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Coastal Navigation – in a digital era

Odd Sveinung Hareide

Navigation is one of many different tasks on board a naval vessel. Situational awareness is very challenging during complex operations on the coast an at sea. Photo: Norwegian Armed Forces.

Abstract: Coastal navigation is known as a complex craft. Technological aids and integrated computer systems have been developed for the ship bridge with the aim of increasing the navigator's situation awareness, and so the control of a passage has become less complex. This paper presents and argues that control strategies used before the digitalization of the modern ship bridge still apply, and are important tasks for the navigator. Even though the navigator has several sensors and systems to assist in the navigational task, errors or failures may occur. System awareness has thus become an increasingly central part of the navigator's situational awareness. The paper emphasises the importance of human-centred design aligned with control strategies and standard operating procedures. Finally, the ongoing pursuit of using the technology of tomorrow in order to reduce head-down-time and increase situational awareness for the navigator, is outlined.

1 Background

Norway has been a major maritime player for several hundred years, with a long and strong history. According to the ICS Shipping statistics on largest beneficial ownership countries, Norway is the world's ninth largest maritime flag state, based on national and foreign dead-weight tonnage (1). With a coastline of 83 291 kilometres and a vast amount of islands and skerries, the Norwegian coastline is known to be both challenging and scenic (2).

To better comprehend coastal navigation, it is important to have an understanding of the complexity of the Norwegian coastline. The amount of fjords, islands, skerries, underwater rocks, obstacles and aids to navigation are enormous. The quality requirements for the craftsmanship of navigation when conducting a passage in such an environment is therefore high. If one could successfully undertake the challenge of such a passage by applying control strategies and methods, then those can also be used in less challenging waters. If a navigator can cope with high speed manouvering in such challenging waters, then the same navigator could use the same strategies and methods in less confined waters and in lower speeds.

During the past decades the ship bridge has been increasingly fitted with technological aids, and the amount of displays presenting information for the navigator has increased. Some of the aids that have had significant impact is the Radar, Electronic Chart Display and Information Display (ECDIS) and both Integrated Bridge Systems (IBS) and Navigation Systems (INS) (3-7). The aim of the aids has been to increase the navigator`s situation awareness (SA), in order to facilitate safe navigation.

Even though the number of navigation aids have increased in the last decade, the craftsmanship of navigation stays the same. The words of Nathanial Bowditch in the book "The American Practical Navigator" is best suited to explain this:

> *"Marine navigation blends both science and art. A good navigator constantly thinks strategically, operationally, and tactically. He plans each voyage carefully. As it proceeds, he gathers navigational information from a variety of sources, evaluates this information, and determines his ship's position… Some important elements of successful navigation cannot be acquired from any book or instructor. The*

science of navigation can be taught, but the art of navigation must be developed from experience." (8).

With the introduction of electronic navigation aids for the navigator, the basic craftsmanship of navigation has been challenged in a new way. This has partly come from an over-reliance in the systems providing information to improve the SA of the navigator (9, 10). There are several examples and studies of for example ECDIS-assisted groundings, which are based on an over-reliance in the information being presented from the ECDIS (11).

The navigator`s work before the introduction of Electronic Positioning Fixing System (EPFS), where the most commonly used system is the Global Positioning System (GPS), was mainly in *finding and fixing* the vessels position, using traditional navigation techniques such as conducting a position fix with position lines, in order to establish the observed position of the vessel (8). With the introduction of Multi-Function Displays (MFDs) with ECDIS application, the navigator`s work during the passage is now to *monitor* the vessels position (12). This makes the navigator an important part of the integrity monitoring of the vessel (13). Maritime navigation, which was considered a special kind of knowledge, understanding and proficiencies, is now become a more integrated knowledge (14). At the same time, the years with the use of GPS as a position source in the navigation system (NAVS) has shown us a need for resilience and robustness in the system (15-17). There are several examples of outage of the signal provided by an Global Navigation Satellite System (GNSS), such as GPS (18, 19). There are also reports on failure of equipment due to lack of maintenance (9). The navigator`s role in integrity monitoring of the systems is important with the increasing need for resilience in the systems in order to provide robust navigation. Robust navigation is the ability for a vessel to navigate safely at all times under all conditions (20), and this consist of all support systems and the navigator itself on a manned vessel. Thus one could argue that the challenges for the modern navigator has changed, and most likely increased with the demands for system knowledge (awareness), with the digitalization of the ship bridge (10).

2 Digitalization on the maritime bridge

The modern ship bridge has a wide variety of sensors that are integrated and connected through various networks. The information is presented on MFDs on the ships bridge, as illustrated in the simplified schematics in Figure 1.

The amount of sensors integrated and connected within the NAVS is variable dependent on the ships type and size. Figure 1 is illustrating that there is a large amount of sensor providing integrated information, which is presented to the navigator in Human-Machine Interface (HMI) at the ship bridge through the MFDs. All of these sensors has their advantages, as well as limitations, which should be known and understood by the navigator to better interpret and evaluate the information provided on the MFDs. As examples, the position sensor has its limitations concerning the low signal power of the GNSS (21), and the navigator should be using ground- or space based augmentation systems to improve the integrity of the GNSS in use. The heading sensor accuracy is dependent on which technology is used, which induce that there are differences in performance between e.g. a mechanical and a fibre-optical gyro compass. This implies that the navigator has to have thorough knowledge of every component in the navigation system, and at the same time master the craftsmanship of traditional navigation (22).

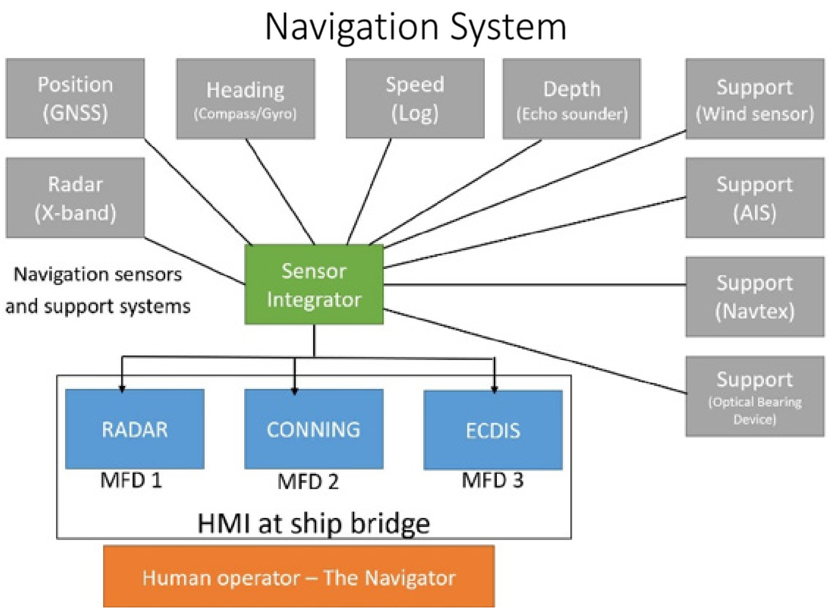

Fig. 1. Simplified general schematics for the navigation system on a modern bridge.

2.1 The modern Navigator`s Situation Awareness

The changes for the modern navigator can be highlighted through a better understanding of the navigator`s SA. SA is basically to be aware of what is happening around you and understand what that information means to you now and in the future (23). The formal definition of SA is *"the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (24).* To better understand SA, the term *system awareness* is important in the context of the new demands set forward for the modern navigator. Wickens (25) argues that SA consist of three components; Spatial awareness, system awareness and task awareness. Spatial awareness consist the navigator`s awareness of the vessels position, and the factors that influence the position such as the weather and environmental factors. Task awareness is related to the task the navigator`s has at hand, mission assurance and the conduct of the navigation task. System awareness concern the complexity of the system in use, which in the maritime will vary with the vessel type. For the maritime navigator system awareness is imperative for knowing what state the INS (and all subcomponents) is in. The ermerging threat from cyber security with the increased digitalization of the vessels is also highlighted (26). With the digitalization of the modern ship bridge, system awareness becomes an important and integral part of the navigator`s SA. Figure 3 highlights the three components of the Navigator`s SA, note that the third line is examples and are not a complete list (27).

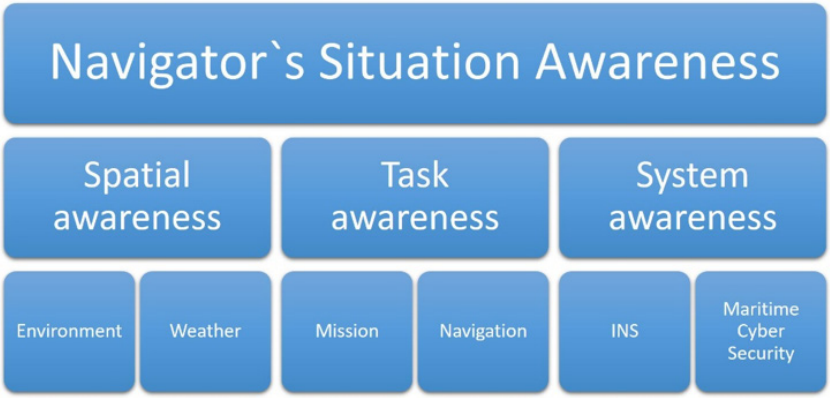

Fig. 2. Navigator`s Situation Awareness (27).

Figure 3 underlines the importance of system awareness for the navigator, and the understanding of the possibilities and limitations, within the systems in use is imperative to increase the SA of the navigator (28).

2.1.1 Maritime Cyber Security.

With the introduction of computer systems on the modern ship bridge, the vulnerabilities of cyber security arrive. The issue of Maritime Cyber Security has been much discussed (29), and there has been conducted demonstrators to show the impact of such an cyber-attack (26). An example of potential attack vectors is given in Figure 3.

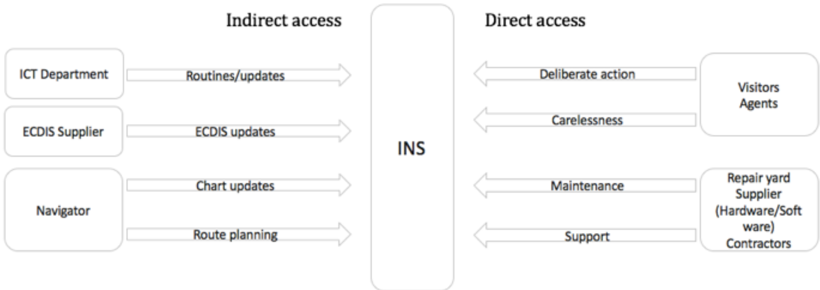

Fig. 3. Example of attack vectors towards an INS (27).

More ships are interconnected with the internet, but the majority of the integrated navigation systems is not. There is a general notion that as long as the navigations system is not connected to the internet, the vessel is safe from the cyber threat. This could lead into a false sense of security, as there are several attack vectors as shown in Figure 2, and the navigator must be aware of these to induce a better understand of the threat from cyber (27). The threat from cyber is a new challenge the modern navigator is facing within the digitalization of the ship bridge and navigation process.

3 Robust Navigation

The modern navigator primary task stays unchanged: To conduct safe navigation of the vessel. The INS aim to support the navigator`s SA to enhance safe navigation (30). Robust navigation is the ability for a vessel to navigate safely at all times under all conditions (20), and has been used in the description of autonomous vessels continuous strive to facilitate navigation and guidance in environments where normal navigations sensors, such as GNSS, is not feasible (17).

In a maritime context, robust navigation could be achieved by utilizing all sensors available, and on a manned vessel this will include the navigator. The modern ships has seen an increase in the use of navigation sensors on board, as an example Maersk is fitting Light Detection and Ranging (LIDAR) on the new built Winter Palace ice-class container ship (31). An example of the range of navigation sensors providing the recognized maritime picture (RMP) to the navigator is shown in Figure 4.

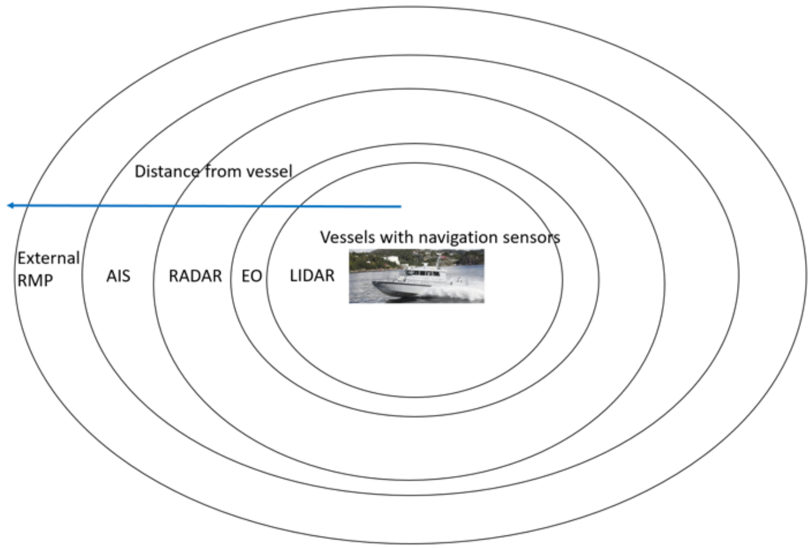

Fig. 4. Navigation sensors and detection range from vessel.

Figure 4 implies the range of the different sensors in use on a modern vessel, and it is important to underline that each of the sensors has it`s possibilities and limitations. E.g. the electro-optical (EO) sensor has limitations in use in fog. It is a challenge that the curriculum for the navigator of today does not include some of the sensors in use (such as FMCW radars – 4G), introducing a possible gap between the technology at hand, and the knowledge of the equipment by the operator (14).

Decision support systems (DSS) has been developed to assist the navigator to safely navigate the vessel (32). The DSS can also be coupled to automation (normally the autopilot - AP), inducing a higher level of automation. Sheridan and Verplanks describes the levels of automation, as shown in Table 1 (33).

Table 1. Levels of automation (33)

Aut level	Automation description
1	The computer offers no assistance, human must take all decisions and actions
2	The computer helps by determining the options.
3	The computer helps determine and suggests options. The human operator can choose to follow the recommendation
4	The computer selects the action and the human operator decides if it should or should not be done.
5	The computer selects the action and implements it if the human operator approves the action.
6	The computer selects the action and informs the human operator in case the operator wants to cancel the action.
7	The computer does the action and tells the human operator what is did
8	The computer does the action and tells the human only if the human operator asks.
9	The computer does the action when told and tells the human operator only if the computer decides the operator should be told.
10	The computer does the action if it decides it should be done. The computer tells the human operator only if it decides the operator should be told

The awareness of the operator (navigator) being surprised by the automation (defined as automation surprise) was described by Sarter et.al in 1997 (34), and it still implies today (35). It is important for the navigator to understand the levels of automation, and at all times which automation level (AL) the system operates in, in order to conduct a safe passage with efficient control.

3.1 The role of the navigator

The modern navigator on ship bridges has faced a paradigm shift the past decade with the introduction of electronic aids, where the most visual and known change is the shift from paper to electronic navigation charts (ENCs). The ENCs are presented on the ECDIS, and with the integration of navigation sensors (Figure 1), the navigator has the ships near real-time position continuously presented on the ECDIS. The paradigm shift has been a major advance for safe navigation, but at the same time different accident boards has reported on groundings due to over-reliance in systems (36, 37). ECDIS-assisted groundings has been introduced, and it has been identified that there is a challenge for the navigator to identify system failure or errors in the ECDIS (38).

Before this paradigm change, the navigator spent most of the time to find and fix the vessels position. Using the ECDIS, the navigator today monitors the system. Monitoring of systems is something that humans are not very good at, and research shows that visual monitoring quality deteriorates after 30 minutes (35, 39). This is something that the navigator needs to be aware of, and there should be implemented standard operating procedures (SOP) with adequate human-centred design of interfaces to support the navigator in the decision making process (34, 40).

4 Case study: Royal Norwegian Navy procedures for coastal navigation

The Royal Norwegian Navy (RNoN) operates a variety of vessels, operating in demanding waters along the Norwegian coastline. The philosophy, and experience, is that if it works on a High Speed Craft (HSC), in demanding littoral waters, it will work on a bigger or smaller ships, in lower speeds in less demanding waters (41, 42). The test platform for evaluation and development of Graphical User Interfaces (GUI) and SOPs regarding navigation has therefore been the Norwegian Corvettes (Figure 5), capable of doing up to 60 knots, and known as the world`s fastest warship (43). Navigation in the RNoN is normally done in a navigation team, so the Officer of the Watch has a navigation team to distribute the different navigational task. On HSCs the navigation team normally consists of two persons.

Fig. 5. Skjold-class Corvette (44).

The RNoN separates between safe and efficient navigation. Efficient navigation is defined as «utilizing the vessels sensors, systems and speed in order to navigate safely to successfully complete the current mission» (42). This implies that if a vessel is able to operate in high speeds, this speed must be utilized in the area of operation.

4.1 Safe and efficient navigation

The safe and efficient navigation of a vessel consist of several factors, and is shown in Figure 6 (40).

Safe and efficient navigation is comprised of both navigational and human factors, and Figure 6 illustrates the complexity of the different factors which must be addressed to achieve safe and efficient navigation.

The navigational factors consist of four main components, which all holds several sub-components with possibilities and limitations.

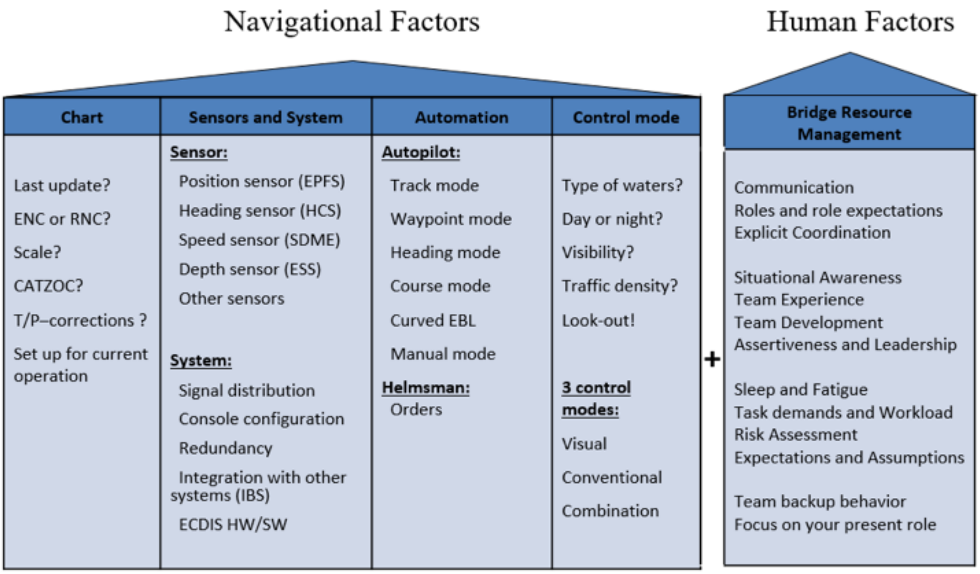

Fig. 6. Factors to address for safe and efficient navigation

The ENC can be used as an example within the *chart component:* One of the challenges with the ENC, is that it holds much information, which might not be presented to the navigator due to the layers chosen for presentation. As an example, the data quality, known as Category of Zone of Confidence (CATZOC), is not normally presented. This is important information for the navigator to hold, as the difference between the data quality within CATZOC A and C is significant (12).

An example of the integration of *sensors and systems* has been shown in Figure 1, and the navigator needs to keep a high degree of system awareness in order to determine failures or errors within the system and the integrated sensors.

The dangers of *automation* surprise have been recognized, and an example is the limitations in the AP concerning turning radius. If the vessel is in automation track mode, and the turning radius has been planned to sharp, the AP automatically shifts to heading mode due to the systems is in AL 7. This will stop the planned turn, and the vessel will continue in a straight line. Turn are made to avoid dangers, and the turning phase of a vessel should be monitored closely by the navigator, independent of AL.

Control mode is an important aid for the navigator in order to maintain a high degree of SA, while at the same time acknowledging that the awareness of the navigator cannot be held on a high level during the whole passage (45-47). There are three main control modes, used in different environmental conditions. With daylight and good visibility, visual control is used. If the passage is conducted during night hours, or the visibility is poor, Radar (conventional) control mode is used. Visual and radar (conventional) is also used in combination, and it is important to understand the methodology, possibilities and limitations of the control modes. The control strategy used within the chosen control mode is known as the Phases of Navigation (28, 40).

The fifth pillar contains the human factors, and comprises the importance of the human operating in the system and in co-operation with other humans in a team. Human factors in relation to bridge resource management is important, especially in HSC where the navigation task normally is conducted as teamwork in a team of minimum two people. The understanding of the navigator`s role in teamwork, and the critical considerations in teamwork and collaboration is imperative (48). The roles in the team, communication and coordination of the tasks at hand is underlined as important for the resource management in the bridge team (49).

4.2 Phases of navigation

The control strategy is shown in Figure 7, and it is an iterative process which is aligned with the bridge communication procedure in the RNoN SOP.

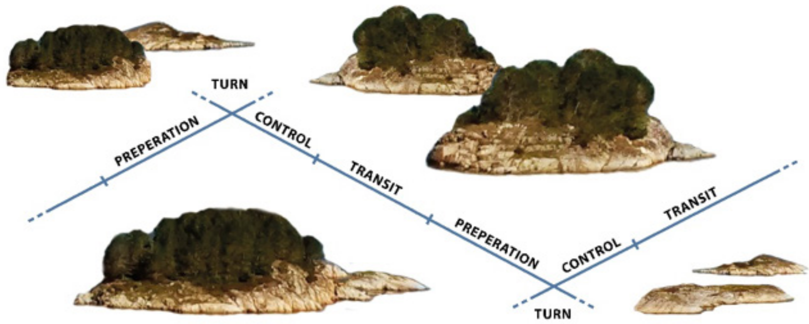

Fig. 7. Overview of the phases of navigation.

The length of each of the four phases is dependent on the type of waters the vessel is operating in. If the vessel is doing 30 knots, and the leg distance is 0,5 nautical miles, the navigation team has 1 minute to complete the phases of navigation. A vessel doing 12 knots, with a leg distance of 0,5 nautical miles, the navigation team or navigator has 2 minutes and 30 seconds to complete the phases of navigation. The different phases consist of the elements shown in Figure 8, and the four phases is given a general outline after the following figure.

Phase 1 consists of the preparation before a turn is initiated. In this phase it is important that the navigator and/or navigation team gather and highlight all relevant information from the system to successfully conduct the turning phase.

Phase 2 is the critical turning phase for the vessel, where the vessel alters course. In this phase it is imperative that the navigators` focus is on the surroundings and conning of the ship, to make sure the turn is executed correctly, i.e. to avoid automation surprise.

Phase 3 consist of the control phase after an alteration of the course. Immediately after the turn, the navigator collects information to establish whether or not the ship is in the predicted (and correct) position. This information is primarily gather

from the surroundings of the ship, and secondly supported by the navigation systems. This phase also consists of the reoccurring cycle of predicting the set and drift, and also predicting the surrounding traffic pattern.
Phase 4 is the transit phase, where the vessel is transiting between two wheel over points (WOP). In this phase it is important that the navigator continuously monitors the position of the vessel, both by visual and conventional control methods (50, 51). Collision avoidance and the decision making process of re-planning the voyage concerning other vessels, objects or changes is the task at hand is within this phase. Phase 3 and 4 is an iterative process until the next planned WOP is reached and the phases of navigation starts over again.

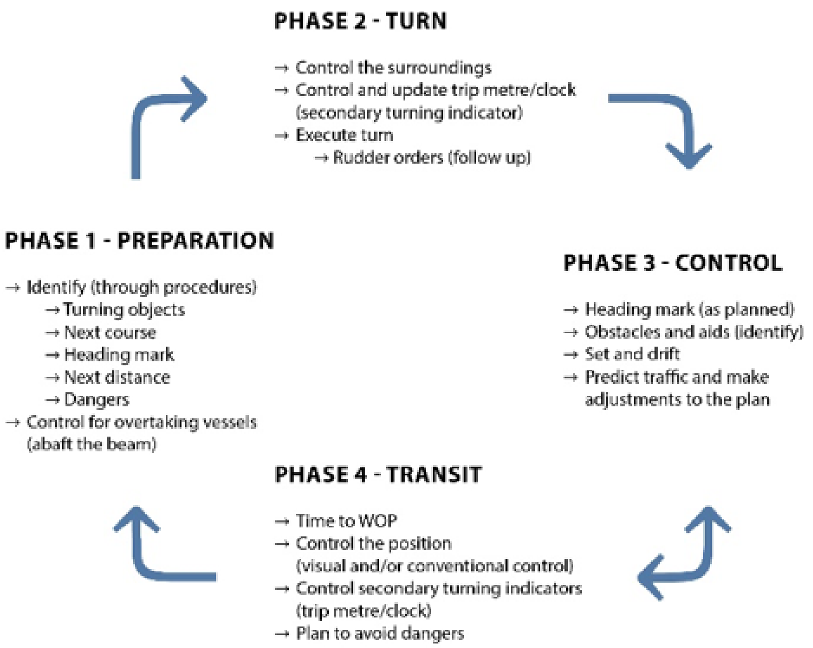

Fig. 8. Content of the four phases of navigation.

Note that the four phases of navigation are utilized after a thorough planning process has been conducted (52), and is the methodology that the navigator is using during the watch. The methodology fits on any type of vessels, but the process is more demanding in confined water and with higher speed.

4.3 Route monitor window for the navigator

The International Maritime Organization (IMO) states that the ECDIS should support route monitoring in a simple and reliable manner. The revised performance standard for ECDIS further lays down the main feature for the route monitoring function, which should support the navigator`s situational awareness in order to facilitate safe navigation (53). It is not presented a detailed description of how this should be implemented in the software. This results in each manufacturer implementing the standards in different ways, resulting in different interfaces for the route monitoring from manufacturer to manufacturer (5, 54).

The RNoN uses several manufacturers of ECDIS and Electronic Chart Systems (ECS). ECS is known as all other systems which is not a type-approved ECDIS.

In order to facilitate the RNoN SOP for the conduct of a safe and efficient passage, a template for the information presentation in the route monitor GUI has been developed. Figure 9 shows the template which has been evolved with the experience from the RNoN in operating HSC, aligned with research supported by eye tracking technology using Eye Tracking Glasses (ETGs) on board a HSC (55-58).

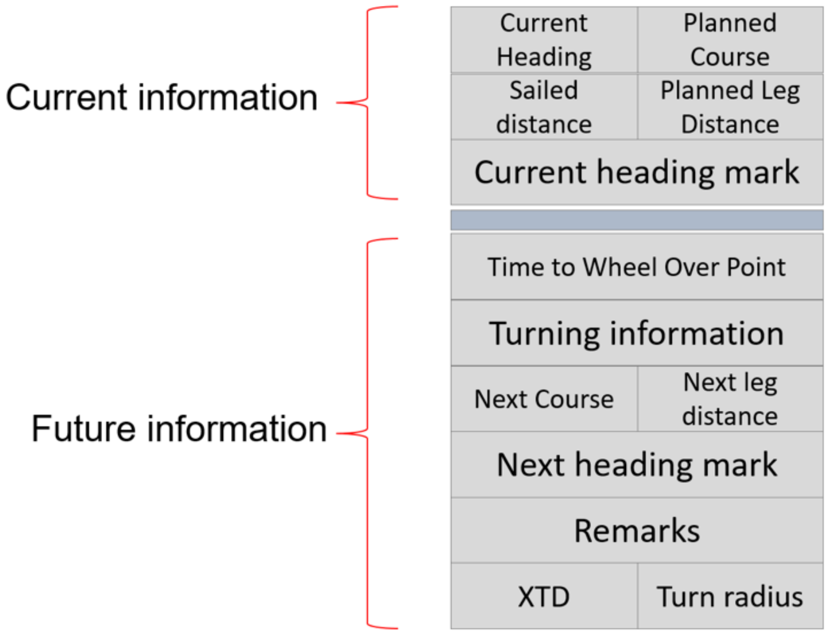

Fig. 9. Overview of the information template used on ECDIS/ECS.

Human-Centred Design criteria are essential for successful design and solutions to be used by the navigator. The conceptual content described in this figure aims to make a higher degree of maritime SA easier to achieve for the navigator, by balancing user requirements with supplier and bridge equipment capabilities and constraints (57).

One such constraint is the size of the window, which limits the amount of information available for stacking. The window size is regulated by the design of the manufacturer ECDIS and must be taken into consideration when designing a new GUI.

In the design-review of the route monitor window, current information is presented on top ("what am I doing now"?) followed by future information ("what should I do next"?) on the bottom (Figure 9). Related information is grouped in sequences, limited by what kind of information that is necessary and sufficient to maintain maritime SA. This allows the navigators` scan pattern to flow from top-to-bottom and left-to-right with data presented in a readily usable form, avoiding loss of critical data (57).

The work with the implementation of the template in the RNoN fleet is ongoing, and has currently only been conducted with one manufacturer. The results have not been truly evaluated yet, but the feedback from the end-users is that the new GUI is a much better tool than they previous had for route monitoring. The preliminary design which is in use on one vessel is shown in Figure 10.

Starting from the top-left corner in Figure 10, the first information for the navigator to compare is the current heading with the planned heading. If these two information boxes are the same, and the vessel is on steering towards the planned heading mark, the navigator is conducting continuous integrity monitoring of the vessel (57). The second line the navigator can compare the current sailed distance (from the trip meter) with the planned leg distance, when the two are the same, the vessel should be at its` turning point. On the third line, the planned heading marked are described with RNoN SOP notations, e.g. >GISO6 means that the heading mark is a green light with characteristics Isophase 6 seconds (42).

Fig. 10. Route Monitor GUI aligned to RNoN SOP.

In the future information, the navigator collects information during the preparation phase. The first line in future information provides instant information to the navigator of how much time (Time to Wheel Over Point) it is until the vessel arrives at the turning point, and the turning phase must be initiated. The second line presents information about what the turning object is, which is used for visual control of the vessel at the turning point. If the vessel has a heading mark, and a turning point abeam, the navigator has also conducted a position fix (50). The third lines present the next course and leg distance to the navigator, which is important to increase the SA for the navigator. The fourth line gives information about the next heading mark, which should be identified during the preparation phase, in order to facilitate a quick conduct of the control phase. The fifth line hold comments, which the navigator can establish during the planning of the voyage. The information should be vital to the conduct of the passage, e.g. information about reporting points, dangerous sea areas, etc. The sixth line presents information about the cross track distance and turning radius for the navigator, which is important information for a successful conduct of the turning phase.

5 Future concepts

The RNoN aim for a reduction in the Head Down Time (HDT) for the navigator, in order to facilitate the navigator in the conduct of the phases of navigation. This could be done by implementing the information template shown in Figure 9 together with the use of new technology. This should also allow the navigator to spend more time on other tasks at hand, helping to achieve and maintain the navigator`s SA (Figure 3).

5.1 Technology readiness level

The Technology Readiness Levels (TRLs) are a measurement system that will support the decision maker in the assessment of the maturity of particular technology, and the consistent comparison of the maturity between different types of technology (59). The TRLs is outlined in Table 2.

Table 2. The different Technology Readiness Levels (59).

TRL Level	TRL description
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical and experimental critical function and/or characteristic proof-of concept
4	Component and/or breadboard validation in laboratory environment
5	Component and/or breadboard validation in relevant environment
6	System/subsystem model or prototype demonstration in a relevant environment
7	System prototype demonstration in the real environment
8	Actual system completed and "flight qualified" through test and demonstration
9	Actual system "flight proven" through successful mission operations

It is an objective for the RNoN to utilize new technology in order to make operations more efficient or safer (60), and TRL should be used as a tool for assessing the maturity levels of the technologies the RNoN are thinking of utilizing, in order to assure a successful implementation.

The further aim of developing tools for the navigator to reduce HDT was examined by the use of TRLs. Two different concept has been trialled, the first being Head Up Displays (HUD), and the second Augmented Reality (AR).

5.2 Head Up Display

HUD has been used for several years, especially in the aviation industry, providing TRL 9. In the maritime domain it has not been much used, and the RNoN decided to co-operate with a company which already had tested and validated HUD in the maritime domain, providing TRL 8 for HUD in the maritime domain. The actual device is shown in Figure 11.

The cooperation consisted of implementing the information template in the HUD, an example of one of three interfaces is shown in Figure 12.

Fig. 11. Afterguard HUD (picture courtesy of Afterguard).

Fig. 12. HUD information interface template (picture courtesy of Afterguard).

The preliminary results indicate a potential for reducing HDT, however there are several challenges with the use of HUD in a Head Mounted Device (HMD). One of the major concerns is the refocus issues for the eyes with many and quick refocused from far distance by checking the surroundings of the ships, to a very short distance (3 centimeters) to the display in the HMD. This could be addressed by mounting the HUD in e.g. the windows of the bridge, as other research programs such as Ulstein Bridge Vision has shown (61). It is also identified challenges with the use of HUD during dark hours, where the HUD increase the light pollution which degrades the night vision for the navigator.

5.3 Augmented Reality

There has been done some research on Wearable, Immersive Augmented Reality (WIAR) in the maritime domain (62), but there is still a need to examine the specific contribution technology should make in enhancing navigational safety performance and processes (63). The use and knowledge of AR has evolved as several larger manufacturers, such as Microsoft and Google, has started releasing commercial products.

In the Maritime Augmented Reality (M-AR) project, the RNoN cooperates with other partners to investigates the use of AR technology in an operational maritime environment. The aim is to enhance the navigator`s SA by reducing HDT by providing the navigator with augmented information where it is needed. The information template in Figure 10 is used as a baseline, but at the same time AR can provide augmented information regarding the surroundings of the vessel. It is important to note that this information should not only be the reproduction of existing system symbology the augmented way (62).

The M-AR project use the Microsoft Hololense (Figure 13), which has TRL 8 in the gaming domain (64). In the maritime domain, the Hololense has TRL level 6. The aim of the product is to increase the TRL to level 7 by demonstrating the use of it in an operational environment.

The project is still in an early phase, and a first version is planned late 2018. The content of the information presentation is shown in Figure 14.
Figure 14 is a preliminary sketch, and the further plan is for interaction designers to work with the information presentation. The key points of the use of WIAR, is that it provides the opportunity to present the virtual parts of the world to the user through embedded or superimposed images, technical information, sound or haptic sensory information, which can be linked to other sensor inputs (63). The challenge for the M-AR project is to design and produce a prototype of this template, which is aimed to provide a higher degree of SA for the maritime (HSC) navigator.

Fig. 13. Microsoft Hololense (picture courtesy of Microsoft)

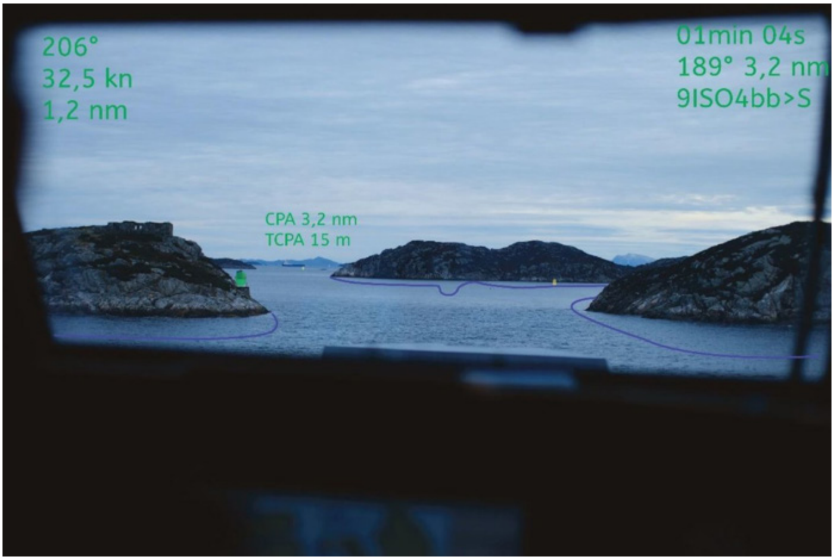

Fig. 14. Example of information presentation with AR.

6 Conclusion

Maritime navigation is evolving with the ongoing digitalization. The ship bridge has seen a rise in the amount of displays presenting information to increase the situational awareness of the navigator, but there has been a concern about the human having an over-reliance in the systems in use.
The craftsmanship of navigation has stayed the same for several hundreds of years, and so has the coastline. The Norwegian coastline is known to be a challenging coastline to navigate in, and it is important that the navigator uses good navigation craftsmanship and utilize the support systems in order to uphold a high degree

of situational awareness. Even though the craftsmanship stays the same, the ships has evolved, and are today larger, faster and with a higher density.
Through the experience gained over several years of coastal navigation and operating a variety of vessel in the RNoN, a control strategy for the navigation process has been developed. The control strategy is known as the Phases of Navigation, and is a decision-making process which needs to be completed to maintain safe and efficient navigation. This also implies the correct use of the electronic aids and sensors in the integrated navigation system, which is an important part of the digitalization of the navigation task.
The navigator`s primary task when performing coastal navigation, is to control the surroundings of the vessel, and collate this information with the integrated navigation system. Reducing the head down time for the navigator could contribute to an increased situational awareness for the navigator, and there are promising features with head up displays and augmented reality technology which needs to be further researched.

7 References

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