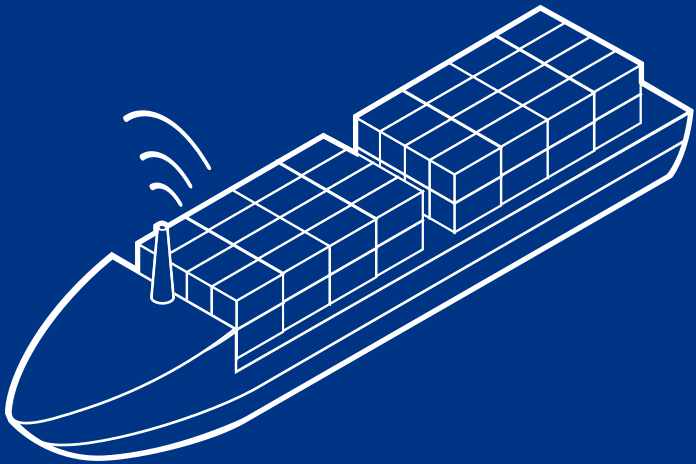
OpenRemote Beta

Exploring systems for autonomous vessels
in Remote control centers



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Design diploma, fall 2022 / AHO

Title
OpenRemote Beta - Exploring interfaces for autonomous maritime systems

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All photograhps, illustrations and content by the author, unless otherwise noted

Abstract

Autonomous vessels are now being used as a safer, cheaper, and more efficient way of transit through the oceans. Despite being capable of autonomous travel, the ships will still be closely monitored by operators in Shore Control Center(SCC), that can take control in critical and difficult situations. It is critical that these new systems are adapted to new situations and allow for effective communication between the autonomous system and the operator monitoring the operation.

Through a lens of interaction design, this project aims to investigate how the operator can monitor and operate the ship from land with a complete view of their situation in order to take the appropriate action when needed. I'll use an open innovative design approach, using the OpenBridge Design System as a starting point, and include users, OICL, other industry partners, and human factor experts to develop the project.

My goal for this project is to explore systems for future control centers for large autonomous vessels, as well as what information should be displayed in various situations to allow the operator to make the best judgments possible. The finished outcome will be feed back into the OpenBridge design system as an open-source resource for use in the maritime industries

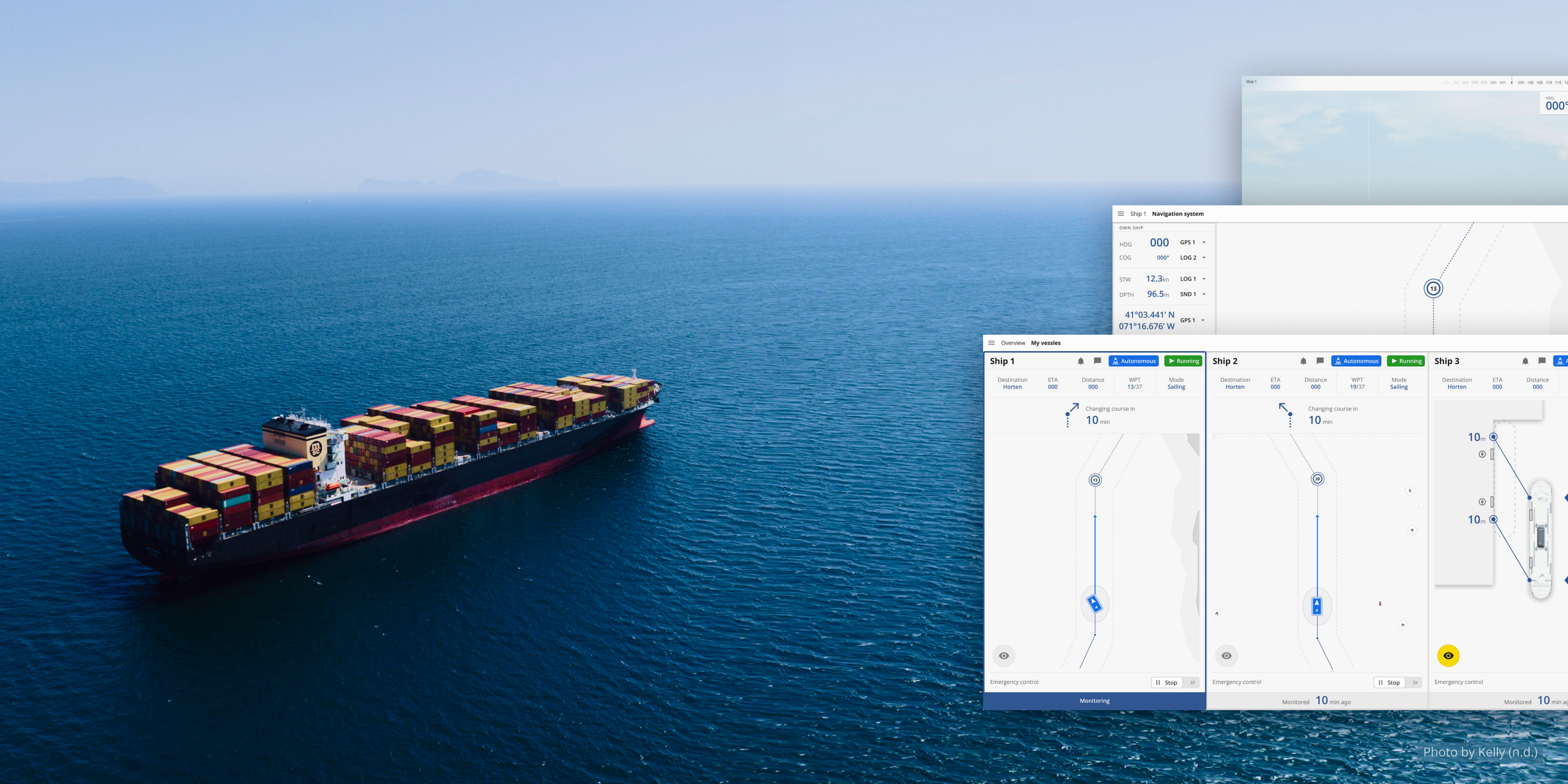

Photo by Kelly (n.d.)

Delivery

My final delivery in this project is a support system that will help the operator in monitoring their assigned ships and being aware of the assigned ship's situation and knowing when to take control. This software is meant to be used in a multiscreen setup at a fixed shore control center, and it is based on the OpenBridge design system.

As this project is a pre-work for a new AHO led research project, OpenRemote, my deliverable is not meant to be a finished product. Rather, it is an exploration of future design proposals that will be feed back to the maritime industries for further iterations.

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INTRODUCTION

Motivation

The new phenomena of autonomous ships are undergoing vast research, but they often stay hidden in the lab. There aren't many public precedents or examples, so there has not much of a critical design debate. This could lead to risk the safety of future operators if important discussions are not taken.

As a designer, I believe great design comes from discussing concrete examples. My greatest motivation has been to use the diploma project to provide open-source designs and findings to the maritime industry and help nudge the development of autonomous ship systems forward.

ocean industries concept lab

Some partners of OICL

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Introduction

Approach

I want to approach this project using an **open innovation design approach,** so that everything I work on could go back to the maritime community.

To do this, I chose to undergo collaboration with OICL to make it possible to reach the maritime community and make my project open-source. As a designer I have seen the major potential of open source design systems, such as material design, that help design development go much faster and I want to apply the same principle to my project. In this way I will help nudge the development of the autonomous system further.

02

CONTEXT

Project scope

Ship type
For this project, I have chosen to focus on autonomous ships used for cargo and logistics. These ships have the same route and predictable schedules they have to follow.

Designing for monitoring
Supervising autonomous ship would potentially include monitoring, micro-adjusting and taking manual control over the ship. However, all functions would depend on an effective monitoring system to alert the operator. Therefore I have chosen to exclusively focus on monitoring systems for my diploma project.

Collision avoidance situation with other large manned ship
Since collision avoidance will be a part of my project, in order to narrow down the project, I have chosen to focus exclusively on collision avoidance situations with other large manned ships.

Context

Project brief

How to design a system that will support the future operator in being aware of the situation of the assigned ships and being able to take control when an unexpected situation happens?

“MASS” phenomenons

In recent years autonomous ships have become a hot topic of discussion, both in the domestic and the international maritime world according to NFAS (The Norwegian Forum for Autonomous Ships). We can see this trend through numerous types of research projects that have been conducted in the past years and through various research projects that are ongoing.

- The EU MUNIN project, the first large-scale study on unmanned and autonomous merchant ships, running from 2012 to 2015. (About | MUNIN, n.d.)

- The Norwegian research project Autoship Horizon 2020, a collaboration between Kongsberg Group, Sintef, and others, received NOK 200 million from Horizon 2020 in 2020. (“EU Gir 200 Mill. Til Norsk Prosjekt for Å Teste Autonome Skip,” 2020)

- Yara Birkeland, the world's first fully electric and autonomous container ship with zero emissions is set to be sailing in 2022 and aims to work on approval activities for the un-crewed vessel (NMA with 3rd party assessment from DNV) by 2024 (Autonomous Ship Project, Key Facts About YARA Birkeland - Kongsberg Maritime, n.d.)

There are many types of autonomous ships but for this project I will be focussing on an autonomous ship type called “MASS”

MASS (Maritime Autonomous Surface Ship) is defined by The International Maritime Organization (IMO), as “a ship that, to a varying degree, can run without human interaction.” (International Maritime Organization (IMO), 5 B.C.E.) MASS is often associated with larger merchant ships that transport either **containers** or **bulk cargo.**

However “can run without human interaction” does not mean no humans would be involved. Human will still need to monitor and take over control in case of emergency from a Shore Control Center.

Photo by Knut Brevik Andersen (2020) obtained with permission.

“90% of the time, they will sit and monitor the ships”

Expert from Kongsberg Group

The challenge

Introducing new technologies and removing the navigator from their environment will also will introduce a new way of working and a new set of challenges we have not faced before.

A new way of working
According to interviews with experts from the Kongsberg Group, the role of a navigator will be changed from actively controlling the ships to passively monitoring the ships and only taking action in critical situations.

Kaber and Endsley emphasize that when an operator is removed from a control loop because the system is in control, human-system contact is limited and operator awareness of system conditions may be lowered. (2004)

Out of the loop - loss of situation awareness
Endsley points out that the main challenge of transitioning to an autonomous ship is when something goes wrong and the user may not understand what is happening and understand why and is not ready to take over when the system unexpectedly passes the control. (2016)

MASS and collision avoidance
By the nature of being out on the ocean, the ship will be sailing together with all other types of manned ships. Therefor a situation where the ship will come into risk of collision with other ships are given. If the ship is not able to handle the situation, it is extremely critical that the ship is able to ask for help from the operator.

For this reason we need to develop an understanding of how humans and machines could and should interact in order to securely and efficiently support them in monitoring the ship. In order to make the system work we will need a lot of multi-disciplined collaborations between partners in the industry.

OICL

My collaborator for this project is Ocean Industries Concept Lab. OICL aims to develop knowledge that supports user-centered innovation processes in the maritime domain by addressing challenges within the maritime industries using design methodology. (About, n.d.)

OpenRemote

OpenRemote is a research project by OICL that will begin in July 2023 - 2027. The project aim at providing an open platform for harmonized and user-friendly design of user interfaces (UI) in multi-vendor remote maritime workstations (RMW). The project will focus on the multi-disciplines design fields from product design to interaction design involving remote operation. (OpenRemote, n.d.)

Beta

My project will function as a pre-work for OpenRemote project that OICL could use as a casework for further development.

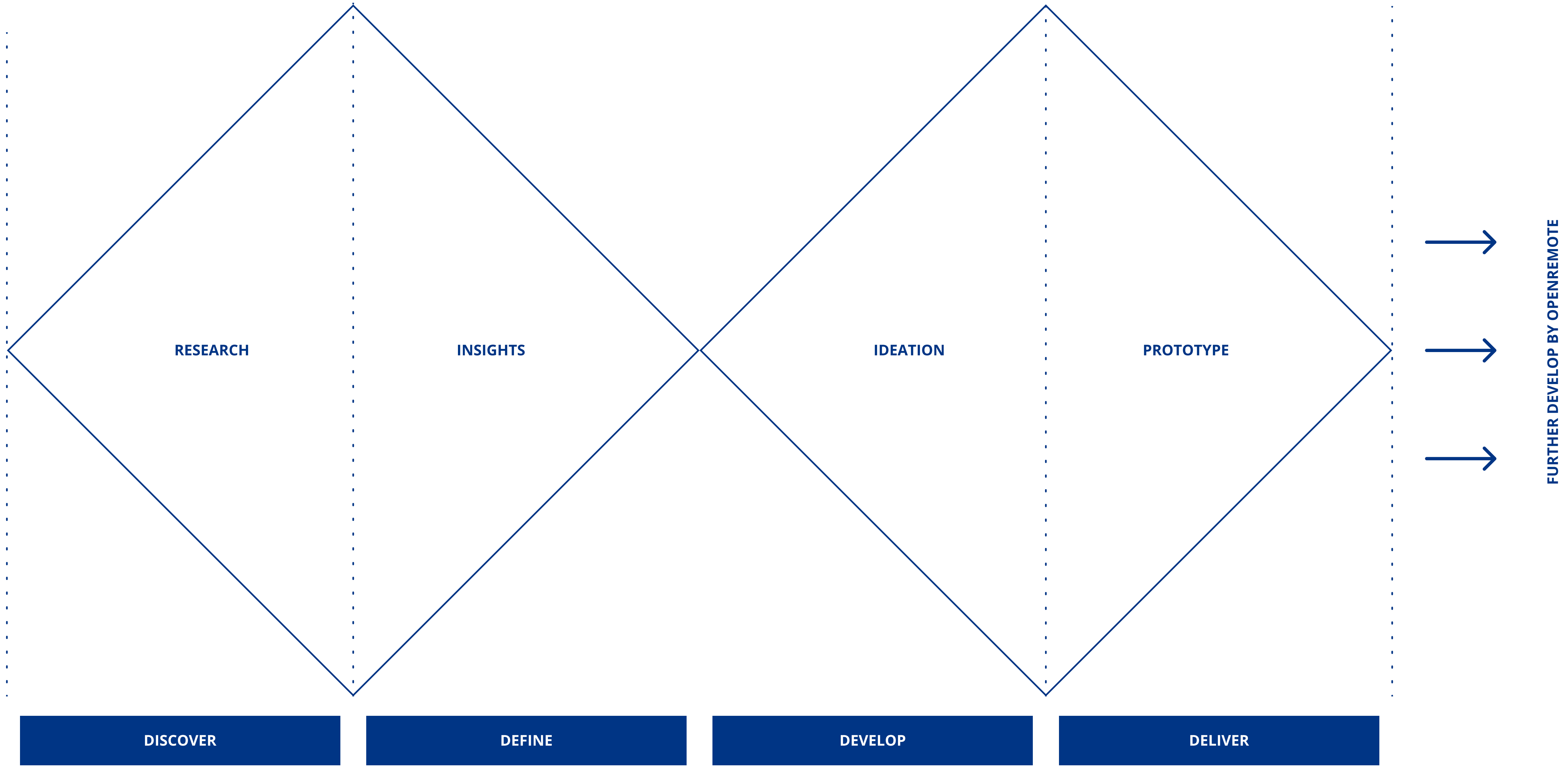
Illustration by Sunniva W. Lislevand and Hanne Lockertsen (2022)

03

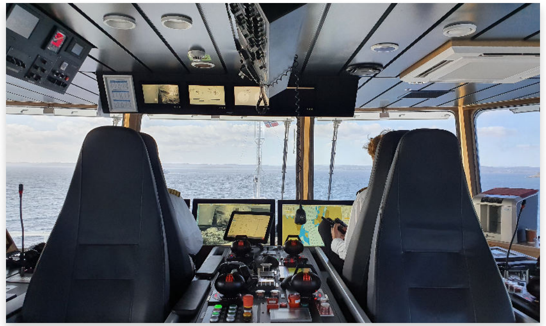
PROCESS & METHOD

Process & method

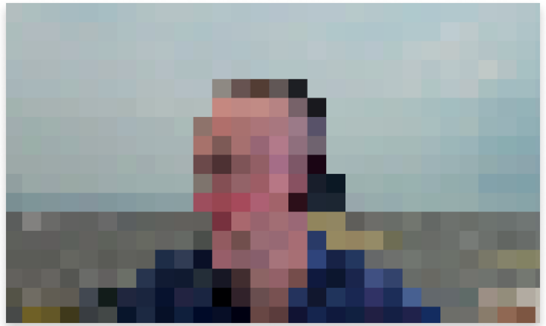
Process



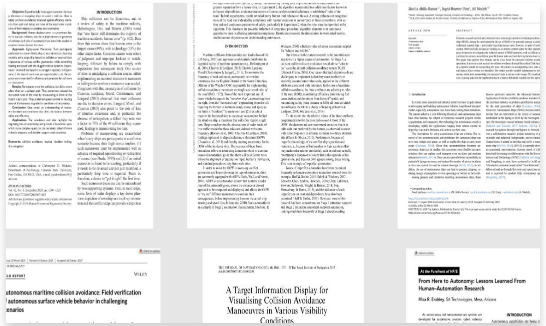
Method



Field study
I visited Bastø Fossen VI to observe and document how the navigator operates the ship and what type of challenges one may come across.



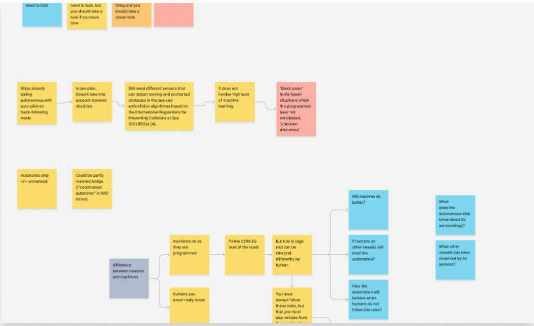
User interviews
Talking with multiple navigators about their experiences and their thought about autonomous systems



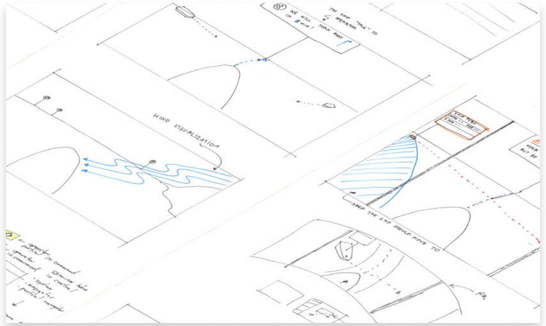
Secondary research
To get an overview of research that has been done. By the nature of my project working with technologies and users that do not exist yet, secondary research has been my main source of research.

KONGSBERG

Expert interview
To get an overview of current offerings and challenges

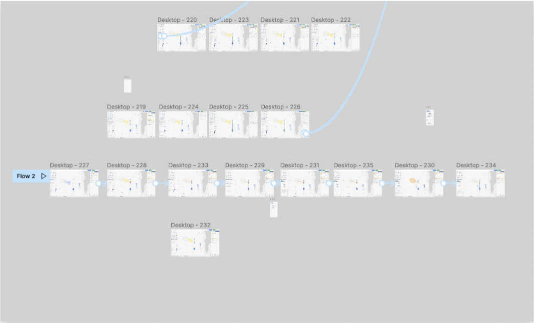


Analysis
Analysis to compare the insights and findings was made to get a bigger understanding of the context.



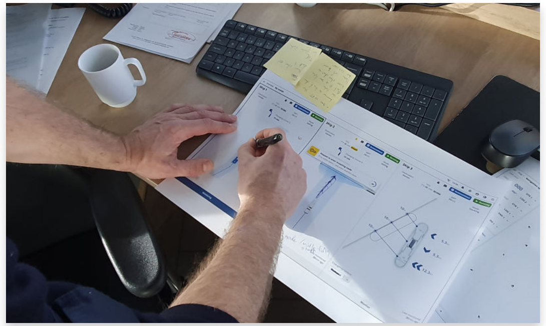
Ideations
To generate and develop ideas that will meet the needs of potential users I, among other things, held a workshop together with other designers from Halogen.

Process & method



Prototyping

Testing out concepts through clickable prototypes



Feedback and testing

To get an understanding of what works and does not work. Showing the design to users, experts, and other designers, helps me iterate on the concepts further.

04

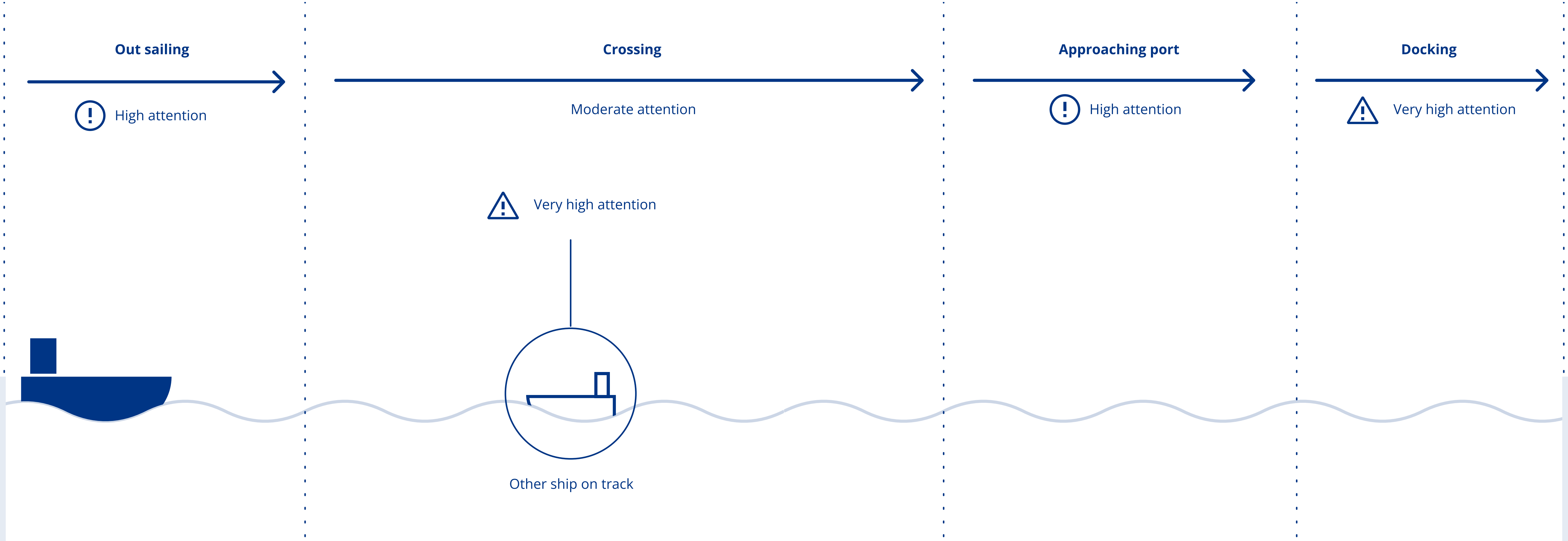
RESEARCH & INSIGHT

Understanding the existing operation

Research & insight - understanding the existing operation

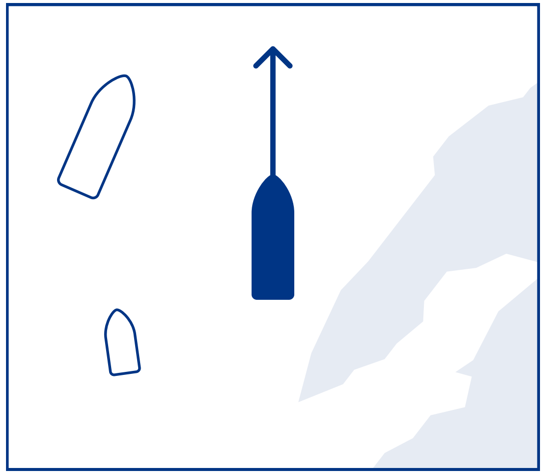
Ship’s crossing phases

In order to get an understanding of how current sailing operates and what type of information one may need, I conducted interviews, desk research, and field study. Through the research, I found out that there are usually four sailing phases where they have different level of attention needs.



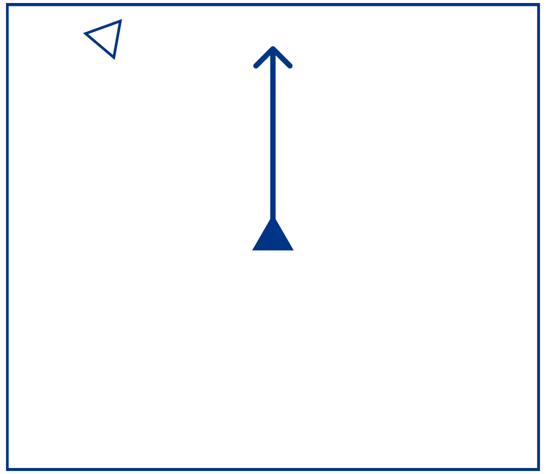
Research & insight - understanding the existing operation

Halogen has done research on unpublished findings from project “Proxima” where they have been using eye tracking technologies to identify what type of information navigators may need for the different phases. (Unpublished) Following shows a summarization of the findings together with my findings from field study.

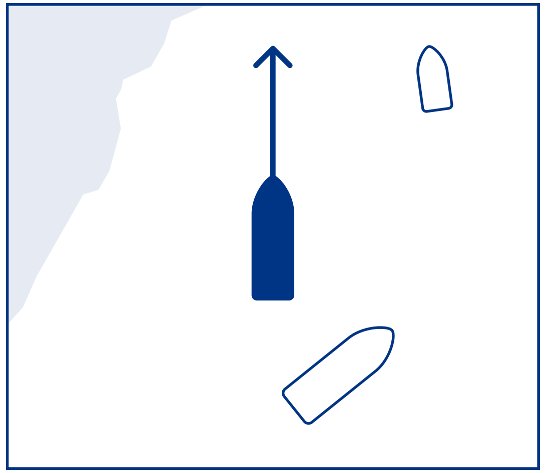


Out sailing
At this stage the navigator needs a closer look at the surroundings to avoid potential accidents, especially with other ships. At this stage, the navigator only used ¼ of the time on screen and mostly used the visual outlook.

From my field study, I found out that communication with VTS (Vessel Traffic Service) also becomes much more important. Here they will have to notify VTS when departing in order to coordinate a successful operation.

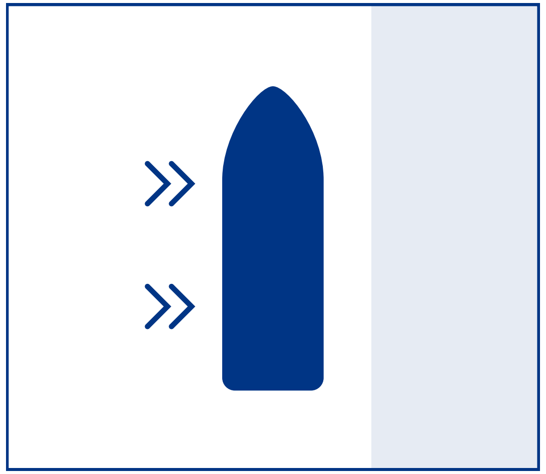


Crossing
At this stage, what is interesting to the navigator is to “know” what will happen in the future to take early precautions to avoid a collision, since the ship is much bigger and therefore needs more time to be able to take action. The navigation system and anti-collision systems are used ⅔ of the time while windows(usually with monocular) are used ¼ of the time.



Approaching port
At this stage the navigator needs a closer look at the surroundings to avoid potential accidents, either with other ships or to land. In this stage, the navigator only used ¼ of the time on screen and mostly used the visual outlook.

From my field study, I found out that communication with VTS (Vessel Traffic Service) also becomes much more important. Here they will have to notify VTS when arriving in order to coordinate a successful operation.



Docking
In the docking stage, the operator needs a much closer look at the ship's surroundings since there is a higher risk of collision with the docking station. At this stage, the navigator relies mostly on the visual of the docking station corner and other land-based objects to align the ship correctly.

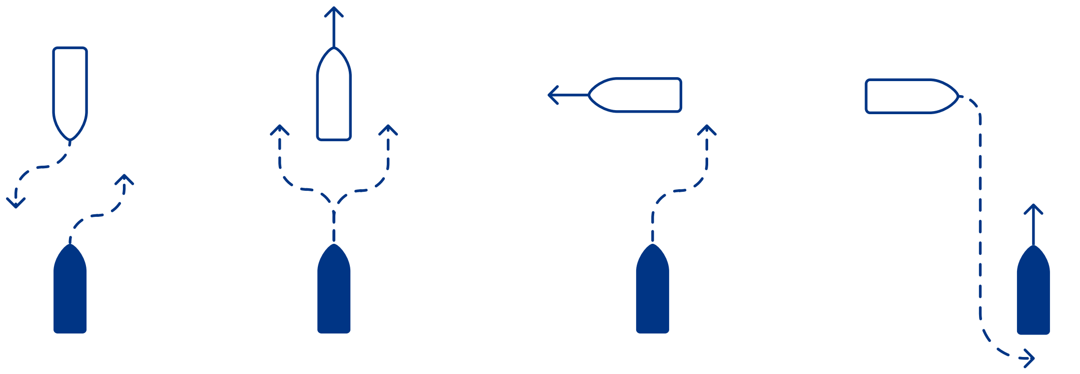
COLREGs - Rule of the road

Just like driver have to follow traffic rules, navigators also have to follow the rule of the road - COLREGs, to fulfill a safe crossing.

COLREGs (Convention on the International Regulations for Preventing Collisions at Sea) are collision regulations developed to provide a “rule of the road” for maritime vessels. The rules covers all aspect of sailing, but the most important ones are the rules regarding what to do when encountering other ships, specifically, head-on, overtaking and crossing situations (Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs), n.d.)

However, although the rules are well written, accidents still accure. Research shows that **56% of collisions at sea are caused by violations of COLREGs.** (Liu et al., 2016)

Porathe points out that CORLEGs rules are ambiguous (2019) This means that even without considering additional human factors (stress, weariness, etc.), navigating against other navigators is unpredictable since each navigator may have a different perspective and behave appropriately.



Head-on Overtaking Crossing A Crossing B

Research & insight - understanding the existing operation

Never one person to blame
Van de Merwe et al. points out that one of the rules even suggests and encourages to override of all other rules to avoid immediate danger.

Rule 2, “responsibility”, states **“**In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from these Rules necessary to avoid immediate danger”. (2022)

This was also pointed out by the navigators I interviewed who empathized this with one interesting question regarding MASS.

“It is never only one person to blame, by the rules, you are also required to do whatever it takes to avoid a collision. My question is if it's a machine that controls the ship, who will get the blame?”

- A Navigator (Translated from Norwegian)

Collision avoidance protocals

From my field trip and user interviews, I learned that communication and understanding of others' intentions and behaviors are significant hidden ways to avoid collisions. VHF radio is used for communication, while the ship's window frame and anti-collision system are used for interpretation. Because, as wonderful as the regulations are, they only operate if all ships comply. Bastø Fossen even introduced VHF radio communication to avert collisions as part of their company protocol. The navigator's collision avoidance methods are shown below. Note that the protocal may differ base on both the navigator and situation.

Arguably, I found out later on through an expert interview, that the VHF communication protocol is not a standard. The experts further indicate that there is **no mention of VHF communication as part CORLEGs rule.** One of the rules actually states that the actions alone (either horn signals or the actual maneuver) should be clear enough that you would not need to contact the other ships. This is to reduce excessive and unnecessary calls being made that could distract the navigator. On the other hand, based on research, verbal communication is still being widely used as a means to handle collision situations. However, they did also point out that this way of communication is **prone to miscommunication.** (Akdağ et al., 2022)

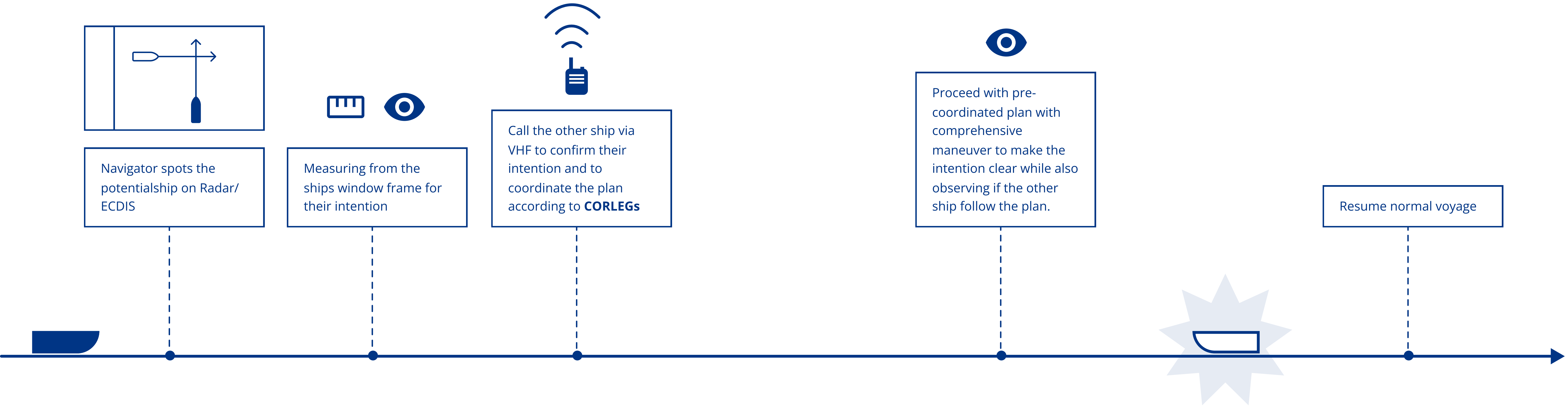
Research & insight - understanding the existing operation

Communication via VHF

Measuring using window frame

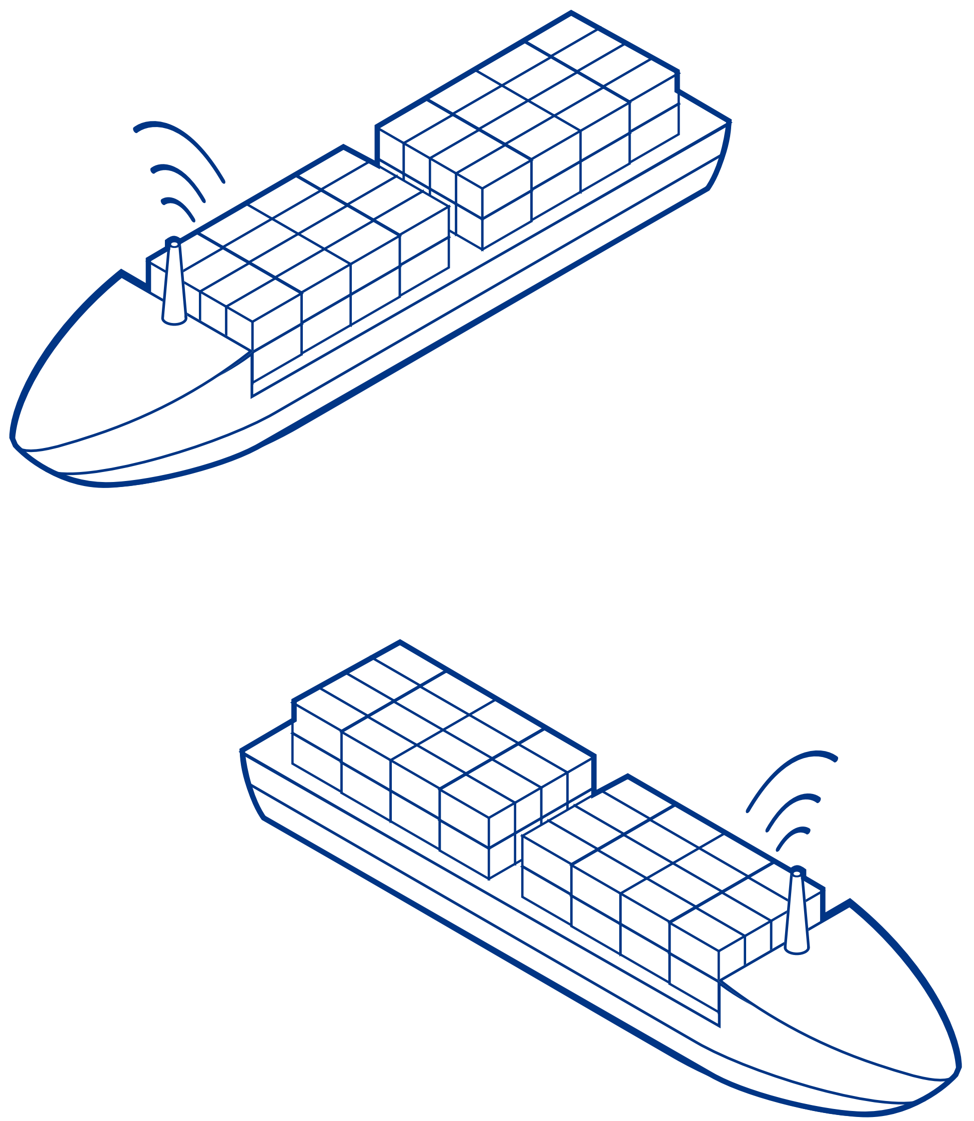
Research & insight - understanding the existing operation

Simplified collision avoidance journey



* The journey may differ based on the navigator and the situation.

Understanding MASS



What is MASS?

MASS (Maritime Autonomous Surface Ship) is defined by The International Maritime Organization (IMO), as “a ship that, to a varying degree, can run without human interaction.” (5 B.C.E.)

Degree of autonomy
IMO divides shipping autonomy into four levels, from decision support to completely autonomous ship. (5 B.C.E.) I discovered through interviews and field study that modern ships with navigators use high-level automation systems during crossings already. Auto-tracking features, for instance, follow a predefined track but don't account for dynamic impediments, thus the navigator must be on board to take control.

Many researchers believed a fully autonomous ship is not possible in the foreseeable future, since today's legal structure requires a human to run the ship, making it hard to deliver advanced and well-tested technology. Thus, most autonomous ships would be partly or constrained autonomous. (Jan Rodseth et al., 2018)

Constrained autonomy
The concept of constrained autonomy has been describe by IFE in their report as the ship can function totally autonomously in most scenarios and has predefined settings for difficulties like collision avoidance. If the problem is outside their predefined solution, they will notify the operators to intervene. This requires the operator to continuously monitor the system in case of emergency. (n.d.) This type of autonomy allow flexible levels of autonomy where the system could take on monotonous tasks in a high level of autonomy (Degree 4) and notify the operator if something unexpected is happening and change to remote control (Degree 3) For this reason, an efficient autonomous system would still depend on the human-autonomy teaming approach. (Endsley, 2016)

Degree of autonomy defined by IMO

Degree 1	Degree 2	Degree 3	Degree 4
Ship with automated processes and decision support	Remotely controlled ship with seafarers on board	Remotely controlled ship without seafarers on board	Fully autonomous ship
• Seafarers on board • Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.	• Seafarers avaible on board to take control and operate the shipboard systems and functions. • The ship is controlled and operated from another location.	• No seafarers on board • The ship is controlled and operated from another location.	• The operating system of the ship is able to make decisions and determine actions by itself.

Constrained autonomy defined by IFE
Ship can function totally autonomously in most scenarios and has predefined settings for difficulties like collision avoidance. If the problem is outside their predefined solution, they will notify the operators to intervene. The operator is required to continuously monitor the system in case of an emergency.

Shore Control Center

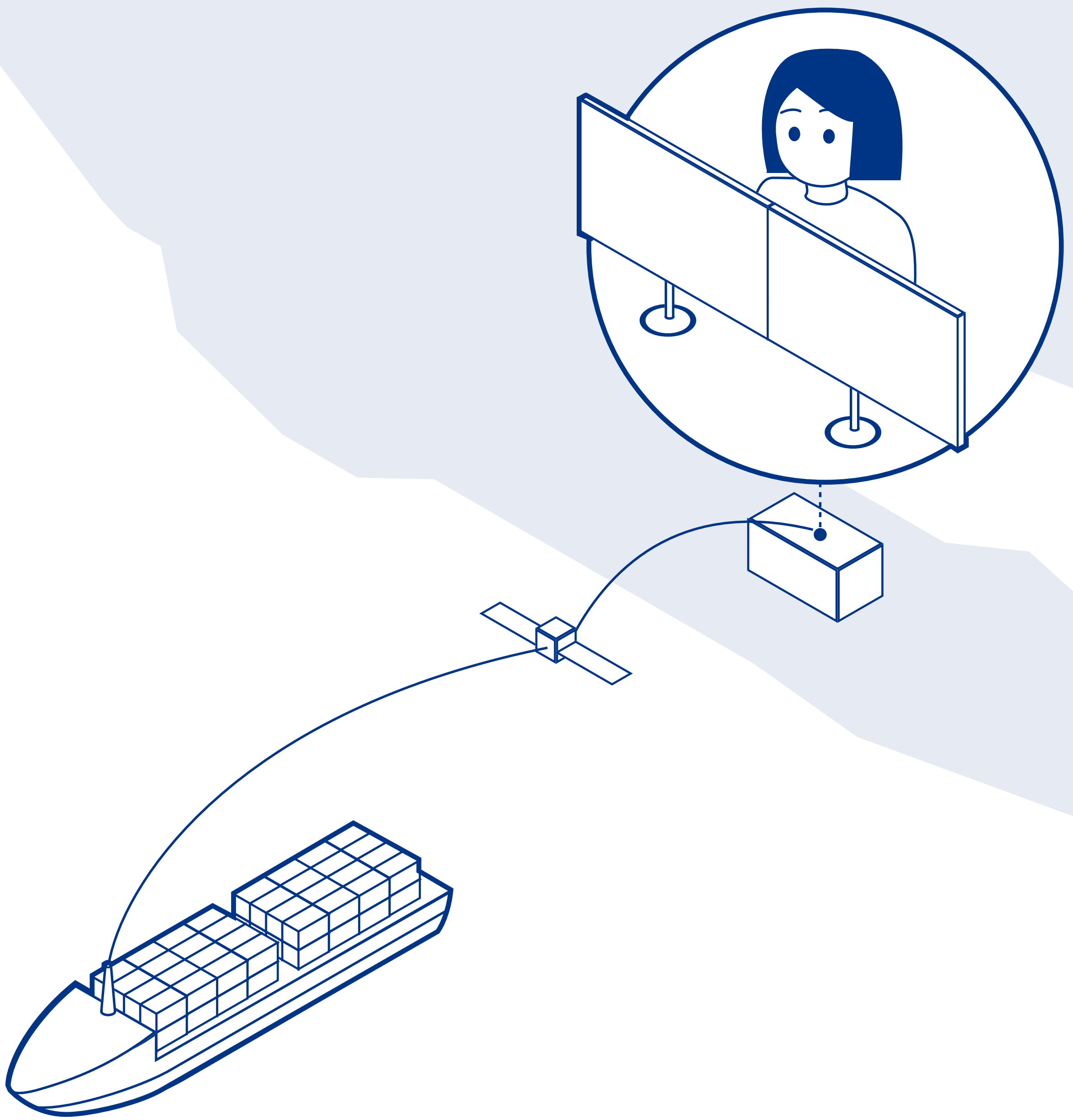
What is a shore control center?

A shore control center (SCC) is a facility used for remote monitoring and operating of autonomous ships. It normally consists of a group of trained operators that utilize specialized software and hardware to manage the ship's movements and make decisions on its behalf. The shore control center is normally situated on land, away from the ship, and can be used to operate the vessel remotely from a safe distance. This allows for increased flexibility and responsiveness, as the ship's operators are able to make decisions in real time and adapt to changing situations. In addition to controlling the ship, the shore control center may also monitor the ship's systems and identify any potential problems that may require attention. The shore control center is a crucial element of autonomous ship operations. (Dybvik et al., 2020)

On going design

The design of shore control center are still under developments. Thus what has been published might also be changed based on further research.

Research & insight - understanding MASS



Why an autonomous ship?

Based on expert interviews, much of the interest in unmanned ships lies in what transportation without humans onboard may have to offer.

Reducing cost due to no crew on-board, allowing newer and more effective ship design and potentially lead to more attractive work space for seafarer because they could operate from shore are a few examples for potential benefits of autonomous shipping. (Kim et al., 2022)

Dybvik et al. notes that the **logistics and cargo distributors** show the most interest in autonomous ships, as shorter crossing and slower speeds will fit the company's needs . (2020) However, the autonomous ship on large scale is still under development, which means we most likely will be faced with challenges we have never faced before and require even more design involvement.

Research & insight - understanding MASS

Envisioned benefits of autonomous shipping	
Safety	Reduce the number of maritime traffic accidents caused by human factors (e.g., fatigue, human errors, violations, improper maneuvering)
	Reduce and reorganize the workload of human operators while decrease the risks of occupational accidents on board
	Decrease the number of human injuries and fatalities from maritime accidents
Environment	Reduce energy consumption through fuel saving measures and innovative ship design
	Support maritime decarbonization and reduction of greenhouse gas emissions
	Decrease the number of human injuries and fatalities from maritime accidents
Economy	Reduce crew cost and proportionally higher cargo capacity due to absences of human-support facilities and systems on board
	Reduce operating costs and improved ship fuel efficiency lead to better economic profitability
Societal influence	Mitigate the shortage of seafarers
	Increase the attractiveness of seafaring professions
	Mitigate gender imbalance issues in the maritime industry

Summarized by Kim et al. (2022)

Research & insight - understanding MASS

The concept is not new

Despite the autonomous ship being a hot topic in recent years, the idea of autonomous ships is certainly not new. IMO's Maritime Safety Committee discussed automated ships as early as 1964. (EMSA, n.d.) One can find research and commercial products of smaller unmanned ships, typically for USV (Unmanned surface vehicles) which are usually used related to Marine Research.

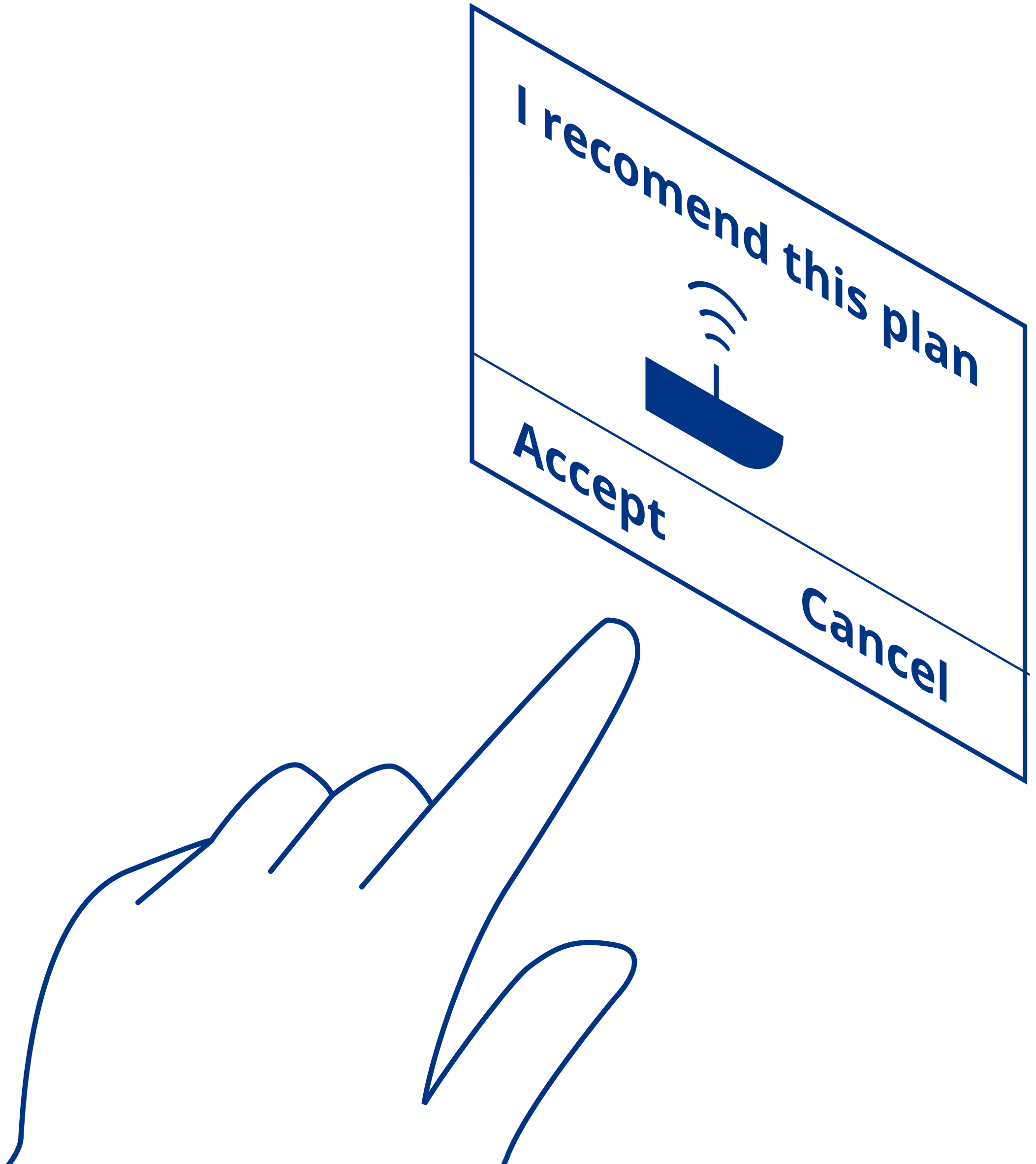
- Voyages by Thomas Wang. Master project at AHO exploring interfaces for autonomous (USV) maritime systems. (Voyage - Exploring Interfaces for Autonomous Maritime Systems, 2021)
- Maritime Robotics offers multiple types of unmanned surface vehicles with software to control the vehicles. (Maritime Robotics | Innovative Unmanned Solutions, n.d.)
- Kongsberg's Sounder USV is a unique multi-purpose unmanned system with design aims to ensure higher hydroacoustic application performance. (Unmanned Surface Vehicle, Sounder - Kongsberg Maritime, n.d.)

However, the USV used for marine research will often operate far from shore and with its smaller size, could move quickly to avoid accidents. The same could not be said for MASS as they are bigger and slower, and would often be closer to shore at times and therefore have a higher risk of accidents that will result in a much bigger damage. Working with the MASS system, therefore, needs to be done carefully.

Examples of USV from Maritime Robotic. Photos obtain with permission.

Research & insight

TRUST IN AUTOMATION



What does it take for navigator to use such a system?

Introducing a drastically new way of working and designing a system that will “do the job for them” that does not exist yet, a question of what it takes for the navigators to use such a system is only natural.

The answer I got was that the system must “think” the same way they do, and able to explain it’s action. This implies that the navigator would trust that the system would behave in a manner similar to what they would have done. By showing its thinking and reasoning, the operator could evaluate its way of operating, and intervene if it behaves differently than how the navigator themself would have done it.

This way of thinking fits into the principle of automation transparency. Automation or system transparency is described by Alonso and de la Puente as “the observability and predictability of the system behavior, the understanding of what the system is doing, why, and what it will do next.” (2018)

This could involve providing the operator with an explanation of how the system arrives at a particular decision, and why it believes that decision is the best course of action. This transparency can help the operator understand the system's reasoning and make them more confident in the decisions that the system is making on their behalf.

Mica Ensley emphasizes that the ability to project the system behavior is a key to successful teamwork between autonomous systems and humans in her talk on “Building Support for SA”(CHCI_VT, 2020). In a meta-study by Jamieson and Skraaning, clear feedback from automation suggests enhanced operator workload, task accuracy, response time, trust, and "possibly also situation awareness. (2017)

“It must “think” the same way I do. It must explain its action, why and how it comes to that conclusion”

A Navigator (Translated from Norwegian)

But could automation transparency alone build trust?

Before trying to break the question down, let's first start with how trust work. Lee and See (2004) define trust as: “the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability”. Endsley (2016) implies that trust in automation has been found to be based on three factors:

1. **System factors**
2. **Individual factors**
3. **Situational factors**

Another factor that are important to trust that have been mentioned by Hoff and Bashir are **initial learned factor** which are existing knowledge of the system, its performance and design. This usually comes in a form of training or on-boarding of a system. (2014)

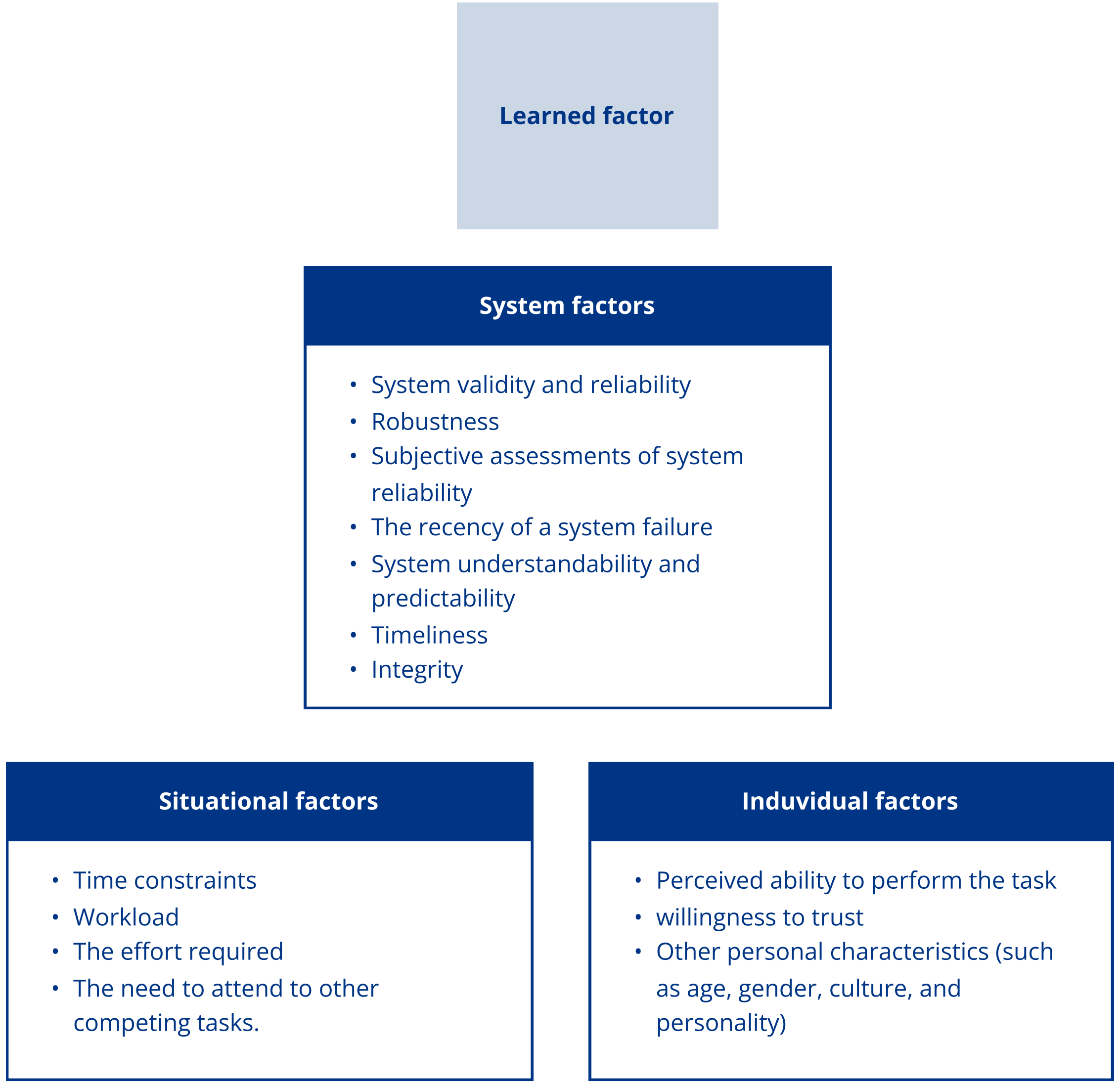
However, Endsley note in her paper which base on Hancock et al. (2011) that a meta-analysis indicated that system characteristics (especially system reliability and performance) had the highest overall influence on trust (2016)

Another interesting point on trust made by one of the navigators I interviewed is that they would trust the system if it's approved by a trustful authority, such as DNV.

“If the system is approved (by authority) then I will trust it.”
 - Navigator (translated from Norwegian)

This does not necessarily imply that the system factors are not part of their trust, but the trust simply was put into their trustful authority (individual factors) that the authority will make sure that the system is robust, reliable, and follows regulations. (system factor)

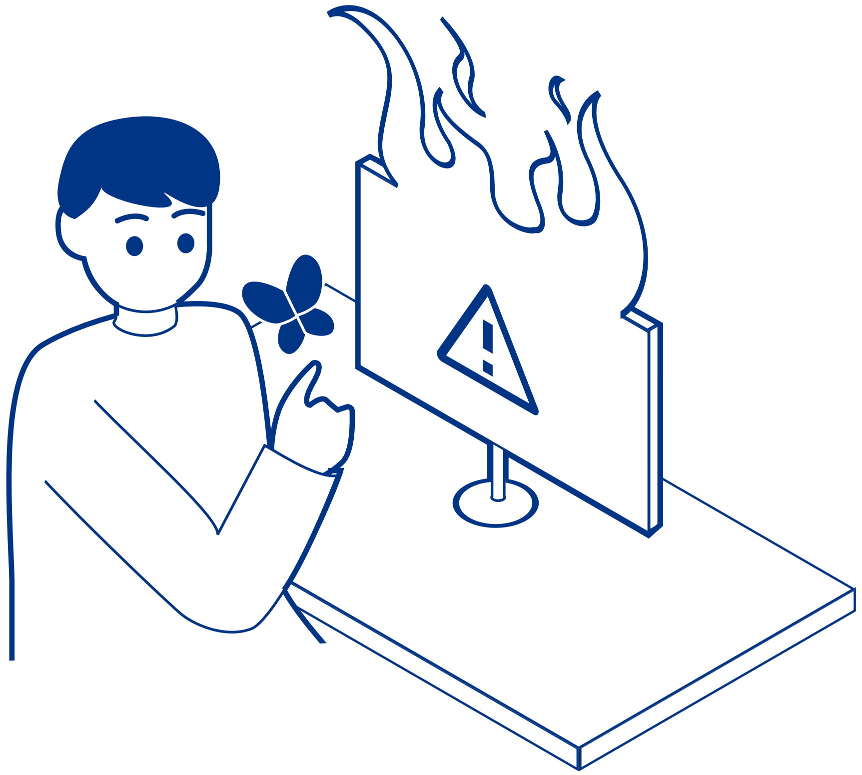
For this reason, the trust could not alone be built through the system, but they do play a big role in enabling trust.



Trust factors summarized by Endsley (2016)

Research & insight

MASS key challenge: out of the loop

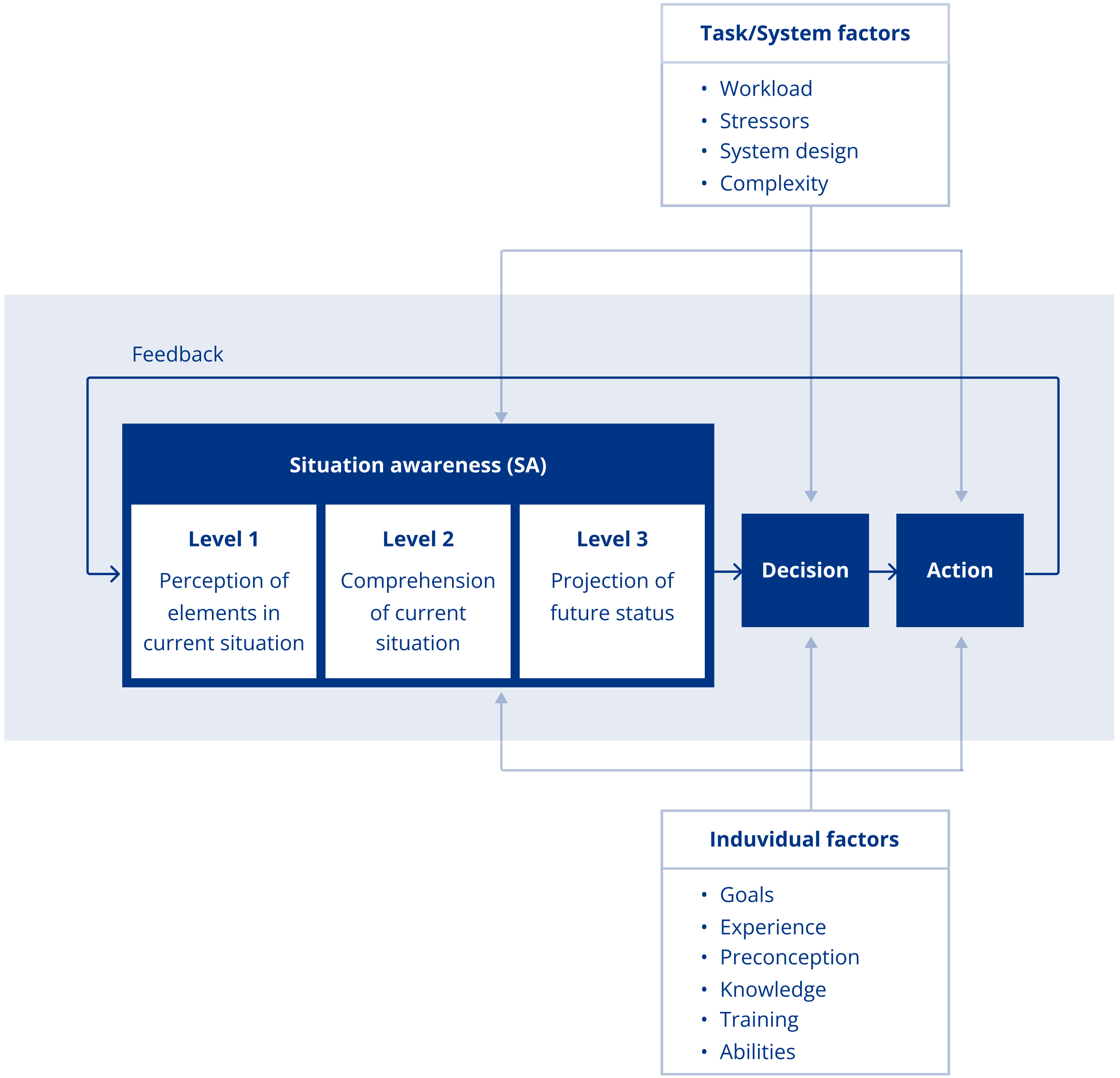


Since sailing include all kinds of unpredictibilities, the human ability to notice and take control to help the system is crucial. However, this requires the operator to have high situational awareness of the autonomous ship.

What is situation awareness (SA)?
Situation awareness is the ability to understand the current state of a situation and anticipate how it may evolve in the future. It involves paying attention to relevant information, making sense of that information, and using it to make decisions and take appropriate action. In the context of autonomous ships, situation awareness is important because it allows the ship's operators to understand what is happening around the ship and make decisions that will ensure its safe operation. This can include detecting other ships or obstacles in the water, monitoring the ship's systems, and responding to changing weather conditions. By maintaining a high level of situation awareness, the operators of an autonomous ship can ensure that the ship is able to navigate safely and avoid accidents. (Endsley, 2017)

Parasuraman points out that the possibility of a decrease in the situation awareness of operators is a key challenge of an autonomous system. Humans tend to be less aware of changes in the environment or in the state of a system when those changes are controlled by another agent, whether that agent is a machine or another person. (1987) This phenomenon of low situation awareness is also called "out-of-the-loop."

Out-of-the Loop
"Out-of-the-loop" is described by Endsley (2016) as a loss of situation awareness (SA) when supervising automation. Out of the loop may lead to the operator not be able to detect and respond to changes in the ship's environment, such as other ships or obstacles in the water. This could lead to collisions or other accidents. Overall, it is important for the operator of an autonomous ship to remain engaged and aware of what is happening around the ship at all times in order to ensure its safe operation.

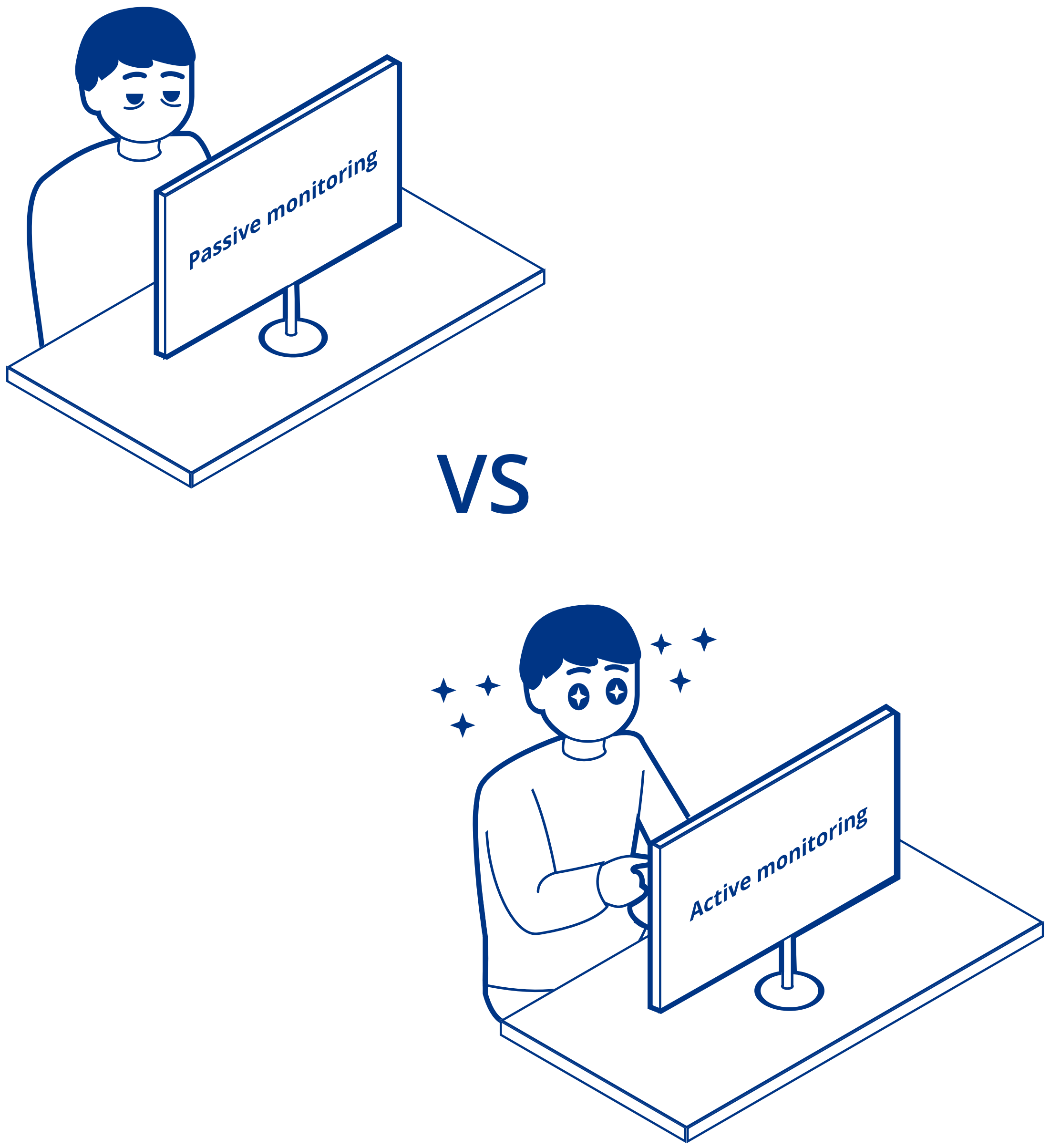


Base on Situation awareness model by Endsley (2017)

Level of engagement
Endsley notes in her talk “Building Support for SA” that one of the most impactful reasons for out-of-the Loop comes down to the level of engagement of the operator, as active and passive processing leads to a different understanding of what is going on. An example of this is the role of a driver and a passenger, the driver would pay much more attention to the road, while the passenger could easily slip the attention elsewhere.

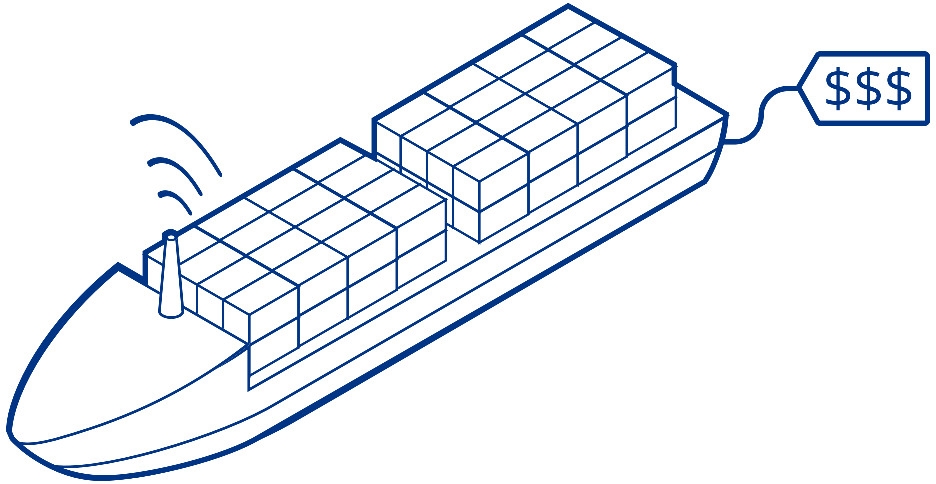
She states further that the biggest challenges with passive monitoring is when the autonomous system works so well most of the time, that it leads to **a false sense of security** where humans start to do secondary tasks, either because of boredom or other reasons, that distract them when the critical situation might happen at any moment. One could compare this situation to the self-driving car which still requires the user to pay attention to the road, but the users are more likely to be distracted by their phone even when they are required to pay attention.

Endsley concludes in her talk that this is a fundamental problem that cannot be solved by training, but by how we design the system to keep people engaged. (CHCI_VT, 2020) The out-of-the-loop effect therefore can be reduced by making the operator more involved with automation and decision-making, thus the collaboration model could be the potential solution (Endsley, 2017)



Research & insight

BUSINESS SIDE OF MASS



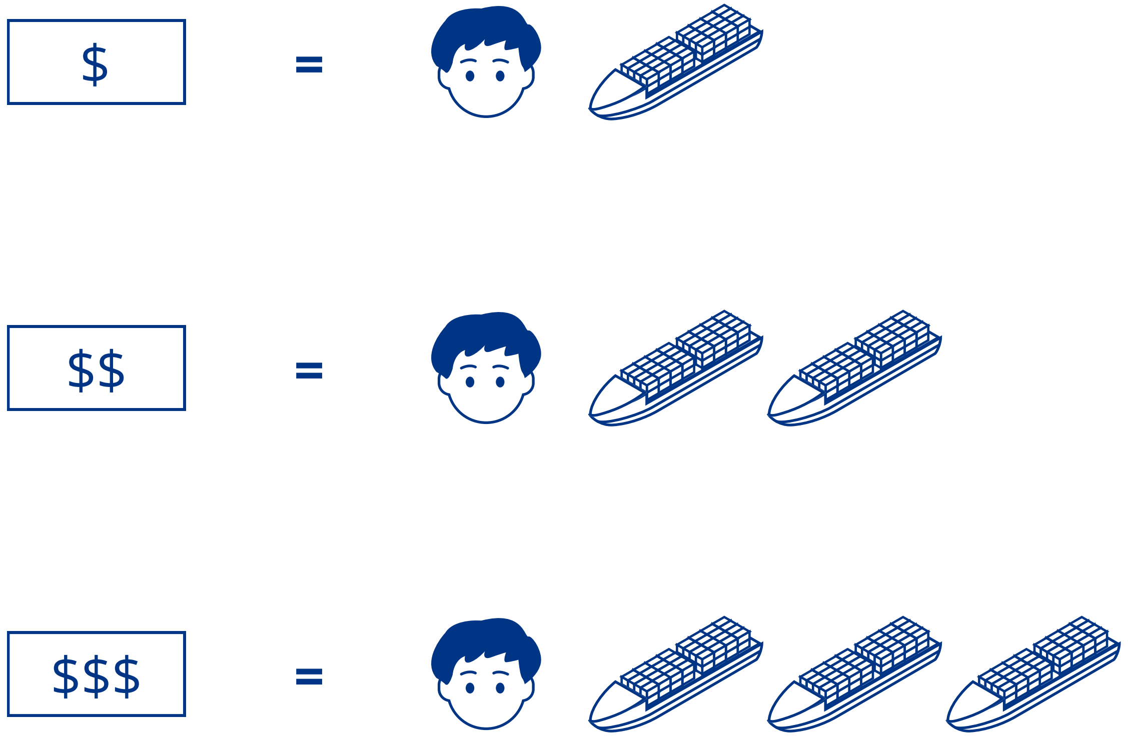
More ships = more profits

As a design student, the business side of the project is often forgotten, however, the business side could also affect how the system and humans will work. One of the opportunities with the autonomous system is it could take on dull and dirty work and free up the workload for the operator and therefore giving the operator time and opportunity to monitor multiple ships at the same time.

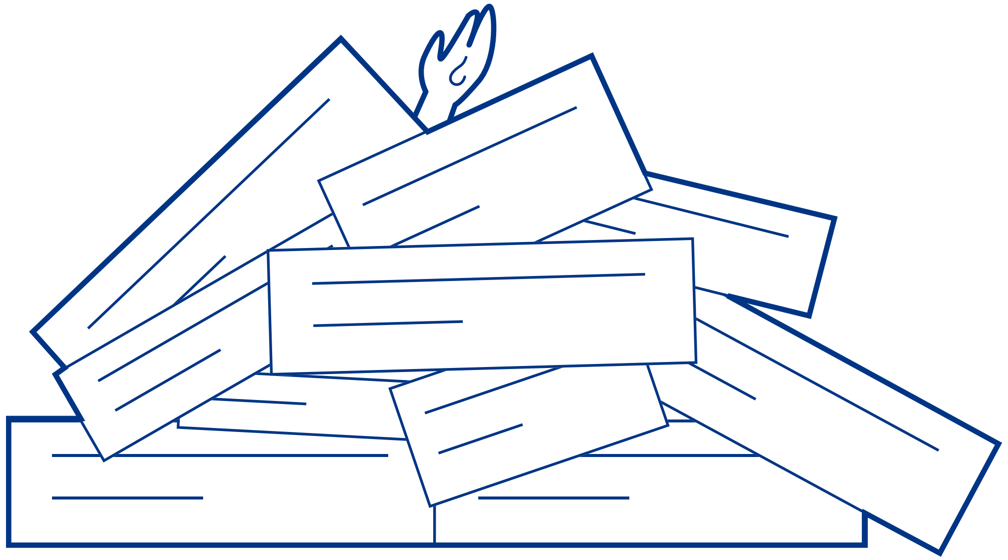
As noted earlier, logistics and cargo distributors show the most interest in the autonomous ship because it fits their needs. In some cases, autonomous ships could also be used to replace truck transportation which could lead to big cost saving elements. However this would also demand more ships that need to be out, and therefore it is suggested that one operator must be able to monitor more than one ship simultaneously. (Dybvik et al., 2020)

This business mindset is also emphasized by the experts I interviewed. In order to make the technologies economically sustainable and profitable, one operator will have to monitor multiple ships at the same time. The more vessels one person or team could monitor, the more profitable the outcome is.

How many ships a person could monitor is inconclusive and research on the topic is still ongoing at the time of my project.



More ships = also more information...



Even if it suggests that one person should monitor more than one ship, as a designer, we will also have to take human factors into consideration. Unlike machines that could process thousands of pieces of information at the same time, the human mind is much more limited. When moving humans from their environments, many of the senses they rely naturally upon just being on board disappear. These senses need to be supplemented through sensors and even more information, on top of the systems they would have used. Multiplying these pieces of information with multiple ships they would have to monitor, could easily lead to information overload and ultimately human error. (Man et al., 2014)

Research & insight

Main takeaways

1

MASS ships are often large and slow, which means that actions take a long time to execute. And, due to the unpredictability of being out in the ocean, the ship may function in constrained autonomy, where it can operate on its own to a certain extent and inform the operator in appropriate time when unforeseen problems occur.

2

Because the navigator needs different information for different stages of the sailing, the system should show information based on which stage of the journey they are to avoid the operator being shown information they don't need. However, this needs to be handled carefully to avoid the operator from missing out on important information in their sailing.

3

In order to reduce the risk of being out of the loop, the system must engage with the user, treating them as teammates rather than a passenger. It allows the system to benefit from the operator's knowledge and expertise, build trust and confidence, and ensure that the ship is operating safely and in compliance with regulations.

4

In order for the operator to trust the system, the system must be transparent and open, providing the operator with clear and concise information about the ship's status and surroundings. This can help the operator understand what the ship is doing and why, which can increase their confidence in the system, and also validate it’s decition.

5

Research shows that 56% of collisions at sea are caused by the violation of COLREGs. As long as the autonomous will be sailing together with other manned ships, the algorithm could not be based on the rules of the road alone, but also other aspect of collision avoidance protocal such as communication, and potencially involve the user in this situation.

6

It has been suggested that to make an autonomous ship profitable, one operator should monitor more than one ship. However, this could also lead to information overload and research on how many vessels one person could handle mentally is still ongoing. This must be handle carefully to avoid information overload.

05

DESIGN DEVELOPMENT

Focus area

1 **Overview dashboard**

To give the operator an overview of the multiple ships they have been assigned to

2 **“Machine brain”**

a navigational tool intends to show what is going on inside the “brain” of the machine.

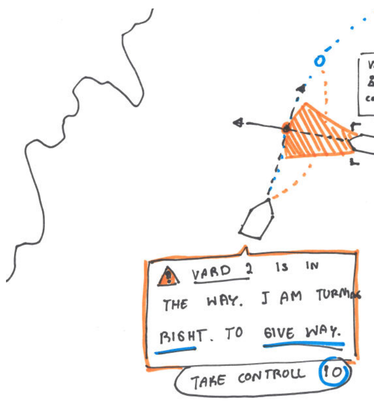
3 **AR overlay**

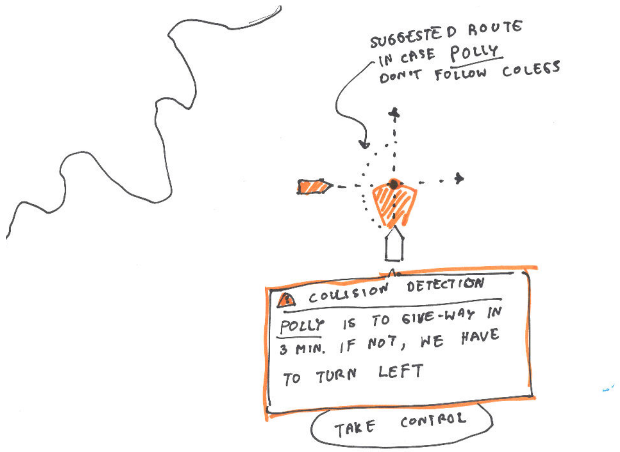
AR overlay on a live video from the ship to provide the operator with a visual of what is going on in the environment. The AR function would supplement the loss of senses from being on the ship.

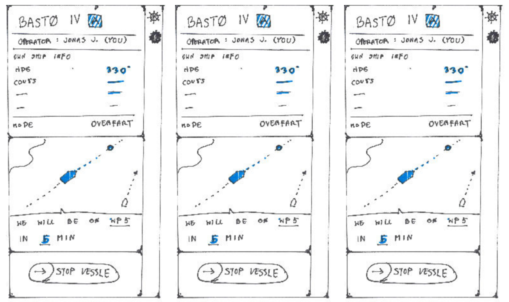
Ideation

Based on the insights, I started paper sketching early on in this project. The sketch drawing was focused on what type of functions the operator would potentially need on the three focus areas and how the interaction could have been.

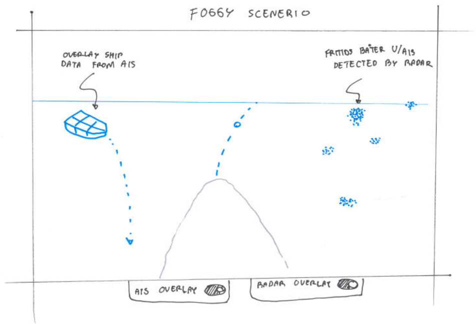
The sketches were used as discussion material together with my supervisors who are also experts in the field, which later helped me shape the concept for my project.



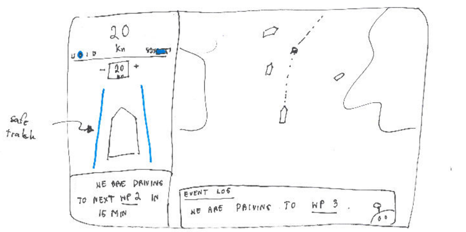




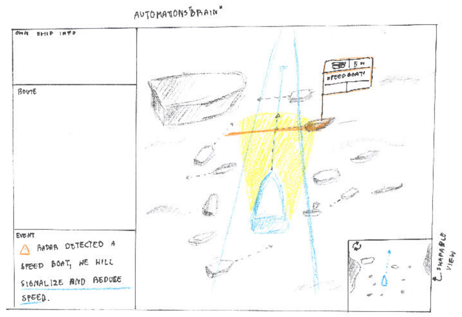
Quick and dirty visualization of overview dashboard



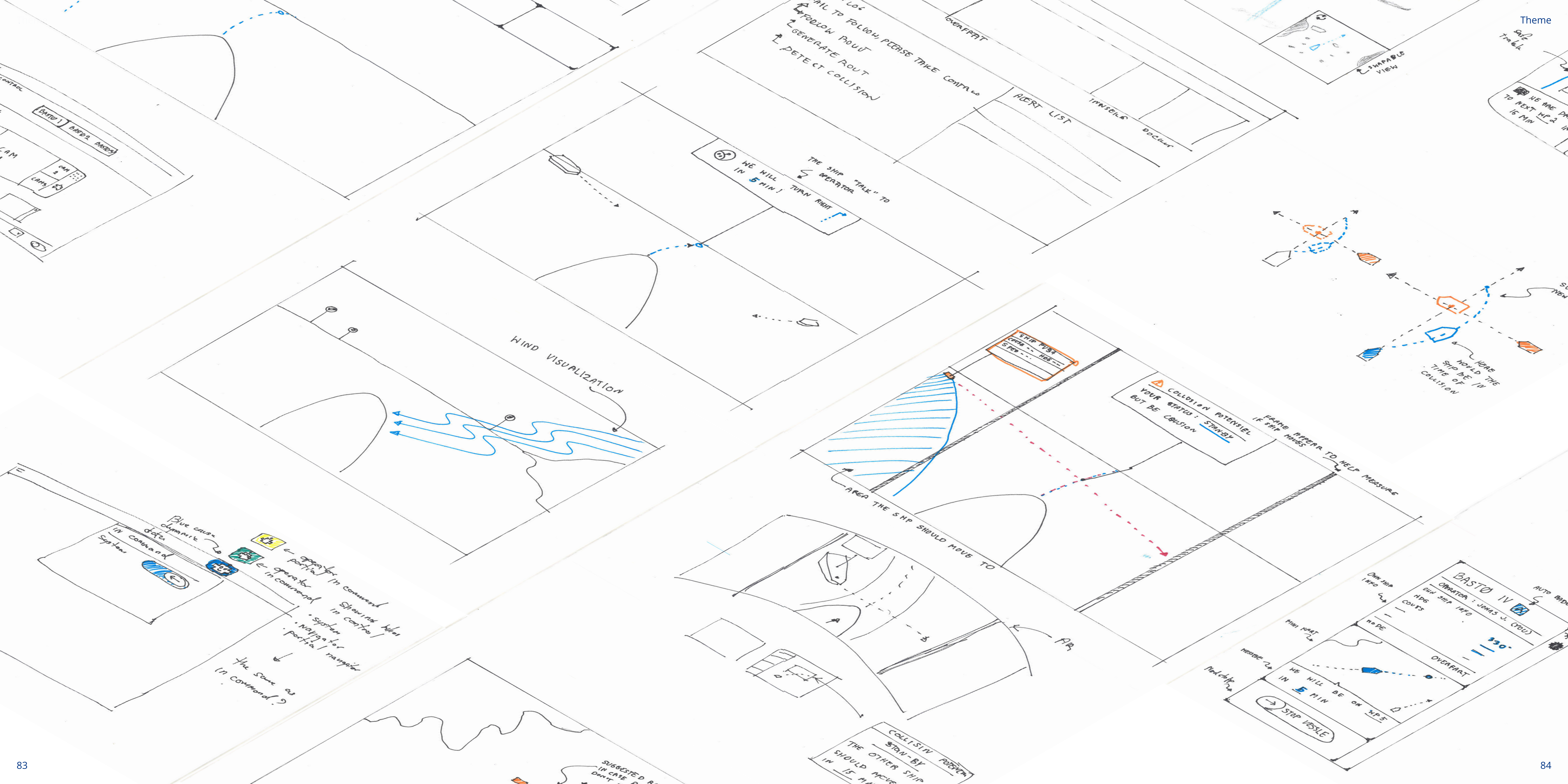
AR overlay in a foggy scenerio



How the “machine brain” looks like based on tesla’s GPS system



3D “machine brain”


FOLLOW ROUT
GENERATE ROUT
DETECT COLLISION
OVERFART
ALERT LIST
THE SHIP "TALK" TO OPERATOR
WE WILL TURN RIGHT IN 5 MIN!
WIND VISUALIZATION
COLLISION POTENSIEL
YOUR STATUS: STANDBY
BUT BE CAUSION
FRAME APPEAR TO HELP MEASURE IF SHIP MOVES
AREA THE SHIP SHOULD MOVE TO
HERE WOULD THE SHIP BE IN TIME OF COLLISION
BASTØ IV
OPERATOR: JONAS J. (YOU)
OWN SHIP INFO
WE WILL BE ON WP 5 IN 5 MIN
STOP VESSLE
the same as in command?

Working with OpenBridge Design System

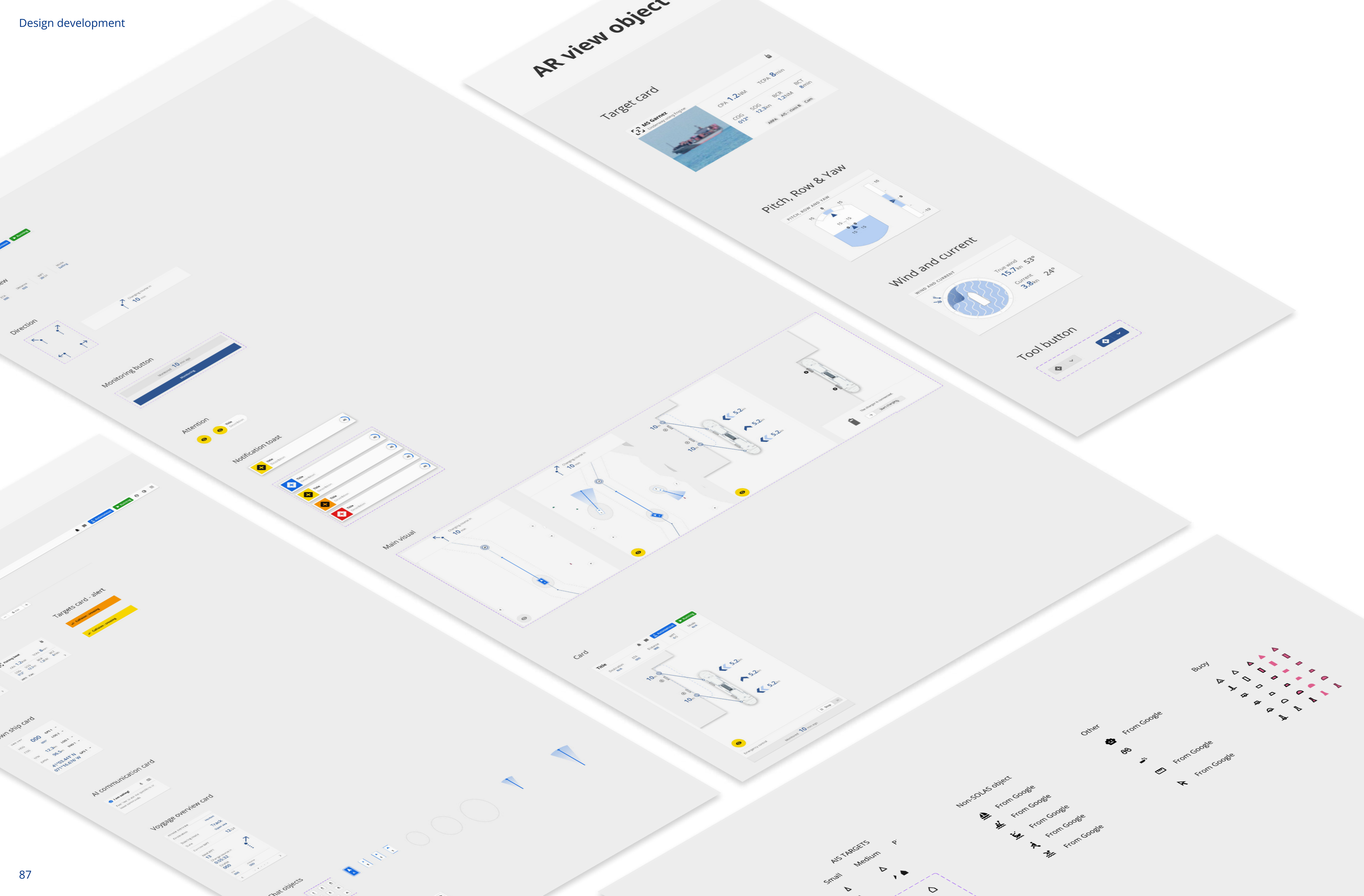
As indicated in the report's introduction, I will use the OpenBridge design system to develop the concepts. The OpenBridge design system is an open-source design system created to standardize multi-vendor user interfaces on ship bridges. The design system has been created with the partners over a four-year period and is well-established and content-rich.

The design system contains:

- Bright, day, dusk, and night color palettes
- Icon library
- Typography
- Component library
- Guidelines, and frameworks

(OpenBridge Design System, n.d.)

Illustration by Jon E. Fauske (2022)



My library

Because the structures and components were already in place, I was able to rapidly begin digitally exploring the concept. As this is only the beginning for OpenRemote, new components that match the autonomous system must be built, which means I will also construct my own library of components. This way, by using the project as a use case, I could help expand the component library, and feed the component back to the industries for iterations.

Early digital sketches

When starting sketching digitally, I based my design for the overview dashboard and “machine brain” on a 27” screen. The reason to use a 27” screen is that the screen is big enough to fit the pieces of information comfortably and still would not take too much space on the table when putting two screens together. However this is only my own hypothesis, and this matter should be researched further.

The focus areas are:

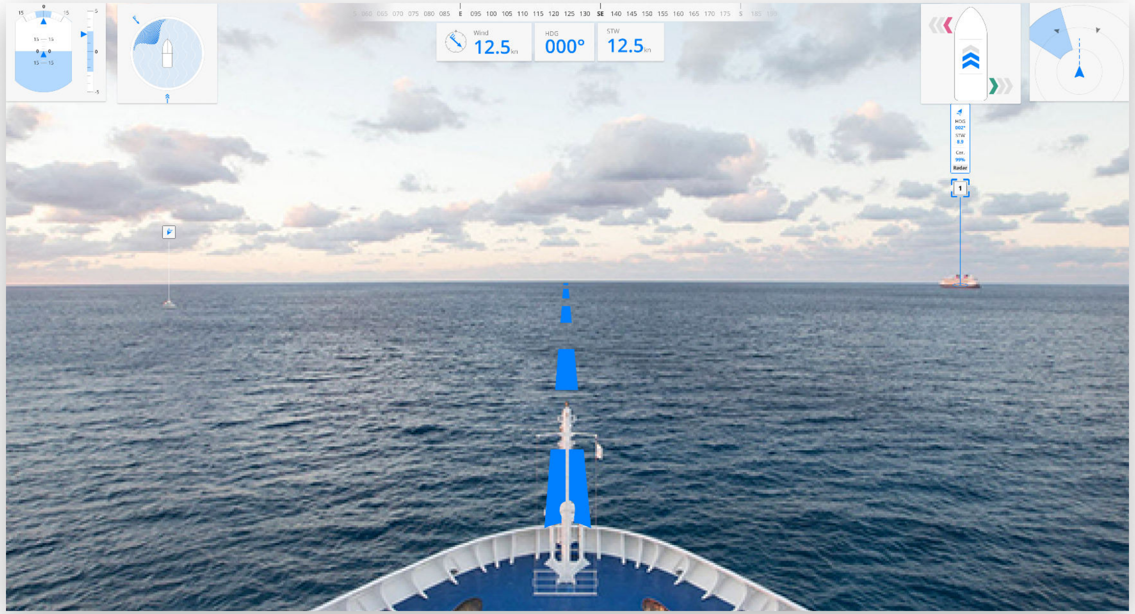
- Identify information needs for all three interfaces
- Automation transparency in collision avoidance scenarios

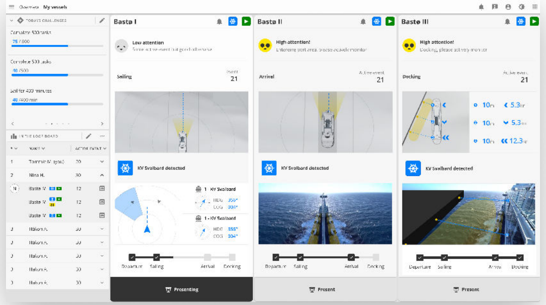
Feedback from early sketches

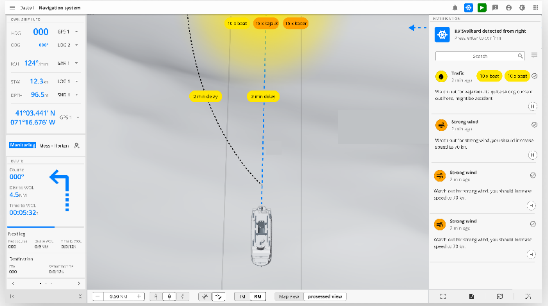
To keep a continuous feedback loop, I showed the sketches to experts early on. The design overall was perceived as having too much going on, especially the overview dashboard. When too many explanations and functions are put together, this could also lead to information overload. I should focus more on prioritizing what should be shown at a glance and what could be shown elsewhere.

“This is too much. Try to think of it more like a traffic light.”

- Expert (Translated from Norwegian)







Ideation workshop with designers from Halogen

To work more on the concept to simplify the design, I held a workshop with 5 designers from Halogen to get a new perspective and hopefully new ideas to develop the design further.

The workshop set-up

Before the workshop, my colleagues and I held a presentation on trust in autonomy and used my diploma project as a use-case to tackle the topic. During the workshop, I decided to ask them to make sketches based on tasks without showing any of my previous designs. Starting from a blank page with with a time constrain, it forces the designer to only focus on the essential information one may need. For this workshop I have focused mainly on collision avoidance scenarios on both an overview and a detail level.

Findings

An interesting finding from the workshop is that all designers sketch the design using visualization as the main focus, together with some supporting text. This reminds me that humans are visual learners and visualization should be the main focus.

The attempt at tackling notification logic

During the design process, I have been focusing on identifying what should be classified as an alert and what as just a notification. Alerts are taken seriously by the maritime industries as they could result in an fatal accident. They usually have specific classification of what classifies as an alert and use colors: red, orange and yellow to classify how critical the alert is. A situation NOT classified as alert should never be associated with alerts.

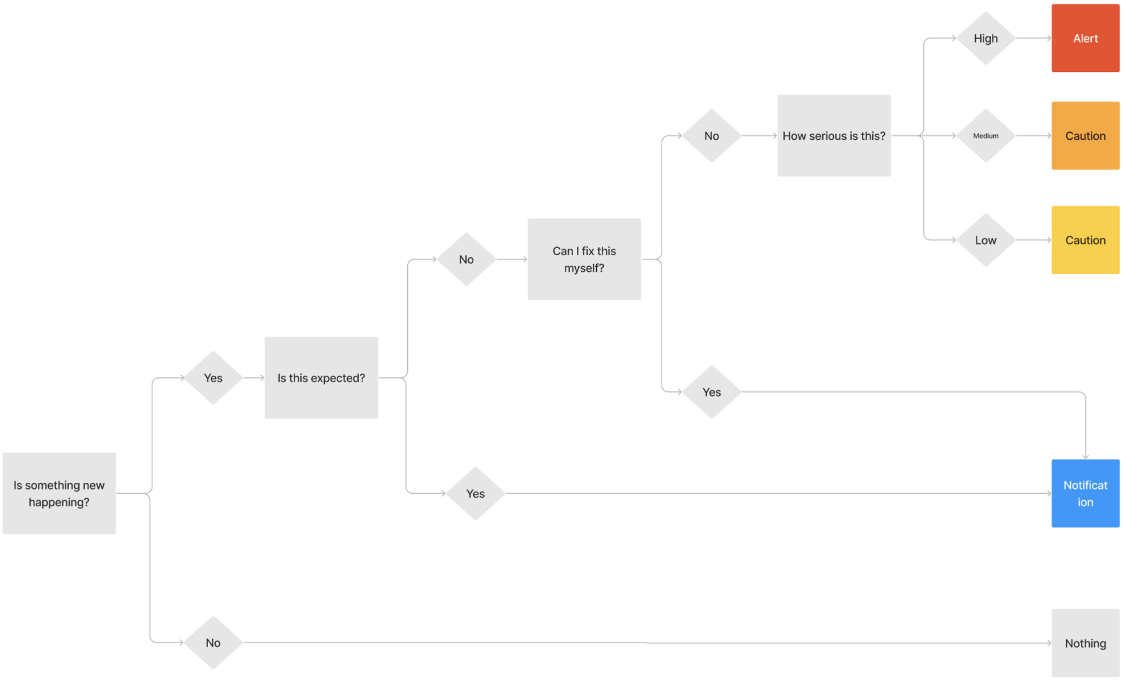
Some of my questions regarding notifications:

- If collision risk should show an alert, then when the machine has come up with a plan to avoid the collision, will it show this as an alert or as notification?

- If the machine is in the process of changing waypoint, what should the machine classify this as?

In order to attempt to identify how the system should notify the operator, I have made a flow chart based on extensive discussions with other experienced designers from Halogen.

Note that the result is only to help me get a rough idea when designing, and is something that needs to be developed further.



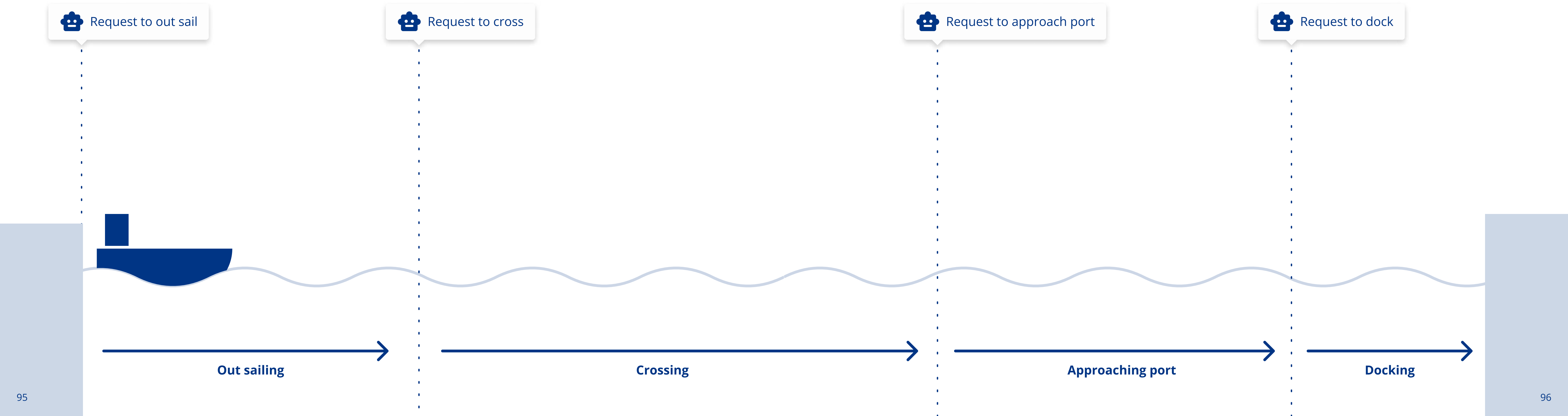
Machine notification logic

Design development

Request to enter ...

As mentioned, different stages of the voyage require different types of attention and have different collision risk. Information about when the ship is entering different stages of the sailing is therefore very important, since missing out this information will give the operator false sense of security.

For this reason, I have established a system requirement where they will need acknowledgement from the operator every time they are entering new stages in its voyage. This way the operator will both be involved in decision making and in being aware of the ship's situation.



Design development

Working with overview dashboard

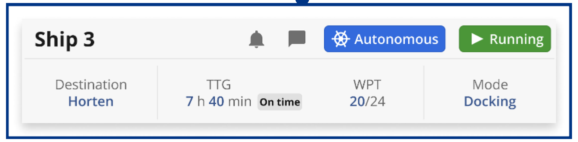
Design exploration

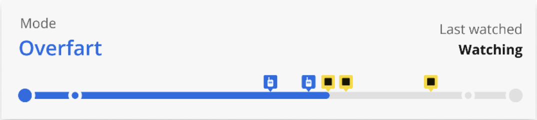
Overview dashboard is the first forefront of all ships, for this reason information shown here needs to be effectively communicated. The purpose of the overview dashboard is to not show everything, but enough for the operator to know which ships they need to pay more attention to.

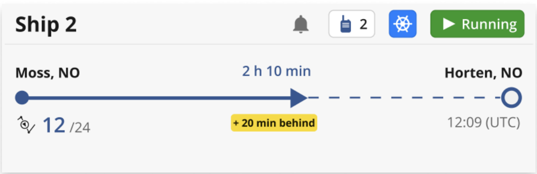
Main focus of this interface has been:

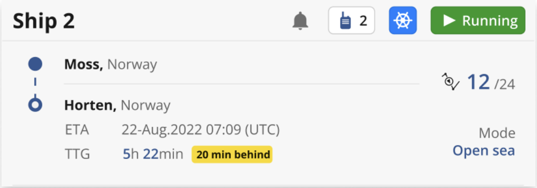
- Identifying how much information one needs to get overview
- Showing how would different sailing stages looks like
- Effective notification
- Giving the operator awareness of their own working progress

Takes less space and is more structured

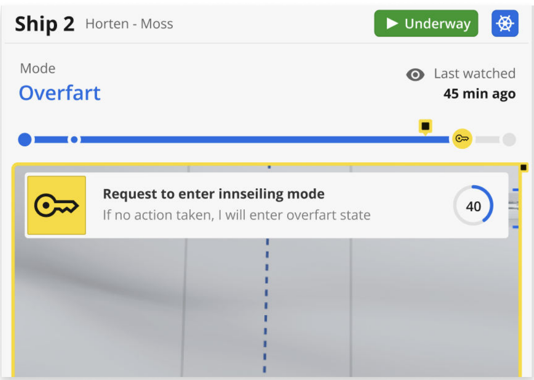


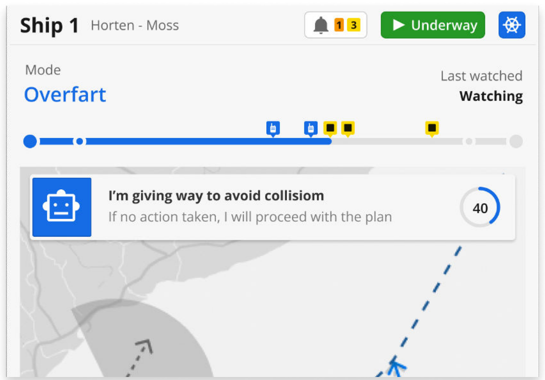




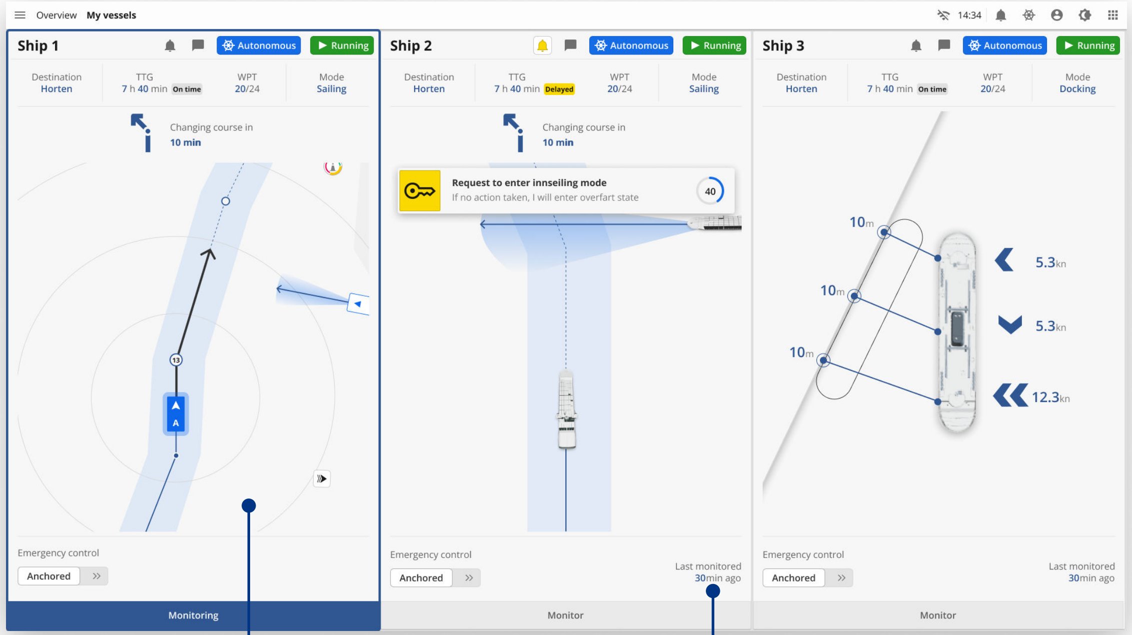


Information structure to help the operator to know where the ships are





Notification exploration



Visualization of the ships situation (smaller version of what is being shown in detailed view)

Making operator aware of their time

Design development

Working with “Machine brain”

Base on existing systems

The machine brain is supported to show the detailed version of what is shown in the overview dashboard. This interface has been my main focus for the project, since this will be where the system will interact with the operator in case of collision.

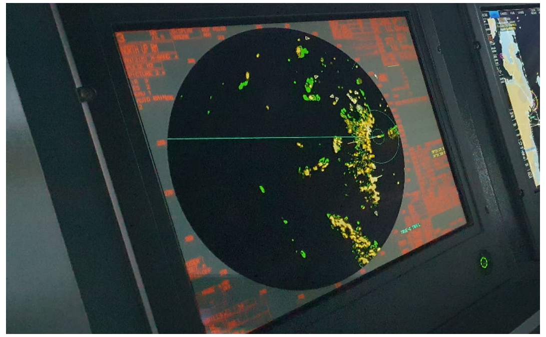
Since the machine brain’s purpose is to give the operator situation awareness of its operation, which include the navigational and collision avoidance part, I have chosen to base the system on existing systems; ECDIS and marine radar.

The machine brain is supported to show the detailed version of what is shown in the overview dashboard. This interface has been my main focus for the project, since this will be where the system will interact with the operator in case of collision.

Since the machine brain’s purpose is to give the operator situation awareness of its operation, which include the navigational and collision avoidance part, I have chosen to base the system on existing systems such as ECDIS and marine radar.

ECDIS

What is ECDIS?
ECDIS (Electronic Chart Display and Information System), is a system that provides digital charts and navigational information so that mariners may better plan their routes and monitor their progress. Other functions such as AIS and radar information could also be displayed as an overlay. (ECDIS Charts & Publications | Marine Navigation System, n.d.)



Marine radar

ARPA function

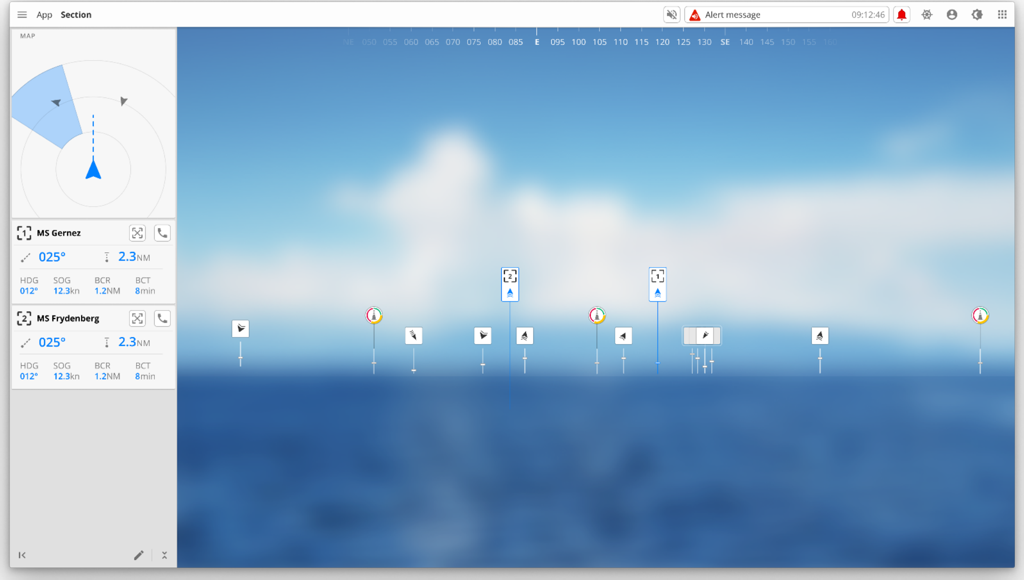
What is a marine radar system?
Marine radar, often employed with ECDIS, is a system used to detect nearby objects to avoid collisions.

Radar's ARPA(Automatic radar plotting aid) function is one of most crucial function of radar where it lets users plot where other ships may be in x minutes. The ARPA function only calculates the vector based on the ship's course and speed at the time, therefore the vector given is simply a guidance to where the ship "might" be. The navigator must closely follow the targets to detect changes. (Radar Best Practice -ARPA – Knowledge of Sea, 2021)

Use OpenBridge's own ECDIS, radar and OpenAR design as my starting point.

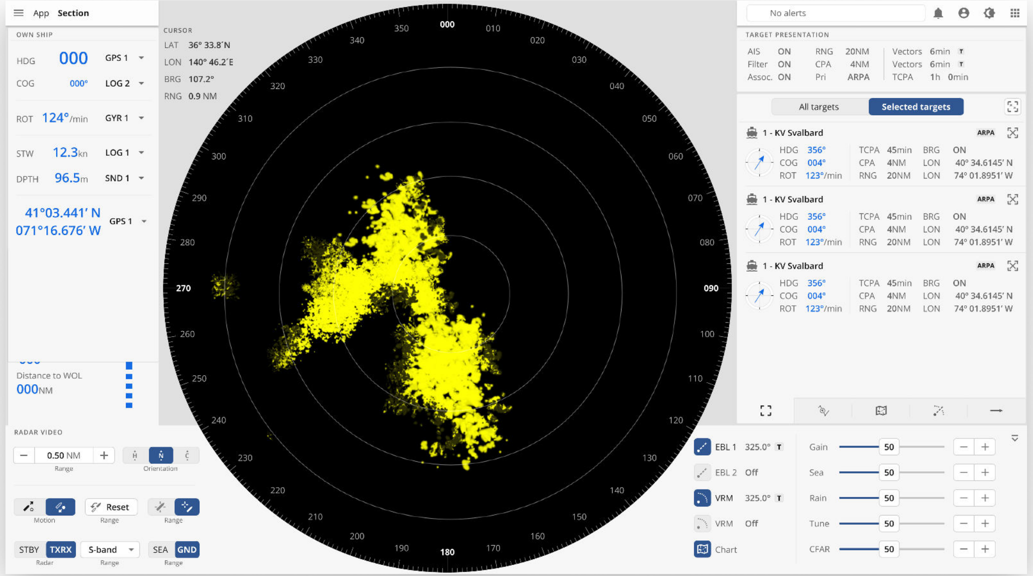
When I started working on the "machine brain" interface I used OpenBridge's own ECDIS and Radar, and components from OpenAR project as my starting point. By seeing examples of existing systems, it helped me establish the structure of the interface and give me guidelines for what type information one would need for the concept.

Since I already know what type of information one may need from the insight phase, I could quickly start experimenting with the design.

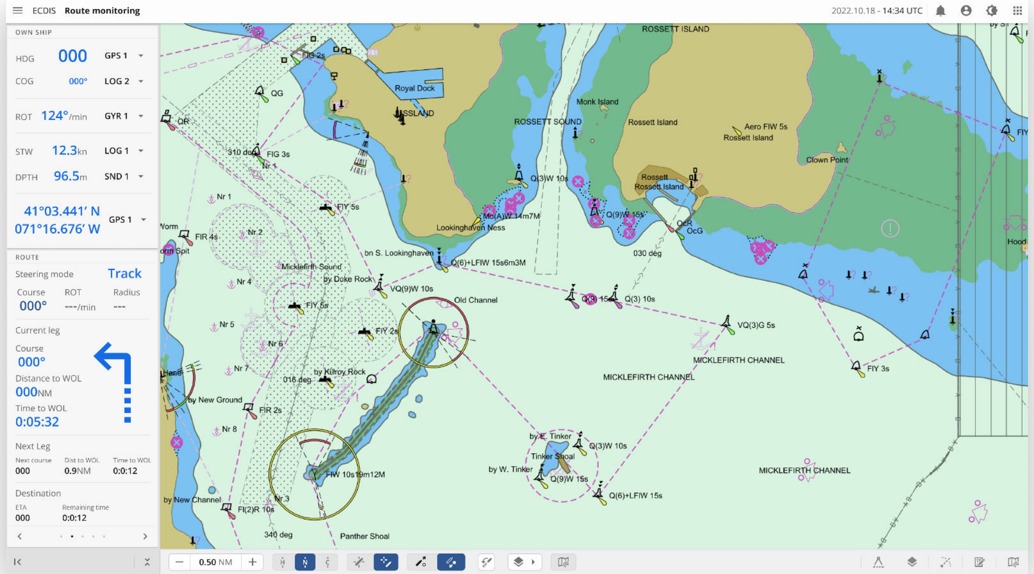


OpenBridge OpenAR design

Design development



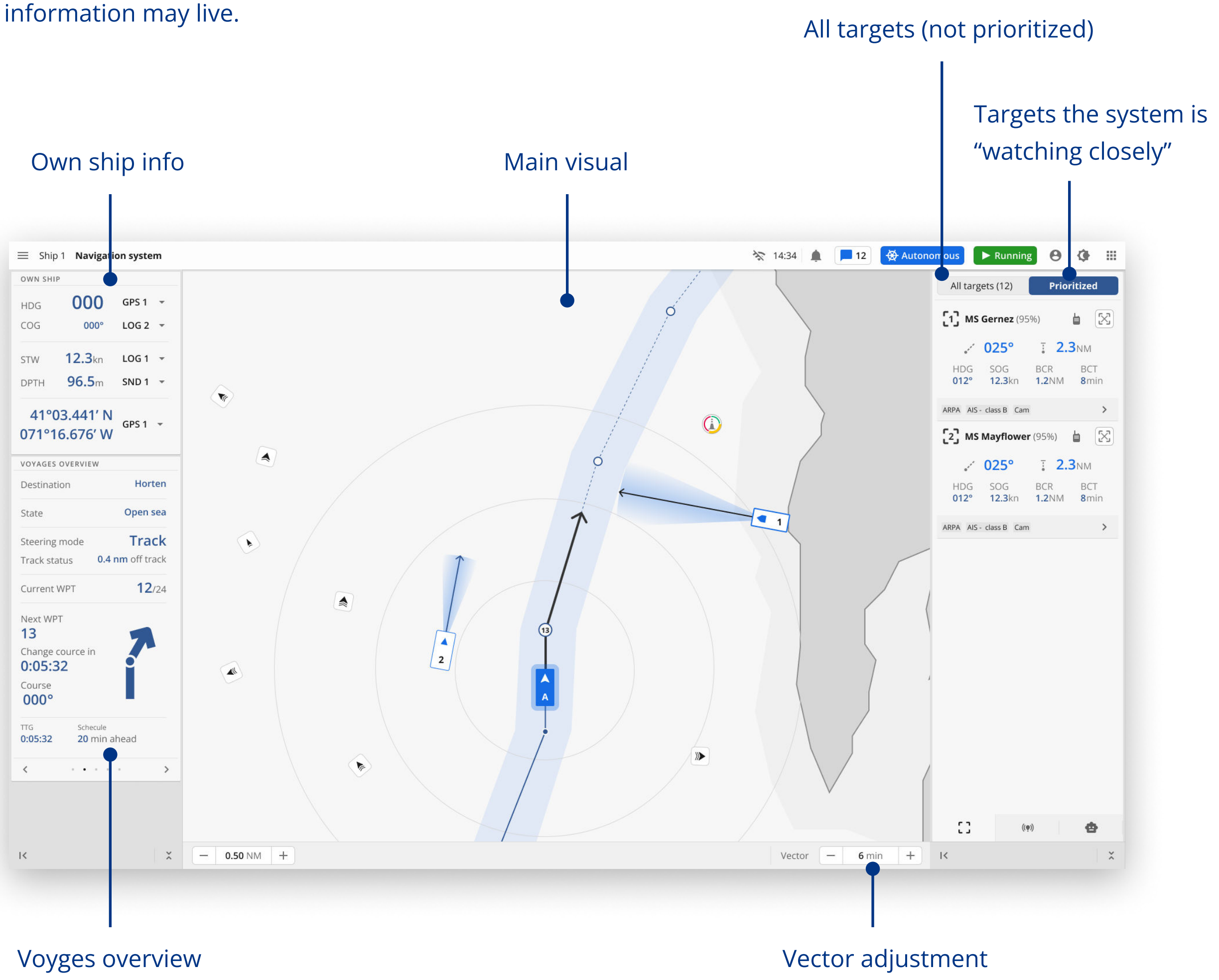
OpenBridge Radar design



OpenBridge ECDIS design

Base design

Using existing design from ECDIS, Radar and Open AR cases, together with the findings from research phase, I have designed a base interface for the "machine brain" where I identified where the various types of information may live.



Collision avoidance scenerios

To improve my design further in collision avoidance support, I have used scenarios as a means to help me determine what type of information one may need for the different situations.

For this project, I have focused mainly on two scenarios:

1. Crossing A
2. Crossing B

Crossing A

Crossing B

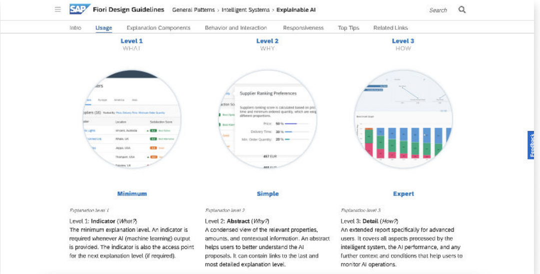
Transparency principles

Once I start exploring design for collision avoidance support, I have looked into transparency principles and concepts made by other researchers and designers as a guideline. According to DARPA , transparency can be achieved by means of a **human-like natural language explanation.**

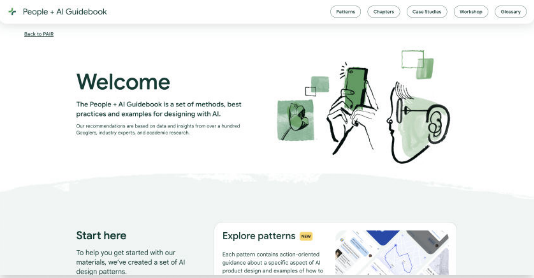
Questions that could be used as a guideline:

- "Why did the system do that and not something else?"
- "When does the system succeed?" and "When does the system fail?"
- "When can the user trust the system?"
- "How can the user correct an error

("DARPA's Explainable Artificial Intelligence Program," n.d.)



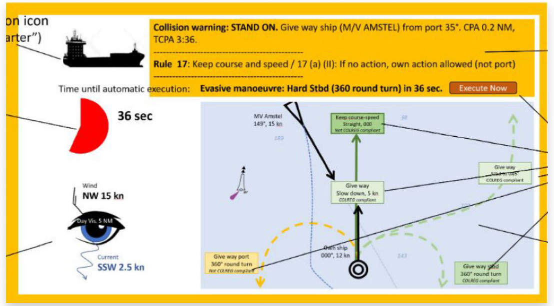
Fiori Design Guidelines - Explainable AI (n.d.) Obtain with permission



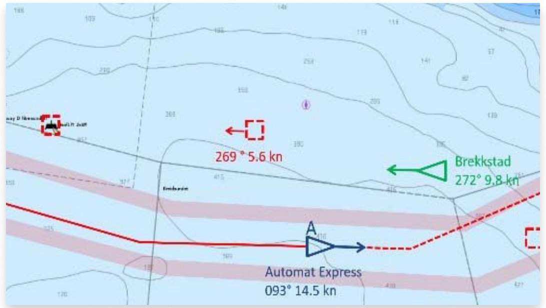
People + AI guidebook by google (n.d.) CC BY-NC-SA 4.0

Examples of automation transparency

Human-like nataural language AI explaination (People + AI guidebook, n.d.) CC BY-NC-SA 4.0



A Quickly Getting into the Loop Display (QGILD) concept. Porathe, 2022. CC BY 4.0



Automation transparency concept (Porathe, 2019) CC BY-NC

Transparency in collision avoidance

To design a decision support system that aids in the situation awareness of the operator it is important to consider several factors.

DNV has divided ship function into four functions: condition detection, condition analysis, action planning and action control. (n.d.) Koen van de Merwe, a PhD candidate working on automation transparency at USN, has made a diagram based on those four different ship function to show how transparency in autonomous collision avoidance could be. (Transparency in Collision Avoidance, n.d.) Based on both research from DNV and the example from Koen, one could potentially support SA through:

Condition detection
First, the operator needs a clear view of the ship's surroundings. Geography, bathymetry, permanent and floating items, weather, and other factors that could affect ship navigation must be identified and addressed immediately. Sensors would gather this data on autonomous systems.

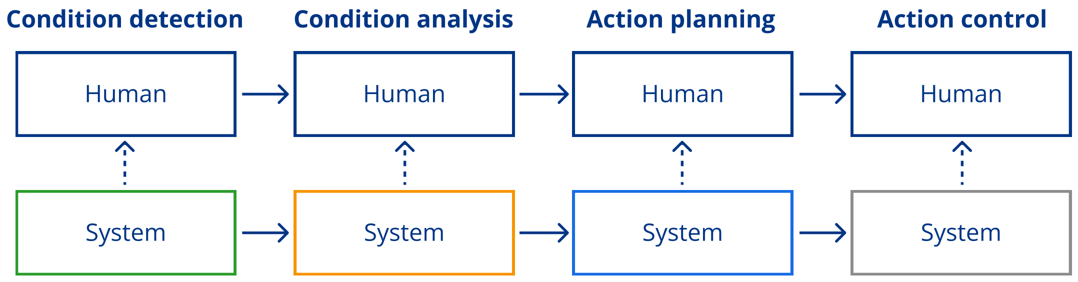
Condition analysis
The decision support system should be able to use this information detected to analyze and identify potential collisions and alert the operator to the risk.

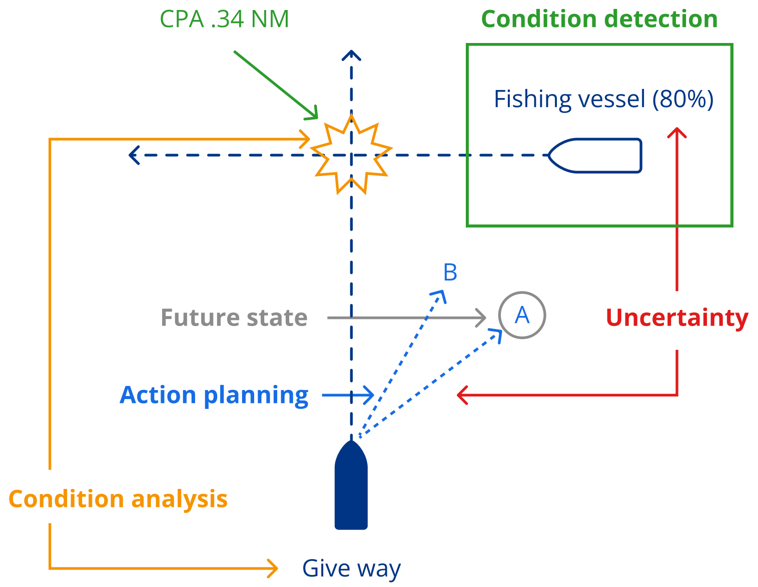
Action planning
When the risk of collision is confirmed, the operator should have access to recommendations for avoiding collisions based on COLREGs rules that can help them make informed decisions.

Action control
Finally, the user may choose an appropriate plan through the system where the plan is carried by the system. At this stage, clear feedback to the user of which plan is being executed are very important as a confirmation from the system.

Additionally, the decision support system should be able to automatically take action to avoid collisions if the operator is unable to do so, either by taking the recommended plans or by stopping the ship.

Ships function defined by DNV





Tansparency in collision avoidance base on unpublished diagram by PhD candidate, Koen van de Merwe. (n.d)

Design development

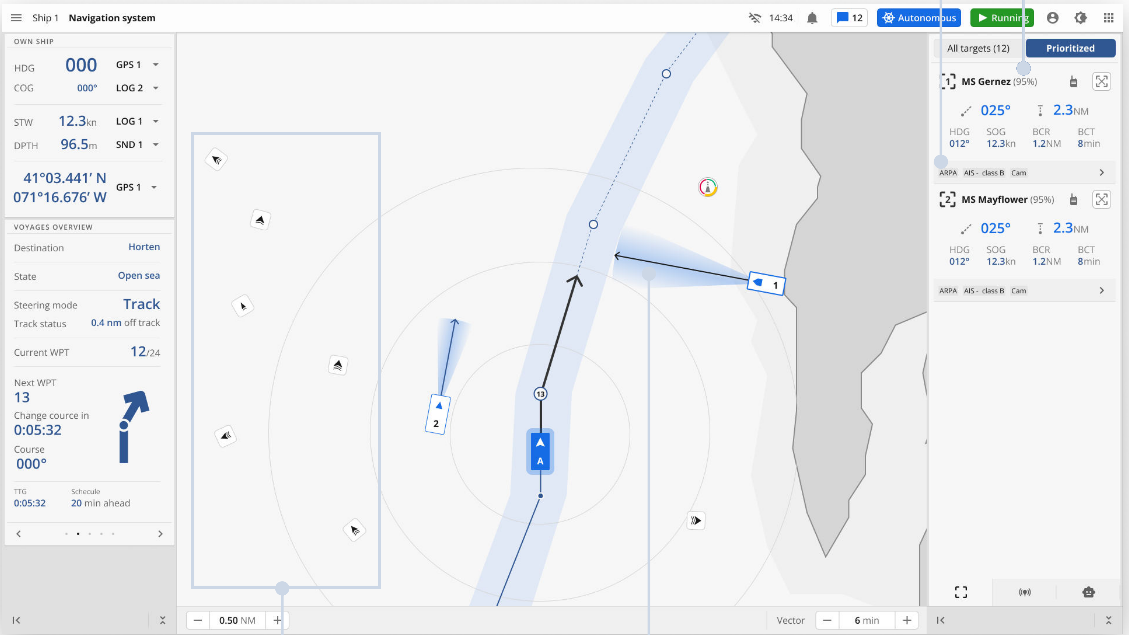
Collision avoidance sequence

CONDITION DETECTION

System confidence

1. System detects two ships that they need to watch closely

Data source

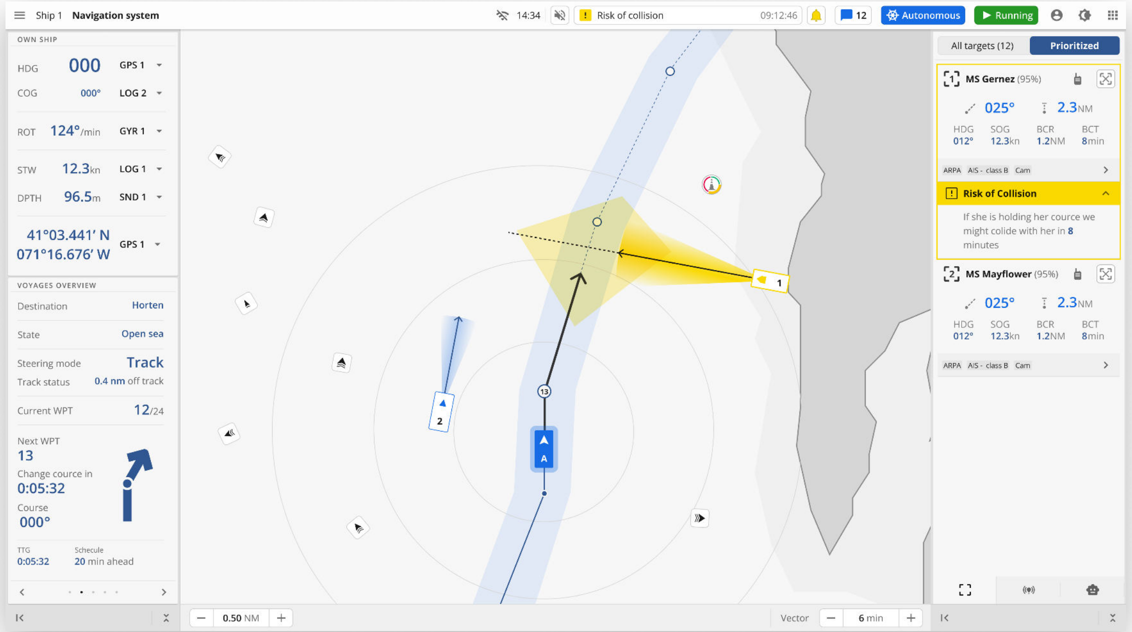


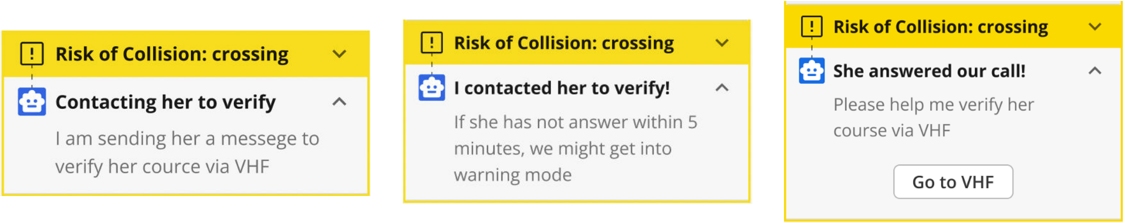
Unrelevant targets

Navigational reliability fans

CONDITION ANALYSIS

2. System detects a risk of collision on one ship





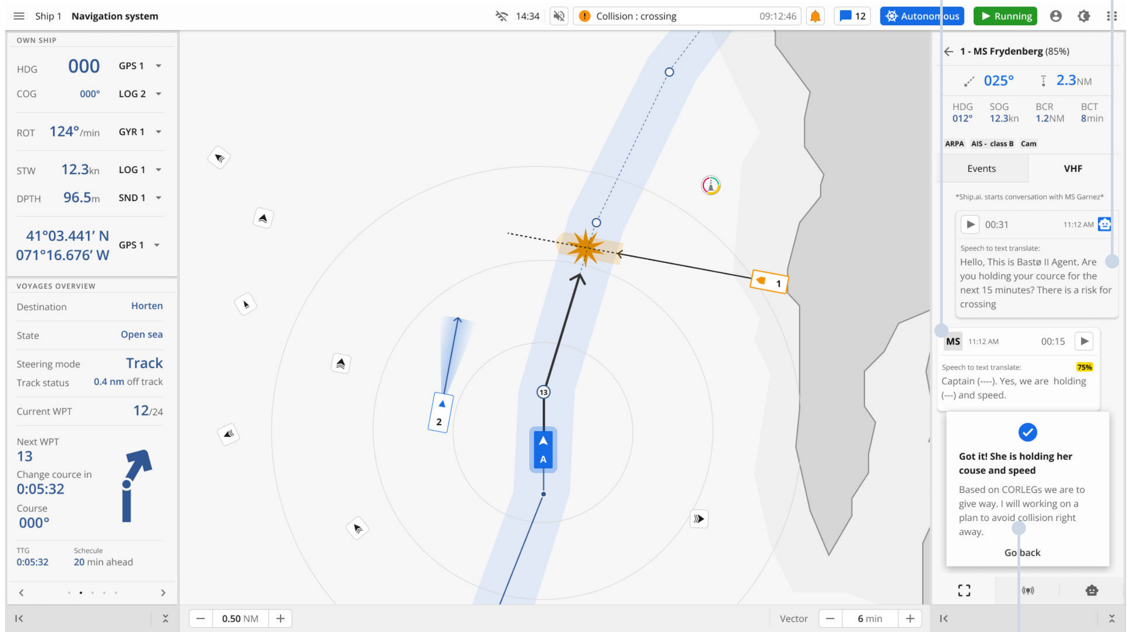
Concept of system contacting other ship to verify their intention

CONDITION ANALYSIS

3. When the risk of collision is certain, the ship shows collision zone and potential collision point.

Messege system sended out

Answer from other ship

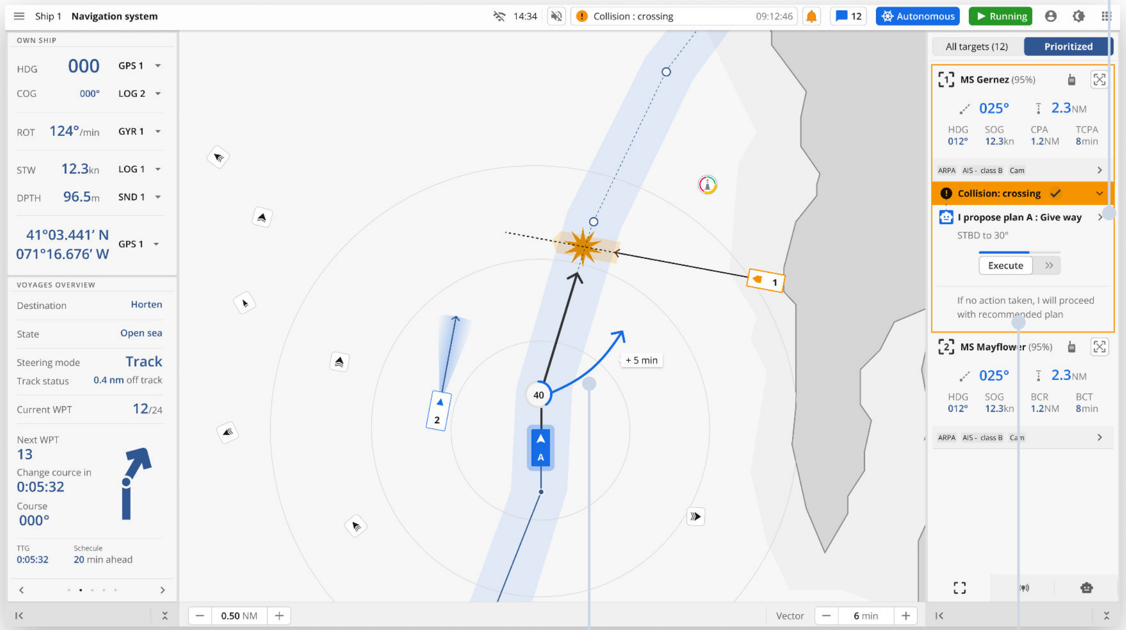


System takes the "first step" but operator must always verify to avoid miscommunication

ACTION PLANNING

4. The system is calculating a plan where it shows a recommended plan.

See more button



Where the ship would be in the next 6 min with the new route

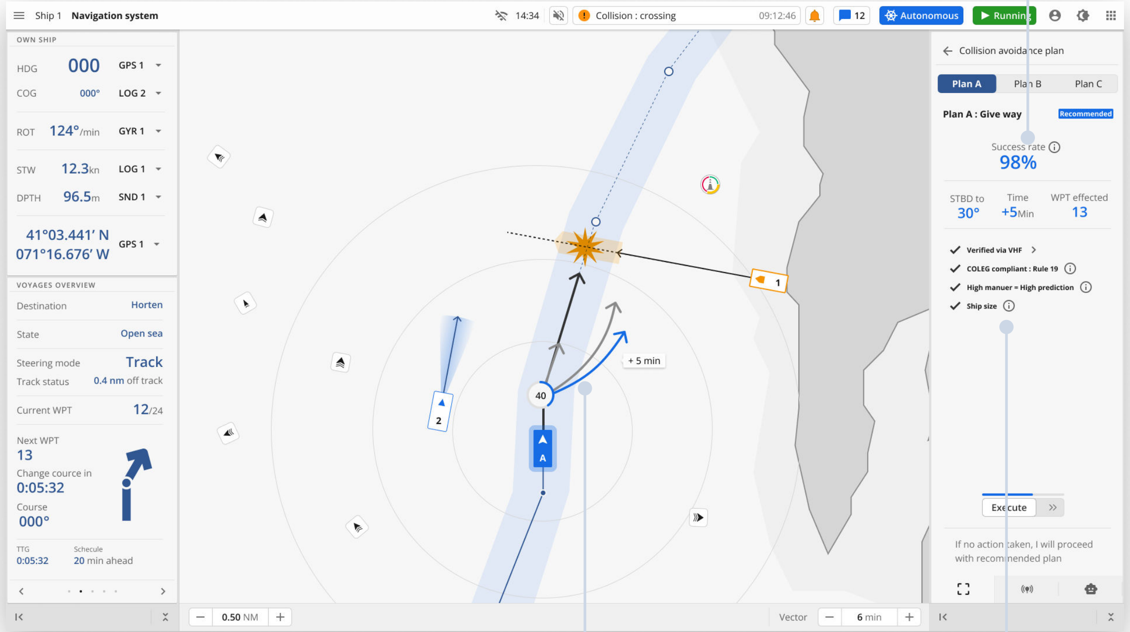
If no action is taken, the system takes action on it's own, either full stop or proceed with the plan

Design development

ACTION PLANNING

5. The user is able to chose an alternative plan or see the reasoning behind the suggested plan.

Decision base on success rate

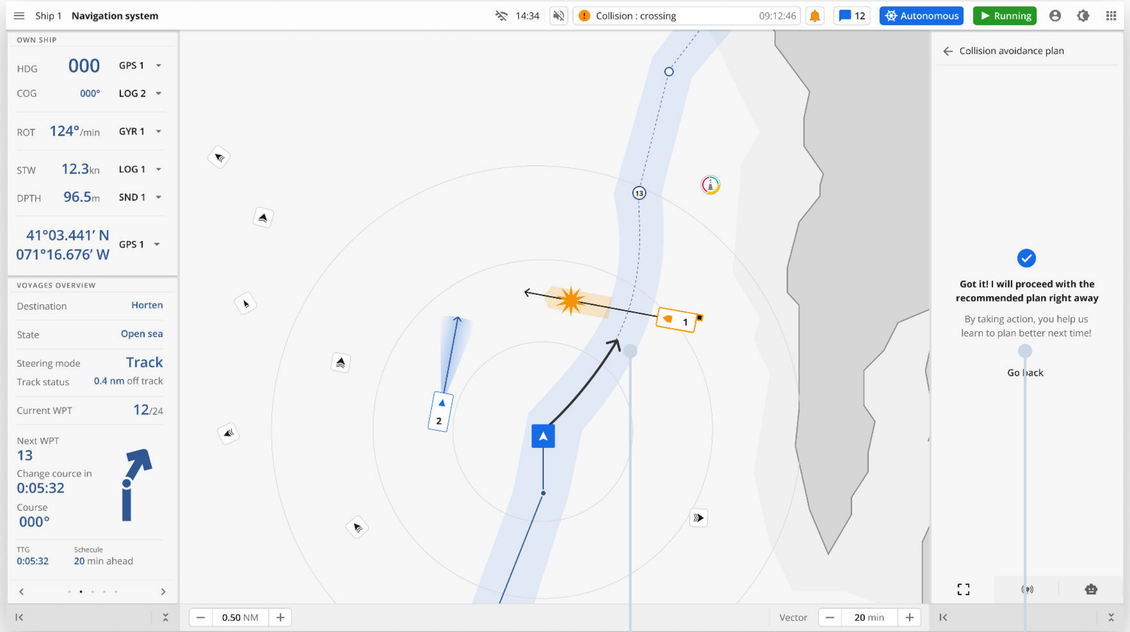


Clickable alternative routes

Parameters used

ACTION CONTROL

6. When a plan is chosen, the system shows the new route and proceeds with the chosen plan



New route

System feedback to the user

Working with AR overlay

Design development

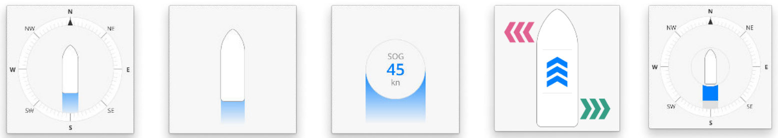
Design exploration

AR overlay is meant to support the operator by giving them "real life" pictures of the situation together with additional information they would need through instruments.
However, the second aim for this interface is also to use this as a means to determine if the information the system perceives is correct. After all, at least at the beginning, the system could still identify wrong objects, thus by having the operator keeping an eye on the surroundings and notifying the system if they spot anything unusual will help the machine learn.

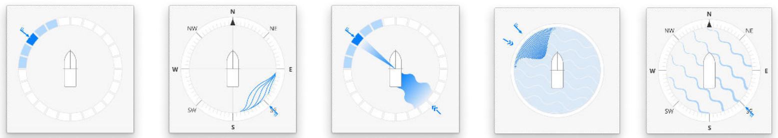
OpenAR project
As this interface is directly linked to what has been made in the OpenAR project, I have taken both inspiration and components from this project.

Main focus of this interface has been:

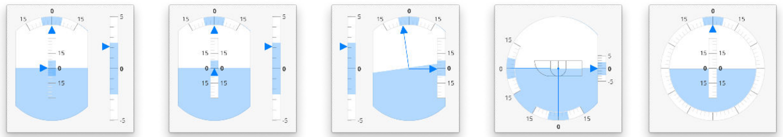
- What information needs to be here
- Instruments
- Showing the targets



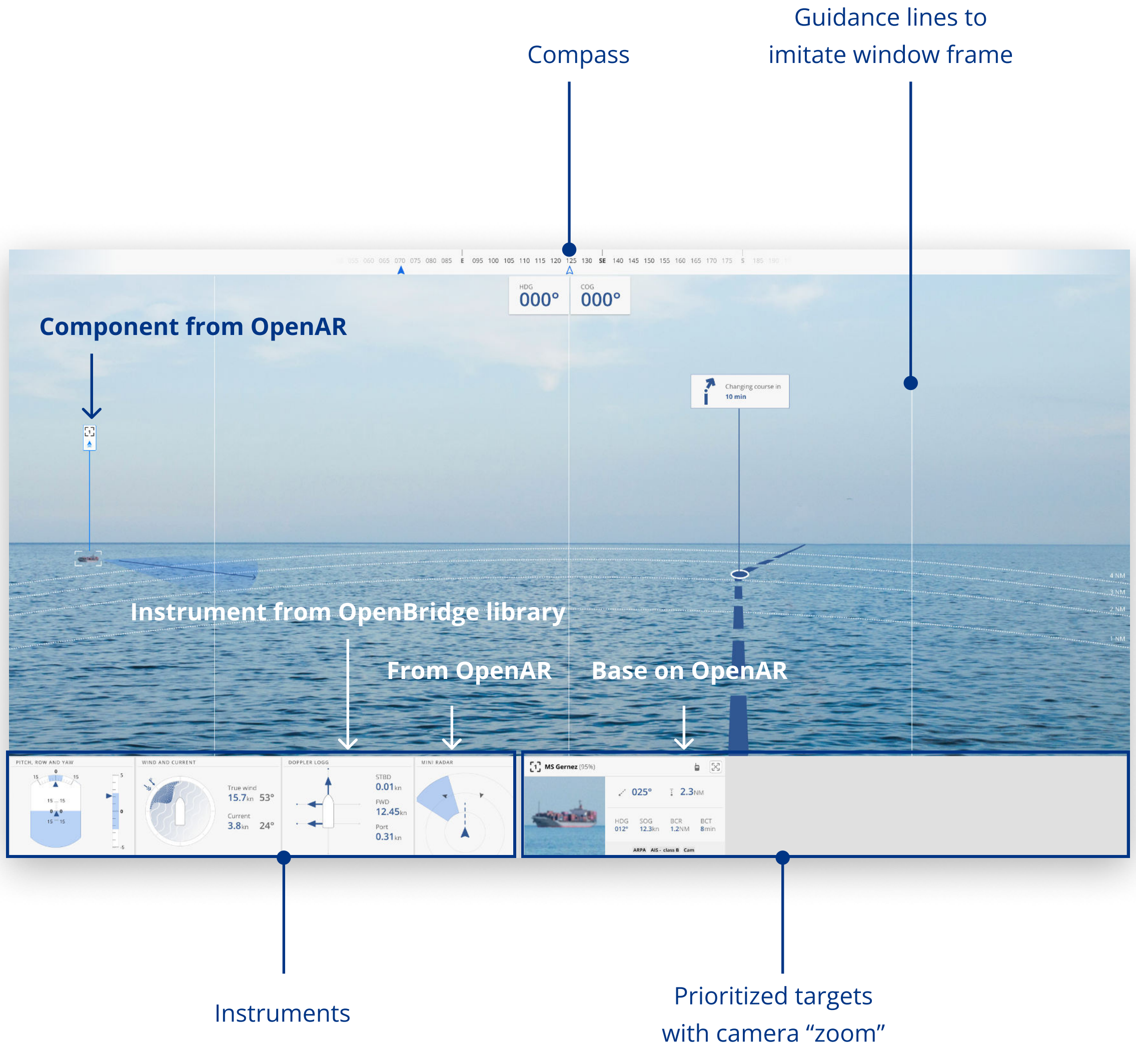
Mini doppler log exploration



Mini wind + current exploration



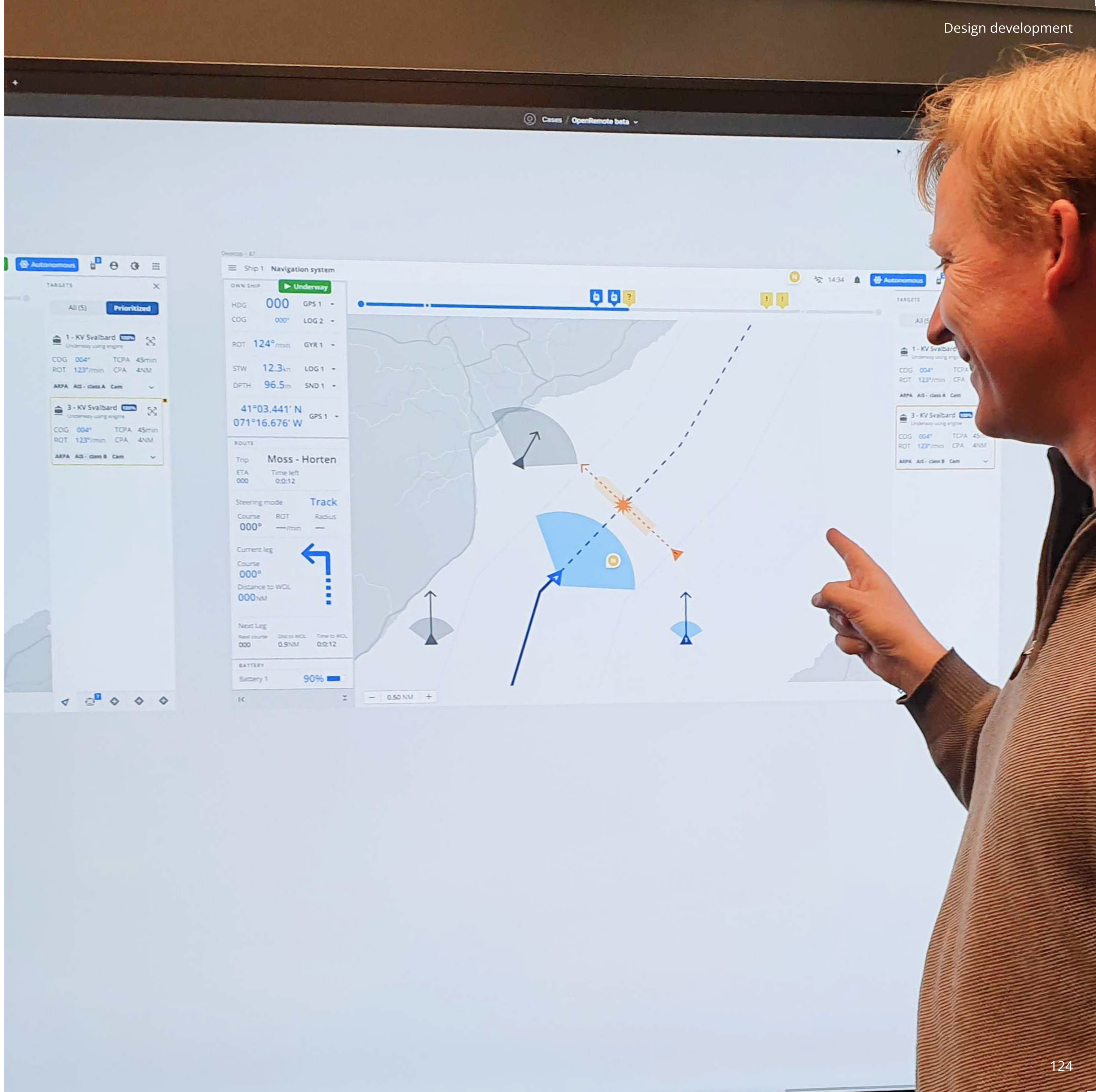
Mini pitch, row & yaw exploration



Continuous feedback loop from multiple experts

Throughout the project I have involved multiple experts(experts from OICL, automation transparency experts, other experienced designers) to push the project in order to iterate on the design. I was lucky to have got a workspace at OICL and thus have access to experts from OICL to have both proper design feedback sessions and quick feedback on multiple parts of the project. This way I could have a continuous feedback loop and iterate on my ideas quickly.

I was also lucky to have the opportunity to have multiple feedback sessions with several experienced designers at Halogen, from which I gained a new perspective on my design



First usertesting

Through connection with OICL, I was able to get user feedback session with two navigators at Bastø Fossen ship. I have divided the session into two sections:

Section 1: Identifying

Objective:
to get general feedback on concepts and identifying the information needed, if there is any unnecessary information or any information missing.

Method:
print outs of the screens so the navigator could draw directly on the “interface”. This way we avoid the user getting scared of “breaking” the design.

Section 2: Collision avoidance scenarios

Objective:
To get feedback on overall thought of the interactions on different stages of the collision avoidance scenarios.

Method:
Clickable prototype. By already going through the design in previous section, the user would already know the basics of the interface, this way we could focus on the interactions in this section.

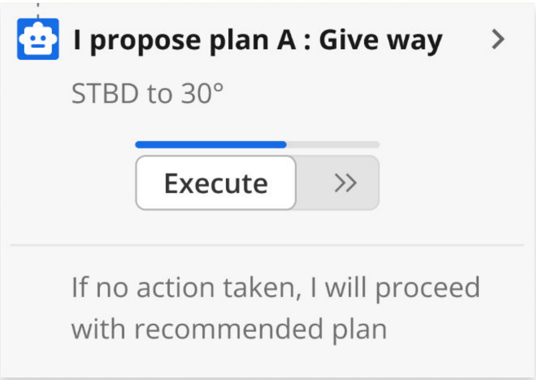
Feedbacks from the users

Overall the concept is perceived as very well structured. The navigator are able to understand most of the information presented. The overview dashboard and AR overlay are positively perceived by the operator.

However, functions in the “machine brain” in collision avoidance sequences are getting the most critique especially functions where the system takes action without consulting with the operator first (system calling other ship automatically)

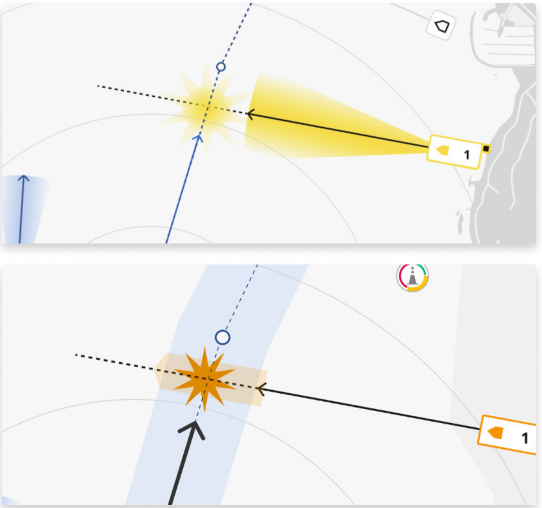
“Em... The robot talking to other ships? I want to do this myself”

Navigator (translated from Norwegian)

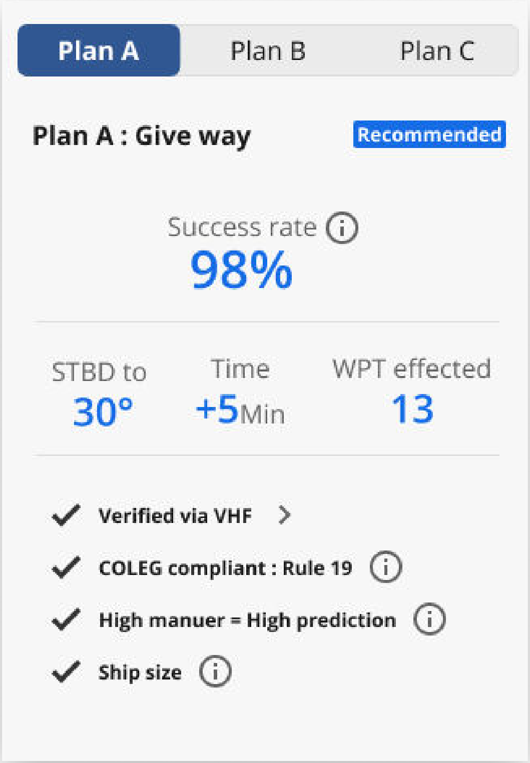


“We navigators hate the under-menu, if there is something important, just make it easy to access!”

Navigator (translated from Norwegian)



Visualization not clear enough ❌
The operators finds the visualization of the collision track confusing, since there are two different visualization of the same situation



“I don’t care if it's 98% or 50%. If it’s less than 100% sure, then stop the ship!”

Navigator (translated from Norwegian)

“If I am already stressed, I don't have the time to go through all the text. I don’t want to read!”

Navigator (translated from Norwegian)

OpenBridge seminar - discussion with the industries partners

At the end of October, OICL held a seminar for the official ending of the OpenBridge project with all the project partners from the Industries. I took this opportunity to present the project during this seminar with all the industry partners present, to share the progress. These actions created a lot of discussions with the industry's actors during and after the seminar.

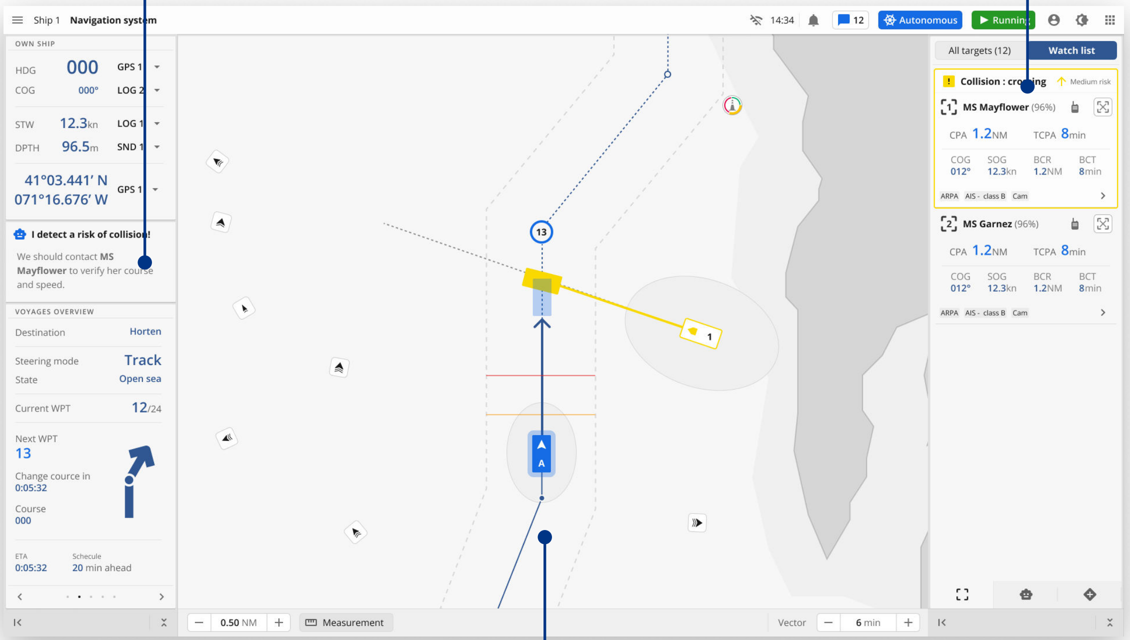
Photo by Kjetil Nordby (2022)

Design development

Iterations

nudging the user to take action rather then the system

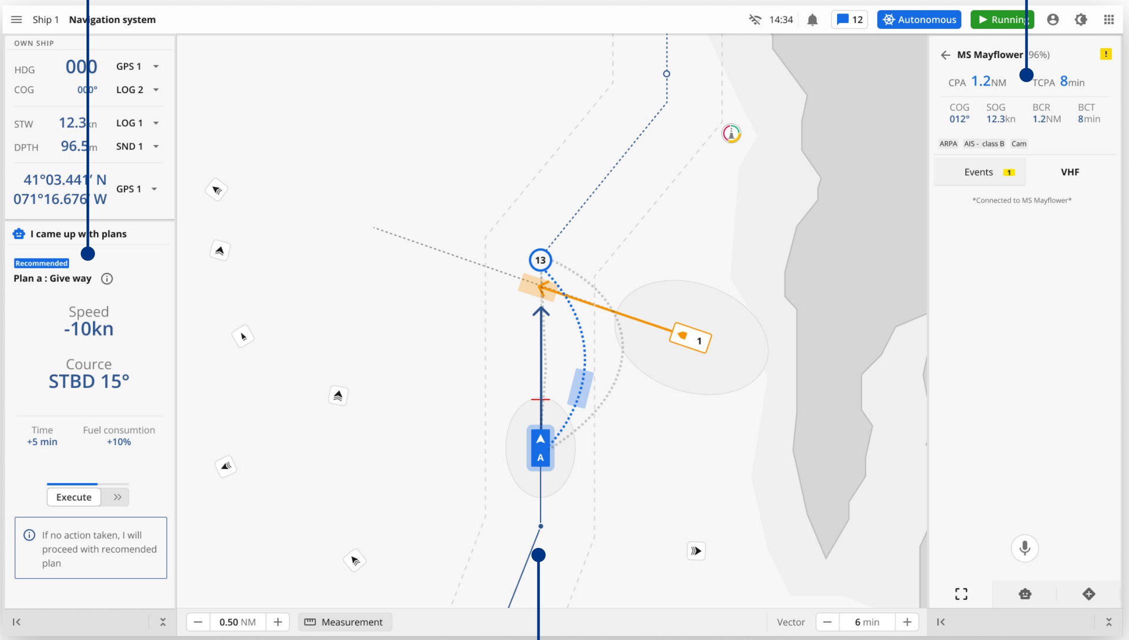
Clearer communication



Clearer and simpler visualization

Dynamic solution & streamline information

User could coordinate the plans together with other ships before deciding



Clearer visualization

Second user feedback

For the second user feedback session, I also traveled to Bastø Fossen and conducted tests with on-board navigators. This feedback session follows the same pattern as the first one, with two parts: identifying information and collision avoidance support.

The user feedback obtained is generally positive. They find the design to be organized, straightforward, and easy to navigate. The support for avoiding collisions seems to be communicated well through graphics and text, and the operators finds collaboration between the system and the operator intuitive.

"I like that it feels like we are working together." - Navigator

However, several parts of the design are still unclear, and the design has to be developed further.

05

PROPOSAL

OpenRemote Beta

Support system for monitoring autonomous vessels

Workstation model designed by Kongsberg Group
Using with permission

Proposal overview

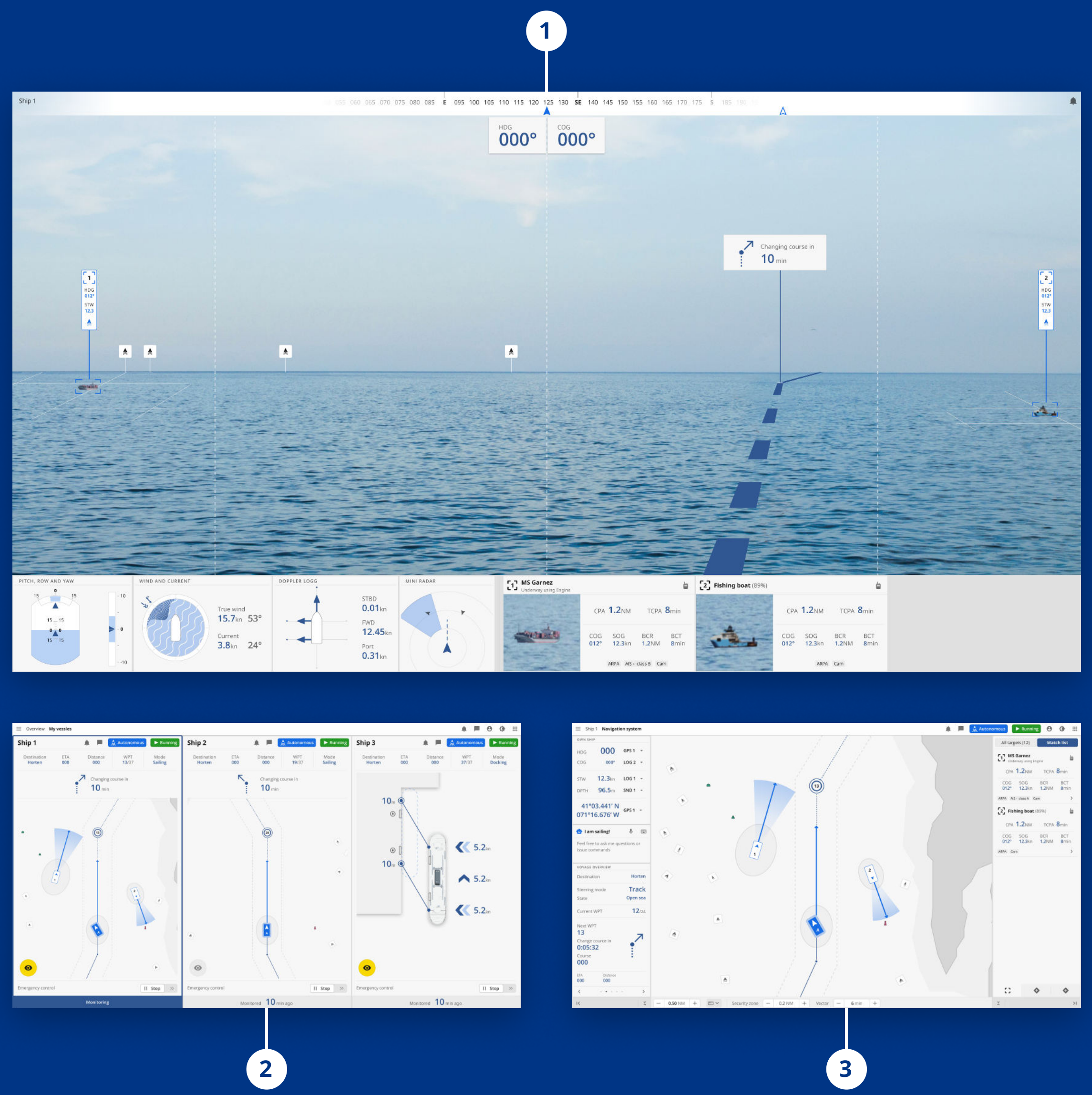
When controlling and monitoring the high level of automation vessels, one may easily get lost in the complexity of the system and not be able to identify or notice if unusual situations are happening.

OpenRemote Beta offers a system that will support the operator in monitoring multiple autonomous ships simultaneously by keeping the system transparent to make it understandable for the user to know when to take action. The design for this proposal are meant to be used in a multiscreen setup at a fixed shore control center.

The 3 main components allow the user to observe the vessels on 3 different levels:

1. **Overview dashboard**; which enables the users to get a quick overview of assigned ships and is used as a remote control to show detailed information about one ship at a time
2. **Detailed dashboard**; allows the user to get detailed information about one chosen ship
3. **AR overlays** allow the user to get a real-life feel of what is going on out there.

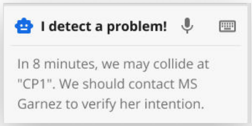
Proposal

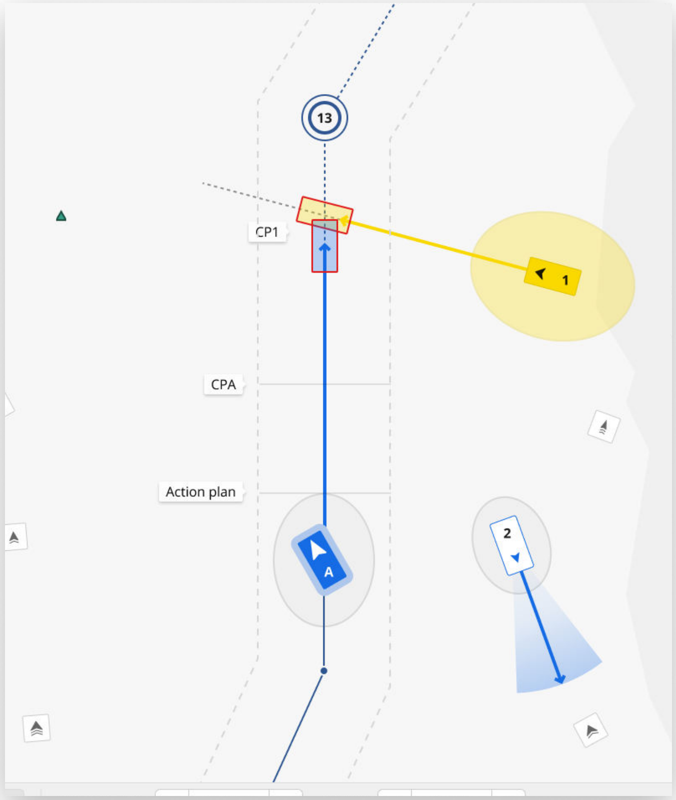


Design principles

From a black box to transparent box

The solution is designed to give a transparent overview to actually "see" what the system sees, and its thought process. This way, the user could base their decisions on the system's understanding of the situation.

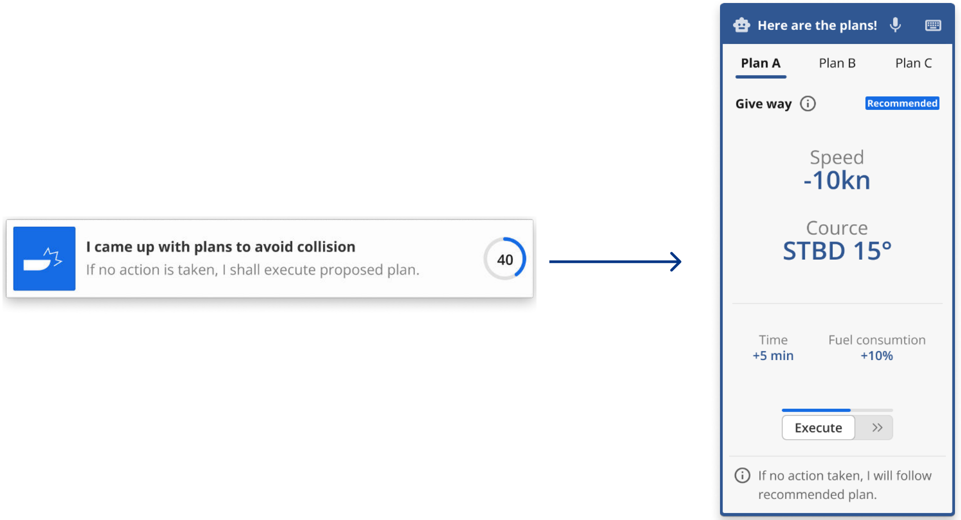




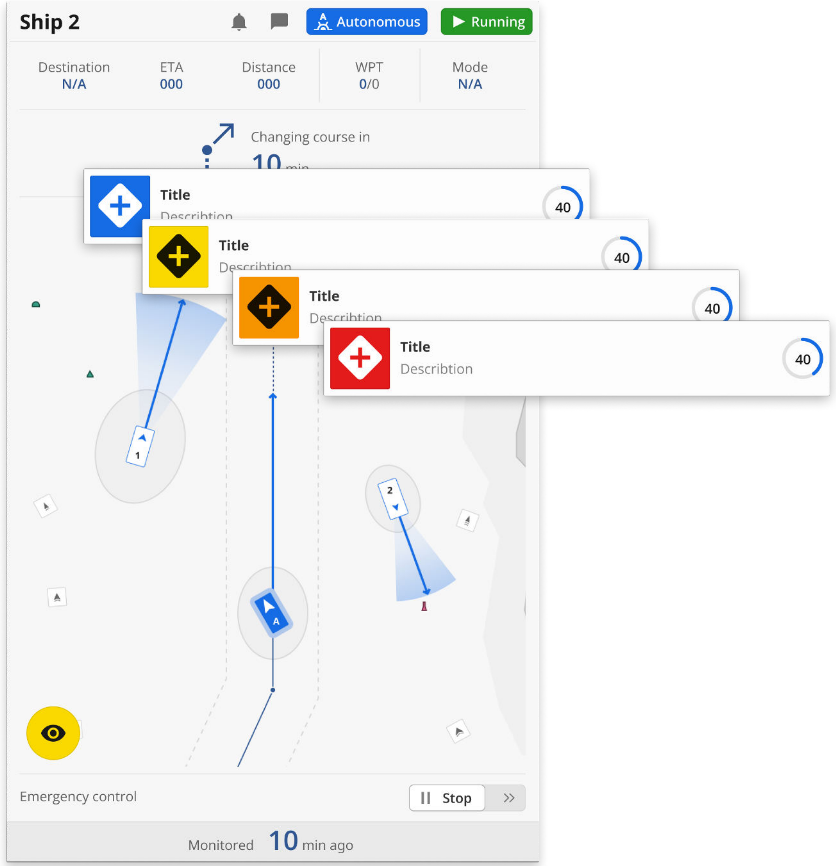
Proposal

Information layers

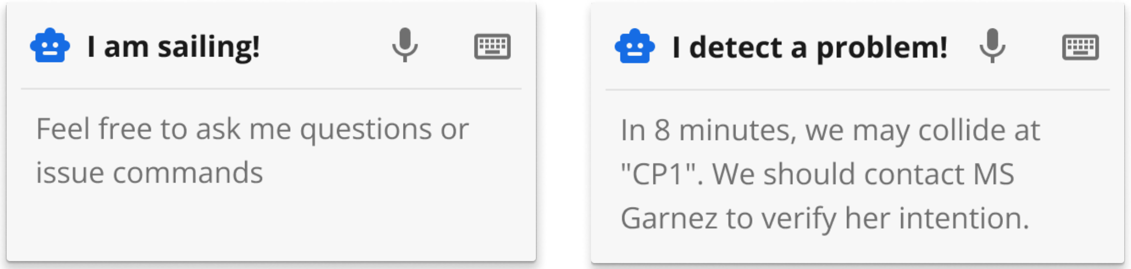
Showing different levels of information gives the operator the opportunity to dig down when needed to, while still giving all the important information in the top level.



Smart notification
Showing notifications when something unexpected is happening is an essential part of the system, to quickly give the operator the right situation awareness.



From monitoring to collaboration
The solution is designed to allow the operator to interact with the system directly. Through either sound or text command, the user could interact with the system to either require information or give command, giving a feel of having a teammate.

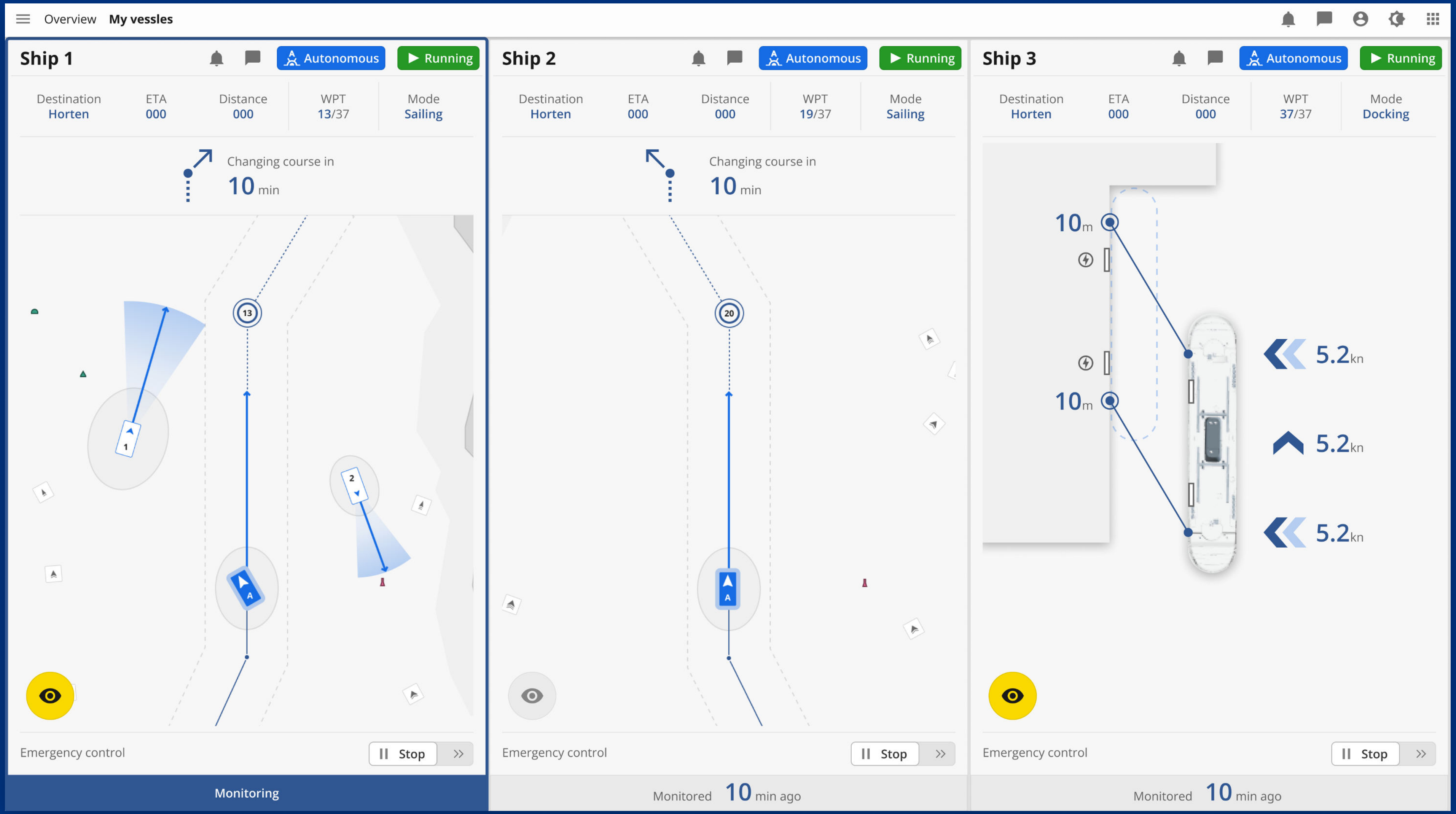


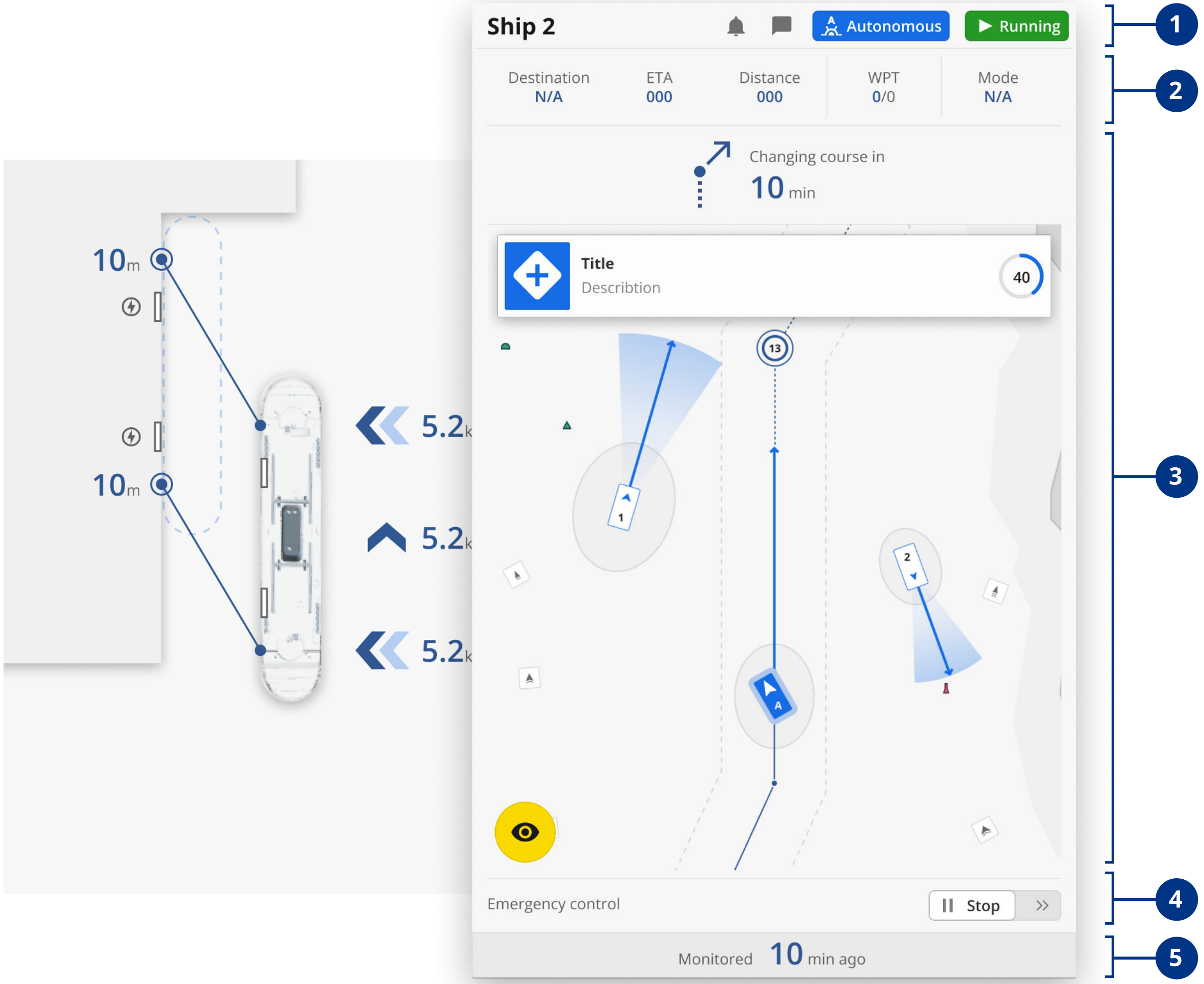
Proposal

Overview dashboard

The overview is meant to be used to get a top-level overview of assigned ships. When something unexpected happens, a notification pop-up will show on the card to notify the operator to be aware of the situation. The ships are presented in modules, and therefore the number of ships could be reduced or increased based on how many ships one operator can monitor at the same time.

The cards used in this interface are also used as a remote control to control which ship to present on the two other interfaces. By showing one ship at a time, we reduce the risk of the operator taking control of the wrong ship





The card’s structure

All the cards have the same structure to avoid confusion, where it has been divided into five parts:

1. **The top bar** displays all controllable features, including active alarms, who is in charge, and ship status. To avoid distracting the operator, the ship status and who is in control are labeled, while the other button is reduced to an icon.

2. **The voyage overview** in the upper half of the cards helps the operator track the ships' progress.

3. **The card's midsection** depicts ships and their environs. The visualization will display ship stage-related data. The ship's trip will provide the user with relevant information. In case of unexpected situation, the system will notify the operator through a notification toast.

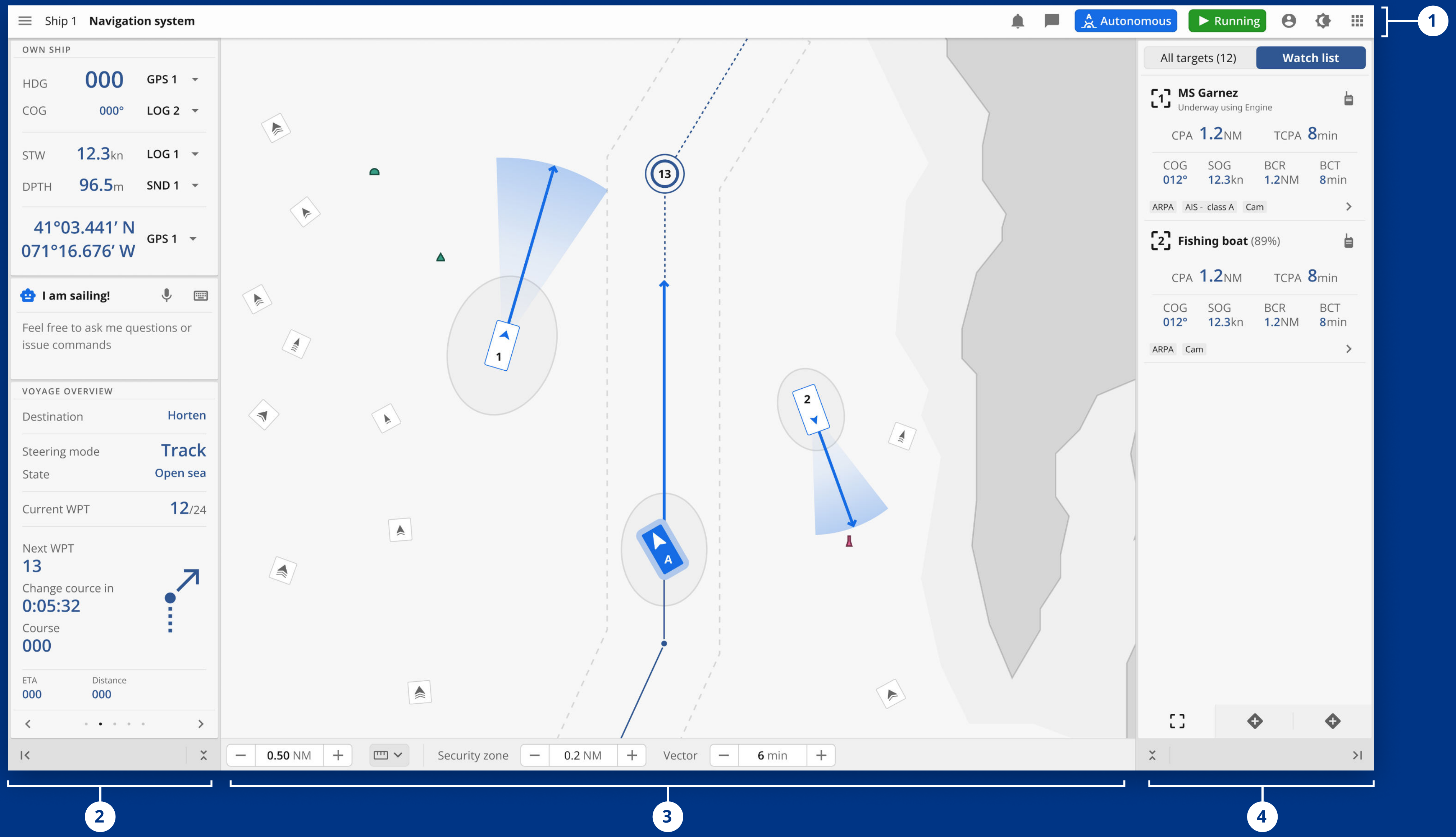
4. **Emergency buttons** allow the operator to halt the ships instantly. If one ship is in danger and they can't focus on the others, by having a stop button accessible by one slide will help them feel in control.

5. The card's bottom shows how long the operator has actively watched the ship, helping them track their progress.

Detailed dashboard

The navigation tools or "machine brain" aims to show the navigator what the machines "see" and its thought process. It is a detailed version of what is shown in the overview dashboard. Here the user will be able to obtain the ship situation and communicate with the system if needed.

1. **Topbar**: Operational global functions such as alert, command, and states
2. **Left panel:** own ship information, voyages overview, and ability to communicate with the system.
3. **Main display**: visualization of the ship and its surrounding.
4. **Right panel**: Additional information related to the ships surrounding. For this project, I have focused mainly on the target list function.



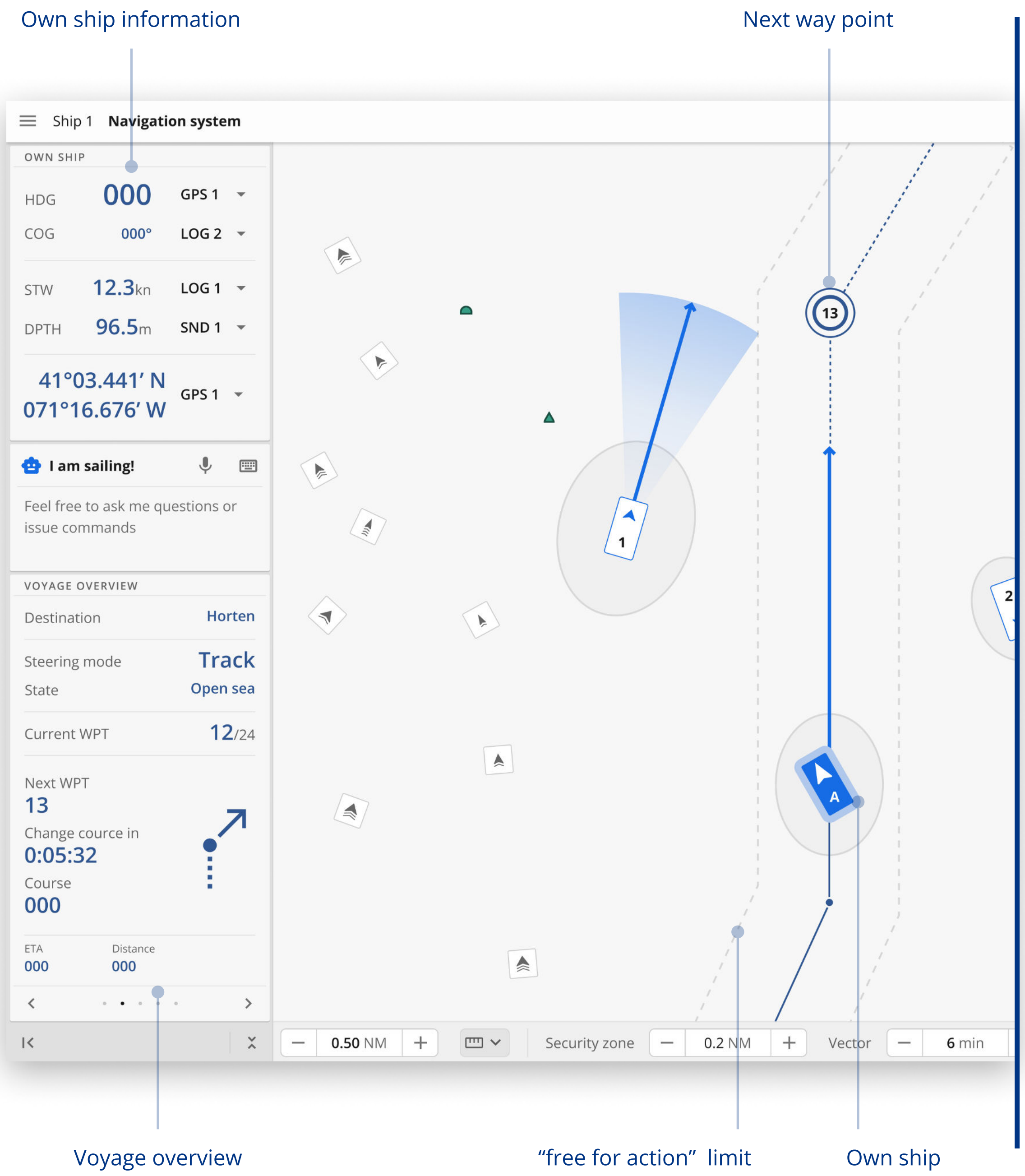
Navigation

Navigation is an essential part of the system, as it is the main purpose of ship transit. For the navigator to orient themselves to where the ship is, information is shown both textually and visually.

Visually the ownership is marked with “A” to visualize that the system is taking control. The ship is placed on a path, and the next waypoint is highlighted both on the display and information panel to make the operator aware of where they will go next.

The two dashed lines beside the path represent a “free of control” area where the ship gets to take smaller decisions without it triggering alarms, this way the operator will not get unnecessary alarms and sensory overload.

If the navigator has any questions or commands to make, they could easily do so by communicating with the system on the left side. This way they don’t need to dig around for information that is not presented directly on the screen. This is essential, especially in situations where the navigator needs to take action quickly.

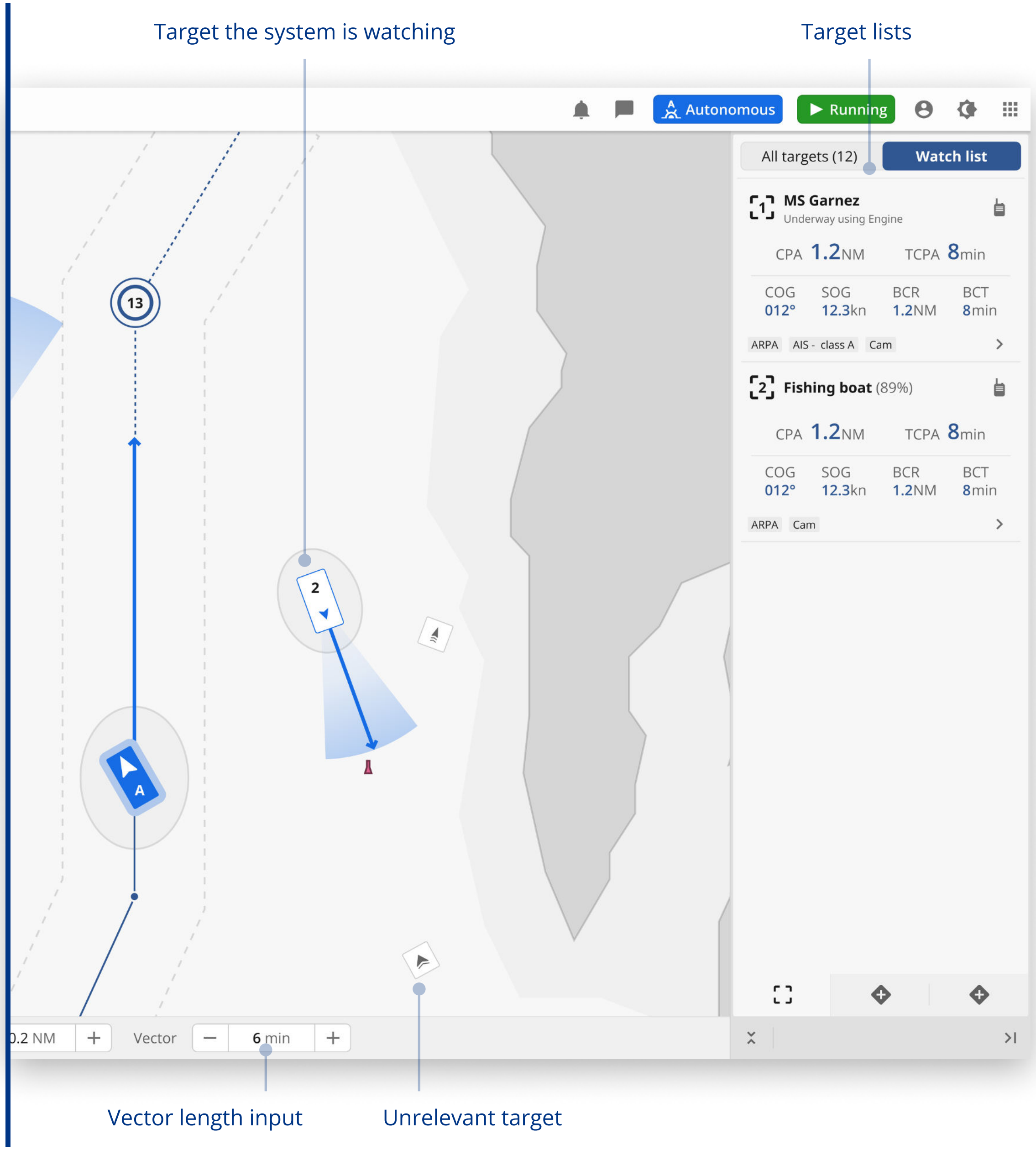


Presenting the targets

Showing the targets is one of the most important parts of sailing to avoid collision with other ships or static objects such as land or lighthouses. For this reason, in my concept, the user could obtain target information both visually and textually.

Relevant targets that the system is looking closer into will show in the watch list with more information while other irrelevant targets are toned down. By showing the source of the data on a watchlist, it gives the user a mental model of how the system works, which in turn will increase trust in the system. This way the operator knows which targets the system is looking closer to while also decluttering irrelevant ships that they don't need to pay attention to.

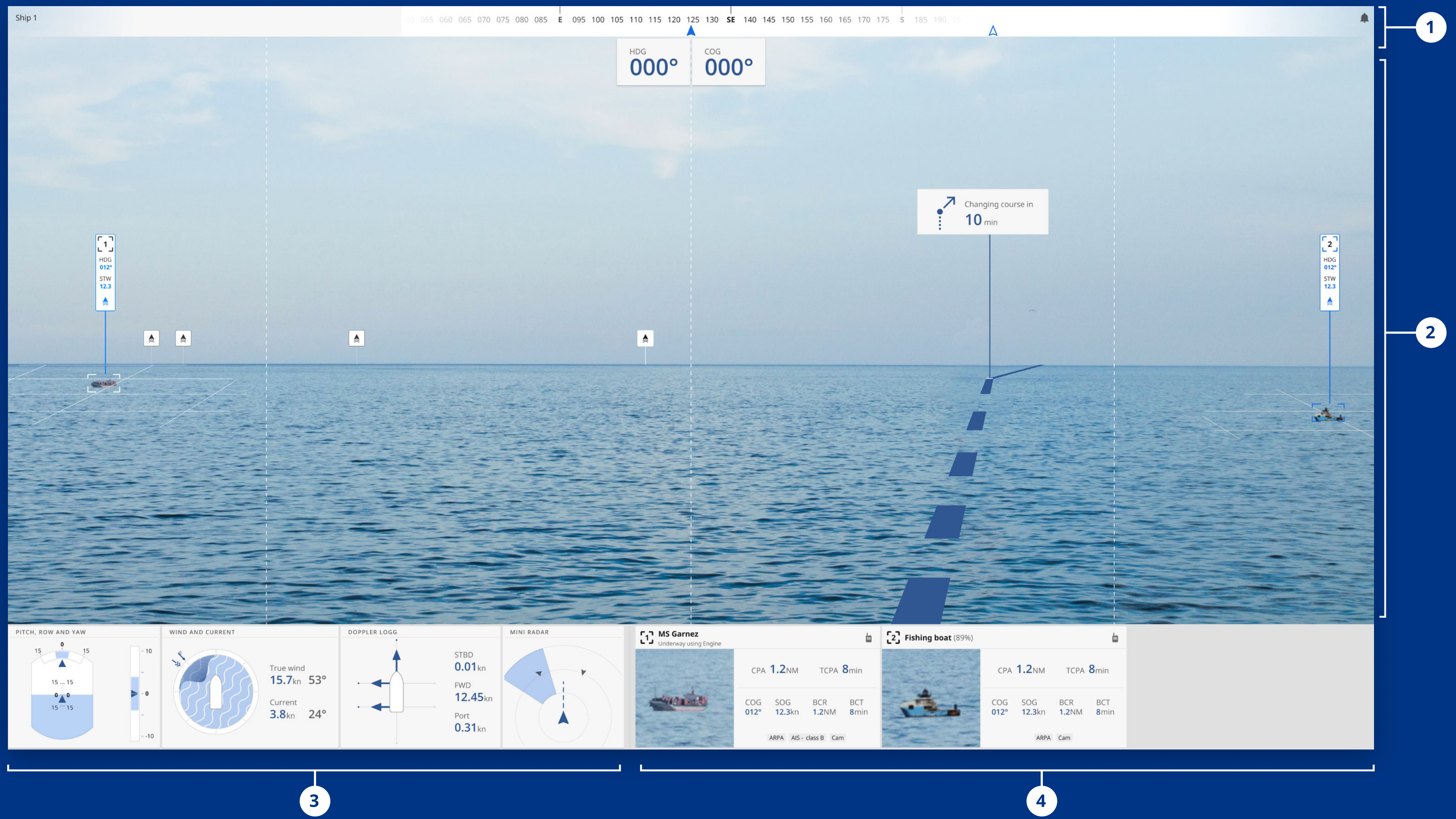
Using vectors, the operator can see where his own ships and target ship will be in the next x minutes. By the nature of the unpredictability of where the other ship could sail next, an "uncertainty cone" is presented together with the vector of other ships to show where they could also have been. Together with the icons and the collision zone, the operator could see what size the vessels are.



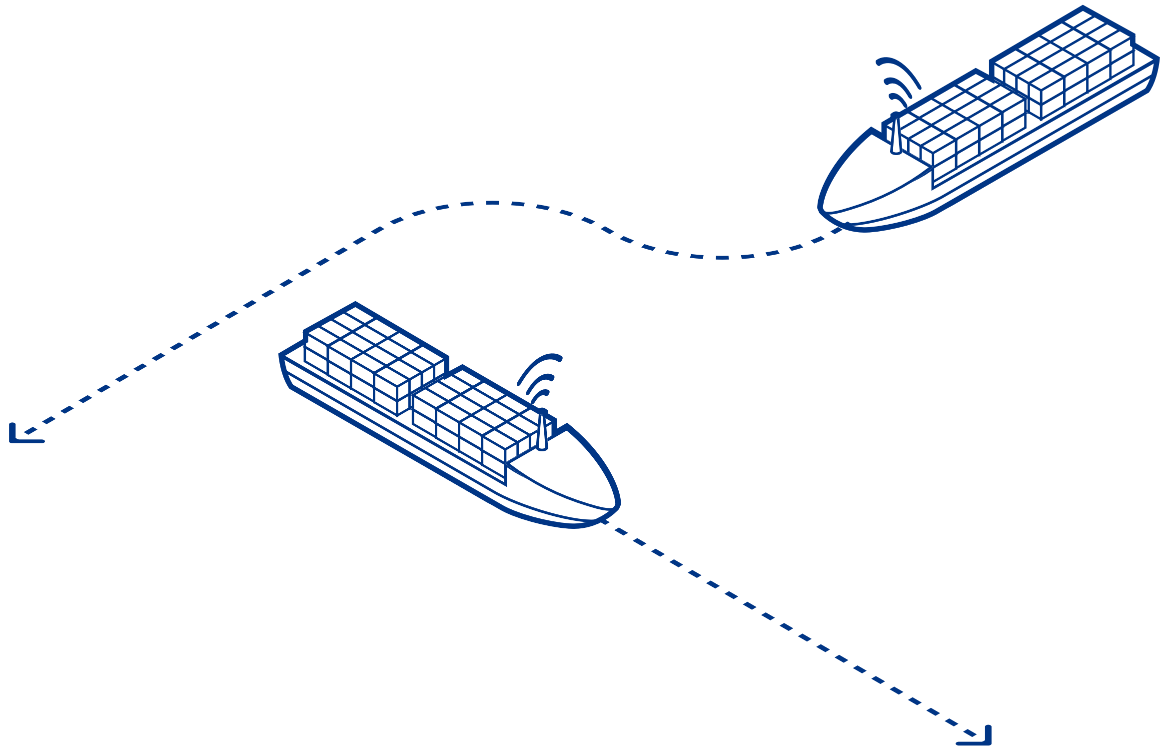
Camera overlay

The camera overlay is meant to give the operator a feel of the real-life situation of the ship. The overlay is essential, especially in a situation where there is low visibility in the surrounding.

1. **The top part** allows the user to obtain compass and HDG and COG information.
2. **The middle part** allows to operator to see the ships path and targets detected, this way the operator could easily locate where the targets are. The guidelines shown can be used to measure the targets ship movement.
3. **Left bottom panel** shows a minimized version of instruments used to obtain additional information of the ship and the ships surrounding.
4. **Right bottom panel** shows targets list with "zoom in" camera of the target so the operator could easily see the target.



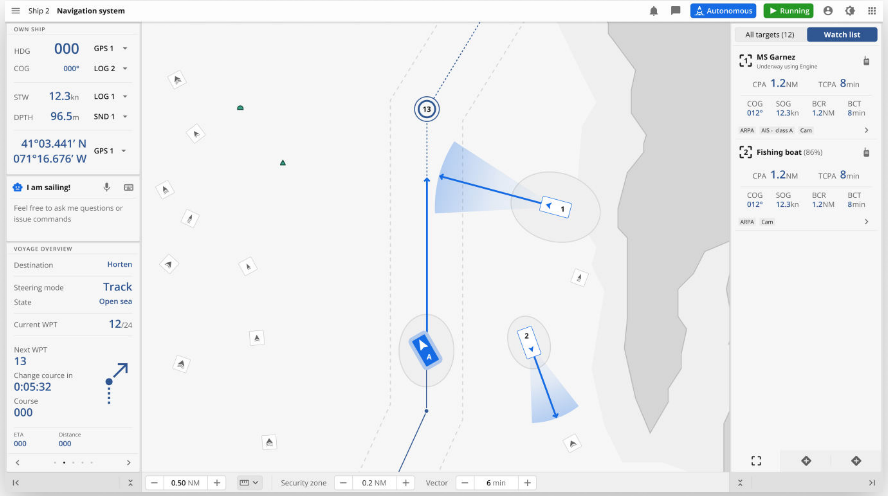
Collision avoidance journey



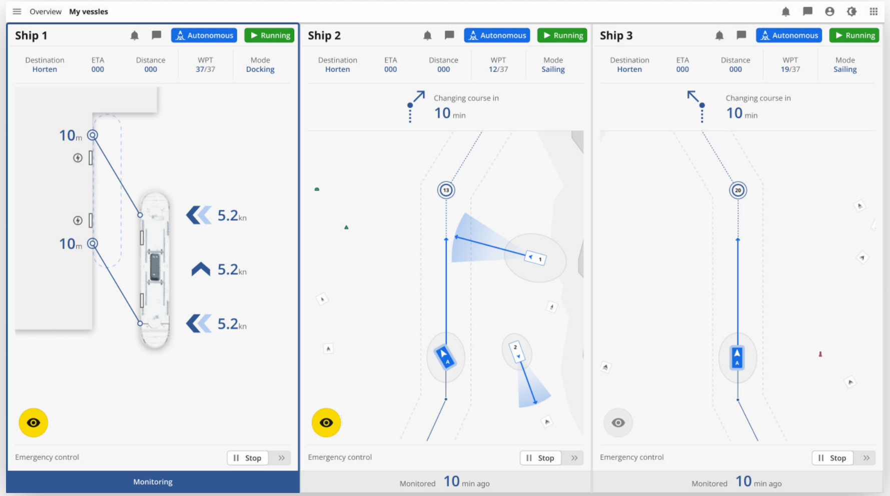
CONDITION DETECTION

1. The system detect two ships they need to look closer into

Active monitored by operator

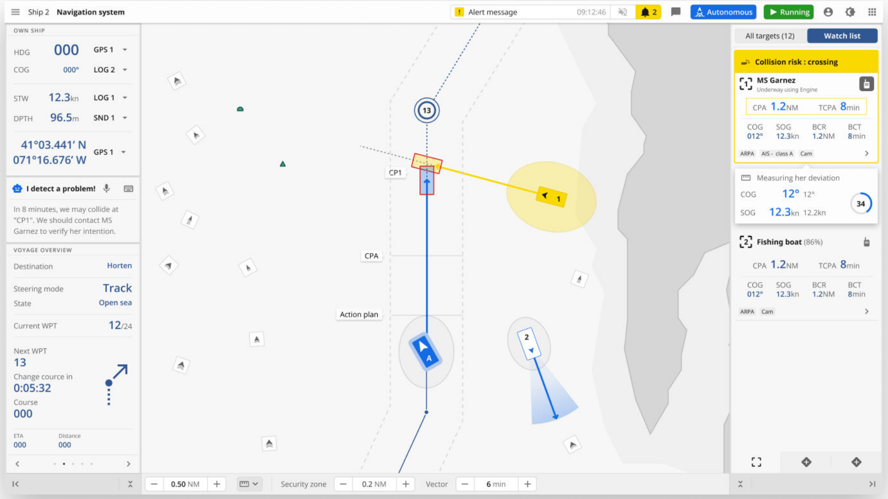


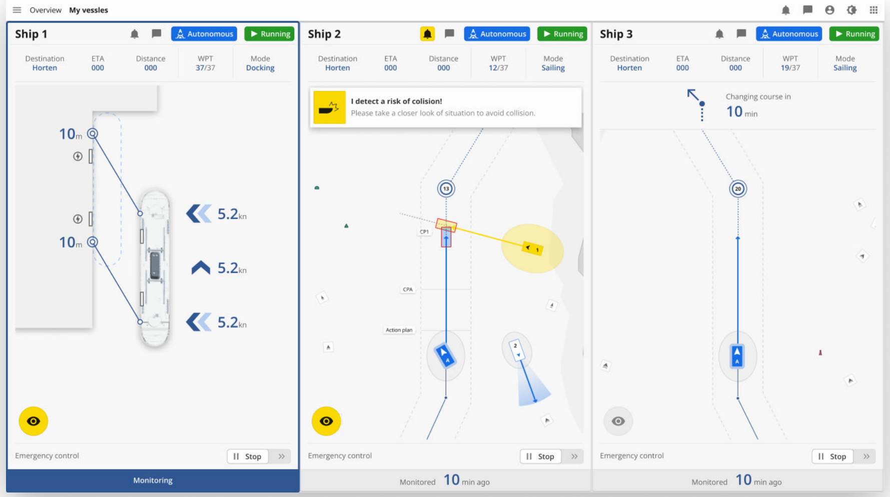
Not monitored



CONDITION ANALYSIS

2. The ship detects a risk of collision with MS Garnez and notify the operator. To determine the chance of collision, the system starts measuring her deviation.

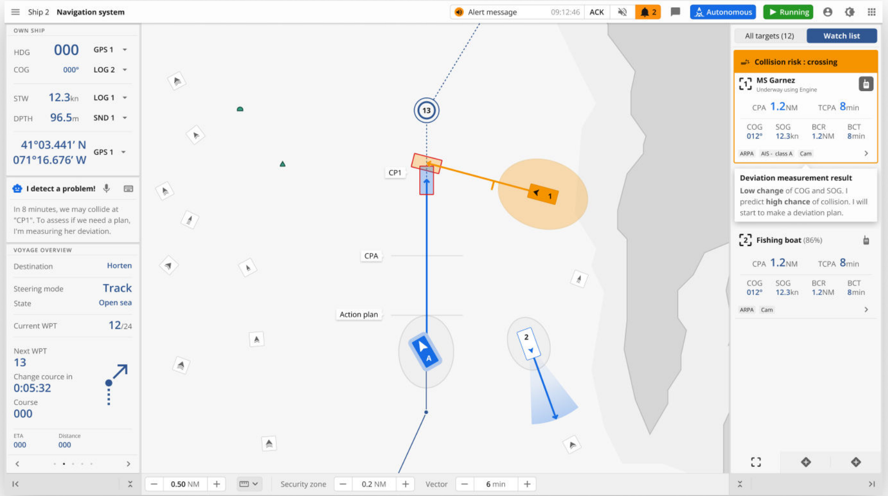




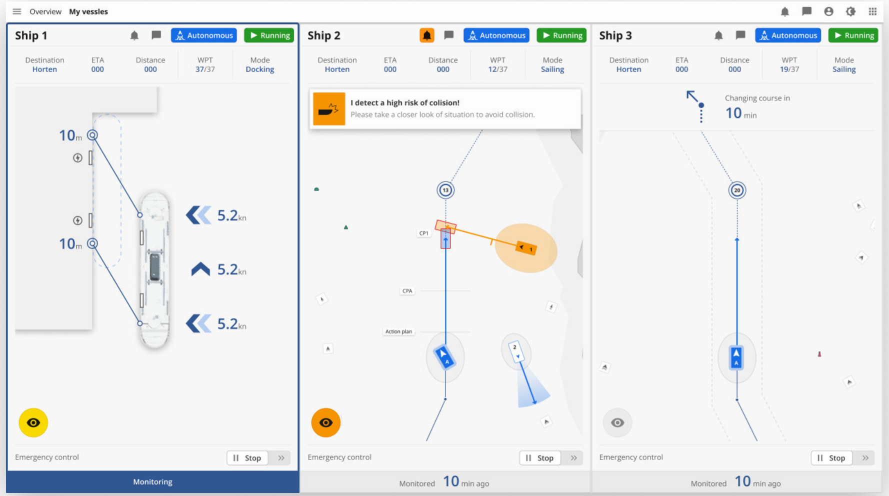
CONDITION ANALYSIS

3. When a high chance of collision is detected, the system will enter into a warning state.

Active monitored by operator

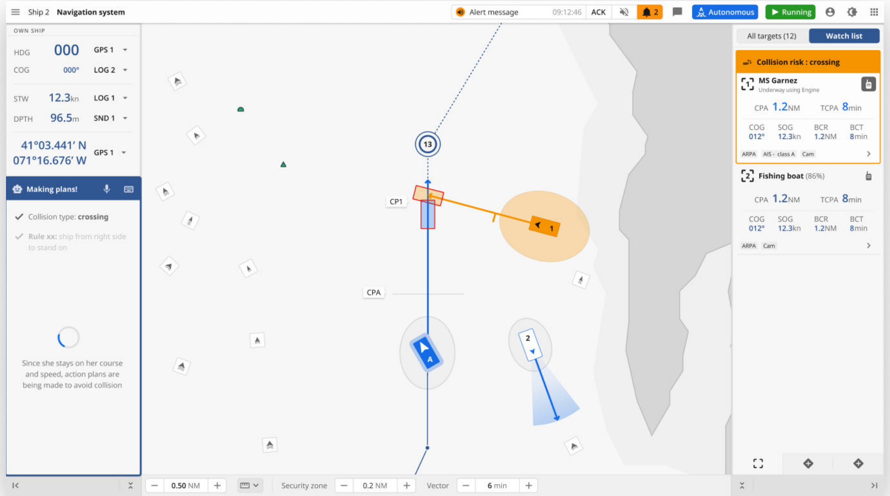


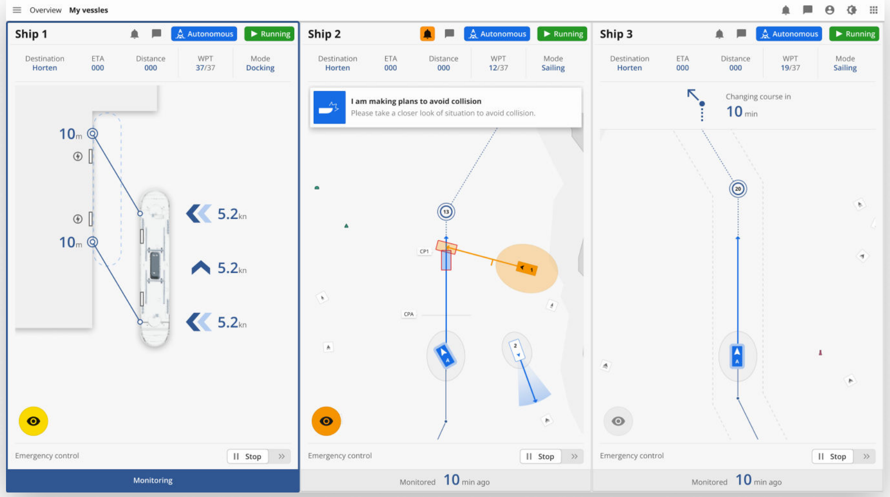
Not monitored



ACTION PLANNING

4. The system will then calculating the plan to avoid collision.

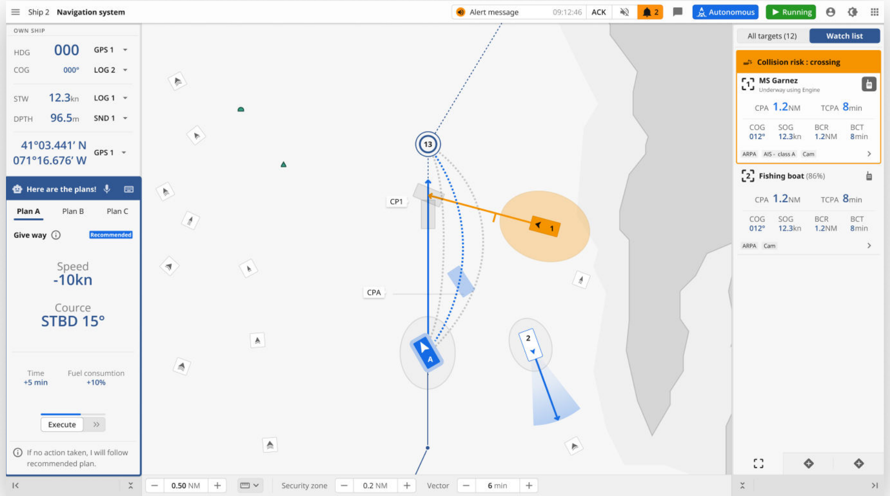




ACTION PLANNING

5. Within a timeframe, users can choose plans. The system shows available plans and where the ship would be at collision time.

Active monitored by operator



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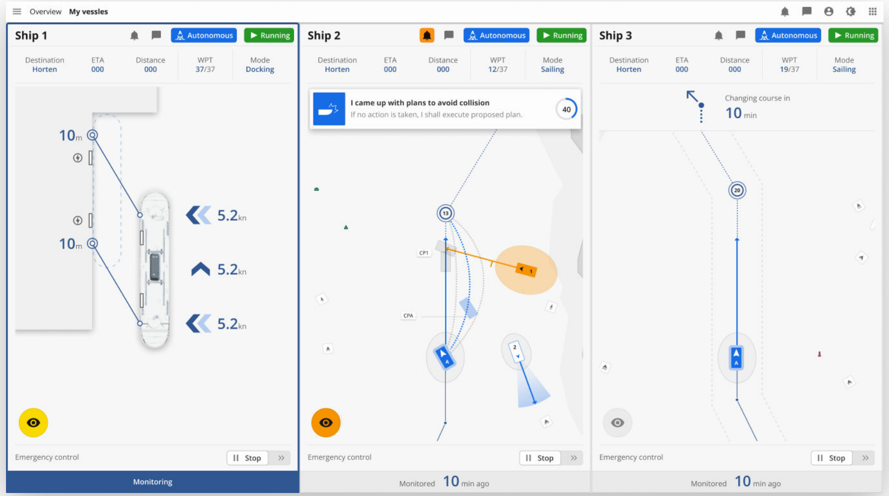
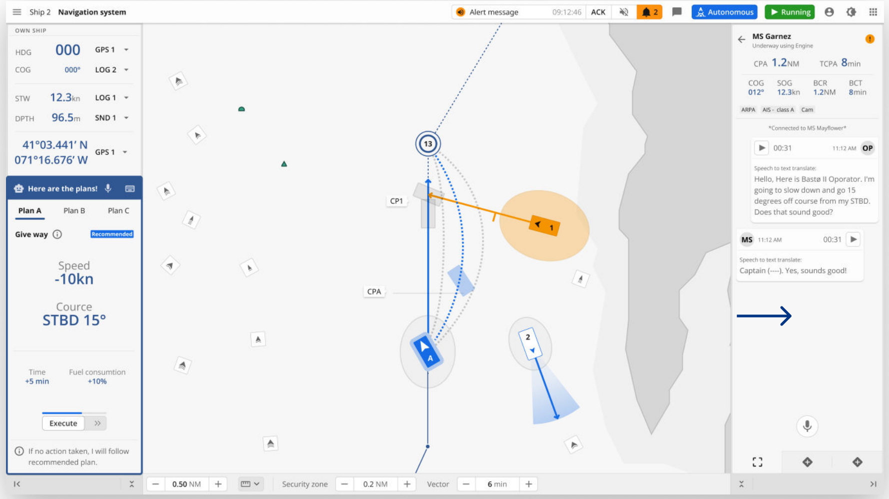
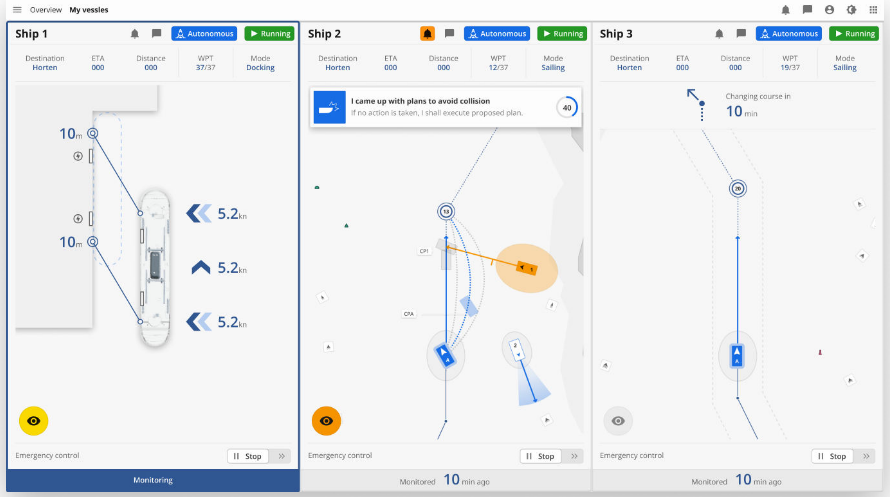


ACTION PLANNING

6. The user also have opportunity to contact other ships to coordinate the plan together before deciding on a plan.

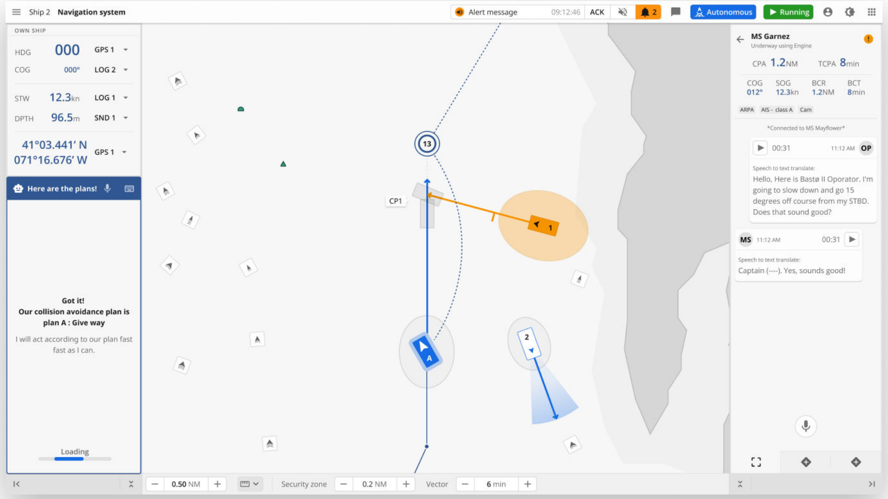




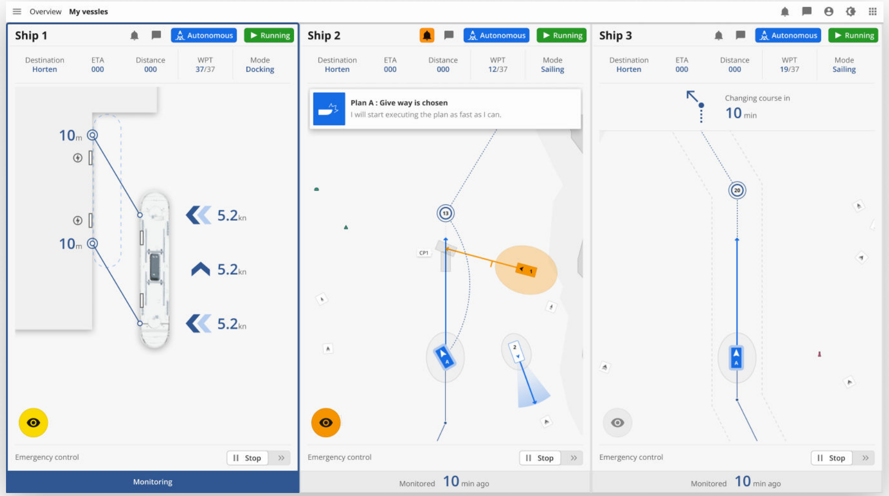
ACTION CONTROL

7. When a plan is taken, the system gives feedback to the user. All other plans disappear from the display screen.

Active monitored by operator

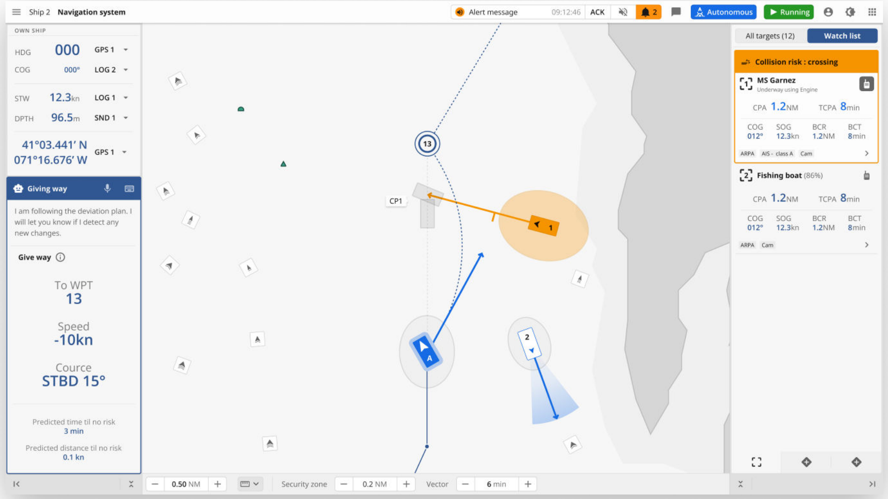


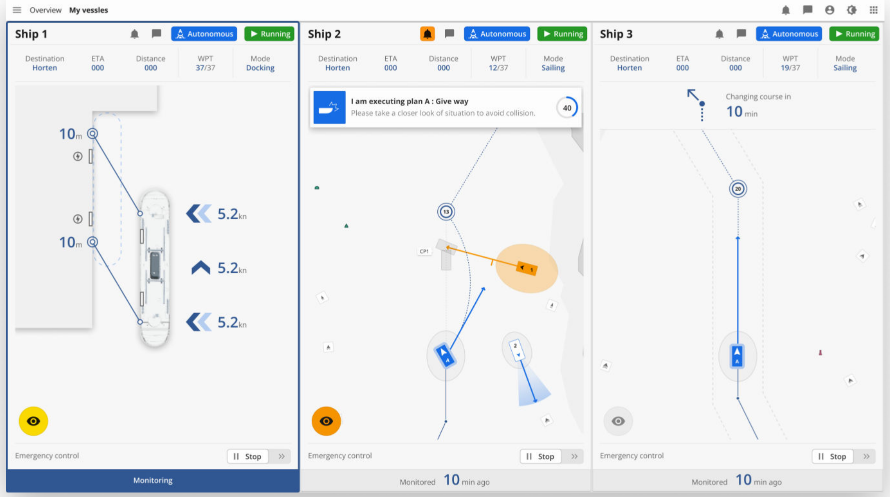
Not monitored



ACTION CONTROL

8. The system provides plan feedback throughout execution. With the vector, the operator may monitor system compliance till there is no risk.





Workstation model designed by Kongsberg Group
Using with permission

06

Reflection

Summary

In summary, I have explored the topic of system for autonomous vessels, with a particular focus on communication between the system and operator in order to keep the operator in the loop. I have done research on both current operations and aspects of how futures autonomous ships could be and its challenges, and have develop a series of prototype across a future user journey.

I have shown how the different stages could be shown in the overview dashboard, focusing on the open sea state and docking. I have also established the system requirements when the system transitions to the new sailing stage. I have also shown how the system could handle collision avoidance scenarios through collaboration between the system and operators. I have also explored different levels of automation in the context of collision avoidance, and established the rules the automation may have and how the system could engage with the operator using collaboration model.

Further exploration possibilities

Since my project only last for one semester, there are not enough time to explore every aspect of the design for the system. Following are lists of potencial exploration areas worth checking:

- Exploration with other more complex collision scenerios such as risk of collision with multiple large vessels and areas with huge amount of other small boats without AIS.
- Build-ins machine learning model where the user could actively teach the system different aspect of sailing in order to progress the alghoritimn.
- Gamification model to keep the user engage in monitoring.
- Long term collision avoidance support where the system could help avoid risk of collision before the risk are even present
- it would also be interesting to see how the docking and departure/arrival stage would look in the details dashboard.
- Explore the design for scenerios where the user have to take manual control of one ship
- Explore the scenerios when the user needs to communicate with other on-site seafarer when docking
- Exploring the “personallity” of the system: tone of voice and possibily the design for avatar of the system
- Collaboration model where a team of user are monitoring multiple vessels together

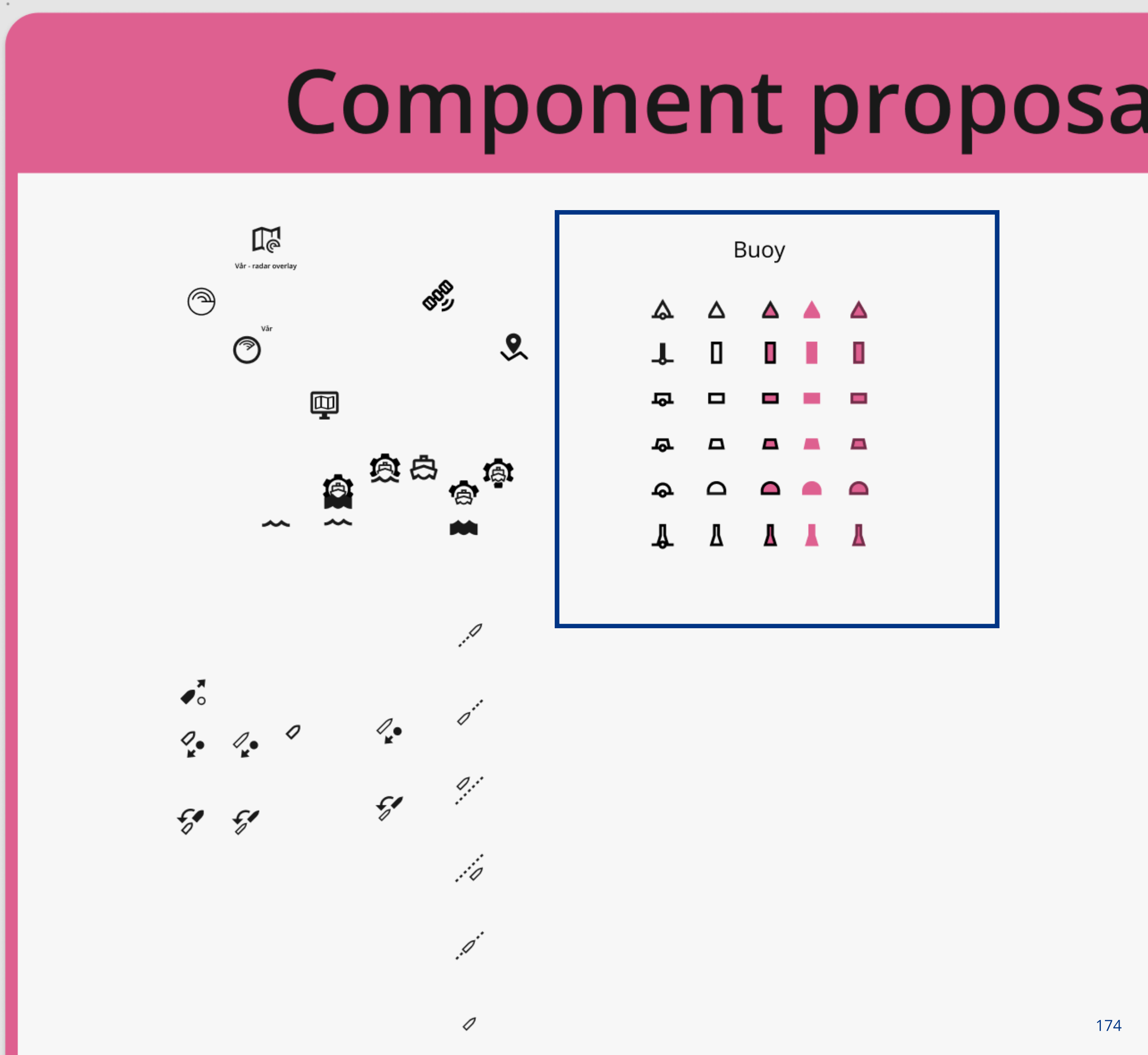
Impact

As mentioned in the beginning of the report, the main challenge of MASS research is that there is little precedence and examples for the public. My main motivation for this project is to create discussion points with the actors in the industries that could nudge the development of systems for autonomous ships forward.

In order to maximize the impact, I have chosen to collaborate with OICL lab, which gives me the opportunity to keep the project open source and connections to the relevant parties. When OICL held an OpenBridge seminar with industry partners in October, I used this opportunity to present my project which led to discussions with relevant industry actors both during and after the seminar. This action also leads to a meeting with a research team led by Kongsberg Group, NTNU and IFE where they would like to discuss both the proposal and findings after the project deliveries.

Furthermore, the components I designed are posted in the OpenBridge design system as a proposal to be determine to add to the design system and to enrich the library even more.

Reflection



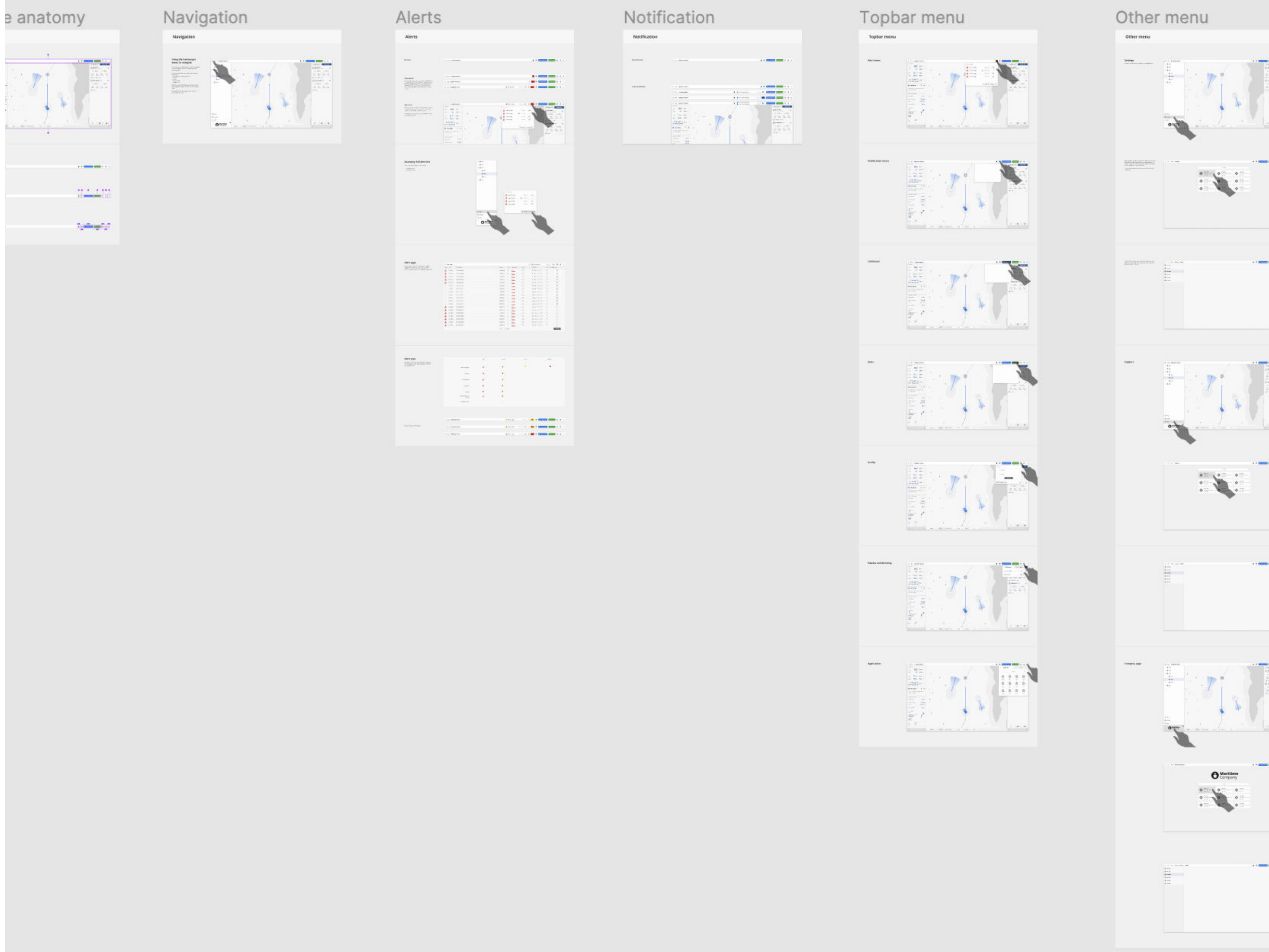
Figma file

Because the major goal of this project as a student is to create a well-rounded design and concept, it is inevitable that the report and presentation would would lay emphasis on the "new" design. However, based on previous professional experience, it is equally critical to see how the design system works as a whole. Even though all of the examples are already included in the design system, we must keep in mind that as a non-designer, this is hard to visualize.

As a result, I created a separate Figma file on top of the delivery requirements to provide an enhanced version of the dashboard with additional OpenBridge content that did not fit into the report or presentation.

In the figma file, I go over several aspects of the design system, such as:

- how design systems are structured in general
- which libraries were utilized and where to get them
- how the primary navigation works
- and how the various top-bar functionality appears on their dashboard.
- etc.



Access figma file here

Reflections

Throughout the whole project, I have learned that autonomous technologies are much more complex than just replacing humans with a machine. Ineffective collaboration between the system and the user may result in someone's life being lost. For this reason I want my design to be as effective as possible, which leads me to read what feels like an infinite number of research reports because I was afraid I would miss out on some important points. However when starting to do the actual design work, and having something to show and discuss, it became easier since the discussions always lead to new ideas and perspectives, and it became fun to explore more design based on the feedback.

Talking to the navigators and getting feedback from them was very valuable, not only on the proposal, but also on their thoughts on the autonomous ship concept in itself. Working on a system that will introduce such a drastic change in their life is not easy, some seem to be positive, others more skeptical and defensive. But by asking more of "why" than "what" questions, it gives me a much deeper understanding of what they actually mean.

Reflection

Thank you!

Lastly, I would like to have this section to thank people that help me making this project possible.

Firstly, the wonderful people at Ocean Industries Concept Lab who have contributed to this project, without them I would not have been able to deliver a thesis on this level.

My supervisor, Kjetil Nordby, for offering guidance through the semester, helping me shape and sharpen the project and for challenging and supporting me.

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Navigators at Bastø Fossen who provide me with deep insights of their operation and for giving me feedback to iterate on the design.

Experts from Kongsberg Group which gave me new and different aspects/perspectives on autonomous ships that helped me scope out and shape this project.

All the wonderful industry partners at OICL for meaningful and interesting discussions at the OpenBridge seminar.

Koen von der Waal, PhD candidate on automation transparency, for helping me shape my project through the whole project, and providing a lot of interesting feedbacks and tips for all the articles for automation transparency and collision avoidance.

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