Risk of misinformation
- Determination of incorrect information representation
- System accuracy, access to primary sensors
- Installation of display
- Operational use of electronic chart
- Route planning
- Route control
- Indication of warnings
- Vessel's position and movement parameters manual correction
- Electronic logbook
- Chart updating
- Operational use of Electronic Chart Systems in case of added ARPA
- Operational use of Electronic Chart Systems in case of added AIS

Evaluation criteria are focused on operational system's parameters evaluation rather than for technical operations evaluation. Developed assessment scale consists of five grades:

- Implemented (I) - described task/option has been introduced, is fully operational and is independent of the other options;
- Defective (D) - described task/option is implemented, but is not available under certain conditions or with certain system settings options.
- Restricted (R) - described task/option is implemented, but with restricted access or are dependent from other options.
- Not reliable (NR) - described task/option is implemented, but it has limited functionality or it is inaccurate.
- Not implemented (NI) - described task/option not implemented.

Grades can be applicable to all criteria. In order to facilitate the progress of system's evaluation, each mark has been granted number of points and, after each criterion checking, for each function was calculated definitive number of points. The maximum points score for all marks is 508 points, which means 100% of the system compliance with the criteria.

All criteria are equivalent; scoring algorithm does not provide preferences for concrete function. At the end of the evaluation is given to mark the entire system. Scoring algorithm is used to compose the tasks list and evaluate the electronic chart system after receiving results of testing. The objectives were drawn up so that the test should considering all criteria (shown on Figure 2).

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- Possibility to adjust radar/chart settings to eleminate the discrepancy between the radar image and the electronic chart; ________________
- Indication in case of chart overscaling or underscaling; ________________
- Possibility to choose positioning system references; ________________
- Own ship's position displayng error indicator; ________________
- Radar, ARPA and AIS error indicator; ________________
- Error indicator in case of different geodetic coordinate systems used; ________________
- Indication about positioning system used; ________________
- Indication of display mode; ________________
- Indication of chart scale used; ________________
- Indication of refernce system; ________________
- Indication of presentation mode; ________________
- Indication of vector type used; ________________
- Posibility to choose ship's sensors; ________________
- Posibility to input the own ship's safety contour; ________________
- Posibility to input safety depth ________________
- Posibility to input events at positions; ________________

System performance and accuracy, access to primary information source ________________

- Information about connected sensors is provided; ________________
- Information about satellite and radio navigation system input is provided; ________________
- Information about Radar input is provided; ________________
- Information about gyro-compass input is provided; ________________
- Information about log input is provided; ________________
- Information about echo-sounder is provided; ________________
- Possibility to manually input compass error on the accuracy of course indication; ________________
- Possible to manually input log correction on the accuracy of speed calculation. ________________

Setting up and maintaining display ________________

Figure 2. Example of composed tasks list.

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Testing results

In Table 1 are presented results of twelve testing (by respondents) after evaluating all four chosen Electronic Chart Systems. Since the respondents' knowledge levels of the systems are different, the final results differ. For ach system was calculated average grade. This can be seen in the Figure 3:

System evaluation results				
Respondents	Navi-Sailor	Navi-Fisher	iSailor	BalticWeb
1	89.4%	86.4%	49.0%	59.6%
2	89.9%	86.8%	49.3%	58.9%
3	90.8%	86.8%	48.7%	59.8%
4	90.9%	87.1%	48.4%	59.5%
5	91.4%	87.3%	49.1%	59.8%
6	89.7%	86.5%	49.4%	59.4%
7	89.5%	86.3%	48.9%	59.3%
8	91.9%	87.7%	48.7%	59.0%
9	89.5%	86.2%	49.2%	58.9%
10	88.1%	86.1%	49.2%	59.1%
11	91.9%	88.2%	49.1%	59.3%
12	91.1%	87.2%	48.3%	59.9%
Average mark	**90.3%**	**86.9%**	**48.9%**	**59.4%**

Table 1. Test results of evaluation algorithm.

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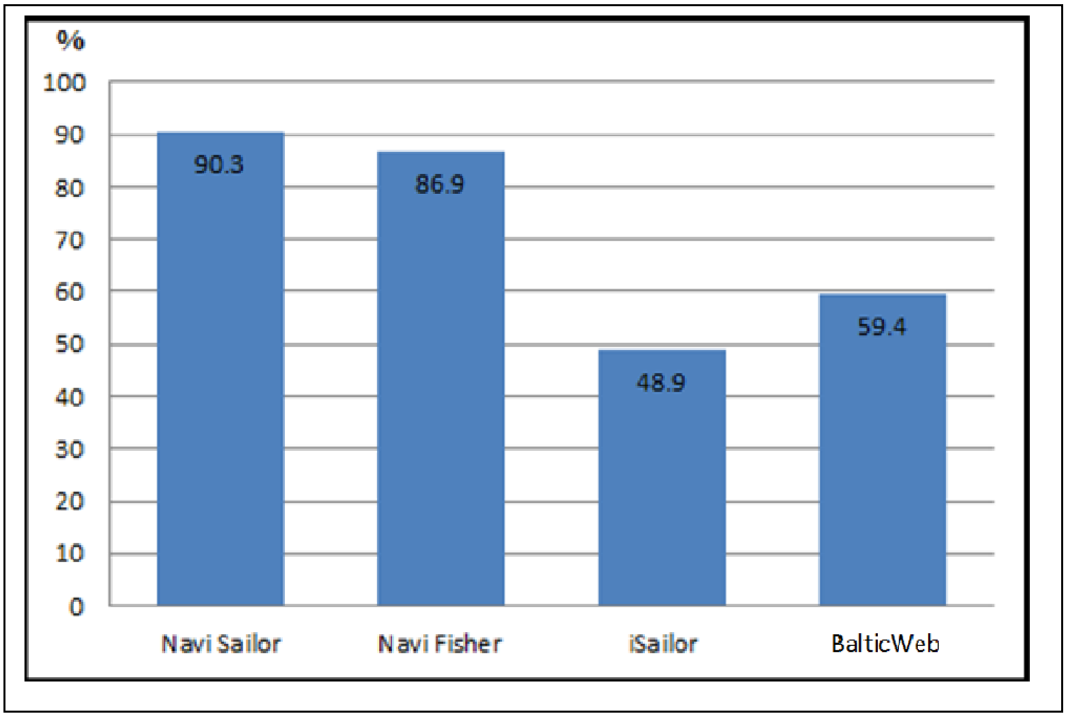

Figure 3. System average mark in percent.

According to diagrams „Navi-Sailor" system meets compiled criteria up to 90.3%, „Navi-Fisher" comply with 86.9%, „iSailor" comply with the to 48.9% and BalticWeb corresponds to 59.4%. „Navi-Sailor" and „Navi-Fisher" Electronic Chart Systems have been already certified for large vessels by IMO and IHO, thereafter gained more points during the examination. But the system "iSailor", used for yacht and small boats navigation scored significantly fewer testing points, when newly developed, and at this moment not officially certified, BalticWeb system. Whereas certified systems have shown better results, we can be conclude that evaluation algorithm shows the difference between Electronic Chart Systems with various level of functioning. So algorithm is useful and can be used to estimate the electronic chart system. Developed evaluation algorithm is not intended for resolving opportunity of certification for tested electronic chart system, it can be applied only for evaluating of examined systems' functional level.

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Conclusion.

Developed evaluation algorithm for Electronic Chart Systems can be used to evaluate full variety of systems, and consequently made available concrete scoring. This scoring can be shown as a percentage and be used for the reference point, comparing existing systems with new prototypes. As well as using it, is possible to obtain information on specific deficiencies in any electronic chart system. The Electronic Chart Systems s' evaluation results may vary because of evaluators' education level and knowledge in case of Electronic Chart Systems s' application. To obtain accurate results is recommended that the evaluators should be fully competent with Electronic Chart Systems using.

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Comparison of the “EfficienSea2” project platform “BalticWeb” with a standard ECDIS.

Project	636329
Project acronym:	EfficienSea2
	EFFICIENSEA2 – efficient, safe and sustainable traffic at sea
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Actual submission date:	
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Dmitrijs Gorelikovs	Latvian Maritime Academy

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Abstract

The paper examines the definition and concept of Electronic navigation (e-navigation), Electronic Chart Systems (ECS) and Electronic Chart and Display Information System (ECDIS). In paper are provided compare of positive and negative aspects for alternative e-navigation platform “BalticWeb”, developed in “EfficienSea2” project with certified, internationally approved and accepted Electronic Chart Display and Information System (ECDIS) using on the STCW based criteria about electronic chart system.

In addition, the paper represent new evaluation algorithms’ testing methods created in Latvian Maritime Academy as part of “EfficienSea2” project.

Paper is intended to familiarize wide range of specialists with positive and negative sides for last developed ECDIS, ECS and e-navigation systems and demonstrate subsequent possible ways of development for those systems.

Introduction

E - Navigation trends are developing fast enough today. This is due to the advancement of technology and the ability to provide faster data transmission, or the availability and quality of the internet on the ships. This direction improved with every moment. The e-navigation concept, as one of the basic ideas, is to create a linked system, with unified data access to users and, as soon as possible, to retrieve instant information in the system. Establishing such a unified system with a well-designed interface that enables the operator (navigational officer) to filter the information provided so that there are no inconsistencies due to the amount of excessive information that could potentially reduce the human factor impact on collisions, grounding etc. Within the framework of this research, the author had the opportunity to work with the European-supported project “EfficienSea2” e-navigation platform "BalticWeb" and the previously created platform "ArcticWeb".

During the research, it became clear, that these two platforms were not evaluated on a single scale, taking into account the functions and capabilities provided by the platforms. Therefore the authors decided to carry out a practical part study with a system analysis only for the platform “BalticWeb”, but to give the respondents the opportunity get acquainted with the platform "ArticWeb" and its functions..

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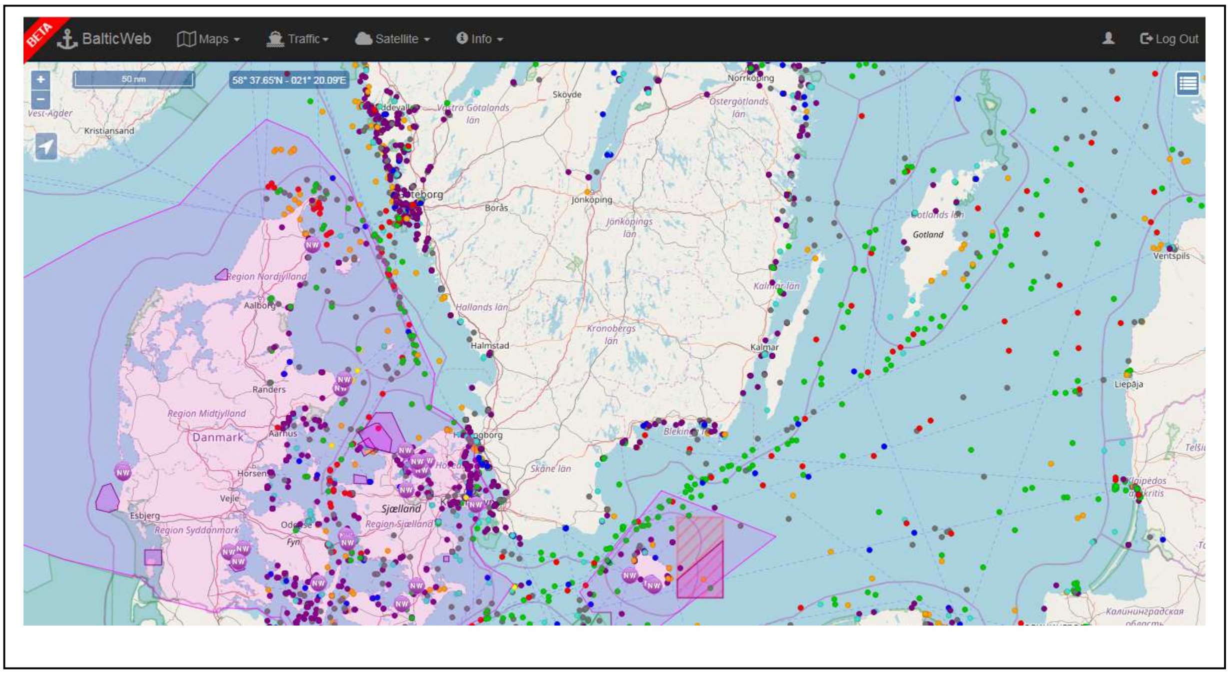

Figure 1 - “BalticWeb”

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Objective of the research.

The aim of the research was to compare the alternate e-navigation platform "BalticWeb" with a certified, internationally approved and accepted Electronic Chart Display and Information System (ECDIS) using an algorithm for the evaluation of the electric chart system developed on the basis of the STCW, developed in the Latvian Maritime Academy. For this purpose, 12 respondents were selected. All involved are the 5th year students of the Latvian Maritime Academy, who also have the appropriate qualification of the operator to perform such a task. The marine experience of respondents and the fact that all participants have passed a state examination provide an adequate assessment of the system at the operator level. The purpose of the task was initially to create two identical passage plans, using ECDIS and alternative e-navigation platforms, but due to the change in the “EfficienSea2” project, several functions were disabled, therefore comparing of program functions was performed. The research task was performed dividing respondents into 2 groups, 6 people at a time.

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Research description.

The work was completed in 4 stages, which took place at the Latvian Maritime Academy in navigational stimulator laboratory premises. Respondents were given two copies of the assessment criteria sheets (see Annex 1), a task sheet (see Annex 2) and a questionnaire, on the e-navigation platform (see Annex 3).

During the first stage of the work, respondents were divided up into navigational stimulator booths and using laptops, 50 minutes were considered for all the functions offered in the "BalticWeb" platform and subsequently according to the evaluation criteria, evaluation of the offered functions and full analysis of the platform. The author did not introduce respondents to the alternative e-navigation platform interface, so that it would be possible to evaluate the complexity of the platform.

In the second stage, respondents were assigned by navigational stimulator booths and were given the task of analyzing the available features and capabilities of the ECDIS Navi Sailor 4000 system using an identical evaluation algorithm that was used in the first part of the practical part. For this task, respondents were given 30 minutes.

In the third stage, respondents were given the task of setting up a small passage plan with four waypoints on the ECDIS Navi Sailor 4000 system and using the "EfficienSea2" platform "BalticWeb" as an additional program. In response to this exercise, respondents assessed whether this platform could be an additional navigation tool that could be used together with the ECDIS system while navigating in the region. After completing this part, respondents looked at the features and capabilities offered by ArticWeb. As part of the fourth part of the work, was filling in a questionnaire on the operation of the "EfficienSea2" "BalticWeb" platform.

For evaluation to be as objective as possible, whether the e-navigation platform to be tested meets the standard requirements, the evaluation criteria are divided into 13 chapters covering a specific function. It was assumed that the total score of 508 points corresponds to 100%. The following 13 positions from the rating algorithm are listed below:

1. Risks of disinformation;
2. Detection of misrepresentation of information;
3. System performance and accuracy, access to primary information source;
4. Setting up and maintaining display;
5. Operational use of electronic charts;
6. Route Planning;
7. Route Monitoring;
8. Alarm indicators;
9. Manual correction of a ship's position and motion parameters;
10. Ship's electronic log;
11. Chart updating;
12. Operational use of electronic navigational systems where radar/ARPA is connected;
13. Operational use of electronic navigational systems where AIS is Connected;

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There were 5 marks on the rating scale:

• Implemented (I) – Described task/option is implemented and is fully operational and independent from other options; (4 points)

• Defective (D) -Described task/option is implemented but is not available under certain circumstances; (3 points)

• Restricted (R) – Described task/option is implemented, but restricted in access or dependant on other functions; (2 points)

• Not Reliable (NR) – Described task/option is implemented, but is limited in functionality or is inaccurate; (1 points)

• Not Implemented (NI) – Described task/option is not implemented; (0 points)

Results of the study. The first “EfficienSea2” platform "BalticWeb" was evaluated according to the developed algorithm. As respondents worked for the first time with this platform, they were given 50 minutes. The compiled criteria were not translated into Latvian so that there would be no incompatibilities when translating professional terminology. Summing up the results, the “BalticWeb” platform got an average of 21.8%, against the 100% algorithm used for evaluation criteria. (see Chart 1).

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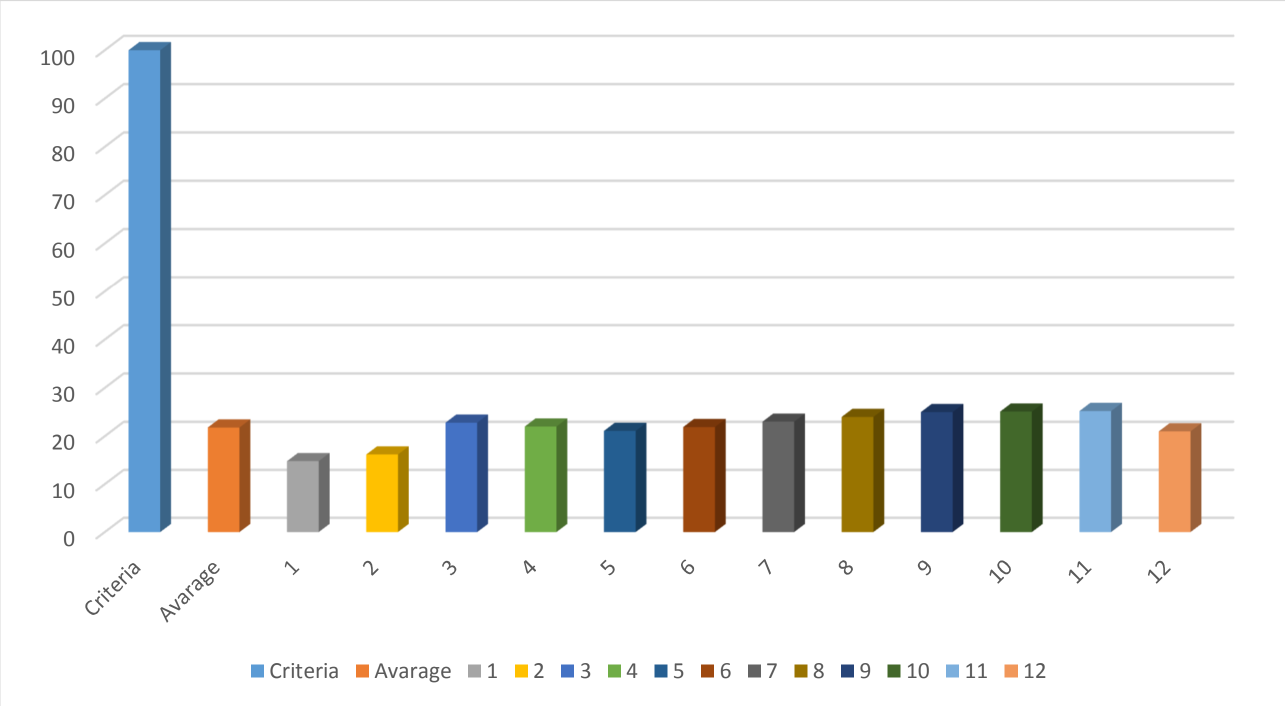

Chart.1 - Comparison of "BalticWeb" with the evaluation algorithm

The responses provided by respondents were different, with percentage rates varying from 14.8% to 25.2%.

Table 1 - The result of "BalticWeb" in percentage

Respondents	Percentage
1	14,8%
2	16,2%
3	22,8%
4	22,0%
5	21,1%
6	21,9 %
7	23%
8	24%
9	25%
10	25,1%
11	25,2%
12	21,0%

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The average percentage score of 21.8% is obtained by adding the final score of all 12 respondents and pulling out the average number. These final ratings were obtained by adding up all the results from each of the 13 chapters. On the chart number 2, the percentage of the average results from each respondent's answers is compiled by each chapter. Accordingly, it will be able to judge which department has received the most negative / most positive assessment. (see Chart 2 for results.)

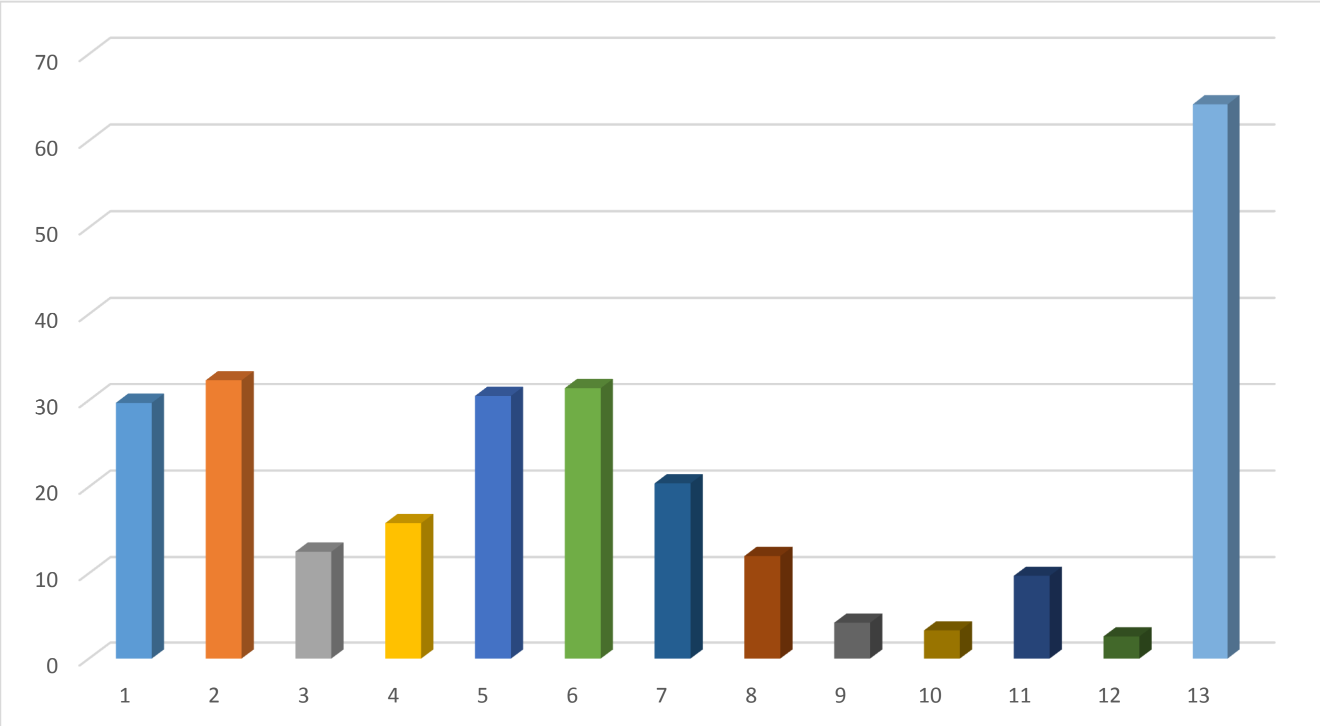

Chart 2 - Average rating of "BalticWeb" Chapters.

As can be seen from Chart 2, the lowest ratings in the "BalticWeb" platform have been received from Chapter 9 - Vessel position monitoring and correction, Chapter 10 - Vessel logbook and Chapter 12 - Operational use of electronic maps in total RLS / ARPA. Compares all 13 chapters in total, with the maximum possible score that could be obtained, it can be concluded that Chapter 13 - Operative use of electronic charts with attached AIS is the only one department that has received more than 50 percent.

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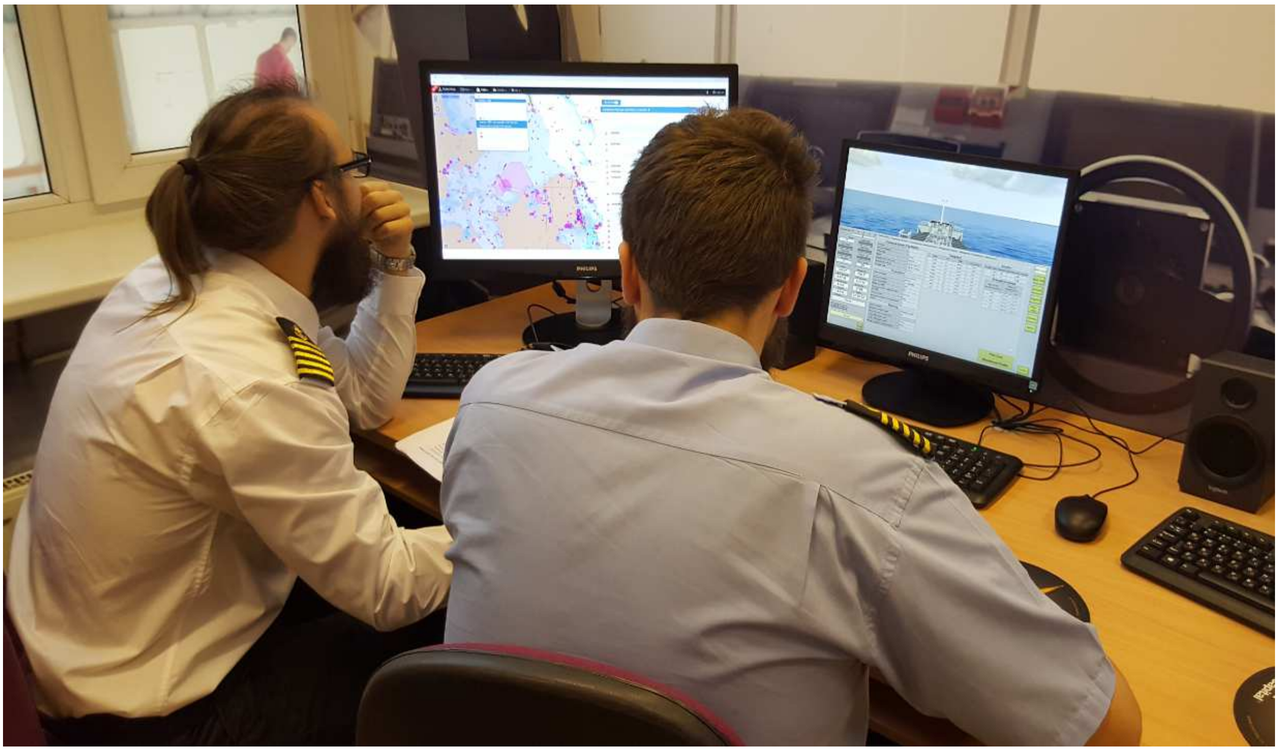

Figure 2 - Respondents are testing the "BalticWeb" platform

In the second stage, the ECDIS Navi Sailor 4000 system was tested. The features and capabilities of this system are well known to respondents, since all of them are ECDIS certified users. Respondents were given the task of using an identical evaluation algorithm as it was used in examining the "BalticWeb" platform. As with this system, all respondents had worked, then 30 minutes were spent on doing this work. Summing up all the results, ECDIS "Navi-Sailor 4000" won 89.5% on average, against the 100% benchmark algorithm used. (see Chart 3).

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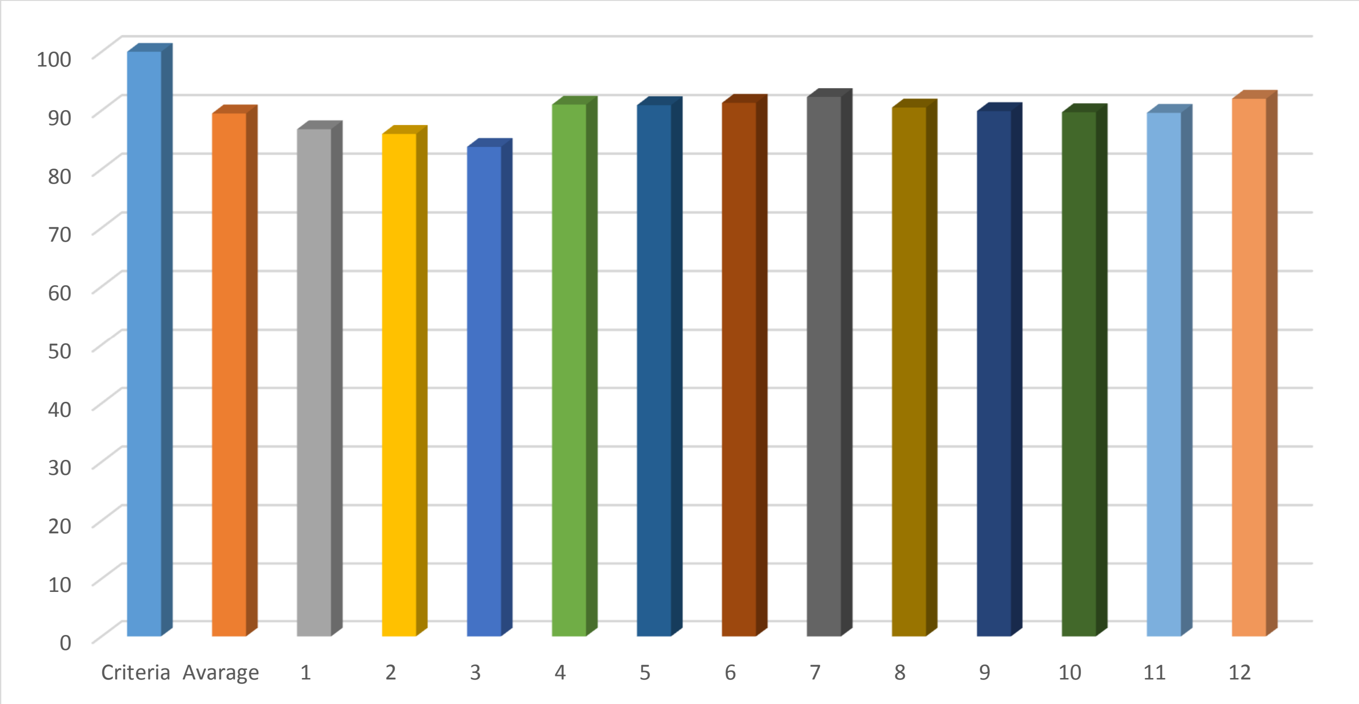

Chart 3 - Comparison of ECDIS with the evaluation algorithm

The responses provided by respondents were different, with percentage variables ranging from 83.8% to 92.3%.

Table 2 - ECDIS result in percentage

Respondents	Percentage
1	86,8%
2	86,0%
3	83,8%
4	91,0%
5	90,9%
6	91,3%
7	92,3%
8	90,5%
9	89,9%
10	89,7%
11	89,6%
12	92,0%

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Chart 4 shows the results for each of the 13 chapters evaluating the ECDIS Navi Sailor 4000 system.

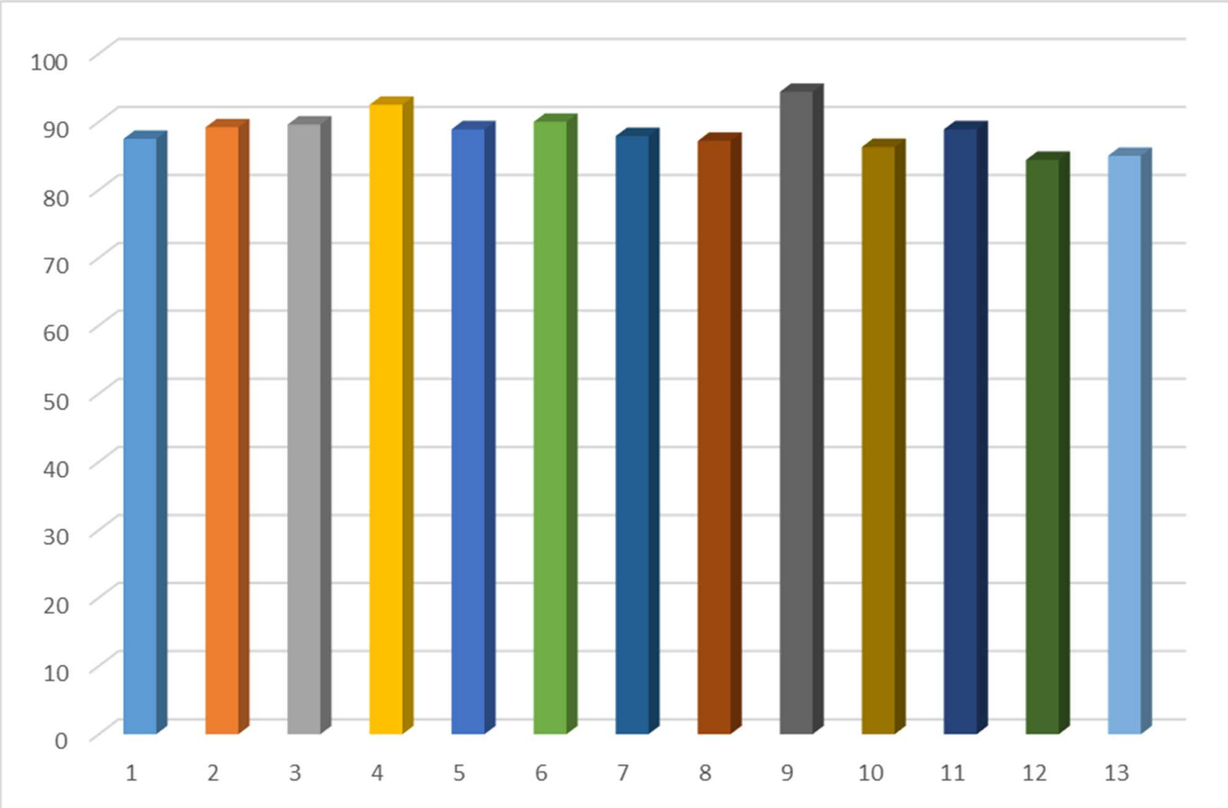

Chart 4 - Average rating of ECDIS Chapters.

As can be seen from Chart 4, all chapters are estimated relatively equally, with the lowest rating of 84.8%, which was received by Chapter 12 - Operational use of electronic maps in total RLS / ARPA (if added) and with the highest result for Chapter 9 - Control and correction of the position of the vessel. When evaluating the results of Chart 4, it is logical that the results of all chapters are about 90% because ECDIS "Navi Sailor 4000" is an IMO approved electronic chart display and information system.

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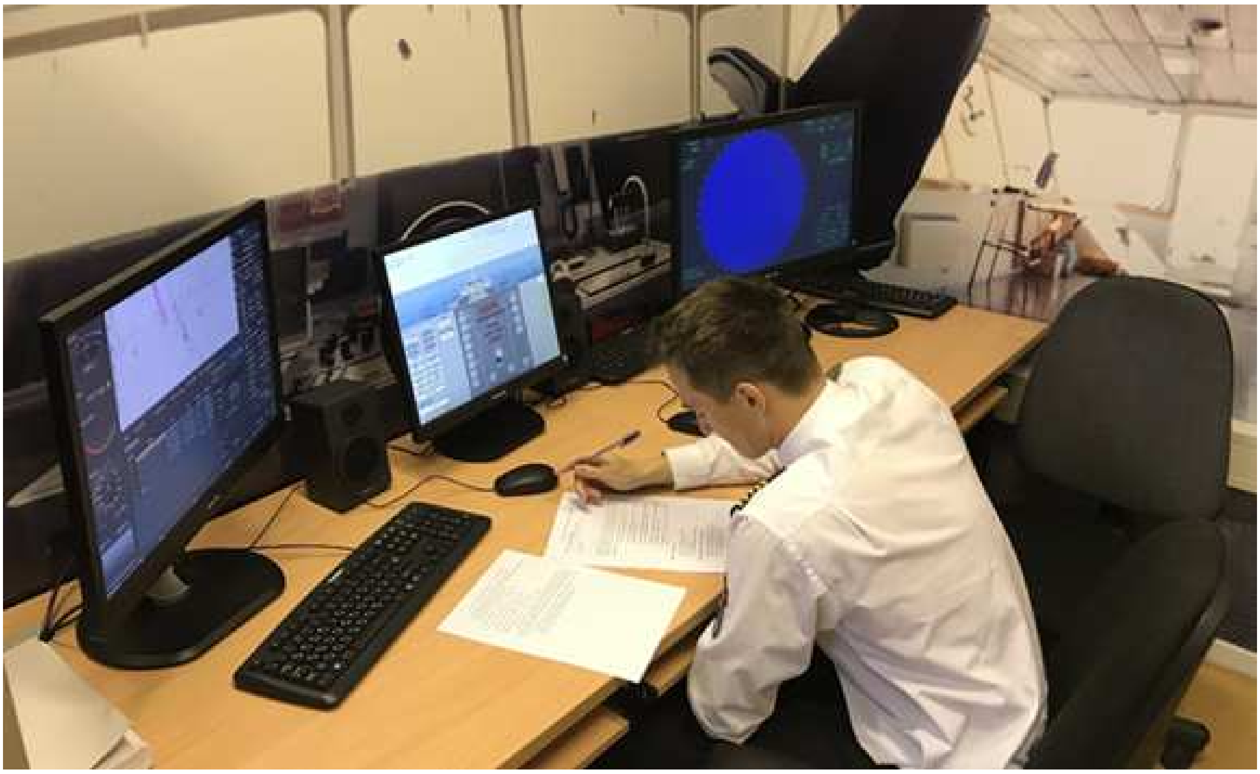

Figure 3 - The respondent carries out ECDIS system testing

In the third phase of the practical work, it was planned that respondents would be given the task of creating passage plan in Danish strait on the ECDIS system and using the "BalticWeb" platform in addition.

Initially, each respondent set up the passage plan individually for the navigator bridge simulator. Later the installation of the "BalticWeb" platform on one of the monitors in the navigation simulator was created. In the third part of the practical work, it was possible to make passage using directly in parallel with the ECDIS system and the "BalticWeb" platform.

When one of the respondents set up a passage plan, each respondent was given the opportunity to use the ECDIS system with the "BalticWeb" platform and create an identical passage as it was done with the ECDIS system only. Thus, the respondent was able to compare two types of workplaces.

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Figure 16 - The respondent uses ECDIS with "BalticWeb"

In the fourth phase of practical work, respondents were provided with questionnaires (see Appendix 3) for evaluating the "BalticWeb" platform. The results of the survey are summarized in diagrams 5 - 14.

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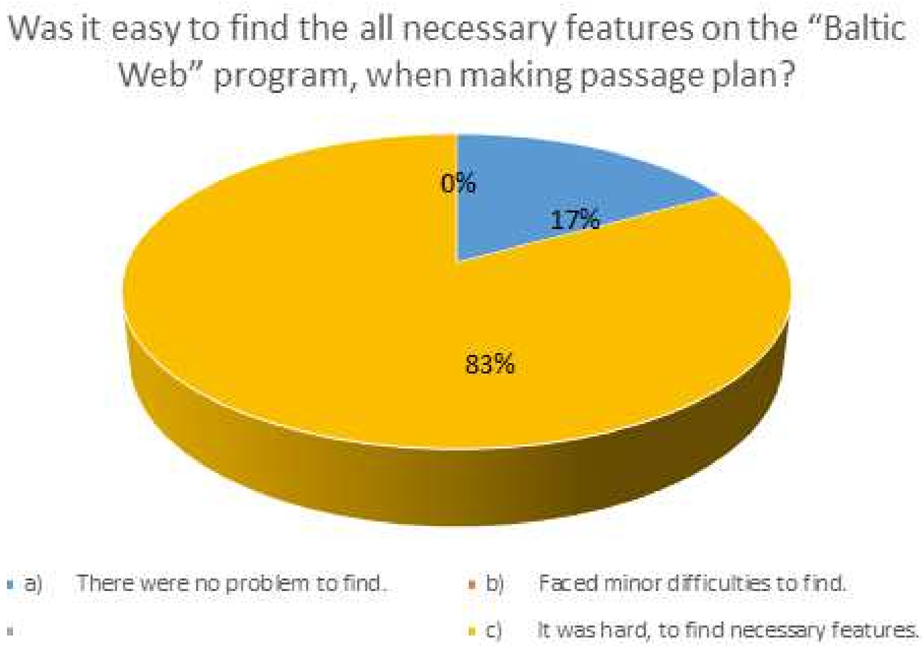

Chart 5 - Respondents' survey results

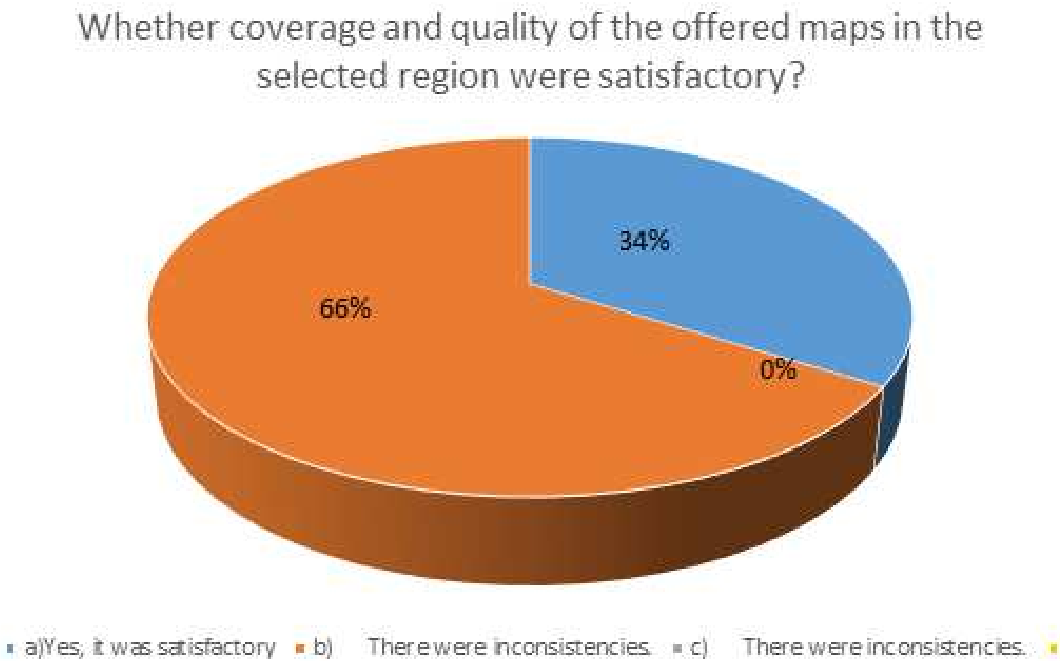

Chart 6 - Respondents' survey results

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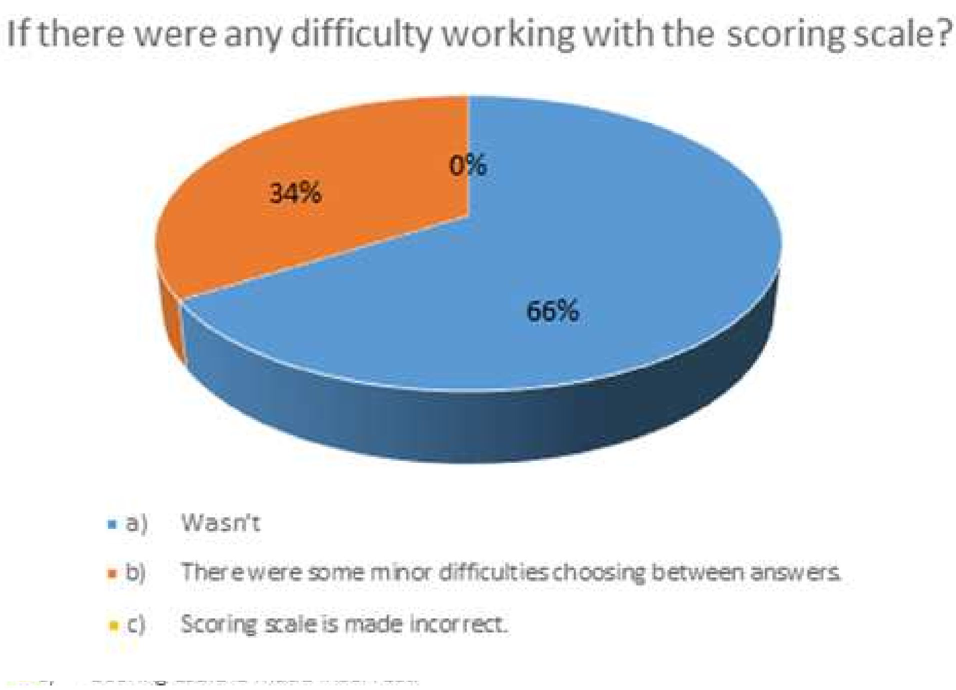

Chart 7 - Respondents' survey results

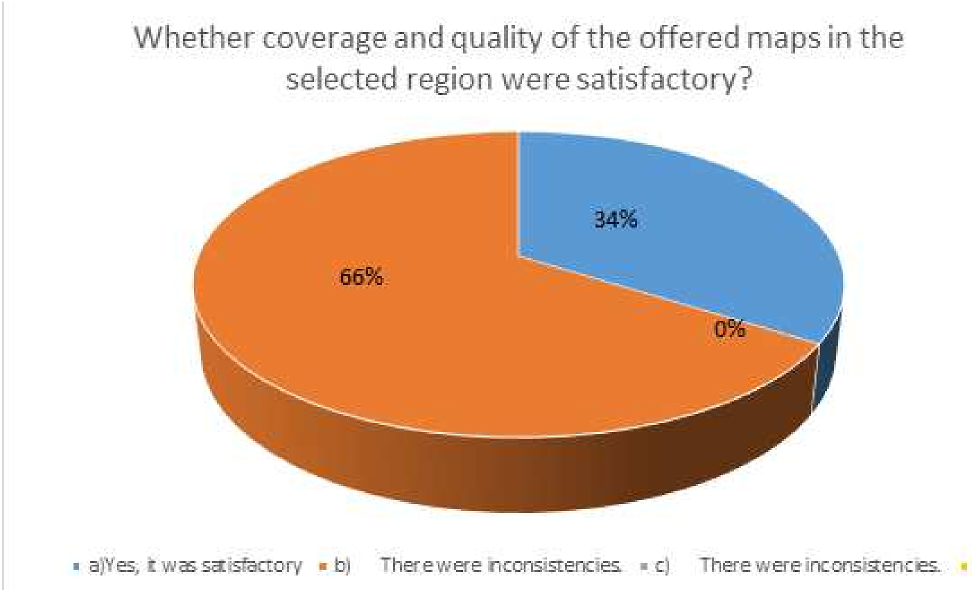

Chart 8 - Respondents' survey results

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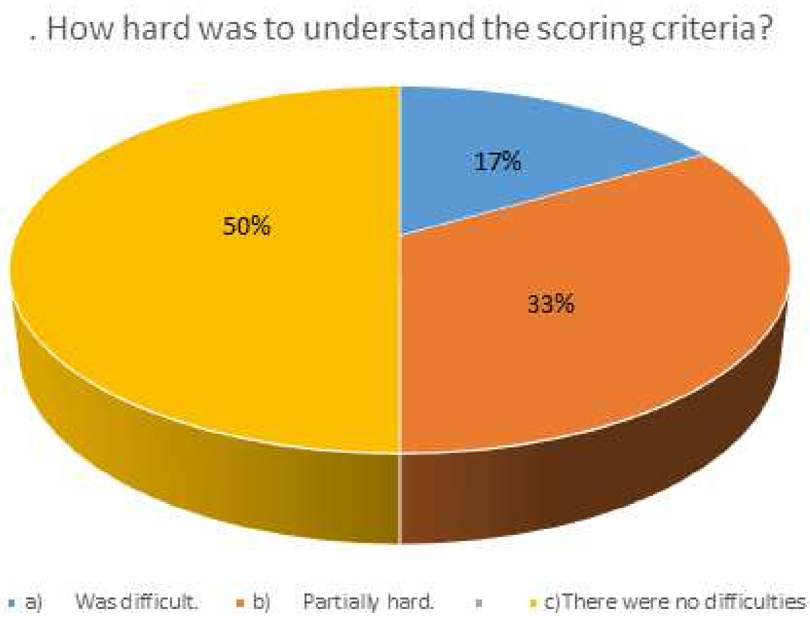

Chart 9 - Respondents' survey results

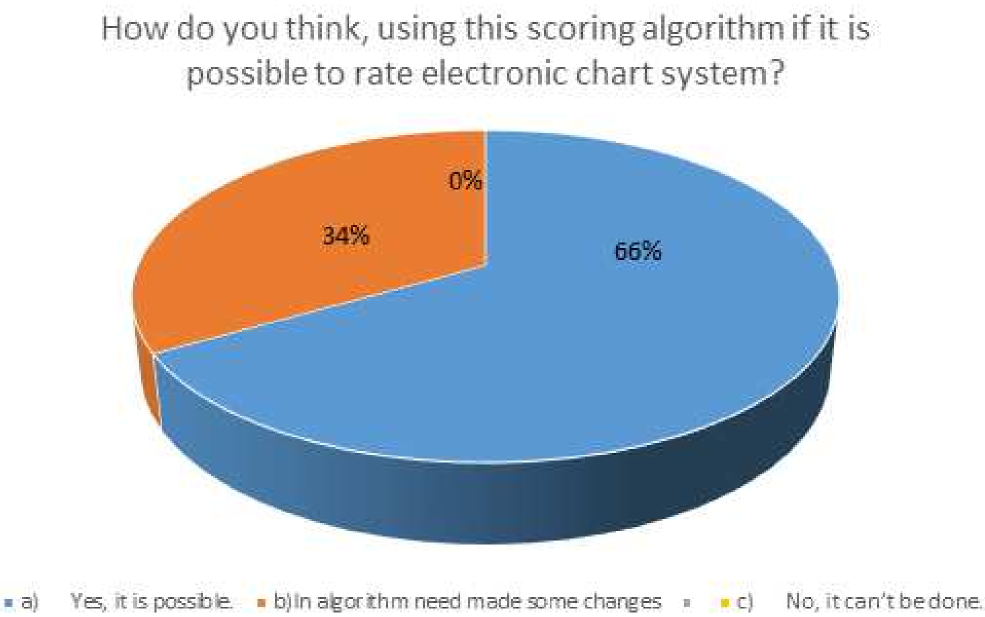

Chart 10 - Respondents' survey results

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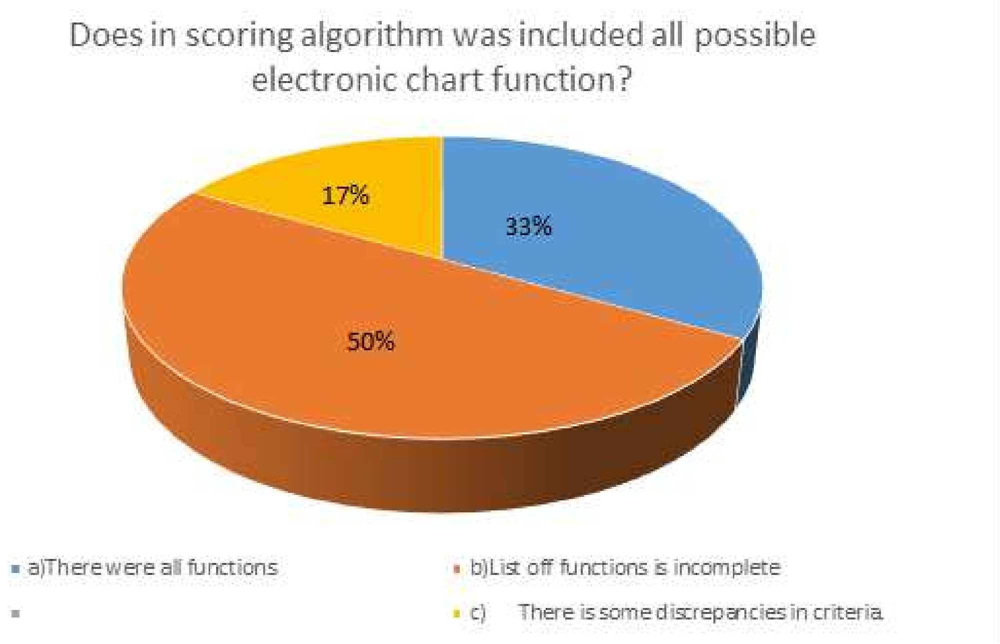

Chart 11 - Respondents' survey results

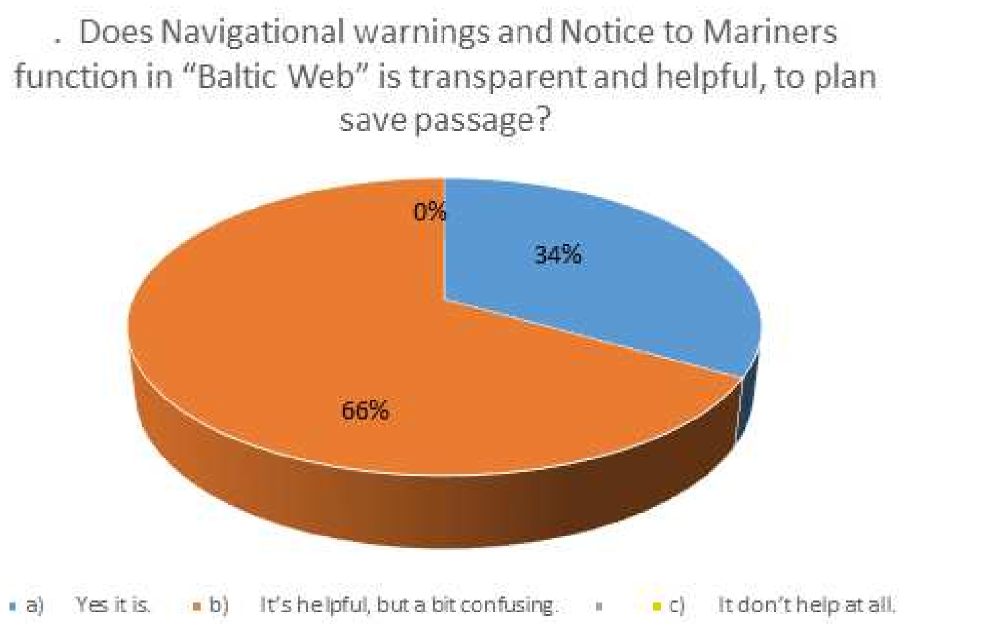

Chart 12 - Respondents' survey results

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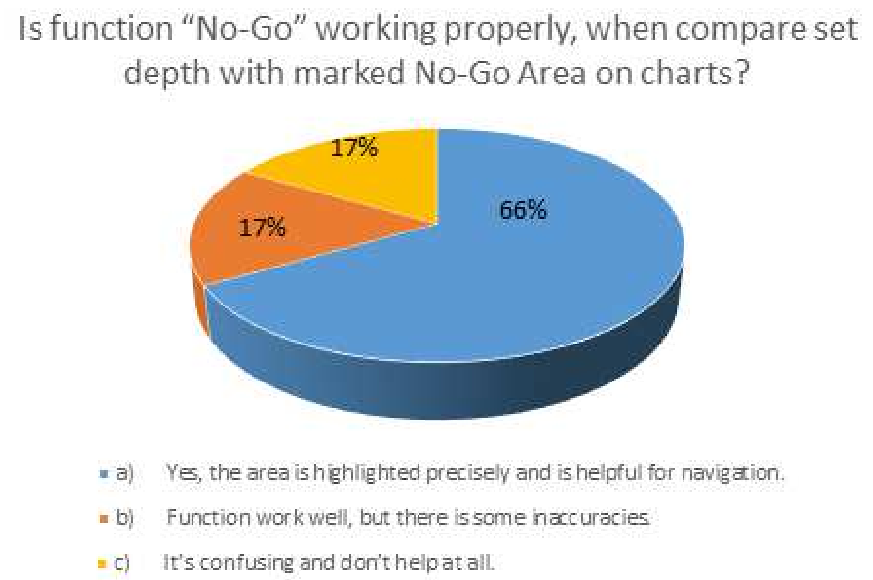

Chart 13 - Respondents' survey results

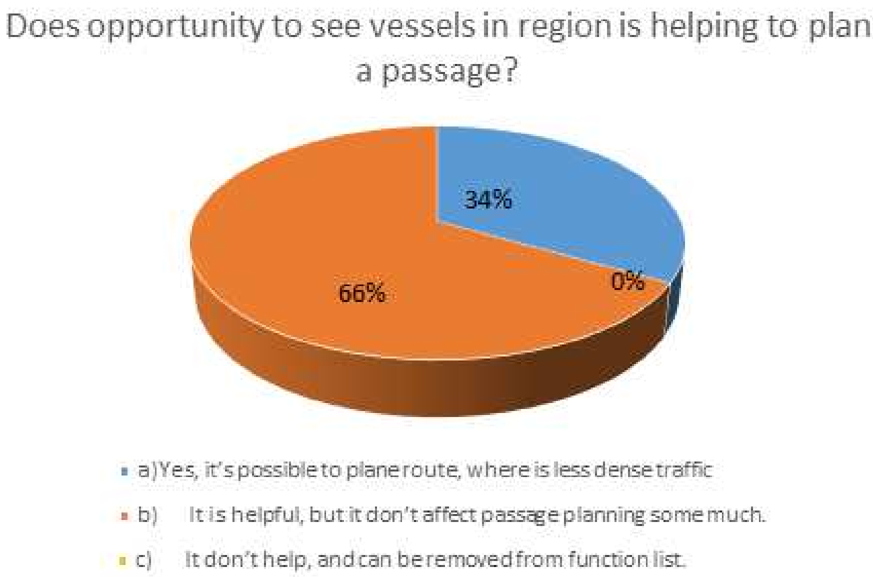

Chart 14 - Respondents' survey results

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After completing the third part, respondents were given an opportunity to be acquainted with the features and capabilities of the “ArticWeb” platform. Such a subtle study was not conducted for the analysis of this program, since the possibilities and functions offered by the ECDIS Navi Sailor 4000 are not in the same ranking criteria table. Respondents acknowledged that the “ArcticWeb” platform had a well-developed and functional ice and meteorological report that would significantly help navigate the Arctic regions. Otherwise, the “ArcticWeb” platform cannot be a complement to the ECDIS system.

Summarizing the results of the evaluation algorithms performed by respondents, where the “BalticWeb” platform was compared with the ECDIS system, it is evident that this new platform needs many improvements. Compared to “ArcticWeb”, based on the “BalticWeb” platform, the latter has far more advanced improvements. The options that are responsible for marking the "No-Go" region, where 66% of respondents rated this option as highly efficient, 17% needed improvements and 17% that this feature does not help, are of high quality. As the next option, portraying navigation alerts and notices to seamen, 34% of respondents said that this option worked great, but 66% rated that a well-functioning option, but where minor improvements were needed and an option with an identical score, where 66% of respondents rated it as good, requiring minor improvements, and 34% said that this option works great as the AIS function for obtaining information on other ships. From this, it can be estimated that the “BalticWeb” platform is a potential auxiliary program for the ECDIS system in the Baltic region, as 66% of the respondents assessed that this platform could be an additional program for the ECDIS system only after improvements.

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Conclusion

The “BalticWeb” platform, after several improvements in the system, could be accepted as a future e-navigation program, which would complement the Electronic Chart Display and Information System for the Baltic Sea Region only.

According to the results of the evaluation algorithm it is observed that the “BalticWeb” platform has potential as a supplement to the ECDIS system in the Baltic Sea. Potentially, the “BalticWeb" can become an additional program for the ECDIS system, due to the user interface that is easy to see and easy to use. There is no need to install specialized navigational technical equipment hardware, you need a computer or tablet computer with secure Internet access.

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Appendixes

Appendix 1

Valuation algorithm

Criteria for Electronic Chart System Evaluation

System that is being evaluated:

____

____

Task Description:

____

____

____

____

Evaluation system have been divided to separate parts, each part represents specific functions of Electronic Chart System performance. Evaluation grade must be chosen strictly according to function title. Grades are listed below in decreasing order according to criteria efficiency. If certain criteria could be evaluated with few grades, then lowest grade must be chosen.

Evaluation system:

Implemented (I) – Described task/option is implemented and is fully operational and independent from other options; (4 points)

Defective (D) -Described task/option is implemented but is not available under certain circumstances; (3 points)

Restricted (R) – Described task/option is implemented, but restricted in access or dependant on other functions; (2 points)

Not Reliable (NR) – Described task/option is implemented, but is limited in functionality or is inaccurate; (1 points)

Not Implemented (NI) – Described task/option not implemented; (0 points)

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Risks of disinformation ____________________
- Access to information about limitation of system; ____________________
- Indicators in case of program failure; ____________________
- Access to primar sensors; ____________________
- Access to information about chart characteristics; ____________________

Detection of misrepresentation of information ____________________
- Possibility to adjust radar/chart settings to eleminate the discrepancy between the radar image and the electronic chart; ____________________
- Indication in case of chart overscaling or underscaling; ____________________
- Possibility to choose positioning system references; ____________________
- Own ship's position displayng error indicator; ____________________
- Radar, ARPA and AIS error indicator; ____________________
- Error indicator in case of different geodetic coordinate systems used; ____________________
- Indication about positioning system used; ____________________
- Indication of display mode; ____________________
- Indication of chart scale used; ____________________
- Indication of refernce system; ____________________
- Indication of presentation mode; ____________________
- Indication of vector type used; ____________________
- Posibility to choose ship's sensors; ____________________
- Posibility to input the own ship's safety contour; ____________________
- Posibility to input safety depth ____________________
- Posibility to input events at positions; ____________________

System performance and accuracy, access to primary information source ____________________
- Information about connected sensors is provided; ____________________
- Information about satellite and radio navigation system input is provided; ____________________
- Information about Radar input is provided; ____________________
- Information about gyro-compass input is provided; ____________________
- Information about log input is provided; ____________________
- Information about echo-sounder is provided; ____________________
- Possibility to manually input compass error on the accuracy of course indication; ____________________
- Possible to manually input log correction on the accuracy of speed calculation. ____________________

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Setting up and maintaining display ____________________

- Possibility to choose display type and information to be displayed; ____________________
- Possibility to adjust all variable radar/ARPA display controls; ____________________
- Possibility to select convenient configurations; ____________________
- Possibility to select the timescale of vectors; ____________________
- Possibility to make performance checks of position, radar/ARPA, compass, speed input sensors; ____________________

Operational use of electronic charts ____________________

- Display of position, heading/gyro course, speed, safety values and time; ____________________
- The manual functions by the cursor, electronic bearing line, range rings; ____________________
- Selecting and modification of electronic chart content; ____________________
- Scaling; ____________________
- Zooming; ____________________
- Setting of the own ship's safety data; ____________________
- Using a daytime or night-time display mode; ____________________
- Using different kinds of cursors and electronic bars for obtaining navigational data; ____________________
- Viewing an area in different directions and returning to thw ship's position; ____________________
- Finding the necessary area, using geographical coordinates; ____________________
- Displaying indispensable data layers appropriate to a navigational situation; ____________________
- Selecting appropriate and unambiguous data (position, course, speed etc.) ____________________
- Entering the mariner's notes; ____________________
- Using North-Up orientation presentation and other kinds of orientation; ____________________
- Using true – and relative-motion modes. ____________________

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Route Planning ______________________________
- Possibility to load ship's characteristics into system; ______________________________
- Possibility to review required waters for sea passage; ______________________________
- Possibility to check chart list, and charts last update; ______________________________
- Able to construct the route on a display, using the graphic editor, taking into considiration rhumb line and great-circle; ______________________________
- Using system database for obtaining navigational, hydro-meteorological and other data; ______________________________
- Possibility to set/adjust turning radius and wheel-over points/lines when they are expressed on chart scale; ______________________________
- Possibility to mark dangerous depths and areas and exhibiting guarding depth contours; ______________________________
- Possibility to mark waypoints with the crossing depth contours and critical cross-track deviations, as well as by adding, replacing and erasing of waypoints; ______________________________
- Posiibility to perform route-check; ______________________________
- Possibility to generate alarms and warnings; ______________________________
- Route planning with calculation in the table format; ______________________________
- Waypoint selection in a table; ______________________________
- Recalling the waypoints list; ______________________________
- Adding notes to waypoint table; ______________________________
- Possibility to adjust planned route; ______________________________
- Possibility to make alternative route; ______________________________
- Saving planned routes, loading and unloading or deleting routes; ______________________________
- Making a graphic copy of the monitor screen and printing a route; ______________________________
- Editing and modification of the planned route; ______________________________
- Setting of safety values according to the size and manoeuvring parameters of the vessel; ______________________________
- Back-route planning; ______________________________
- Connecting several routes; ______________________________

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Route Monitoring ___________________

- Possibility to use independent data to control ship's position; ___________________
- Possibility to use look-ahead function; ___________________
- Changing charts and their scales; ___________________
- Reviewing navigational charts; ___________________
- Vector time scaling; ___________________
- Possibility to predict ship's position for some time interval; ___________________
- Possibility to add independent data for the calculation of wind drift and current allowance; ___________________
- Possibility to enter corrections for discrepancies of the geodetic datum; ___________________
- Displaying markers on a ship's route; ___________________
- Possibility to measure coordinates, course, bearings and distances on a chart. ___________________

Alarm indicators ___________________

- Abscene of the next chart in the ECDIS database; ___________________
- Crossing a safety contour; ___________________
- Exceeding cross-track limits; ___________________
- Deviation from planned route; ___________________
- Approaching a waypoint; ___________________
- Approaching a critical point; ___________________
- Discrepancy between calculated and actual time of arrival to a waypoint; ___________________
- Under-scaling or over-scaling; ___________________
- Approaching an isolated navigational danger or danger area; ___________________
- Crossing a specified area ___________________
- Selecting a different geodetic datum; ___________________
- Approaching other ships; ___________________
- Watch termination; ___________________
- Switching timer; ___________________
- System test failure; ___________________
- Malfunctioning of the positioning system; ___________________
- Failure of dead-reckoning; ___________________
- Inability to fix vessel's position using the navigational system. ___________________

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Manual correction of a ship's position and motion parameters ______________________

- Possibility to correct ship's position in dead-reckoning mode, when the satellite an radio navigation system reciever is switched off; ______________________
- Possibility to correct ship's position, when automatically obtained coordinates are inaccurate; ______________________
- Possibility to correct course and speed values. ______________________

Ship's electronic log ______________________

- Automatic voyage recording; ______________________
- Recording media; ______________________
- Possibility to set up recording intervals; ______________________
- Verification of database in use; ______________________
- Possibility to check records in electronic ship's log; ______________________
- Instant recording in the electronic ship's log; ______________________
- Possibility to change ship's time; ______________________
- Possibility to enter additional data; ______________________
- Possibility to print ship's electronic log; ______________________
- Interface with a voyage data recorder (VDR). ______________________

Chart updating ______________________

- Possibility to perform manual updating of electronic charts; ______________________
- Possibility to perform semi-automatic updating of electronic charts; ______________________
- Possibility to perform automatic updating of electronic charts; ______________________

Operational use of electronic navigational systems where radar/ARPA is connected ______________________

- Possibility to connect ARPA; ______________________
- Indicating target's speed vectors; ______________________
- Indicating target's tracks; ______________________
- Archiving target's tracks; ______________________
- Viewing the table of the targets; ______________________
- Checking alignement of radar overlay with charted geographic features; ______________________
- Possibility to simulate one or more manoeuvres; ______________________
- Possibility to make corrections using the ARPA's cursor and electronic bar; ______________________

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Operational use of electronic navigational systems where AIS is connected ______________________

- Interface with AIS ______________________
- Interpretation of AIS data; ______________________
- Indicating target's speed vectors; ______________________
- Indicating target's tracks ______________________
- Archieving target's tracks ______________________

Summary grade of the system (points / percentage) ______________________

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Appendix 2

Survey of “Baltic Web” program Usage

1. Was it easy to find the all necessary features on the “Baltic Web” program, when making passage plan?
    a) There were no problem to find.
    b) Faced minor difficulties to find.
    c) It was hard, to find necessary features.

2. Whether the interface of the “Baltic Web” program was easy to use?
    a) Yes, it was.
    b) Was a bit uncomfortable.
    c) The interface need to be, redesigned.

3. If there were any difficulty working with the scoring scale?
    a) Wasn’t
    b) There were some minor difficulties choosing between answers.
    c) Scoring scale is made incorrect.

4. Whether coverage and quality of the offered maps in the selected region were satisfactory?
    a) Yes, it was satisfactory.
    b) There were inconsistencies.
    c) The chart catalog is incomplete.

5. How hard was to understand the scoring criteria?
    a) Was difficult.
    b) Partially hard.
    There were no difficulties.

6. How do you think, using this scoring algorithm if it is possible to rate electronic chart system?
    a) Yes, it is possible.
    b) In algorithm need made some changes.
    c) No, it can’t be done.

7. Does in scoring algorithm was included all possible electronic chart function?
    a) There were all functions.
    b) List off functions is incomplete.
    c) There is some discrepancies in criteria.

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8. Does Navigational warnings and Notice to Mariners function in “Baltic Web” is transparent and helpful, to plan save passage?

a) Yes it is.
b) It’s helpful, but a bit confusing.
c) It don’t help at all.

9. Is function “No-Go” working properly, when compare set depth with marked No-Go Area on charts?

a) Yes, the area is highlighted precisely and is helpful for navigation.
b) Function work well, but there is some inaccuracies.
c) It’s confusing and don’t help at all.

10. Does opportunity to see vessels in region is helping to plan a passage?

a) Yes, it’s possible to plane route, where is less dense traffic.
b) It is helpful, but it don’t affect passage planning some much.
c) It don’t help, and can be removed from function list.

11. In overall, does systems “EfficienSea2” program “Baltic Web” is potential addition to ECDIS “Navi Sailor 4000” using in Baltic and Arctic region?

a) Yes it is.
b) After making some improvements it may be.
c) It seems to be unlikely.

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Appendix 3

Task for comparing Baltic Web and ECDIS Navi Sailor 4000.

1.) Fill out scoring algorithm about systems EfficienSea2 program “Baltic Web”.

2.) Fill out scoring algorithm about systems ECDIS “Navi Sailor 4000”

3.) Make passage plan using ECDIS “Navi Sailor 4000”, in strait between Helsingborg (Swe) and Helsingor (Den), using following waypoints.

0. Pilot boarding point ϕ = 550 58.102’N; λ = 0120 42.598’E

1. Entering TSS ϕ =550 58.831’N; λ = 0120 41.771’E

2. Turning point ϕ = 560 03.244’N; λ = 0120 39.539’E

3. Exiting TSS ϕ = 560 07.685’N; λ = 0120 32.024’E

4. Pilot departure point ϕ = 560 11.793’N; λ = 0120 29.398’E

4.) Using EfficienSea2 program “Baltic Web” assemblage with ECDIS “Navi Sailor 4000” make the passage plan, using same way points, given in part 1.

5.) Fill out questionnaire, about both “Baltic Web” and ECDIS’’

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