Master's thesis

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Julie Karine Schmidt Solberg

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NTNU
Norwegian University of
Science and Technology
Faculty of Architecture and Design
Department of Design

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Design of additional radar features to improve the usability of radar tuning

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Julie Karine Schmidt Solberg

Industrial design
Submission date: June 2022
Supervisor: Erik Styhr Petersen
Co-supervisor: Ole Andreas Alsos

Norwegian University of Science and Technology
Department of Design

PREFACE

This master thesis was written at the Institute for Design at NTNU during the spring of 2022.

I would like to thank Erik Styhr Petersen, who came up with the original idea for the project and gave valuable feedback and supervision throughout the year. In addition, thank you for guiding me through an otherwise unknown field and sharing your knowledge and experience. Secondly, I would like to thank the NTNU Shore Control lab, for the support throughout. Lastly, thank you to all who have participated in the interviews, sketch discussions and final usability tests. Your knowledge and feedback have been invaluable, and I am very thankful for all the time and commitment you gave during this spring.

Lastly, I would like to extend a thank you to my friends and family, for staying supportive and patient with me throughout.

ABSTRACT

BACKGROUND

Today's navigators have a range of instruments on the bridge, including the ECDIS (an electronic chart display), and the radar, which gives the navigator an overview of shorelines and objects in their vicinity. The main purpose of the radar is collision avoidance and to ensure safe navigation. However, adjusting the radar settings to a proper level can be challenging, and bad settings can make the navigator blind to certain dangers in the water. Thus, the goal of this project has been to develop additional radar functions that makes it easier for the navigator to adjust the settings to a good level.

PROCESS

This project followed a human-centered design approach throughout. Navigators were included during the insight phase, conceptualization and in the final usability test. This ensured that the final product was in touch with the user needs and requirements.

RESULTS

During the initial interviews, it became apparent that many of the navigators found the radar settings difficult to adjust properly. Today's radars are prone to clutter that can hide relevant echoes, and the navigators must adjust the settings to filter away this interference from the radar image. However, they can quickly filter out too much and suppress these echoes in the process, but there are no indicators telling them when they have filtered out too much. A final prototype was developed as a possible solution to this problem. This was an interactive prototype that emulated a real radar with some added functions. The results from the usability tests showed that the navigators utilized the added features as a support during the test, and all of them adjusted the settings to a good level. This shows that these functions were effective in use and helped the navigators throughout.

SAMMENDRAG

BAKGRUNN

Dagens navigatører har en rekke instrumenter på broen, inkludert ECDIS (et elektronisk kartdisplay) og radaren som gir navigatøren oversikt over kystlinjer og objekter i nærheten. Hovedformålet med radaren er å forhindre kollisjon og å sørge for sikker navigering. Å justere radarinnstillingene til et godt nivå kan imidlertid være utfordrende, og dårlige innstillinger kan gjøre navigatøren blind for visse farer i vannet. Målet med dette prosjektet har derfor vært å utvikle ekstra radarfunksjoner som gjør det lettere for navigatøren å justere innstillingene til et godt nivå.

PROSESS

Dette prosjektet ble gjort fra en brukersentrert tilnærming. En rekke navigatører ble inkludert i innsiktsfasen, konseptualiseringen og i brukertestingen i slutten av prosjektet. Dette sørget for at sluttproduktet var knyttet opp mot brukernes behov.

RESULTAT

I løpet av de første intervjuene kom det frem at mange av navigatørene synes det var utfordrende å justere radarinnstillingene til et godt nivå. Dagens radarer er tilbøyelige for støy som kan skjule relevante ekko, og det er opp til navigatørene å justere innstillingene for å kunne filtrere bort denne støyen fra radarbildet. Imidlertid kan de raskt filtrere ut for mye og undertrykke ekko i prosessen, men det er ingen indikatorer som informerer dem om når de har filtrert bort for mye. En prototype ble utviklet som en mulig løsning på dette problemet. Dette var en interaktiv prototype som emulerte en ekte radar med noen ekstra funksjoner. Resultatene fra brukertestene viste at navigatørene brukte disse funksjonene som støtte under testen, og alle justerte innstillingene til et godt nivå. Dette viser at funksjonene var effektive i bruk og hjalp navigatørene med å justere innstillingene.

DELIVERED MATERIAL

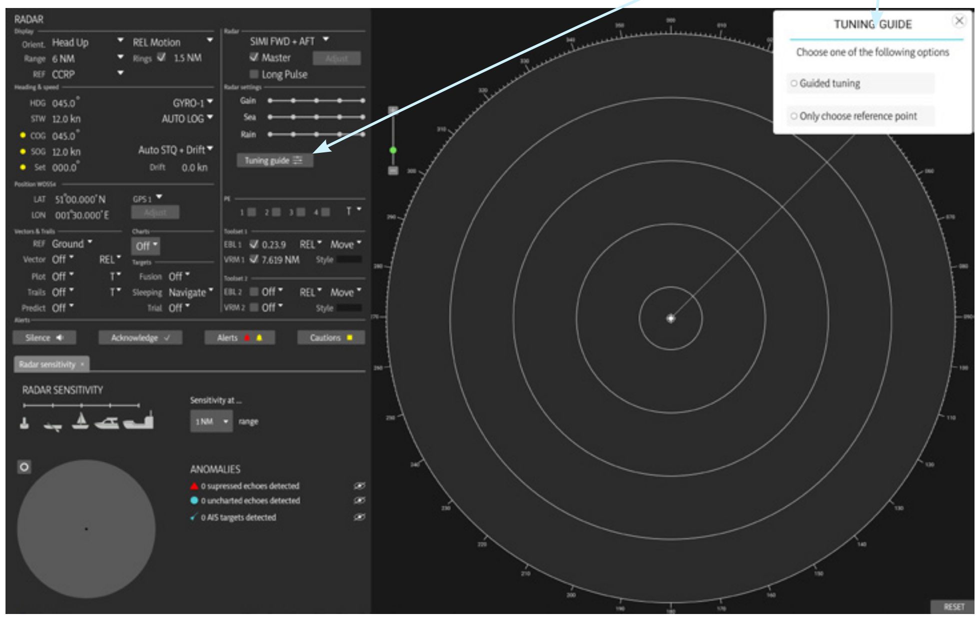
This report makes up the main deliverable in this project.

Additionally, a prototype was developed, which can be reached through the following link:

https://www.figma.com/proto/f9sf4xzo258kTa7OcFHrMu/Radar?node-id=276%3A106426&scaling=contain&page-id=116%3A81&starting-point-node-id=276%3A106426

When the site has loaded, I recommend that you click the options in the upper right corner and click ”fit to screen”, as this will give a good overview of the entirety of the prototype.

Additionally, the prototype contains two paths that can be followed. Both can be reached through a button in the left menu in the prototype, called ”Tuning guide”. Then you can choose between the options ”Guided tuning” or ”Only choose reference point” and start adjusting the gain, sea and rain clutter parametres in the menu.



TERMS

RADAR TUNING

In this thesis, the term ”radar tuning” is used to describe the action when the navigator adjusts the gain, sea and rain clutter sliders on the radar. It is not to be mistaken for the adjustment of the ”tune”-function present on the radar.

ECDIS

The ECDIS (Electronic Chart Display and Information System) is a navigational instrument used for position verification and route handling. It contains sea-charts with depth contours, sea markers etc (Kjerstad, 2015, pp. 2-149).

RADAR

The radar is the navigators main instrument for collision avoidance, whose purpose is to ensure safe navigation. It gives the navigator an overview of surrounding shorelines and objects in their vicinity (IEC, 2013, p. 31).

PPI

The PPI is a part of the radar, more specifically the circular map presented on the display. This will be updated in real-time, as new radar signals are being received (Bole et al., 2014, p. 5).

ECHO

Echoes appear as shapes in the radar image when the radar signals are being reflected back to the receiver. These echoes can show pieces of land, sea markers, vessels etc (Kjerstad, 2015, pp. 2-3).

SUPPRESSED ECHO

When the gain settings are set too low, or the anticlutter too high, it can make small echoes disappear from the radar image. Such disappearing echoes are called suppressed echoes (Kjerstad, 2015, pp. 2-64).

SEA CLUTTER

Sea clutter is interference on the radar, caused by the radar signals bouncing off waves etc (Kjerstad, 2015, pp. 2-13).

RAIN CLUTTER

Rain clutter is interference on the radar caused by downpour (Kjerstad, 2015, pp. 2-13).

GAIN

The gain is a parameter on the radar that can be adjusted by the navigator. The gain settings decide the amplification of the signal from the radar, and will affect how many echoes will be shown in the radar image. Additionally, it will affect how much clutter that will appear in the PPI. (Kjerstad, 2015, pp. 2-62).

AIS

AIS (Automatic identification system) transmits information about the chosen vessel. It shows where the other ship is headed and where it will be positioned in a set amount of time. It is a required feature for ships above a certain size (IMO, 2015, p. 2)

ANTI-CLUTTER SEA

This is an adjustable parameter on the radar that will reduce the amount of sea clutter close to the ship (Kjerstad, 2015, pp. 2-64).

ANTI-CLUTTER RAIN

This is an adjustable parameter on the radar that will reduce the amount of rain clutter in the radar display (Kjerstad, 2015, pp. 2-64).

ARPA

Automatic Radar Plotting Aid (ARPA) is a radar feature that will detect moving targets in the area and notify the navigator of “new targets” in the vicinity (Kjerstad, 2015, pp. 2-92).

RCS

RCS is an abbreviation for “Radar Cross Section”, and is a measurement of how much of the radar signal is being reflected back by the receiver (Knott et al., 2004, pp. 1-10).

COLREGS

International Regulations for Preventing Collisions at Sea. (Zhou et al., 2020)

VHF

The VHF is a radio that taps into high frequencies. VHF stands for “Very High Frequency” (van Leersum et al., 2017, p. 1)

OPTICAL NAVIGATION

Optical navigation is a term used when the navigator observes through the window (NOU2000:31, pp. 111-114).

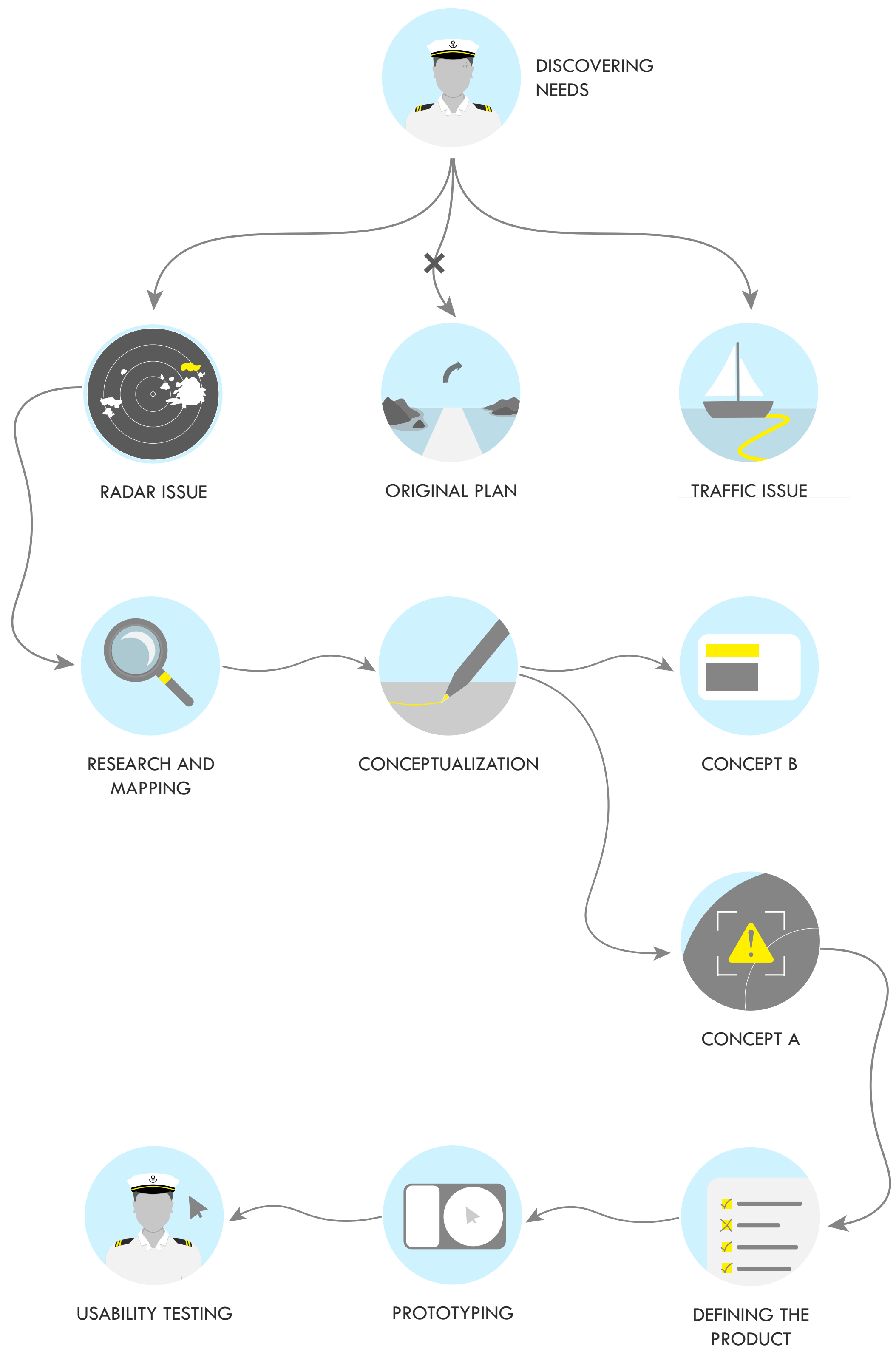
IMO

IMO stands for ”International Maritime Organization” (IEC, 2013, p. 31).

TABLE OF CONTENTS

INTRODUCTION

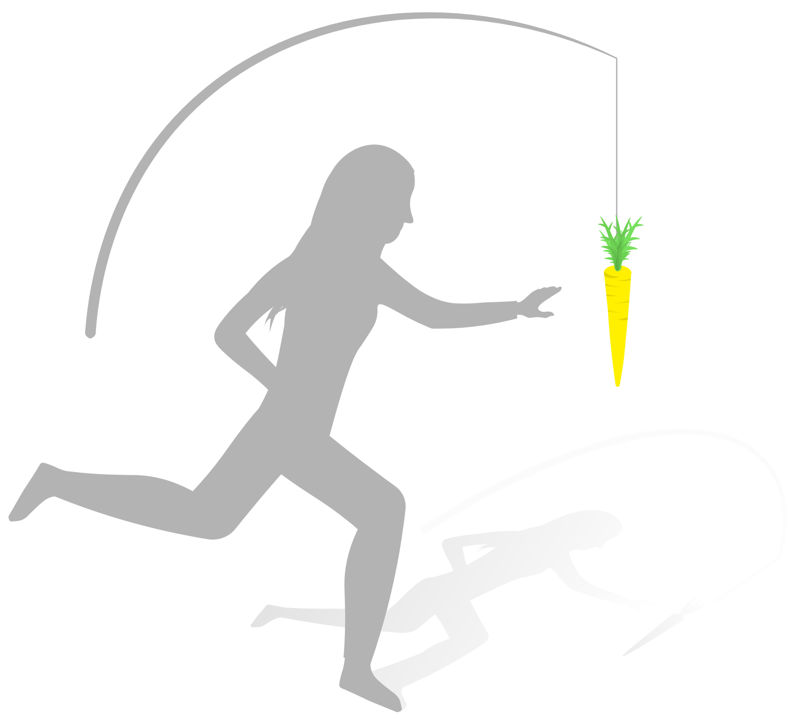
This chapter explains the background for the project and introduces some relevant aspects. In addition, the scope and focus of the project is explained. Lastly, it will provide an overview of the overall report structure.



MOTIVATION

Last semester, I worked on a project regarding alarm design onboard ship bridges. Throughout that project, I saw a clear lack of usability in several of the systems I encountered, as well as the system design as a whole. Thus, I found the shipping industry to be an interesting field with many present challenges.

When my previous supervisor pitched the idea of making a tool for improving the navigators' situational awareness, I found the thought intriguing. My last project made it apparent that it is crucial that the navigator has a good situational awareness. Thus, I clearly saw the value of such a tool and was exited to approach the project from an interaction design perspective.



ORIGINAL PROJECT DESCRIPTION

NTNU
Fakultet for arkitektur og design
Institutt for design

Masteroppgave for Julie Karine Schmidt Solberg

Tittel: Design av informasjonsdisplay for navigatører på skip (midlertidig tittel)
Title: Designing an informative display for navigators onboard ships (temporary title)

Bakgrunn for oppgaven
Dagens skipsbruer inneholder en rekke ulike typer utstyr, der målet med hver enhet er å gi navigatøren en bedre situasjonsforståelse. Imidlertid så er det slik at de fremstiller mye informasjon på en gang, som kan gjøre det vanskelig å forstå hvilken informasjon som er viktig.

Oppgavens innhold
Prosjektet går ut på å utvikle et brukergrensesnitt til et display som gir navigatøren en oversikt over viktig informasjon om kommende farvann. Dette brukergrensesnittet kan være i form av et slags 2D/3D-kart som gir en mer fokusert oversikt enn dagens systemer. Det blir en del kartleggingsarbeid for å undersøke hva grensesnittet skal inneholde.

Oppgavens gjøremål
- Kartlegge informasjonsbehovet (hvem, hva, hvordan)
- Utvikle konsepter/mockups
- Brukerteste løsningen(e)

Oppgaven utføres etter "Retningslinjer for masteroppgaver i Industriell design".

Ansvarlig faglærer (hovedveileder ID): Erik Styhr Petersen
Eventuelt biveileder: Ole Andreas Alsos
Bedriftskontakt: N/A

Utleveringsdato: 07.01.2022
Innleveringsfrist: 07.06.2022

Trondheim, NTNU, 4/1 2022

Erik Styhr Petersen
Ansvarlig faglærer

Sara Brinch
Instituttleder

BACKGROUND

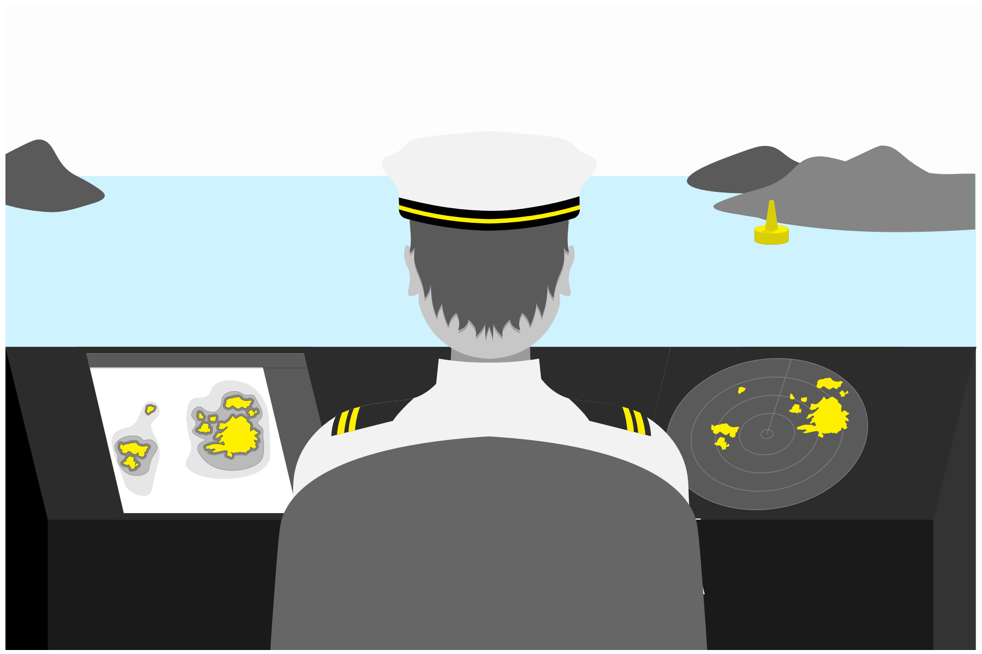
SITUATIONAL AWARENESS

Today's navigators have access to a lot of information through their displays and optical navigation. However, accidents still occur today, even though they are sitting on all this information. Studies indicate that approximately 80% of reported shipping accidents can be traced back to human error (Hasanspahić et al., 2021, p. 1), whereas 71% of these can be tied to a lack of situational awareness (Grech et al., 2002, p. 1720, as cited in ; Hetherington et al., 2006).

This awareness is dependent on what they observe in the environment and how they are able to process all this information (Endsley, 1995, p. 36). Mica Endsley, a renowned researcher on the field, describes it as such:

> *"Situation awareness is the perception of the 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." (Endsley, 1995, p. 36)*

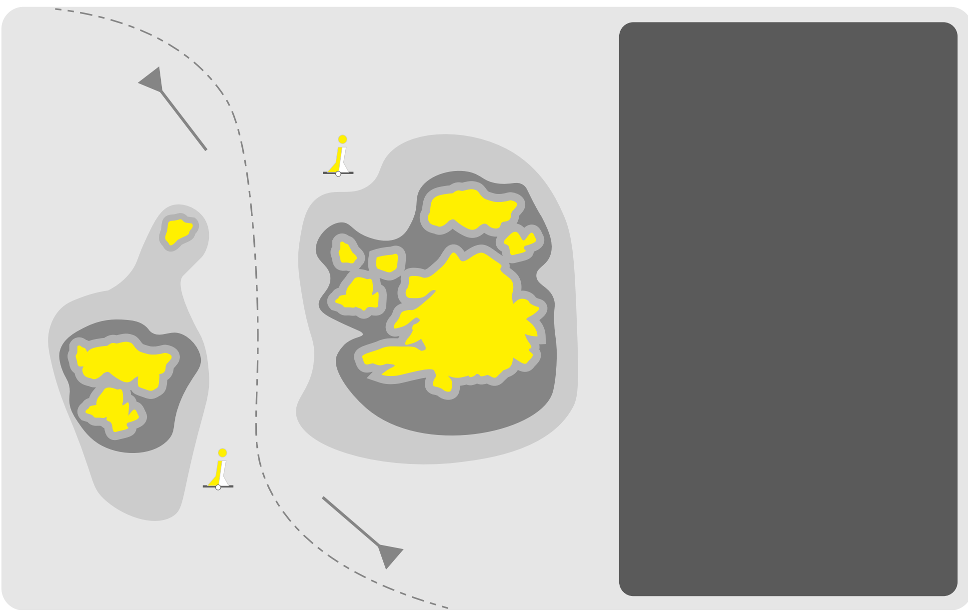
In short, it revolves around what the navigator perceives and how they perceive it, and how they are able to use this information to consider possible outcomes (Endsley, 1995, p. 36).



INSTRUMENTS

The navigational instruments on the bridge can provide valuable information and improve the situational awareness of the navigator, provided that they give an accurate depiction of reality. The use of such navigational displays has been embraced during the last decades, and new equipment, like the ECDIS (Electronic Chart Display and Information System) has been introduced, and existing equipment – like the radar – has been improved further (Kjerstad, 2015, pp. 2-1).

The ECDIS (Electronic Chart Display and Information System) is one of the primary instruments used for navigation. IMO lists that it will assist the navigator by ”displaying selected information from a system electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring” (NEK, 2015, p. 25). In short, it shows the ship's position, as well as its planned route and other relevant information, like depth curves, lighthouses, known wrecks, buoys etc. (Kjerstad, 2015, pp. 2-149).

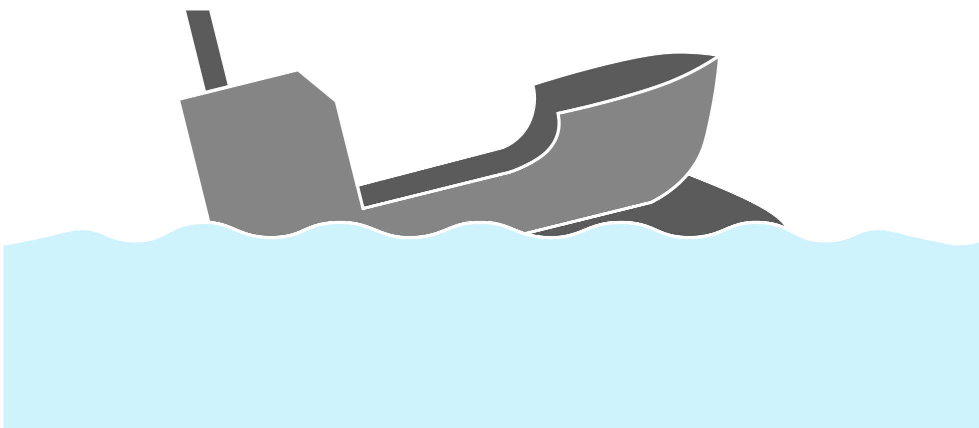


The purpose of the radar is defined by the international standards as the following: ”The radar equipment should assist in safe navigation and in avoiding collision by providing an indication, in relation to own ship, of the position of other surface craft, obstructions and hazards, navigation objects and shorelines.” (IEC, 2013, p. 31). In short, it sends out a pulse that will be reflected back in the shape of echoes. These echoes are shapes on the radar display and gives the navigator an overview of surrounding shorelines and objects in their vicinity. Some echoes will be less visible than others, depending on a range of factors, like the material of the object. For example, a small wooden boat will be far harder to spot on the radar than a large, steel tanker, as the tanker will give a much brighter echo (Bole et al., 2014, p. 145). Meanwhile, the weather conditions might affect the radar image, and hide relevant echoes behind interference known as clutter. This clutter can be filtered away by adjusting the settings, but there is a risk that relevant echoes might be filtered away in the process (Kjerstad, 2015, pp. 2-13). These limitations can have dire consequences, as shown by a well-known accident in Norwegian waters: The Sleipner Accident.

SLEIPNER

The Sleipner was a passenger vessel that ran aground in 1999. The ship was sailing through known waters at night-time, with the captain and chief officer present onboard the bridge. The captain utilized optical navigation as his main source of information, with the radar being his second. He looked for lights and landmarks to verify his position underway. Meanwhile, he knew that there were two rocks in the waters, each of them marked with lights. However, he was only able to spot one of the lights and was uncertain of the position of the other rock (NOU2000:31, pp. 111-114).

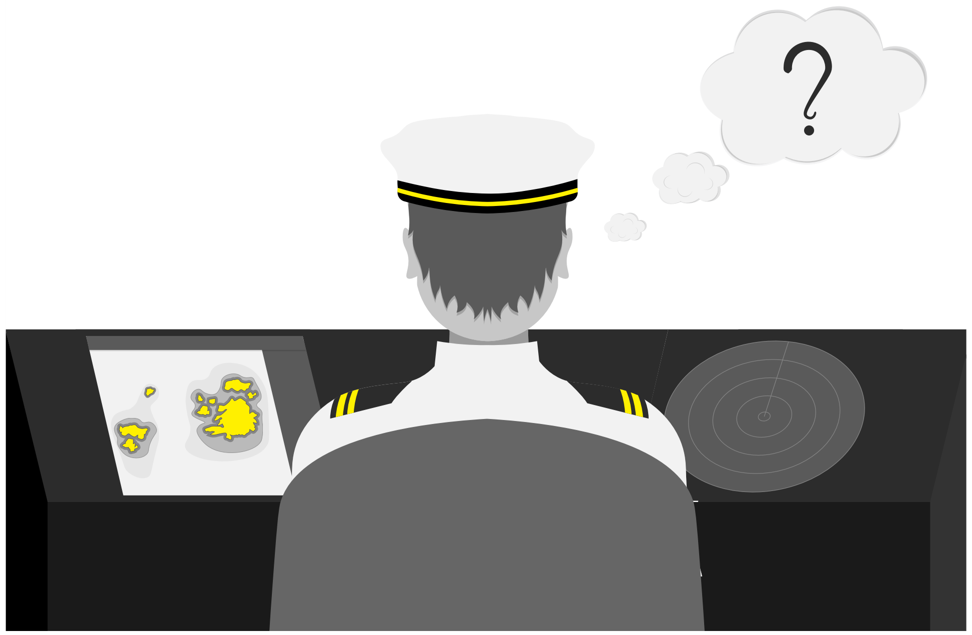
Thus, he turned to his radar to try and discover its position. However, he could not find either rock in the radar image. The bad visibility in combination with the badly tuned radar meant that he was blind to potential hazards in the waters, so he tried to adjust his radar settings. Meanwhile, his chief officer was manually adjusting his settings to filter out the clutter in the image. In short, both the captain and chief officer were occupied with each their radar, which meant that none of them were looking outside the window or at other instruments on the bridge. A few seconds later, the chief officer looked up from his radar and realized that they were about to hit the rock they had been looking for. They ended up crashing into the rock, resulting in an accident that claimed 16 lives (NOU2000:31, pp. 111-114).



A PERTINENT PROBLEM

This accident shows the present challenges with the radar. At times with reduced visibility, the navigator is dependent on this instrument to spot potential hazards in the waters. However, if it is not tuned correctly, they will not receive an accurate representation of the surrounding waters and thus cannot ensure safe navigation. Adjusting these settings can also prove challenging and require both time and attention from the navigator. The Sleipner shows how a badly tuned radar can compromise the situational awareness of the navigator and make them unaware of potential dangers in the environment (NOU2000:31, pp. 111-114).

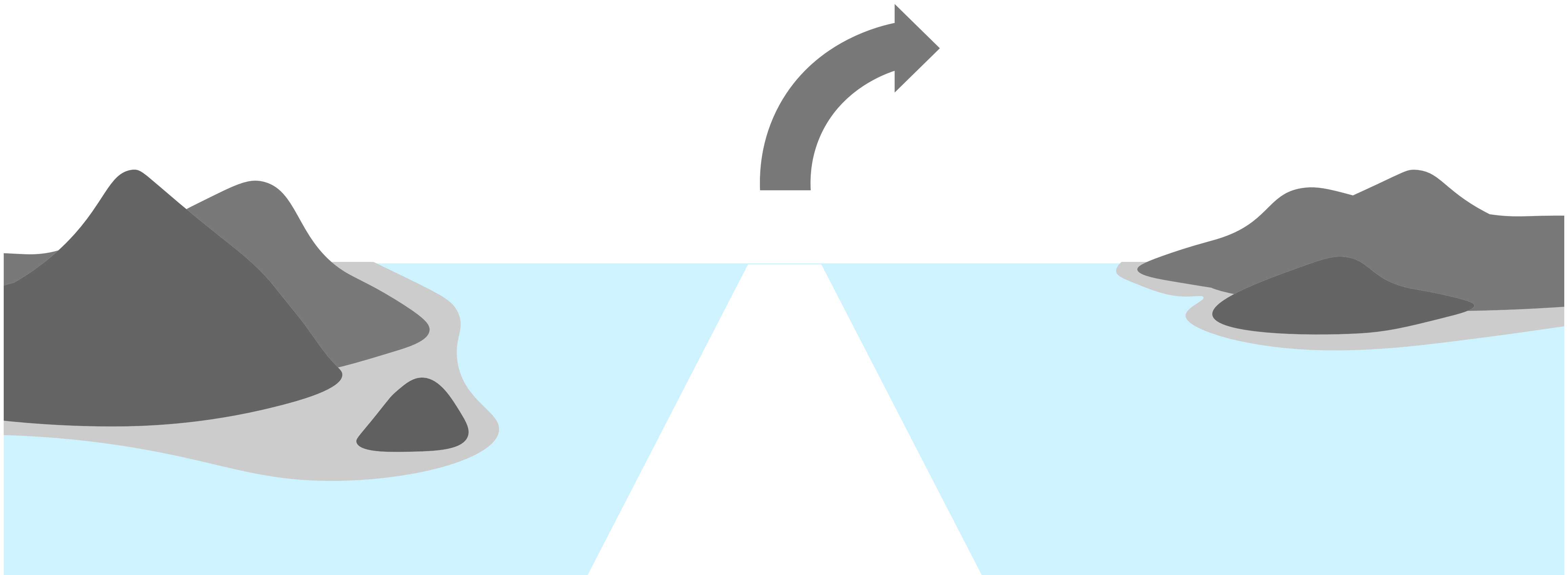
This problem later became the focal point of this project, as the feedback from the initial interviewees made it apparent that this was a recurring, substantial issue.



RELEVANT RESEARCH

However, the initial goal of this project was to improve the navigator's situational awareness. This approach was based on existing research.

A lot of research has been done on this field, but one particularly interesting approach originated from the research of Thomas Porathe, a Norwegian researcher. In short, he developed a 3D display with representations of real life elements, to reduce the cognitive load of the operator, as they would not have to "translate" the information from 2D, to the more "natural" 3D-perspective. In addition, some of his iterations involved the planned routes of large vessels, so that the navigator could see the planned course of an approaching ship. This research made the basis for the initial goal in this project; to create a device that would improve the situational awareness of the navigator (Porathe, 2006, p. ii). The need for such a display was researched in the early stages of the project.



USER GROUP

NAVIGATORS

The user group consists of navigators from the age of 20 to 70. This includes navigators with varying degrees of experience. The common denominator is that they are located on ships equipped with both ECDIS and radar equipment. This category includes a range of different vessels, from fishing vessels to containerships.

PROJECT GOAL

ORIGINAL PROJECT GOAL

The initial goal of this project was to develop a tool that would supplement the current ECDIS and radar on the bridge and improve the navigator's situational awareness. However, the goal was changed as a result of the user feedback, which did not support this approach.

USER-DRIVEN PROJECT GOAL

The results from the interviews highlighted a different problem that became the main focus of the project. The new goal was formulated as the following:

The goal of this project is to develop a set of additional radar functions that will make it easier for the navigator to adjust the settings to a good level.

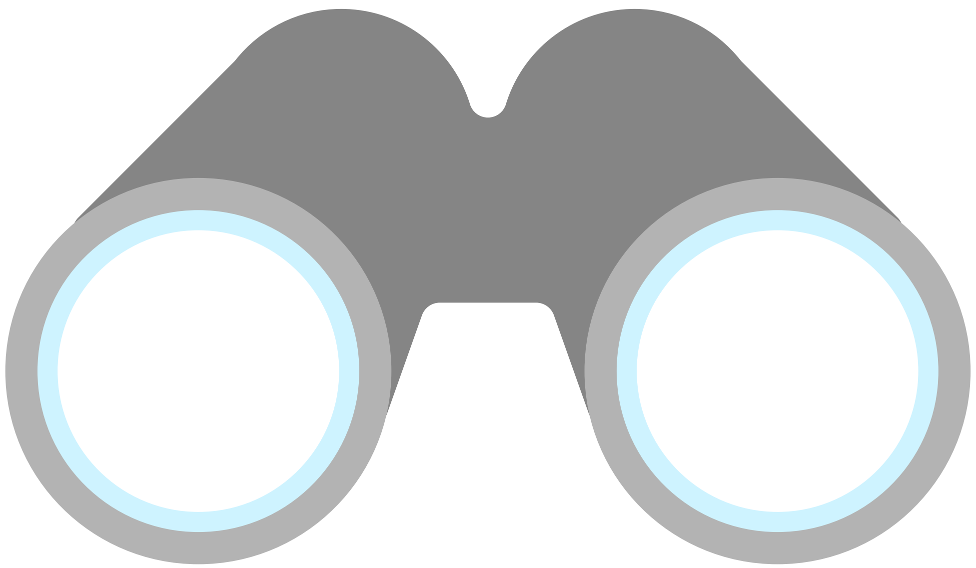
These functions should...

- Indicate which echoes are visible, and which echoes are being suppressed
- Indicate the quality of the current radar settings
- Indicate how one can adjust the radar settings to make suppressed echoes visible

PROJECT SCOPE

INTERACTION DESIGN

This project was mainly focused on interaction design. Thus, aspects like system design and the product design of a possible such display, were not addressed. The main focus was the interface itself.



REPORT STRUCTURE

METHODS

The “Methods”-chapter covers the different approaches and methods utilized throughout this project.

DISCOVERING NEEDS

This project had several detours and dramatically changed course underway. Initially, the plan was to follow Porathe’s research and develop a kind of situational awareness display. However, after the initial interviews and analysis, it became apparent that they had no need for such a display and were occupied with different issues than initially thought. They were struggling with radar tuning and erratic traffic at sea, two issues that were completely detached from the initial idea. Thus, it made sense to change course, to ensure that the product in development would fill an actual user need. All of these aspects are covered in the chapter “Discovering needs”.

RESEARCH AND MAPPING

In the end, the choice fell upon the radar issue, a critical issue as the radar is their main tool for collision avoidance and safe navigation. However, this change of course meant that it would be necessary to gather some more knowledge regarding this issue. Thus, an additional research trip was planned, and another round of literature research was conducted. Additionally, user journey maps and a requirements list was used to map the user needs and requirements. This is addressed in the “Research and mapping”-chapter.

CONCEPTUALIZATION

The insight gathered throughout the project made the basis for the conceptualization phase. Low-fidelity sketches were made and utilized in sketch discussions with representative users. This concept development and user involvement is included in the ”Conceptualization”-chapter.

DEFINING THE PRODUCT

The feedback from the sketch discussions was used to prioritize the concepts. This made it possible to decide which features should be implemented as a part of the prototype. Additionally, workflow diagrams were created to map the different paths the users might take. Lastly, the requirements for the prototype were defined . These are the topics addressed in the chapter “Defining the product”.

PROTOTYPING

Later, a prototype was developed based on the these requirements. This prototype emulated a radar with some added functions. These functions were developed to make it easier for the navigator to know the quality of their current radar settings and to indicate when they were suppressing relevant echoes. The prototype design and functionality is addressed in the “Prototyping” chapter.

USABILITY TESTING

The prototype was then tested by several navigators. Their feedback and actions during these tests were recorded, and became the subject for an extensive qualitative analysis. Lastly, a set of possible design alterations were created based on the findings from the usability tests. These topics are covered in the chapter “Usability testing”.

DISCUSSION

The “Discussion”-chapter will address the validity of the results, the effectiveness of the prototype and potential future work.

SUMMARY AND CONCLUSION

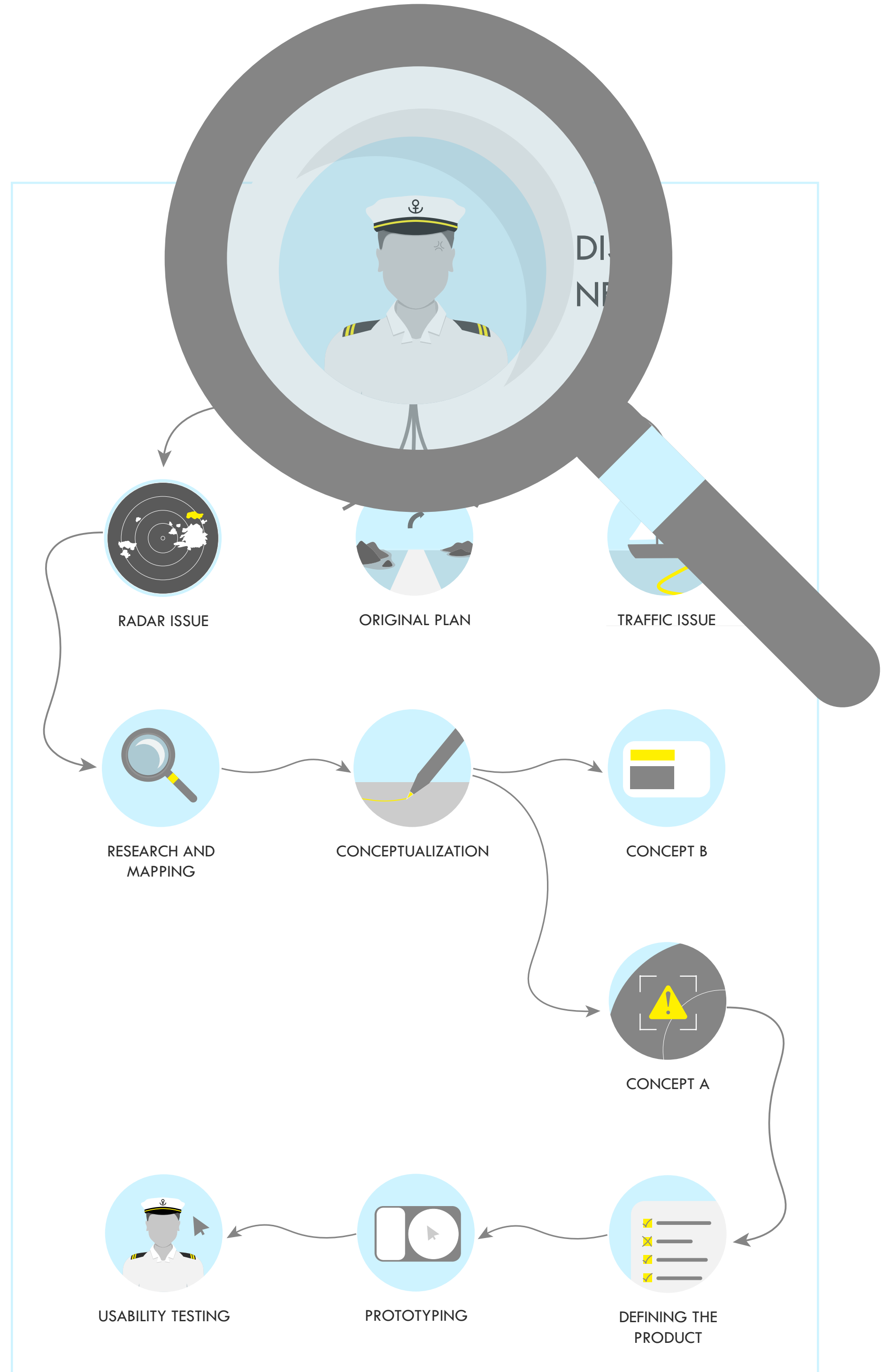
This chapter contains the main conclusion.

EVALUATION

Lastly, the ”Evaluation” chapter adresses what I learned throughout the project, as well as the challenges I faced. This is reflected upon on a personal level.

METHODS

This chapter addresses the approach and methodology utilized during the project.



HUMAN-CENTERED DESIGN

Human-centered design (HCD) was a key focus throughout the project. This approach is iterative and focuses on understanding the users' needs and requirements and using this data as a basis for further development. HCD focuses on a number of factors, like efficiency, effectiveness and user satisfaction (ISO, 2019, p. 12).

Understanding the users and their tasks is paramount in HCD. In short, one must ensure a good understanding of the users' needs and requirements before proceeding into development. During the project, the users will evaluate the design, and their feedback can also be used to iterate upon the previous steps (ISO, 2019, p. 18) . In short, human-centered design is an iterative approach, where one might revisit previous work steps if new, relevant findings come to light (Kurosu, 2013, p.).

In this case, the users were involved in the initial interviews, validity check and sketch discussions. Additionally, they tested the usability of the final prototype. This ensured that the final product was in tune with their needs.

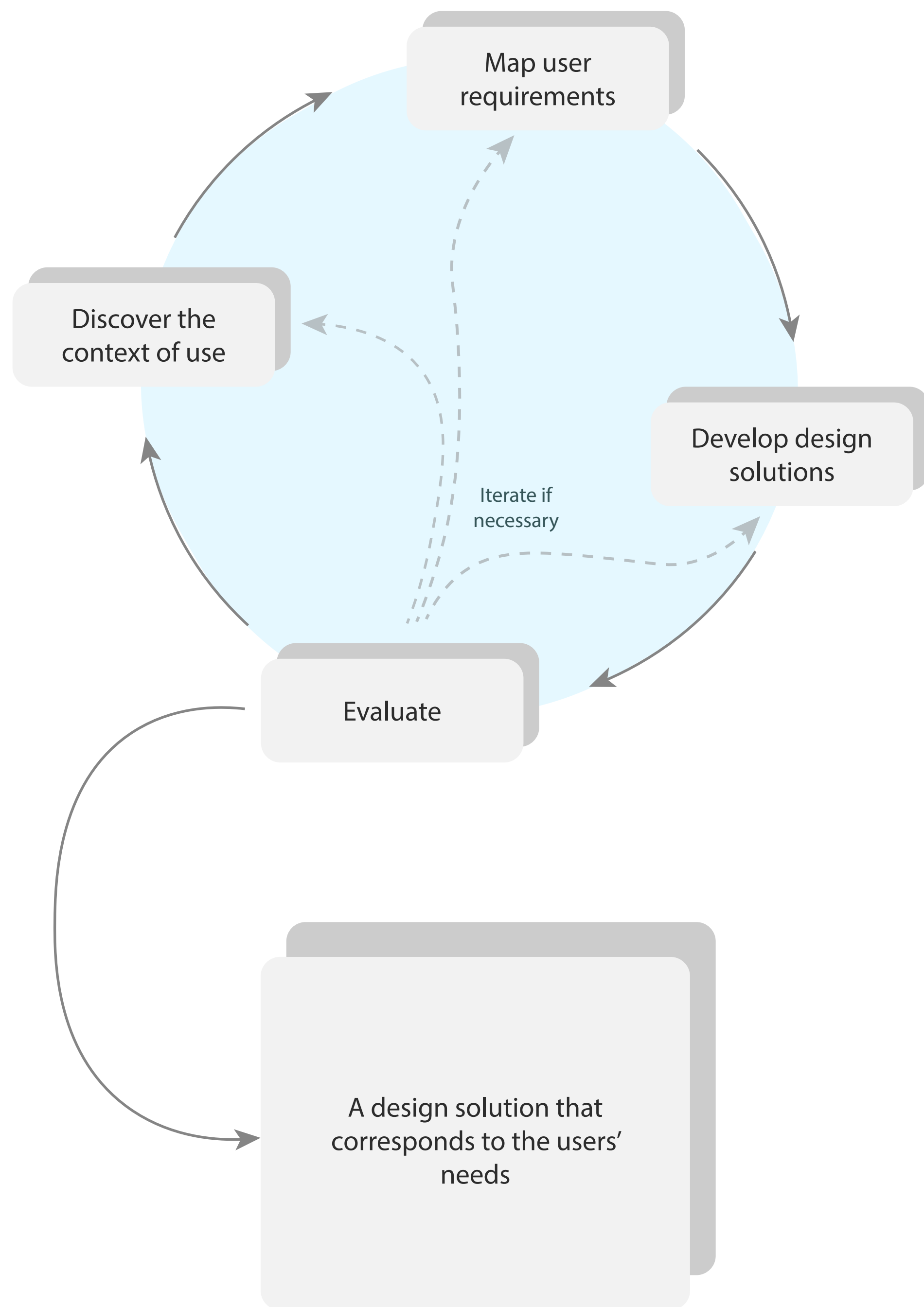


Figure 1: Illustration of the human-centered design process. Based on an existing illustration by Kurosu (Kurosu, 2013, p. 89).

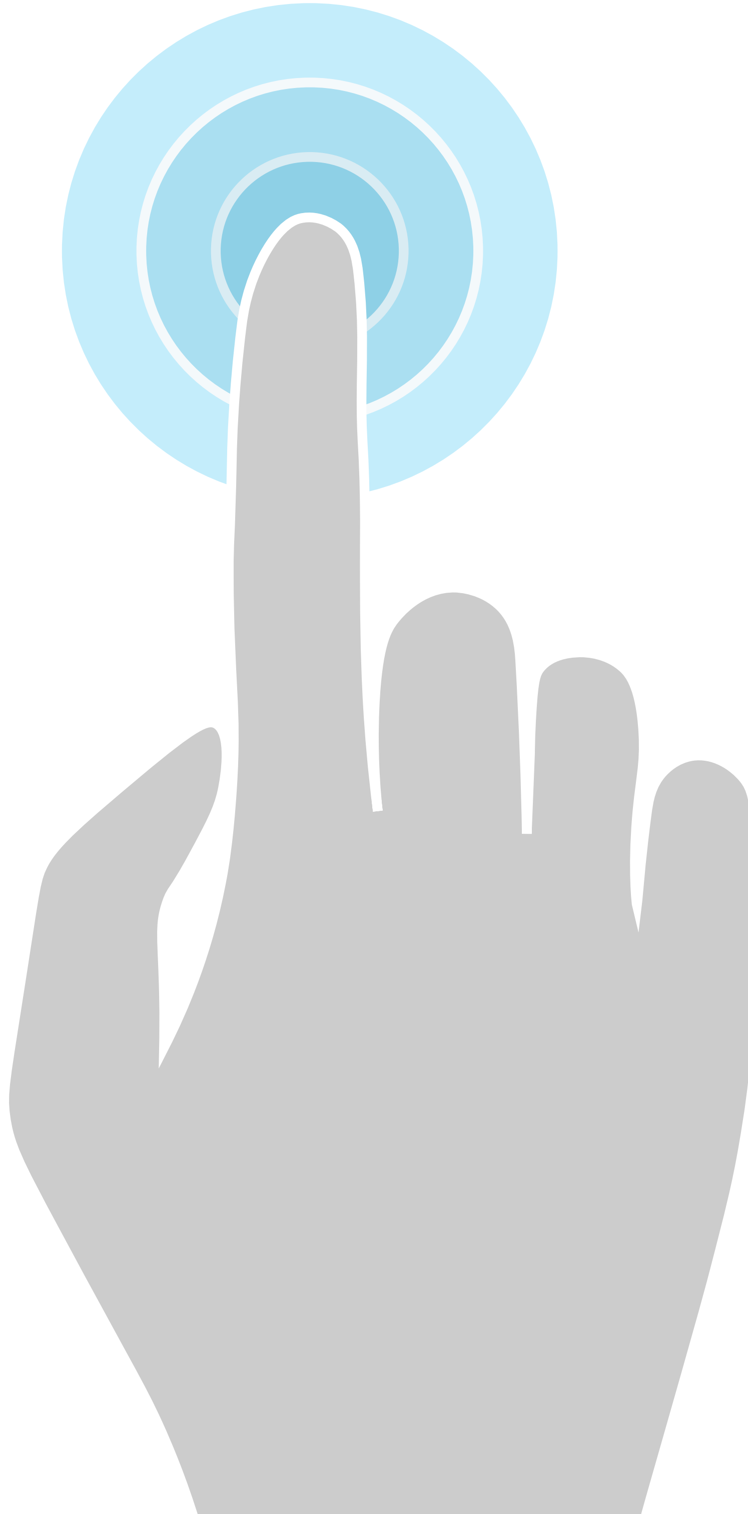
INTERACTION DESIGN

This project was done via an interaction design perspective. Preece et al. defines interaction design as:

“Designing interactive products to support the way people communicate and interact in their everyday and working lives”
(Preece et al., 2015, p. 9)

This approach includes a range of different perspectives, everything from academic disciplines to interdiciplinary fields. Meanwhile, design practice is a key aspect here, as well as a focus on human factors and human-computer-interaction. In short, it is vital that the designer focuses on the user’s needs throughout the design process, and does research on other relevant fields (Preece et al., 2015, p. 10).

In this case, this meant that it was necessary to gather insight regarding the existing pieces of equipment onboard the ship’s bridge. Additionally, the user needs were discovered through continous user involvement.



QUALITATIVE APPROACH

It was chosen to proceed with a qualitative approach throughout the project. As a large portion of this project would be dedicated to understanding the users' needs and challenges, it was deemed the most suitable approach. Qualitative data regarding their current practices, challenges and views could bring relevant insight that would not be present in statistical, quantitative data. In short, it was considered more valuable to gather detailed insight, compared to quantitative data (Preece et al., 2015, p. 259).

INFORMED CONSENT

When conducting such qualitative research, it is paramount to ensure that the project follows ethical guidelines, as well as the present guidelines for informed consent. Such forms often include information regarding how the data will be treated, where it will be presented and so on. Additionally, they often inform the participant that they have the possibility to withdraw from the project at any time. Lastly, a consent form is included after all this information, where the participants are asked to sign if they agree to participate in the study (Sharp et al., 2019, p. 262)

In Norway, one must register the student projects to NSD – The Norwegian Centre for research Data. NSD is a national centre who specializes in the use and handling of such research data (NSD, n.d.).

In short, the a project description and relevant documents were sent to NSD prior to any user involvement in this project. Both the project and the form was then approved. As this project gathered data in the format of voice recordings and video recordings, all the participants were asked for consent prior to this. This step was repeated throughout the project, prior to the interviews, validity check, sketch discussions, research meetings and usability tests. This ensured that the project followed the set ethical guidelines.

See Appendix B and C for the consent forms with the attached information.

DESIGN THEORY

Design research was done prior to the concept development. Relevant fields were researched to ensure that the concepts would follow important design principles.

USABILITY HEURISTICS

One should follow certain principles when developing an interface. Jacob Nielsen developed a set of ten such guidelines, which he named “usability heuristics” (Nielsen, 1996, p. 1). These are listed below.

1) ”Make screens simple and natural” (Nielsen, 1996, p. 1)
One should limit the number of elements on the screen to ensure that it does not become cluttered and confusing. Meanwhile, they should be in sync with the expectations of the users.

2) ”Speak the users’ language” (Nielsen, 1996, p. 1)
Utilize clear, and concise language that the users will understand.

3) ”Minimize the user memory load” (Nielsen, 1996, p. 1)
Limit the number of things that the user should have to memorize. The options should be easily accessible through menus, while the commonly used functions should be available buttons that are easy to access.

4) ”Be consistent” (Nielsen, 1996, p. 1)
Consistency is another important element, and each screen should have the same, basic structure. Meanwhile, if the interface contains some similar functions, these should include the same steps to prevent confusion.

5) ”Provide feedback” (Nielsen, 1996, p. 1)
Acknowledging the actions of the users is paramount, to make them aware of the consequences of their actions. Error messages should be somewhat different from the rest of the user interface, to make sure that they grab the users’ attention

6) ”Provide clearly marked exits” (Nielsen, 1996, p. 1)
The user should not have a hard time navigating through the user interface. For one, there should be a clearly marked “exit” that leads back to the home screen. Meanwhile, they should easily see how to move forward or go back.

7) ”Provide shortcuts for advanced users” (Nielsen, 1996, p. 1)
The novice user would probably not utilize shortcuts right away, but this can be relevant to experienced users. Such shortcuts should be available for the most common functions, to give the experienced users the possibility to utilize them.

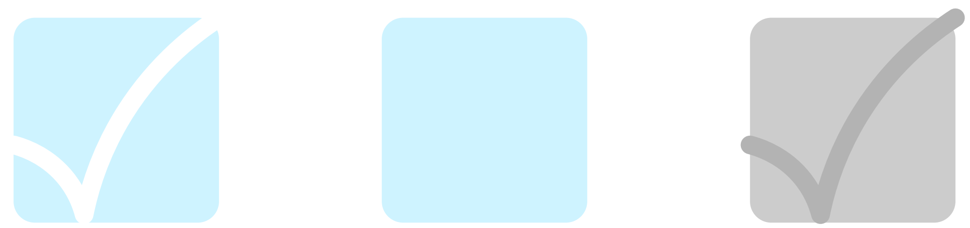
8) ”Use plain language for error messages” (Nielsen, 1996, p. 1)
Clear and concise language is important throughout the user interface but is especially important in the error messages themselves. They should clearly present the problem without too much room for interpretation.

9) ”Prevent errors” (Nielsen, 1996, p. 1)
However, the ideal is to prevent errors from the get-go. The designer should try to predict problems and add features to prevent them.

10) ”Make the help simple and task-focused” (Nielsen, 1996, p. 1)
Lastly, if the user interface contains a help-feature, this should be simple in use and explain things to even the novice user. It should revolve around the main functionalities of the user interface.
(Nielsen, 1996, p. 1)

VISIBILITY PRINCIPLE

The visibility principle revolves much about transparency in the user interface (UI). In short, the user should get an overview of possible actions and their potential consequences. Meanwhile, it is important to communicate the status of certain elements, for example indicate that function is enabled or disabled. Lastly, one should continuously provide feedback to the user after they have performed a certain action. This approach can prevent the user from being confused and disoriented (Lidwell et al., 2010, p. 250). In short, the visibility principle has many similarities with Nielsen’s usability heuristics
(Nielsen, 1996, p. 1).



AFFORDANCES

Affordances revolve around the function an element implies, and how it affects the usability of a feature. For example, a three-dimensional button on a screen will imply that it is clickable. Such images or illustrations of real-life elements in a simulated user interface can communicate possible interactions to the users, further increasing the usability of the UI (Lidwell et al., 2010, p. 22)

USE OF COLOR

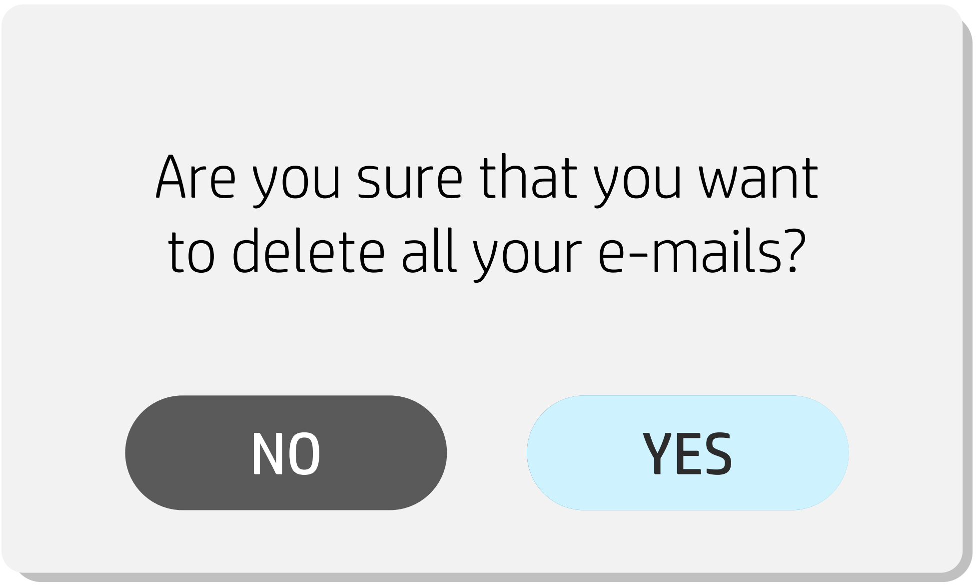
The use of colour in a UI can for example highlight some important elements, indicate the status of others. In general, one should use colours sparingly, and stick to roughly five colours, to ensure that the UI stays aesthetically pleasing. Meanwhile, the saturation of said colours can affect how they affect the users. Highly saturated colours will attract the attention of the user, and is often used on alert symbols or important notes (Lidwell et al., 2010, p. 48).

CONSISTENCY

Consistency is an important principle in UX design, that is extenuated throughout Nielsen's usability heuristics (Nielsen, 1996, p. 1). It increases the learnability of a product, as there are similarities between screens and functions. Aesthetic consistency revolves around the style of a certain system. If the style is coherent and repeating across pages, can make it easier for the users to recognize certain elements. Meanwhile, functional consistency implies that different functions will perform somewhat similarly, meaning that similar actions will yield similar results. For example, consistent use of symbols will improve the learnability of a product, as the users encounter them throughout the product and recognise them. Internal consistency, however, is more about the coherence between elements in an interface. The aesthetic of these elements should be coherent, to imply that they belong in the same system. Lastly, external consistency has many similarities with internal consistency, but this kind refers to how the system corresponds to other similar systems. For example, whether the same symbols are being used across multiple systems to indicate the same function (Lidwell et al., 2010, p. 56).

CONFIRMATION

The confirmation technique focuses on communicating possible consequences to the user. This approach utilizes verification to prevent the user from making any errors.. Confirmation can take shape as a simple dialog box, asking the user a question. However, an excessive number of such dialog boxes can irritate the user over time. Thus, they should be used sparingly (Lidwell et al., 2010, p. 54).



FORGIVENESS

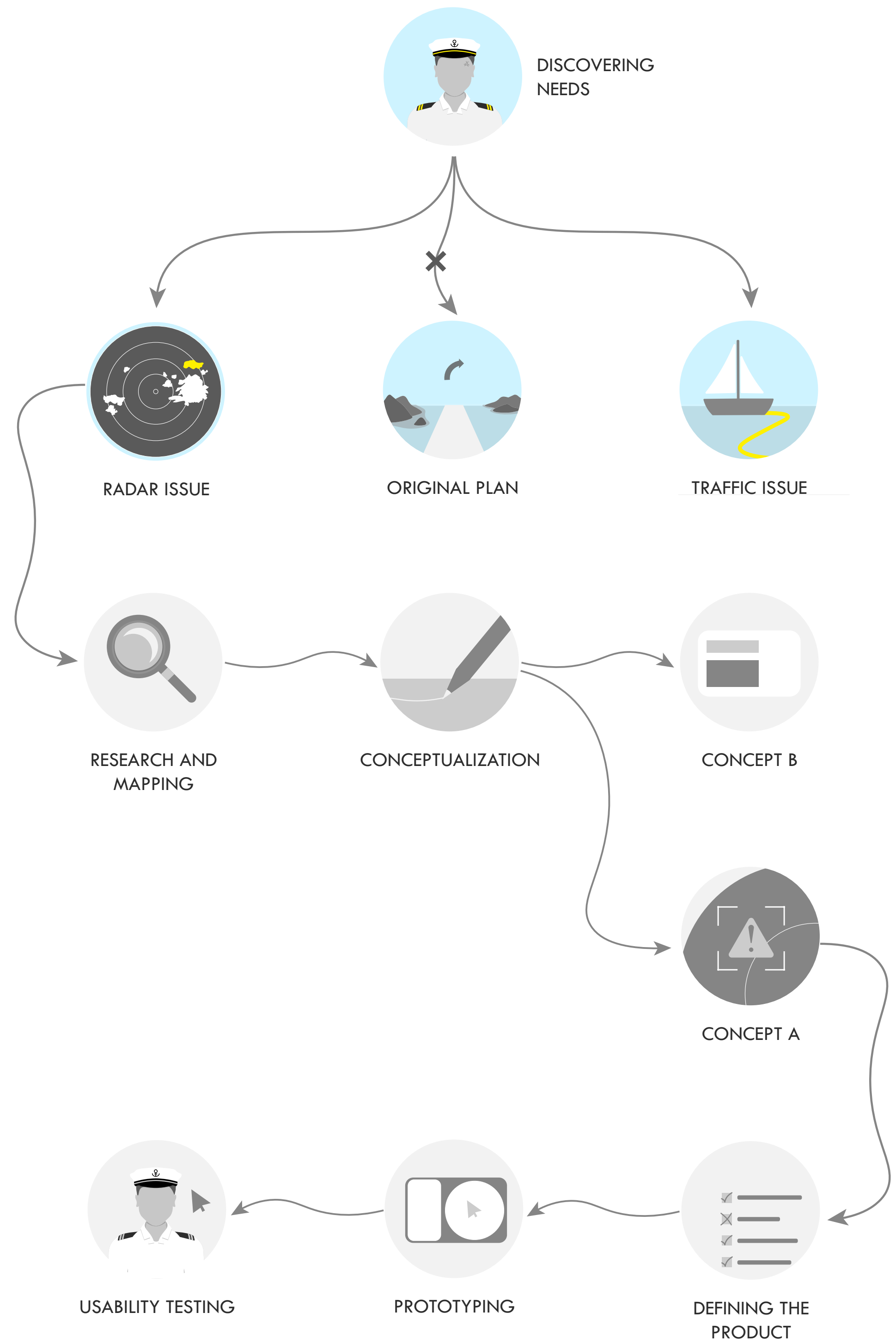
Forgiveness in design can reduce the likelihood of user errors, in addition to reducing their potential consequences. Several techniques and principles can be utilized to ensure that the design stays forgiving. For one, good affordances can give good indicators to the users, increasing the likelihood that they will avoid errors. In addition, making certain actions reversible can also be of great importance here. If a person deletes something my mistake, for example, they can reverse this by clicking an “Undo”-button. In that way, one can give the user a chance to rectify certain errors. Thirdly, ensuring that the user must confirm a certain choice before performing the action will also reduce the risk of error, as they are required to verify their intent before proceeding. Lastly, the use of warnings can give a similar result, as they communicate potential consequences to the user (Lidwell et al., 2010, p. 104).

FINAL APPROACH

These design principles were utilized throughout the concept development, as well as the later prototyping phase.

DISCOVERING NEEDS

This chapter revolves around the qualitative data gathering executed in the beginning of the project, where to goal was to investigate the possible need for Porathe's display.



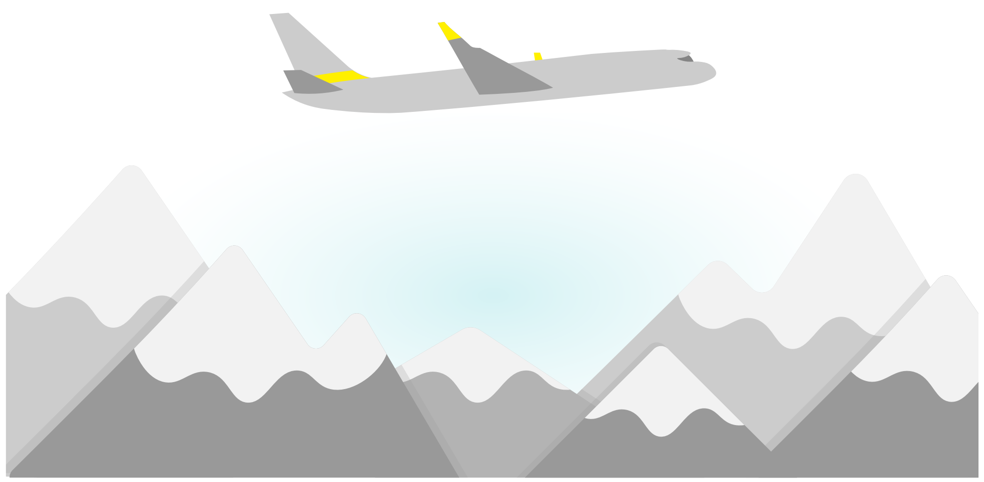
RESEARCH TRIP #1

GOAL

The initial literature search proved to be insufficient to get a complete perspective regarding the navigators' current approach. Thus, I decided to visit a vocational school for navigators to get some hands-on experience. The goal of this trip was to see how the navigators would use their instruments in combination with their optical navigation. This was done as a part of the preparation for the interviews.

More specifically:

1) how the navigator would use the ECDIS during the voyage
2) how the navigators would use the radar during the voyage



METHOD

During the visit, one of the instructors explained how the navigator would use the ECDIS during a sail and set up an appropriate simulation to allow for testing of the different functions. The session made it possible for me to steer the vessel, manage the route and combine the instrument handling with optical navigation. The instructor was present during the session and explained the procedures and thought processes throughout. All in all, this visit gave hands-on experience, which resulted in some improved insight regarding the equipment and work steps the navigator must follow. This proved to be valuable during the later interviews.

RESULTS

Table 2 contains the findings from the research trip. These findings correspond to the existing ECDIS literature (NEK, 2015, p. 25). Additionally, it gave some insight regarding how one might utilize optical navigation throughout the sail.

ECDIS INFORMS OF...	RADAR OBSERVATIONS
The ship's position on the map	The instructor chose the same orientation on the ECDIS and radar, to make it easy to compare the two
The charted route and its boundaries	
Shallow waters and no-go areas	They changed the settings on the radar to get a better overview of what was in front of them than what was behind
Markers in the environment	
When to initiate the next turn	They changed the range (scale) of the radar image underway
Which course to set to stay on the planned route	
The position and direction of approaching ships	

Table 2. Main findngs from the first research trip.

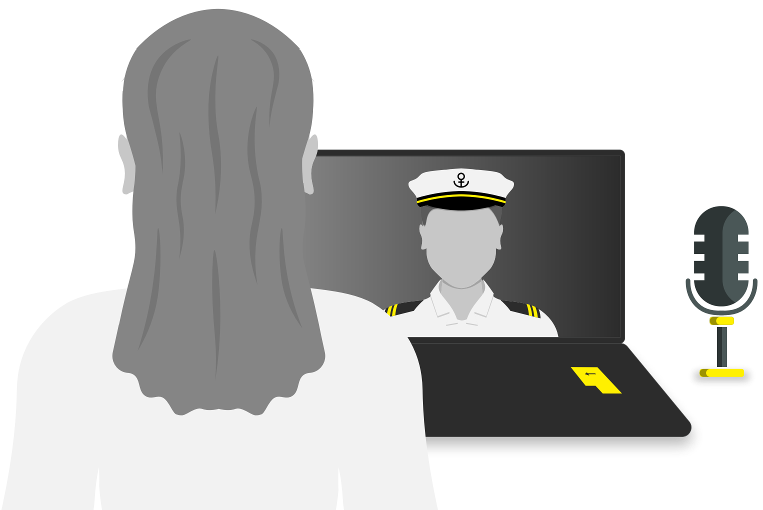
INTERVIEWS

GOAL

The research trip gave some idea of the navigators' approach, but most of the data from the insight process was collected via interviews with members of the user group. These interviews were done with the original project goal in mind, specifically to investigate the need for a situational awareness display, as well as the current practices and challenges.

The focal points were the following:

- How the navigators ensure a good situational awareness today, and what information they need to do so
- How the navigators would use their instruments (mainly radar and ECDIS)
- Shortcomings or challenges with this equipment
- How the navigators use optical navigation to navigate (terrain, buoys etc)
- How they would plan their voyage and manoeuvres



METHOD

A semi structured interview is a method used to collect qualitative data. It includes some pre-planned questions that will be asked in each interview. However, this method includes some flexibility, as the interviewer will ask additional, unscripted questions, based on the input from the interviewee. In that regard, it is more flexible than structured interviews for example, which sticks to a rigid set of questions. Open interviews would – on the other hand – make it more difficult to analyse the results and find common denominators, as the input and output would vary from interview to interview (Preece et al., 2015, pp. 269-270). Thus, semi structured interviews were deemed as the most suitable method for the data gathering process of this project. These interviews provided detailed information regarding the users' experiences and views. In addition, the flexible structure of the interviews made it possible to tweak the interview guide along the way, for example by asking non-planned questions if an interesting point appeared.

All in all, ten navigators were interviewed, including three women and seven men. They were deployed on different kinds of ships and had varying degrees of experience. Some were still active at sea, while others had been ashore for several years. The navigators were between 24 and 60 years old.

The interviews were done via phone calls or Microsoft Teams, as the participants were scattered over different corners of Norway. The interviews were recorded, which made it possible to transcribe them afterwards. The recordings helped ensure that the findings from the interviews were detailed and precise, which in return gave a more solid data foundation for the later decision making. Informed consent was collected prior to these interviews.

ANALYSIS

GOAL

In Vivo coding was the chosen method for the analysis of the interview transcriptions. This method was used to discover recurring challenges from the interviews.

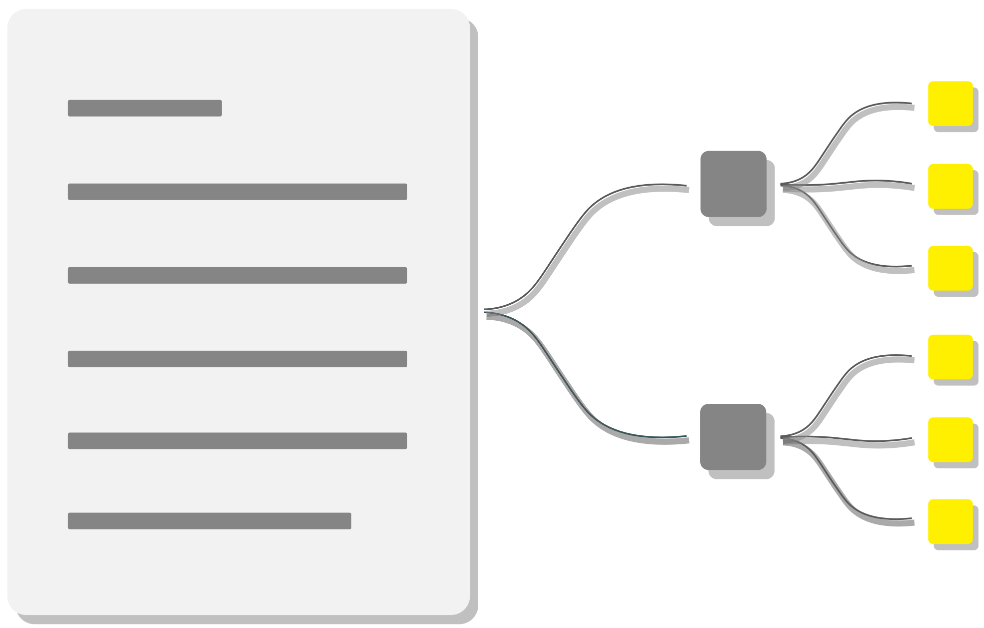
METHOD

The programme NVivo was used for the coding process. Such In Vivo coding lets the data "speak for itself", as it presents raw quotes associated with certain categories. In this case, the coding was based on grounded theory. This approach develops a theory after analysing the data, and also goes under the name "inductive approach" (Aljaroodi et al., 2020, p. 3; Lazar et al., 2017a, pp. 304-305).

In Vivo coding has a range of advantages and disadvantages. On one hand, it is directly based on raw data, which can prevent bias. In addition, it makes it possible to systematically analyse the data at hand. However, Lazar et al. mentions that one can quickly get lost in the data, and focus only on the small, minute details. In that way, the researcher might not see the bigger picture, and the overall context of it all. Lastly, there is a possibility of biases affecting the coding process (Lazar et al., 2017a, pp. 304-305).

An alternative method for the data analysis would be affinity mapping. This method is a thematic analysis that analyses the data and looks for relevant patterns. The first pass through the data will uncover recurring themes, while the second pass is used to confirm or refute these. In that way, it has some similarities with In Vivo coding, but it will often use notes or simplifications of the findings from the interviews. Therefore, it does not always stay as close to the source material as In Vivo coding (Preece et al., 2015, p. 322). Thus, In Vivo coding was deemed as the most suitable analysis method for this project.

Specific codes were used to describe the groups of findings. The codes were sorted after positive and negative feelings in the early stages of the coding. However, in later stages, they were more specified into terms such as "uncertain", "confident", "alert" and so on. This is called affective coding, when the data is coded based on emotions (Lazar et al., 2017a, p. 309). The use of such emotionally guided codes made it easier to discover which situations made the navigators uncertain, for example, thus highlighting existing problems and pressure points during their navigation.



RESULTS

The analysis highlighted a selection of different issues brought forth by the navigators. Below are a set of descriptive quotes extracted from the interview transcripts. Al in all, these problems became apparent during the interviews:

Other vessels are disregarding the rules and are somewhat unpredictable.
«Du vet jo aldri hva de finner på å gjøre da. Det å planlegge der, det er håpløst."

> *[You never know what they might do. Planning in these situations, it's hopeless.] (Authors translation)*

The navigators prefer to plan ahead, call them up on the radio and figure out a plan that works for both parties if there are challenging waters ahead. Thus, erratic vessels can be difficult to handle.
"Er du usikker så avtaler du med motgående fartøy eller medgående fartøy»

> *[If you feel unsure, you will (call and) plan with the incoming vessel.] (Authors translation)*

Some of the navigators had been **uncertain of their position**. Meanwhile they mentioned that they used markers in the environment as reference to validate their position and orient themselves.
" Ja, det jeg gjør er jo at jeg egentlig ser mye ut, og ser på lykter, ser på terreng, ser på navigasjonsmerker og hjelpemidler."

> *[Yes, what I do is that I actually look out the window a lot, and I look at lights, look at terrain, look at navigation marks and navigational aids.] (Authors translation)*

Adjusting the radar settings to a good level was very important, but also challenging.
At times with reduced visibility, they could be highly dependent on the radar to track other targets, but the radar image would be filled with clutter. Thus, they needed to tweak the settings until it was clear enough, without suppressing relevant echoes.
"Det som er utfordringen er når det er dårlig vær og mye bølger og skvulp og sånn. For da vil jo det bli forstyrrelser i radarbildet. Og hvis du tar for mye av det bort, så vil du miste bildet av den staken eller den holmen som du ser der.»

> *[The challenge is when there is bad weather and a lot of waves and splash and such. Because then there will be disturbances in the radar image. And if you remove too much, you will lose the image of the stake or the islet that you see there.] (Authors translation)*

There is **a lack of standardization** between suppliers. One ECDIS might have a certain setup, while an ECDIS from a different supplier might have a different interface, which could make it difficult to find the proper settings.
"Problemet er å hoppe fra en båt til en annen igjen også er det et nytt system også skal man lære det på nytt igjen.»

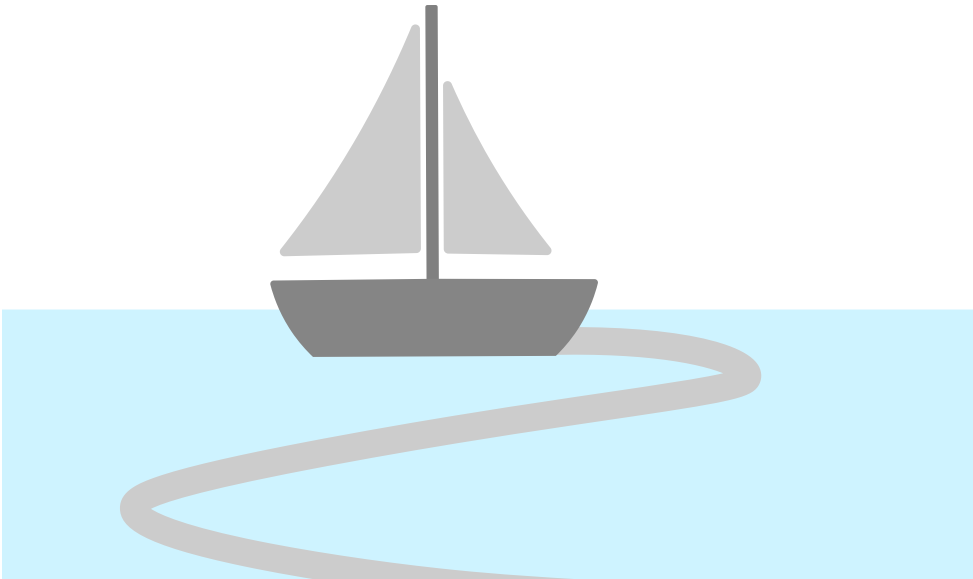
> *[The problem is when you are jumping from one boat to the next and then there is a new system. And then, you have to learn the system anew.] (Authors translation)*

RESULT - 2 MAIN CHALLENGES

The issue of uncertainty regarding the ship's position was not a common issue, but rather a problem that would occur if the equipment would malfunction or in the past when the equipment was less advanced, for example. Thus, this issue was disregarded, as it was not a major issue in their day to day navigation.

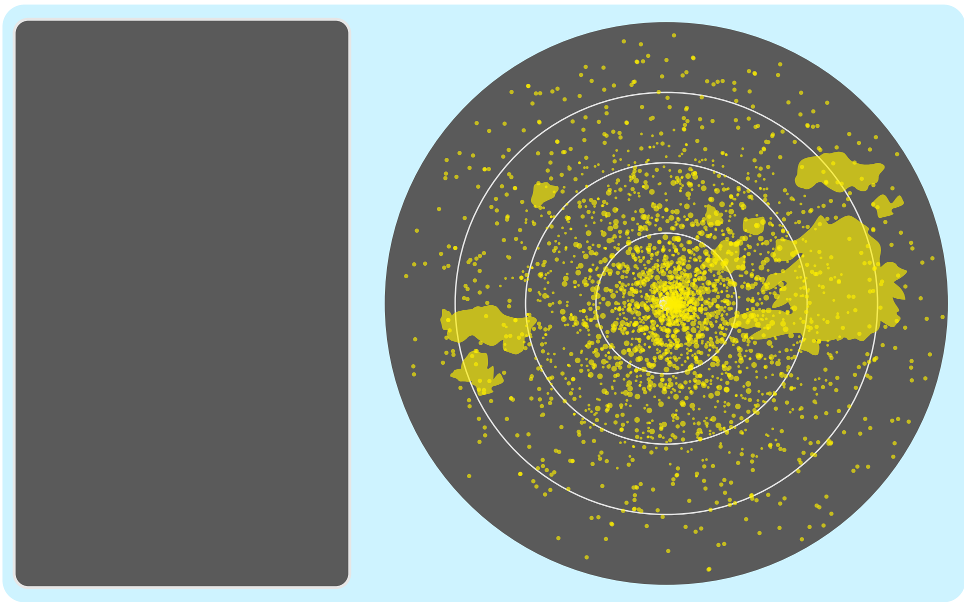
In addition, as the fourth and last issue had more to do with the regulations and lack of standardization than a concrete design issue, it was set aside in favour of the other, more specific challenges that could be resolved by design.

Additionally, the issue of unpredictable traffic was a recurring theme during the interviews. The navigators sometimes found themselves stuck between a rock and a hard place, wanting to follow the COLREGS but being forced to break them to ensure the safety of the ship. Another traffic situation that required their alertness was when facing incoming traffic in narrow waters. They often had to plan well in advance to ensure that they would have enough space when encountering incoming vessels.



The challenge of adjusting the radar settings to a good level was another recurring issue. This problem could affect the safety of the ship, as a badly tuned radar would give a insufficient overview of the nearby waters. In that way, the navigators main tool for collision avoidance would prove deficient and leave the navigator "blind" to possible dangers.

Meanwhile, it became apparent that the navigators had interesting techniques to test the accuracy of the radar. Many would keep an eye on the echo from a small marker or pole in the environment while they were tuning. They would stop tuning when the radar image was clear, and the echo was still visible. In that way, they knew that they would most likely be able to spot small vessel echoes, as the radar would even show small markers with the current radar settings. However, they still found it challenging to find the balance between a clear image, meanwhile not suppressing any relevant echoes.



VALIDITY CHECK

GOAL

A validity check was conducted to investigate the ecological validity of the findings from the analysis.

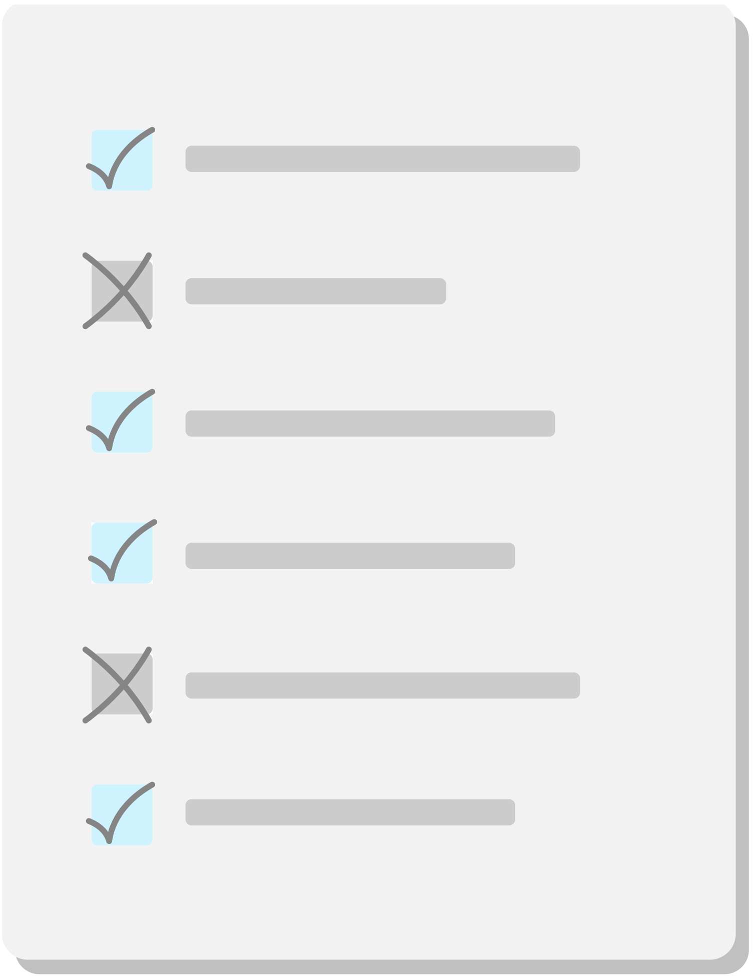
METHOD

Such ecological validity is defined as “whether the study findings can be generalized to real-life settings” (Andrade, C, 2018, p.1). The ecological validity of the results was addressed by presenting the main findings to the navigators and seeing whether they found these results representative for their observations.

Seven out of the ten interviewed navigators did partake in such discussions, where the main findings from the analysis were discussed. A summary of the main findings was sent to the interviewees in advance of the discussion, so that they could read through the points and decide whether they did agree or not.

The discussion took place over Teams, and the findings from the analysis were presented via a simple PowerPoint presentation. In that way, the navigators could read through the different statements during the presentation, to see whether they agreed or not. These sessions were voice recorded and notes were taken at a later stage to ensure that all relevant information was included. Informed consent was collected prior to these recordings.

This made it possible to discover how many agreed or disagreed with the presented statements.



RESULTS

Table 3 shows an overview of the responses from the validity check..

STATEMENT	AGREE	DISAGREE
It is challenging to tune the radar in bad weather conditions, at one can quickly tune away vessel echoes if not being careful.	7	0
Sometimes it's difficult to spot the echoes before they are quite close to the vessel	4	3
In bad visibility, the navigator is dependent on the radar to get a good situational awareness.	7	0
When in doubt about an echo, comparing the ECDIS and radar image is a good way to check it, to see whether the echo is a charted pole, for example, or an uncharted vessel.	7	0
Naval vessels sometimes turn off their AIS	7	0
There are many vessels that choose not to follow the COLREGS	7	0
Fishing vessels and sail boats are the most recurring vessel types in this category (disobeying the COLREGS)	7	0
Meeting traffic in narrow waters can be challenging	7	0
It is valuable to call other vessels through the VHF, especially when two larger ships are about to meet in narrow waters	7	0
Not everyone will reply when called via the VHF	5	2

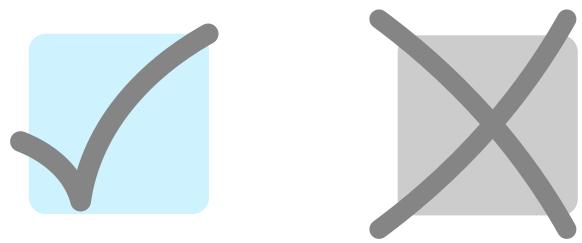
Table 3. Results from the validity check.

The majority of the results were unanimously verified by the navigators. However, there were a couple statements that brought forth some discussion.

For one, the issue of detecting echoes far away seemed to divide the group. Four people agreed with this statement, whereas the remaining three disagreed and had some interesting observations in this regard. One mentioned that they had a blind zone on the radar around the ship, meaning that echoes that were quite close would not appear on the display. Another navigator stated that some small echoes could be difficult to spot, as they would not appear on each radar sweep.

Five navigators agreed that contacting other vessels can have varying results. The remaining two navigators disagreed and stated that they usually reply.

The verified statements made the basis for the rest of the project. Meanwhile, the disproven statements were excluded from the data pool.

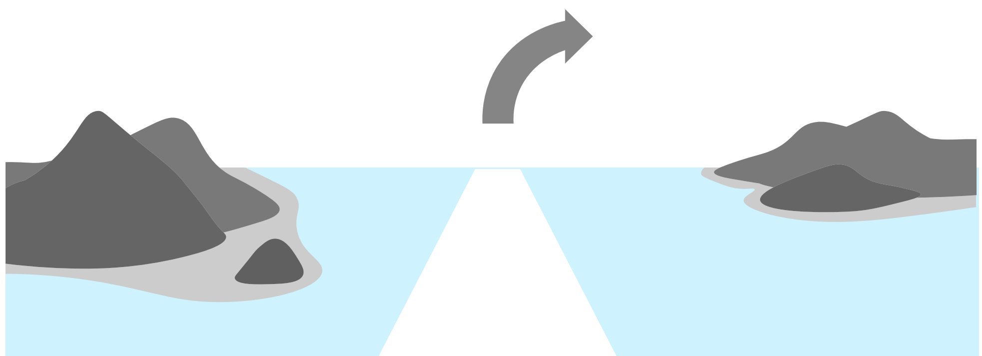


DESIGN DECISIONS #1

MOVING AWAY FROM THE SITUATIONAL AWARENESS DISPLAY

The findings from the interviews two main challenges; the radar issue and traffic issue. However, these challenges were not tied to the issues that Porathe's display was trying to solve. His display could reduce the cognitive load of the navigator and give them a better overview of the planned routes of large vessels. However, the findings from the interview had no mention of issues with cognitive overload. Additionally, the results from the interviews rather showed that the smaller vessels were erratic and unpredictable, and not the larger vessels that were Porathe's focus (Porathe, 2006, p. ii). Thus, it was chosen not to proceed in the direction of a situational awareness display, as the findings from the interviews did not find a need for such a tool.

These findings show the value of the user centered approach; it keeps you in touch with the market. The continuous user involvement ensured that this project would deal with a real problem, a challenge mentioned by multiple members of the user group. On the other hand, if one had proceeded with the original idea of a situational awareness display, it could have resulted in a tool that the navigators did not have a use for.



CHOOSING THE PROBLEM

There were – however – two clear challenges present in the shipping industry today, that had been mentioned and validated by multiple navigators.

The radar challenge is mainly tied to the filtration that happens during the manual tuning process. At times with waves and downpour, the radar image will be filled with interference that can cover and hide other, relevant echoes, like vessel echoes (Kjerstad, 2015, pp. 2-64). Meanwhile, the navigator can adjust three main parameters:

- Gain – this setting decides how much the radar signal will be amplified.
- Anti clutter sea – this setting reduces the amount of clutter in close vicinity to the ship
- Anti clutter rain – This setting will reduce the overall clutter in the radar (Kjerstad, 2015, pp. 2-64).

If the navigator does not add enough gain, they will suppress echoes. If they add a lot of gain, however, they will add more clutter to the image. Meanwhile, they can adjust anti clutter sea and anti clutter rain to reduce the amount of clutter, but they might suppress relevant echoes in the process. The suppression of such echoes means that the radar will not show them potential hazards in the water and will not ensure safe navigation (IEC, 2013, p. 31). This is a major problem that can have potentially dire consequences, further extenuated by the Sleipner report (NOU2000:31, 2000, pp. 111-114).

The radar can also help them get a better overview of the traffic situation, as it lets them target possible vessel echoes in the area. In that way, helping them adjust the radar settings properly might also have a certain effect on the traffic issue.

On the other hand, the traffic issue was mentioned by just as many navigators and highlighted some interesting challenges at sea. However, there are many variables that make this a rather complex issue in comparison.

For one, the erratic behaviour is tied to their attitude towards the COLREGs; the international regulations for preventing collisions at sea (Zhou et al., 2020). This is a result of the choices of the sailor, something that cannot easily be predicted or controlled.

Meanwhile, the navigators also mentioned unpredictable behaviour from some naval vessels. In short, the naval vessels would sometimes turn off their AIS (Automatic Identification System), a feature that transmits where the other ship is headed and where it will be positioned in a set amount of time (IMO, 2015, p. 11). This would lead to a lot of confusion for the navigators, as they would be able to see a shape on the radar, but no AIS signal accompanying it. However, this issue is intertwined in existing regulations, as these naval vessels are allowed to turn off their AIS signals (Statens havarikommisjon for transport (SHT), 2018, p. 13).

The radar and traffic issues are closely intertwined. The findings from the interviews show that many of the erratic vessels are smaller vessels, like sailboats and pleasure crafts. Where most larger vessels send out AIS signals that can be spotted on the radar, this is not the case for the smaller vessels (IMO, 2015, p. 2). This means that the small, erratic vessels will only give an echo on the radar, which can quickly be suppressed if the radar settings are not decent. Thus, the navigator's primary tool for collision avoidance might not inform them of these vessels. Lastly, these echoes will disappear once they enter the blind sector close to the ship, no matter the settings (Kjerstad, 2015, pp. 2-21). This is an additional factor that will make it more difficult to spot the echoes from the erratic vessels.

Additionally, the traffic issue would be useful in certain situations that only occur when a certain set of parameters are met. In comparison, the radar issue would be present each time they would adjust the radar settings. They would likely adjust their radar settings once or more per watch, according to relevant research (Vu et al., 2019, p. 8).

In short, a radar-oriented solution could help the navigators each day, thus also having a larger impact and a more substantial value to their day-to-day tasks. It could make them aware of possible dangers in the waters that they might not spot today. Thus, the radar issue became the chosen focal area of this thesis.

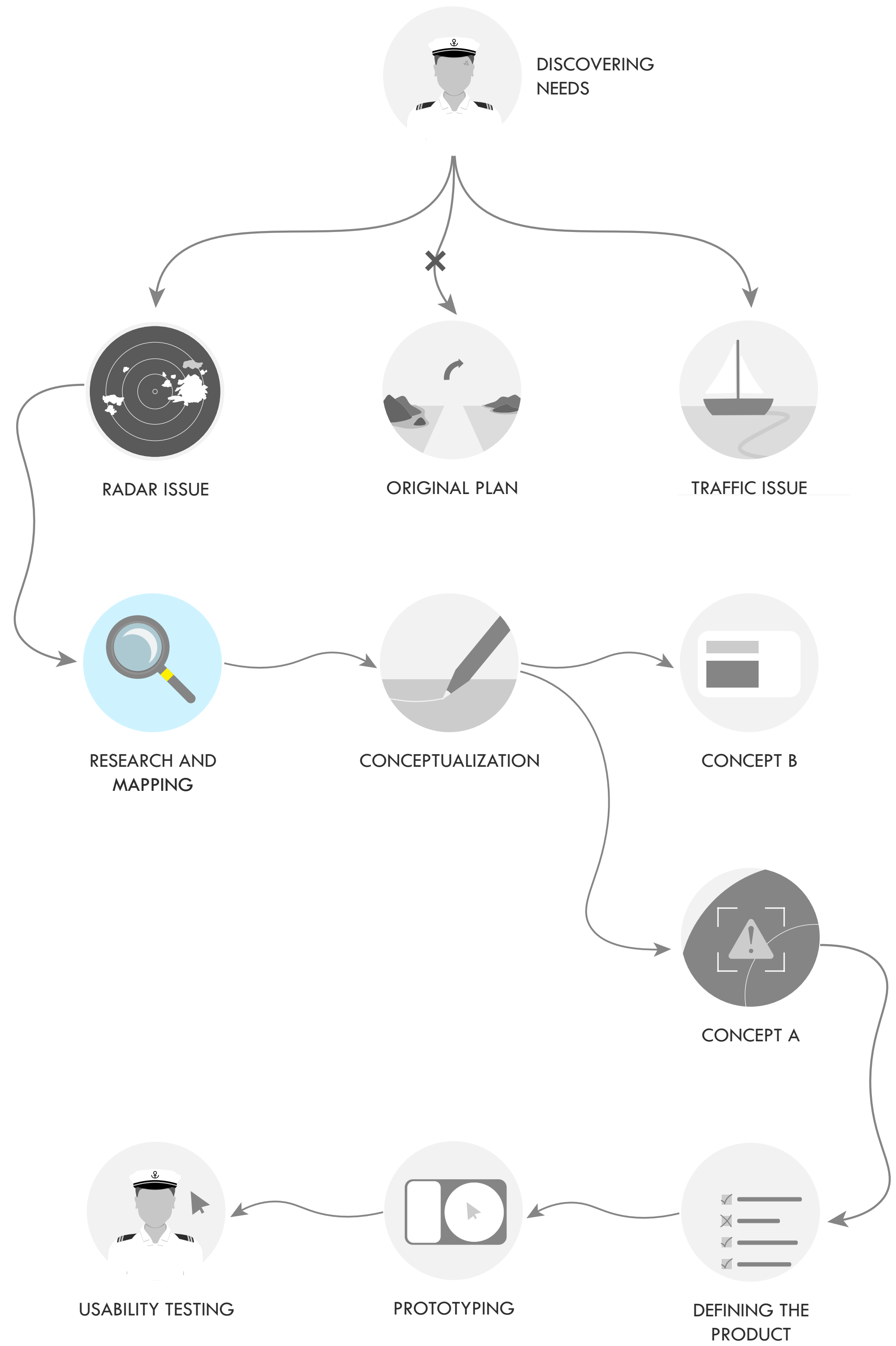
In short, the new goal was defined as the following:

The goal of this project is to develop a set of additional radar functions that will make it easier for the navigator to adjust the settings to a good level.

These functions should give the navigator an overview of which echoes are visible on the radar with their current radar settings. In short, they should give them an idea of the quality of their settings. Meanwhile, they functions should inform the navigator of how they can improve their settings and stop suppressing relevant echoes.

RESEARCH AND MAPPING

The change of direction in the project made it necessary to gather some more insight. This chapter revolves around the new research and mapping of the user's needs, when approached from a new perspective.



RESEARCH TRIP #2

GOAL

The change of direction in the project made it necessary to gather more insight regarding the chosen problem. Thus, I went on another research trip to aquire more knowledge of the recurring challenges and practices.

METHOD

An instructor at a maritime vocational school was interviewed to investigate how the navigators are taught to tune the radar. He demonstrated how he adjusted the radar settings on a real radar. During the demonstration, he adjusted the gain and clutter sliders, and simultaneously explained the thought process behind their actions. The session was video recorded, to ensure that interesting findings were brought back from the trip.

RESULTS

This gave some interesting findings. The key points from the radar tuning were the following:

- He would adjust the settings when the vessel was far from the dock
- He would wait to adjust the settings until he saw an object that was clearly visible on the radar
- He would first enable auto-tune, that would adjust the “tuning”-slider on the radar to a good level automatically (this feature was not the focal point in this project, but another adjustable parameter on the radar)
- He would adjust the gain until it was possible to see the weakest echoes from small, charted objects (like a buoy)
- He would adjust the sea clutter upwards and then maybe down again, to see when the buoy echo would appear. He would use the buoy echo as a measurement of the quality of the settings.
- He might change the sea clutter settings underway, depending on the stability of the weather conditions. If the weather changes, he might have to re-adjust the sea clutter settings.

In addition, he had some remarks regarding the radar

- He might enable the radar overlay on the ECDIS, but it would bring a lot of clutter
- If he was unsure of whether the echo would be a vessel echo, he would enable trails on the radar
- If he was unsure of whether it was a real echo or just clutter, he would check whether it was a recurring echo. If it would be in the same spot each sweep, it would probably be a real echo

These findings proved to be valuable during the concept development.

USER JOURNEY MAPS

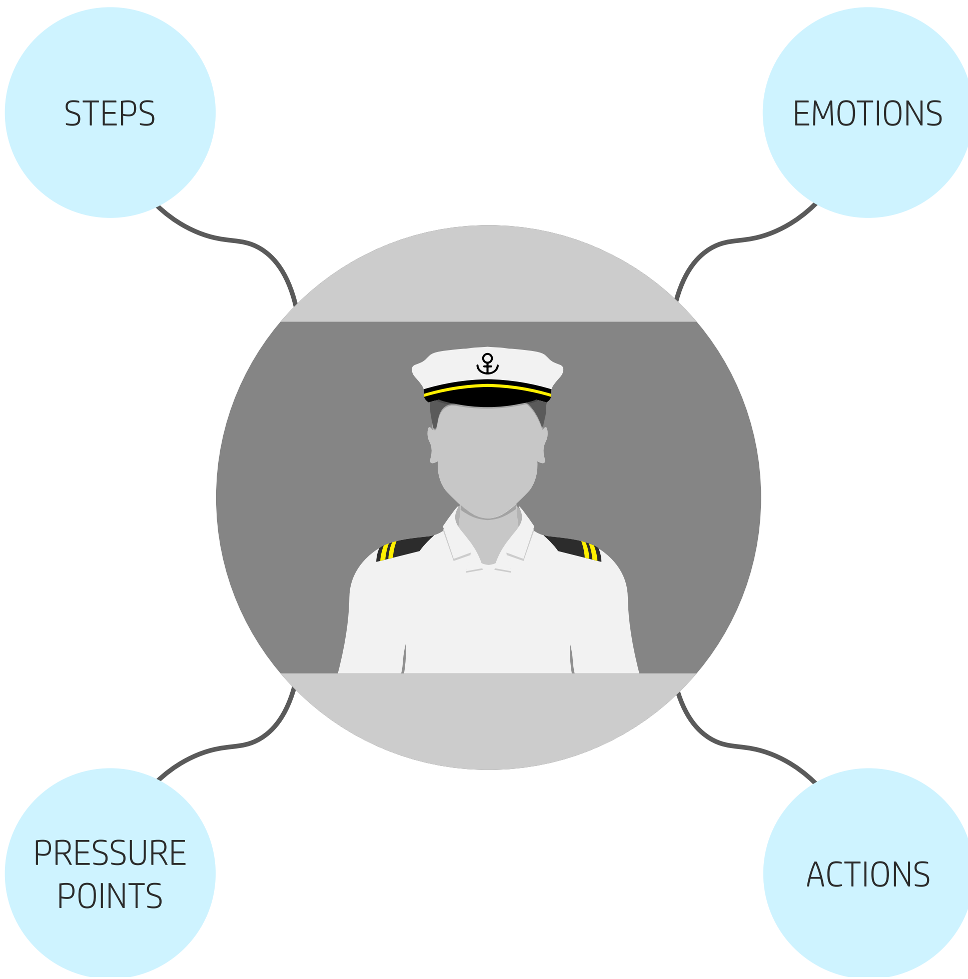
GOAL

User journey maps were utilized to map the users' actions and related pressure points during their radar tuning. This mapping could highlight potential user needs.

METHOD

Such journey mapping focuses on a person's experience when using a certain product or service. It includes the most important steps, as well as their emotions and actions during those steps. It is a good way to get an overview of relevant pressure points, but it is dependent on a good level of detail to get an accurate depiction. The quality of data extracted from this mapping will be mirrored by the quality of the data inserted into the map. It is important to be aware of these limitations, and thus make sure to have a decent foundation of data. (Stickdorn et al., 2018, p. 44)

An alternative method to journey mapping is task analysis. This method also focuses on the actions and steps the user will go through, but it leaves out their emotional state. In this project, however, the navigators' emotions during these activities were deemed as quite important (Papautsky et al., 2020, p. 2). Thus, journey mapping was seen as a more suitable method in this project.



RADAR TUNING DUE TO CHANGING WEATHER

Something that was mentioned during the interviews was that a well-tuned radar might turn out to be obsolete later in the watch, as the weather conditions would change and require new settings. Additionally, several navigators mentioned that they would use a charted object in their close vicinity as a kind of reference point while tuning. They would ensure that this object would remain visible with their current settings.

REFERENCE POINT

ESPEN

Espen is an experienced navigator in his mid 40s. He is currently assigned as first mate onboard a ship that transports fish feed to several fish farms. The ship's bridge is equipped with two radars (3cm and 10cm), as well as an ECDIS. He has plotted a rough route on the ECDIS, which plays more an advisory role than being completely accurate.

EXPECTATIONS

Today he is sailing a route he has traveled before, but he is expecting a somewhat challenging sail due to some strong winds. In addition, the weather has been clouded throughout the day, and it just started snowing heavily. Due to the poor visibility, a lookout has been positioned on the bridge.

1. BAD OVERVIEW	2. ADJUSTMENT	3. SUPRISE!	4. QUALITY CONTROL	5. REGAINING CONTROL
As Espen struggles to see what is hap-pening outside because of the snow, he tries to look at the radar. However,, the settings were tweaked when there was no downpour, resulting in a radar image filled with clutter., making it difficult to see anything.	To get a better overview, Espen tries to adjust the settings on the radar. He adjusts the sea and rain clutter until the image looks better. However, he is unsure whether he has gone too far and is now supressing small echoes.	As Espen is unsure whether his set-tings are correct, he starts looking for a set object in the environment that he can use as a reference point. He sees a post charted on the ECDIS not too far away.	He adjusts the different clutter settings until he can clearly see the post on the radar. He uses the overlay function to check that the echo on the radar is - in fact - the charted post.	Now, he has faith that he will probably see incoming, small vessels as he is able to see the small post on the radar.
"What am I not seeing?"	"Are the settings okay at this time?"	"Okay, I can use that as a reference"	"The settings should be decent now"	"Okay, it should be good now"

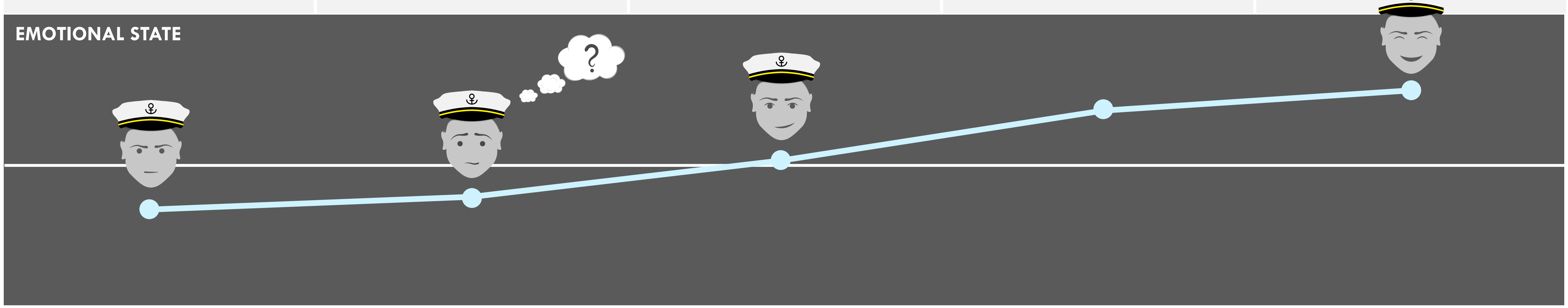


Figure 4. User journey map for tuning from a reference point.

IDENTIFYING ECHOES

Several navigators explained how they would try to identify certain echoes on the radar.

This was sometimes done manually by physically measuring distances with a ruler.

IDENTIFYING ECHOES

ESPEN

Espen is an experienced navigator in his mid 40s. He is currently assigned as first mate onboard a ship that transports fish feed to several fish farms. The ship's bridge is equipped with two radars (3cm and 10cm), as well as an ECDIS. He has plotted a rough route on the ECDIS, which plays more an advisory role than being completely accurate.

EXPECTATIONS

Today he is sailing a route he has traveled before, but he is expecting a somewhat challenging sail due to snow and strong winds.

1. BAD OVERVIEW	2. ADJUSTMENT	3. SUPRISE!	4. QUALITY CONTROL	5. REGAINING CONTROL
The weather conditions are poor; it is snowing and wind of 10 m/s, so there are some waves. As Espen struggles to see what is happening outside because of the snow, he tries to look at the radar. However, the radar image is full of clutter, which makes it difficult to see anything. "What am I not seeing?"	To get a better overview, Espen tries to adjust the settings on the radar. He adjusts the sea and rain clutter until the image looks better. However, he is unsure whether he has gone too far and is now supressing small echoes. "Are the settings okay at this time?"	A while later, Espen looks as the radar and suddenly sees an echo he has not noticed before. He is unsure whether the echo is a small piece of land or a small vessel. "What is that echo?"	He wants to chech whether it is a charted echo. Thus, he first checks whether the ECDIS and radar are at the same scale. Then, he measures the distance from a set point on the ECDIS screeen to a charted rock in roughly the same location as the echo. Then, he checks whether it is the same distance between the echo and the set point on the radar. It is..	Thus, Erik concludes that the small echo is probably just a small piece of land. "Okay, so nothing to worry about"

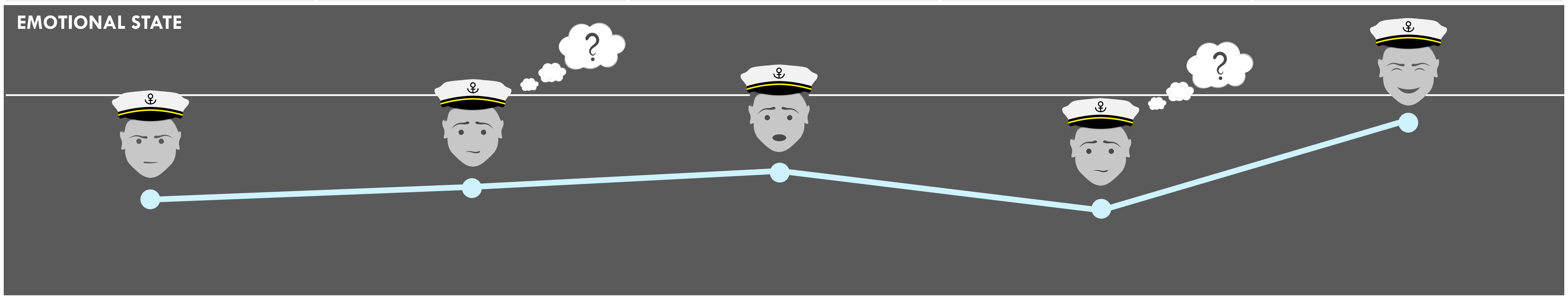


Figure 5. User journey map for identifying echoes.

RADAR RESEARCH

GOAL

As the radar issue belonged to a rather unknown domain, it was necessary to conduct literature research to get a better understanding of the problem. Such research is often conducted to gather more insight about a specific topic. In this case, this insight was needed to ensure clear communication with the users.

METHOD

The topic of echoes and clutter were researched, to get some insight on which elements could be present in the radar's PPI. In addition, the effect of the different radar settings was a vital topic. Lastly, it was decided to try and find a recommended tuning procedure. The main findings from this literature search are listed below.

RESULTS

AUTO-FEATURES

Many of today's radars have a function called "Autoclutter", that will automatically adjust the levels of sea and rain clutter. This feature does have some limitations and may suppress the echoes from vessels or other elements in the image (Kjerstad, 2015, pp. 2-64).

GAIN

Gain is a parameter that will amplify the returned radar signal from surrounding objects. Is the gain is set too low, certain echoes will not be visible on the radar. However, the more gain is added, the more clutter will appear (Kjerstad, 2015, pp. 2-62).

ANTI-CLUTTER SEA

The sea clutter parameter is actually a feature that will reduce the clutter in close vicinity to the ship. It will mainly target the clutter that originates from waves, but will also dampen other, possible relevant echoes in the area (Kjerstad, 2015, pp. 2-64).

ANTI-CLUTTER RAIN

Lastly, the rain clutter settings will reduce the clutter from downpour and result in a more "clean"-looking radar image. However, much like the sea clutter, this setting will also affect other echoes in the vicinity, and give the coastline a somewhat "choppy" appearance (Kjerstad, 2015, pp. 2-64).

ADJUSTING THE SETTINGS

Instructions on how to adjust the radar settings were found. Two examples were discovered throughout the literature search. The first example was from Furuno, a known radar supplier (Furuno, n.d.). The second set of instructions were found in a textbook for electronic and acoustic navigational systems(Kjerstad, 2015, pp. 2-70). They had certain common denominators. These can be summed up as such:

1) Adjust the gain slider first, until there is some faint noise in the radar display
2) Adjust the sea clutter setting
3) If necessary, adjust the rain clutter
(Furuno, n.d.; Kjerstad, 2015, pp. 2-70).

These findings also correspond with the results from the latest research trip, and were utilized during the later concept development.

REQUIREMENTS LIST

GOAL

A requirements list was defined to prior to the conceptualization. This list converted the discovered user needs into concrete requirements for the product. This ensured that the later sketches were based on real user needs.

METHOD

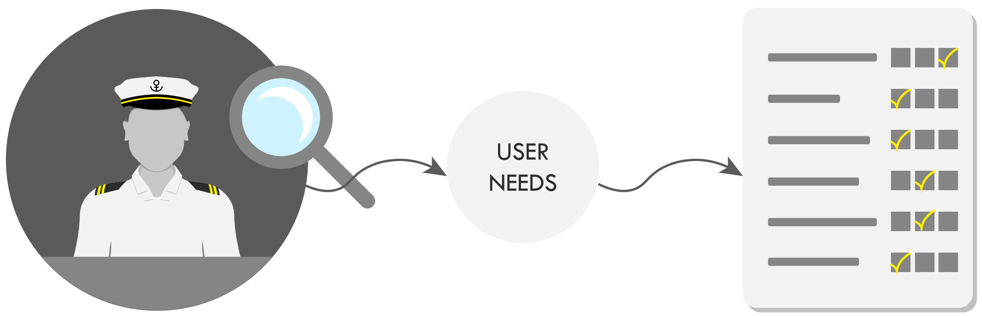
In short, the product should help the navigator answer the following questions:

- What am I seeing and what am I not seeing on the radar?
- Are the settings okay at this time?
- How should I change the settings so that I do not suppress small echoes?

These needs formed the basis of a requirements list. Such a list is a helpful tool to concretize the requirements for a product, both to discover which elements should be in place, and to map their importance in the overall picture. (Preece et al., 2015, p. 259). The requirements list was made to ensure that the sketches would be focused on the problem at hand.

Such requirements can be distilled down from insight gathered in various parts of a project. They can emerge from findings from interviews or lessons from the prototyping process (Preece et al., 2015, p. 259).

Another way of presenting the different aspects of the product could be to create a mind map with the different functionalities. However, this method is not as structured and will not sort the requirements based on their importance, for example (Davies, 2011, p. 280). Thus, a requirements list seemed as a more suitable method for this project.



RESULTS

The requirements were developed based on the findings from the insight process. In short, the challenges had been broken down through journey maps etc, and the requirements were aimed specifically to solve these challenges. For example, the navigators struggled with knowing whether their settings were decent or not. Thus, a corresponding requirement would be that should be alerted when they were suppressing echoes. The list was iterated upon and changed throughout the project, as new findings and insight emerged. These requirements would in turn form the basis for the concepts developed later on.

In short, the product should help the navigator regain control of the radar. The purpose of this product was not to adjust the radar settings for them, but rather show them how to improve their settings. This approach was chosen to prevent de-skilling (Baum-Talmor & Kitada, 2022, p. 1). The goal was rather to show them how their settings affect the radar image, as well as to teach them how to improve them.

The requirements were sorted into three different categories based on the ISO standards (ISO, n.d.):

- Must: This is a requirement
- Should: This is a recommendation
- Could: This is a suggestion that could be implemented

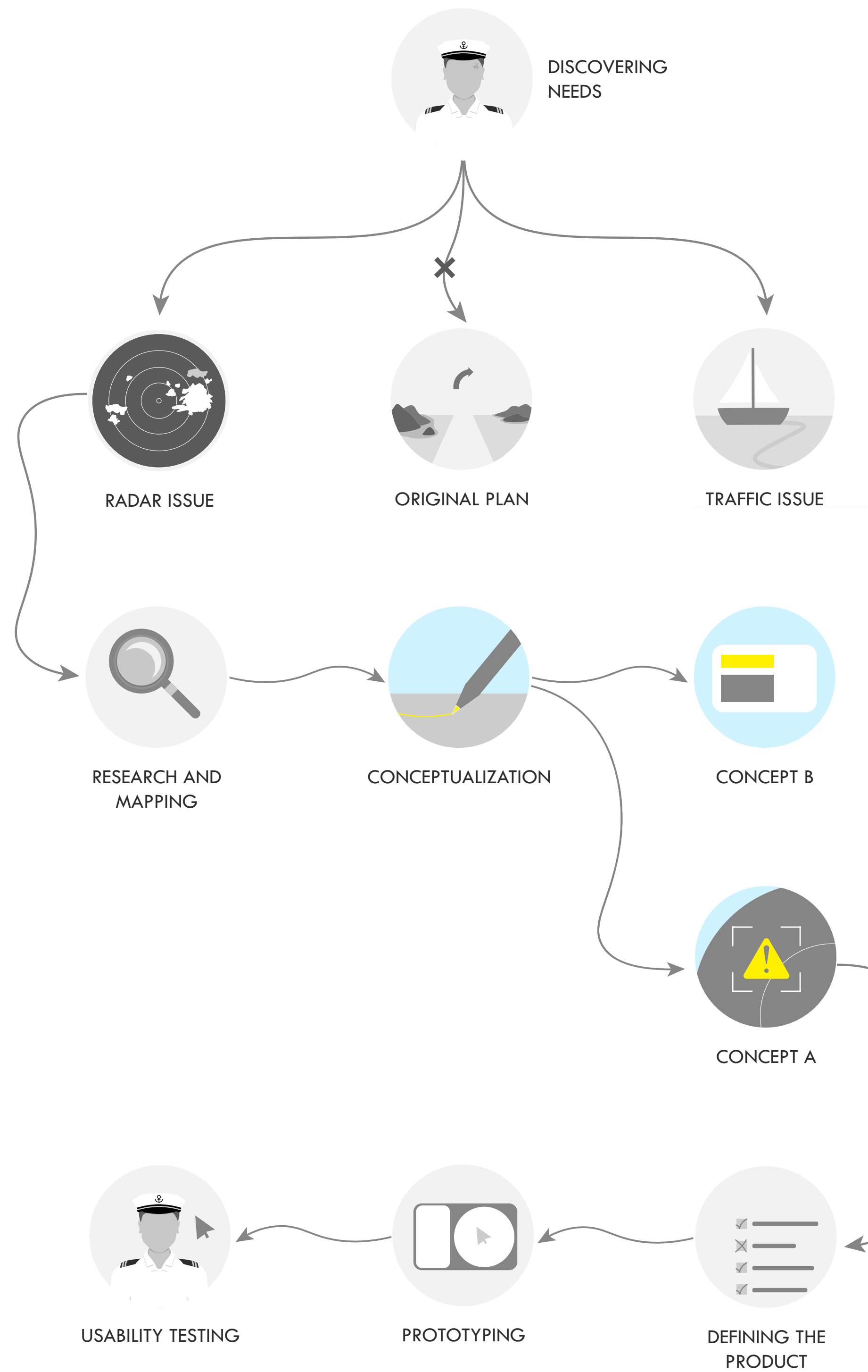
Table 6 contains the set requirements and shows how they were prioritized.

REQUIREMENT	MUST	SHOULD	COULD
Overall goal: Make it easier for the navigator to adjust the settings to a good level.			
Improve the navigator’s situational awareness regarding what is present in the surrounding waters	x		
Let the navigator adjust the radar settings while observing a charted element in the surrounding waters (reference point)	X		
Goal 1: Indicate which echoes are visible, and which echoes are being suppressed			
Let the navigator know when they are suppressing echoes above a certain size		X	
Inform the navigator of the size of echoes they are suppressing (estimate)		X	
Show the navigator a scale, showing them the size of the echoes that are being suppressed at the moment			X
Let the navigator check whether an echo is a charted object or an uncharted one (for example a small vessel)		X	
Automatically highlight the uncharted echoes (vessel echoes)			X
Goal 2: Indicate the quality of the current radar settings			
Let the navigator know when their settings are “bad” (suppressing echoes)	X		
Add a popup or an alert message etc, something informing them of the issue		X	
Goal 3: Indicate how one can adjust the radar settings to make suppressed echoes visible			
Indicate which settings should change improve their radar settings	X		

Table 6. Requirements list for the first concepts.

CONCEPTUALIZATION

After the requirements list had been defined, the next step was to create some low-fidelity prototypes, which took the form of simple sketches. These were shown to a set of navigators and their feedback was used during the development of the next iterations.



LOW-FIDELITY PROTOTYPING

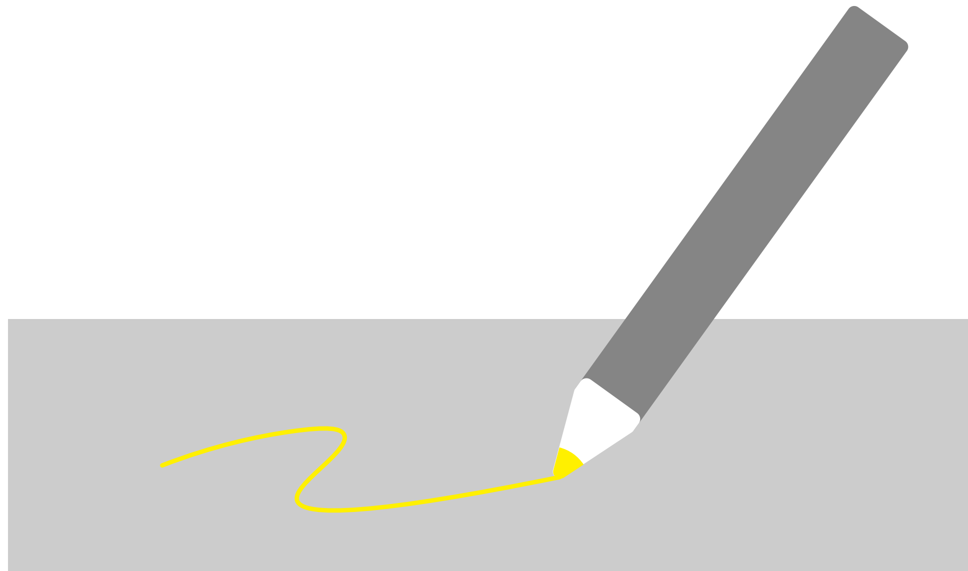
GOAL

A set of low-fidelity sketches were made based on the requirements list. This low-fidelity prototyping made it possible to present the core idea to the users, without spending a lot of resources to do so.

METHOD

The use of such low fidelity sketches encourages users to discuss the ideas themselves, and lowers the threshold for commenting, as it is presented as an unfinished concept. (Preece et al., 2015, p. 426). In addition, it requires little effort to make changes to the concepts, thus facilitating for rapid prototyping. However, simple sketches do not represent the concepts in great detail, and are mere simplifications of the product (Preece et al., 2015, p. 426). High-fidelity prototypes, however, tend to start discussions regarding small details in the design, instead of the idea itself. Such detailed prototypes also require a lot more time and effort (Preece et al., 2015, p. 431). Thus, it made sense to start with low-fidelity sketches at this stage of the project to present the basic concepts to the navigators.

This approach is a key aspect of agile development, where it is preferred to “fail fast” and quickly discover whether a concept works or not. This approach ensures that one does not spend a lot of resources on developing a product, before discovering substantial issues later on. In that way, one can develop a basic concept and test it early on to check whether it is viable or not (Cobb, 2011).



RESULT

The concepts consisted of simple sketches that mostly described one function each. In that way, it was possible to present the ideas to the navigators one at a time. Table 7 shows the focal points of the different concepts.

CHALLENGES	A	B	C	D	E	F	G
What am I seeing and what am I not seeing on the radar?			X	X	X	X	X
Are the settings okay at this time?	X	X	X	X	X		X
How should I change the settings so that I do not suppress small echoes?							X

Table 7. Focal points of the different concepts.

The sketches are presented in the results of the “Sketch discussion” on the following pages.

SKETCH DISCUSSIONS

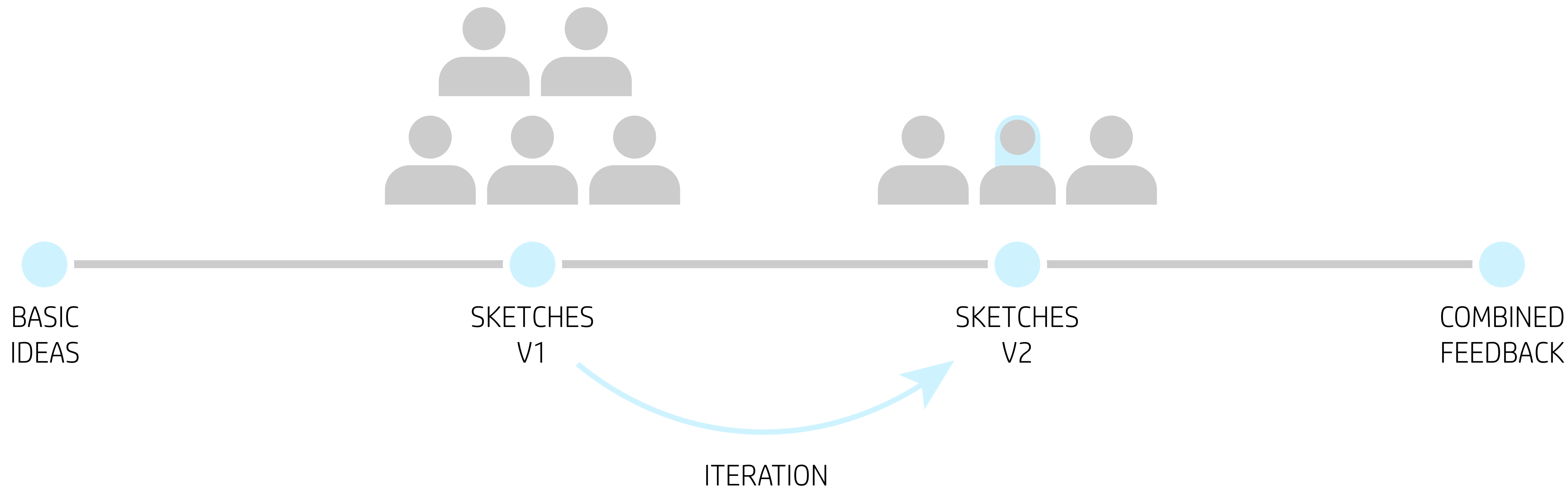
GOAL

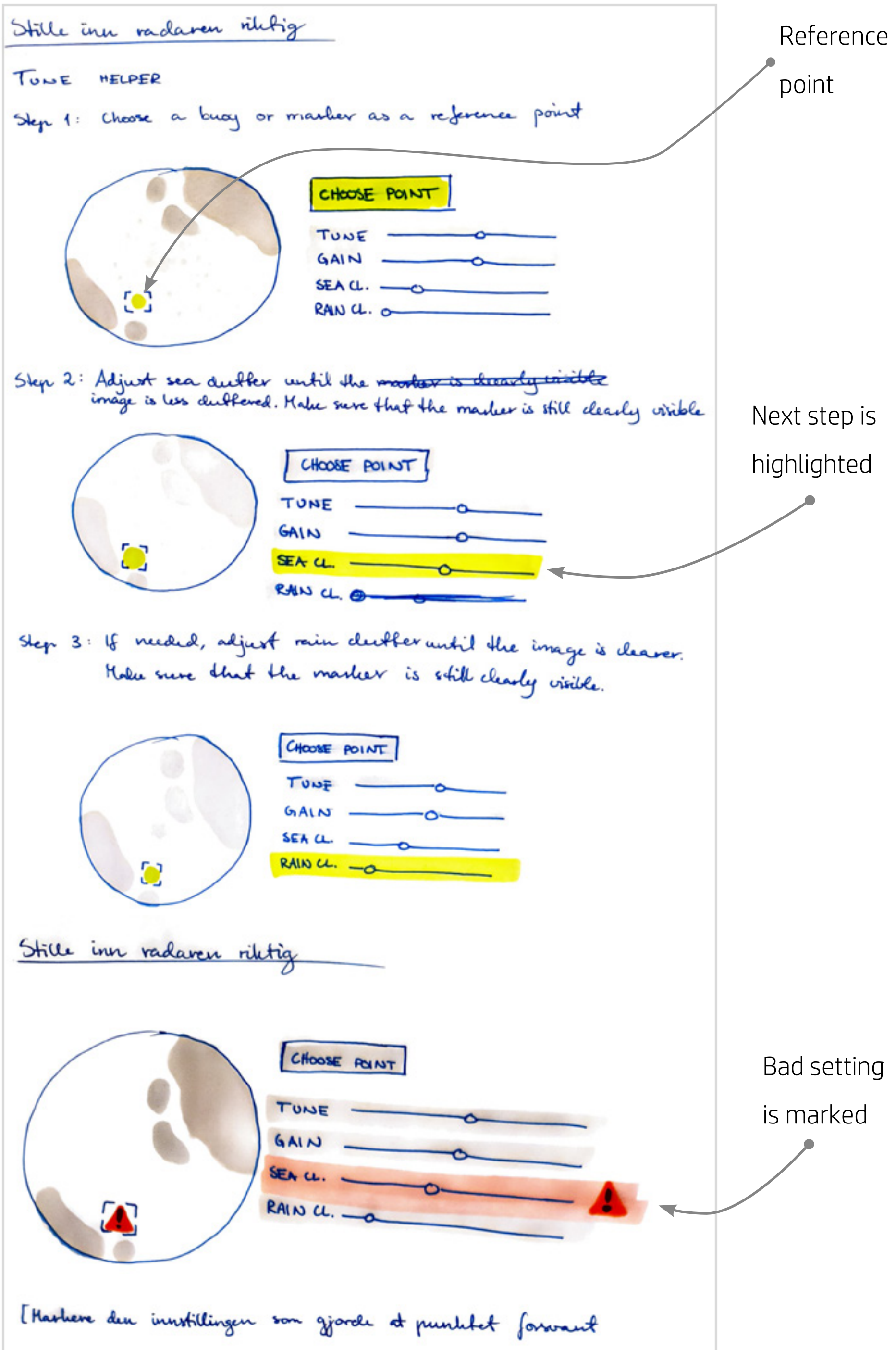
User involvement was one of the main focal points during the project and was a result of the human-centered design approach (Kurosu, 2013, p. 70). As the navigators were well aware of the current challenges with the radar, it also made sense to include them in the development of the potential solutions.

METHOD

The first sketch iterations were presented to five people and the ideas were quickly explained. Their feedback was used to make some changes to the sketches, and the second iteration was then presented to three additional navigators. During each meeting, the overall ideas were discussed, as well as their potential value to the navigators. This qualitative approach gave valuable insight regarding the navigator's opinions on the different concepts.

The discussions were audio recorded and the feedback from these discussions was noted at a later stage.





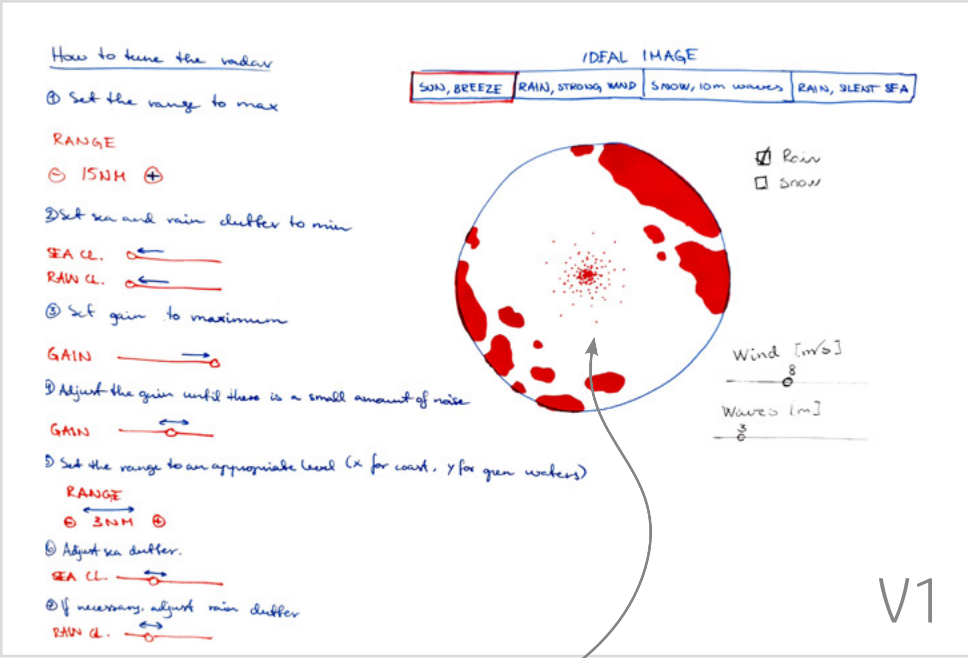
CONCEPT A - TUNING GUIDE FROM REFERENCE POINT

THE IDEA

This is a guide that helps the navigator tune the radar correctly. It does so by tapping into a known method for the navigators, where they use a charted element in their proximity as a reference point. The idea is that they choose such a reference point from the map and are then told to tune gain, then sea clutter, then rain clutter etc. Each step contains descriptive text for instructions. These instructions can be hidden or not, depending on the navigator's preferences. In that way, they can read and use the instructions as long as they feel like they need them, and hide them once they are familiar with the "protocol". In addition, if they adjust the settings to the point where the echo for the reference point disappears or gets too weak, they will get an alert. This alert will show a danger symbol on the map, indicating that something happened to the echo. In addition, a similar symbol will appear next to the last slider that was used, telling them which setting should be tweaked back to the previous setting. In that way, they are simultaneously learning what settings might make echoes disappear. The guide was based on the instructions found as a part of the radar research.

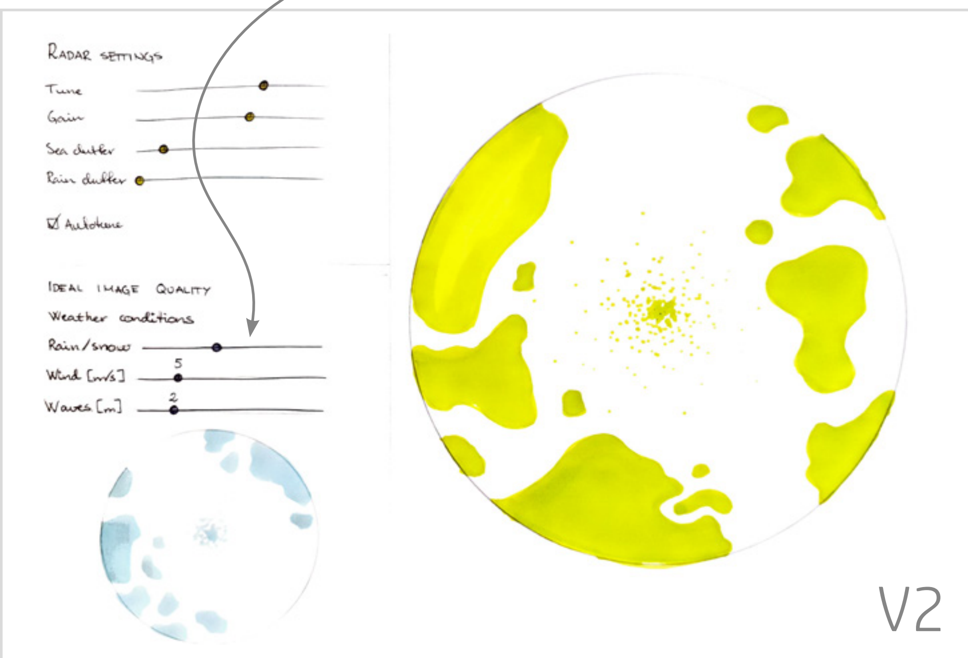
FEEDBACK

Seven out of eight navigators liked the idea. Meanwhile, two people wanted automatic tuning from a chosen point, that would automatically adjust the gain, sea clutter and rain clutter sliders. One navigator did not see the value of this function, as she felt confident on how to tune the radar properly. One mentioned that it is important to choose a suitable reference point, so that none try to tune from a large piece of land, for example.



Expected image quality

Added sliders for weather conditions



CONCEPT B - TUNING GUIDE WITH EXAMPLE IMAGE

THE IDEA - VERSION 1

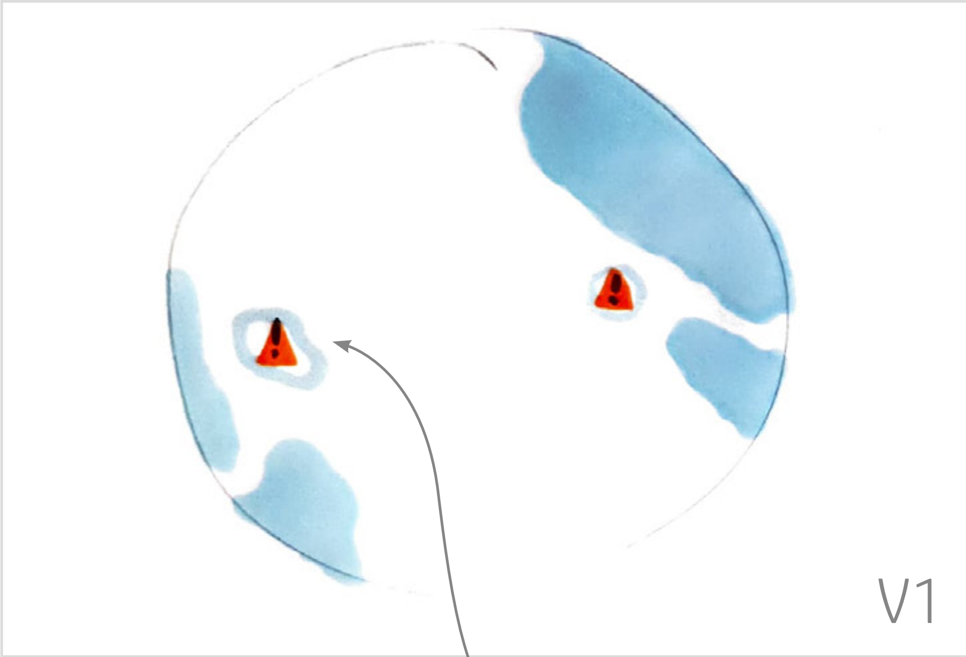
This sketch shows a somewhat similar setup as concept A. On the left, one can see the correct steps one should follow to get a decent radar image. In addition, there is an illustration to the right, showing them what kind of an image to expect in these weather conditions, as the waves and downpour will affect the amount of clutter. There, the navigator can choose the current weather conditions (rain, snow, wind, waves) and then see an example of what a "good" radar image could look like in these conditions. This might stop them from trying to achieve a completely "clean" radar image, at times when this is unachievable without suppressing small echoes.

THE IDEA - VERSION 2

Some changes were made to this concept after the initial five sketch discussions. For one, someone mentioned that there were varying degrees of rain and snow, so an additional slider was added. In addition, the "ideal" image illustration was placed in the lower left corner, as it would never be allowed to cover the radar image due to the IMO regulations (IEC, 2013, p. 184).

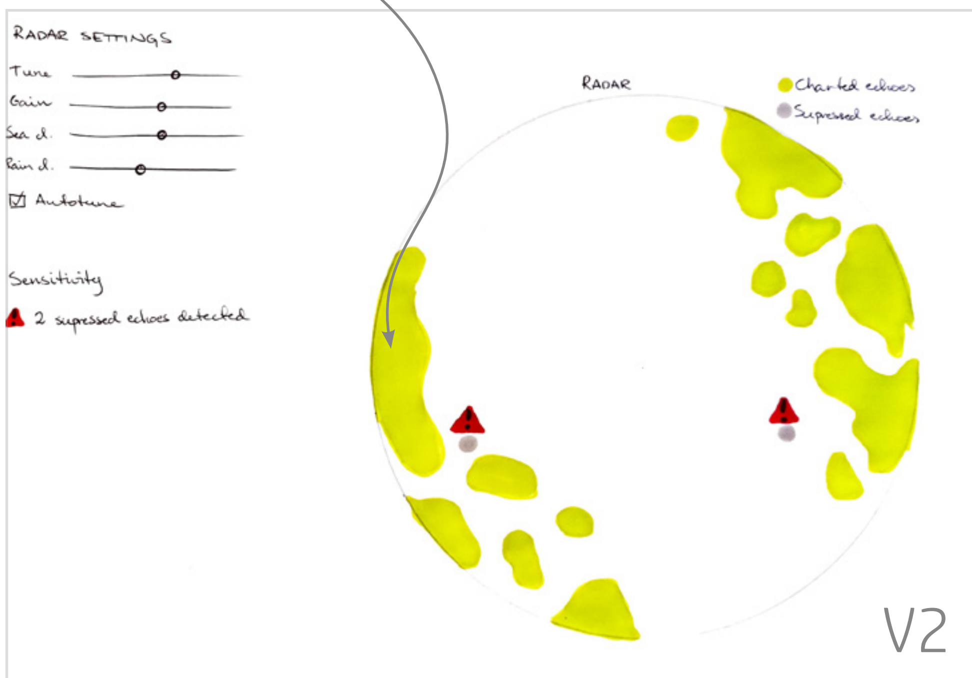
FEEDBACK

Five out of the eight navigators were positive to this idea. However, two preferred the first solution before this one. One mentioned that he would test this against his manual settings and see whether they would differ in any way, as a kind of a quality-check of the system.



Changed color scheme

Suppressed echo



CONCEPT C - SUPPRESSED ECHOES INDICATOR

THE IDEA - VERSION 1

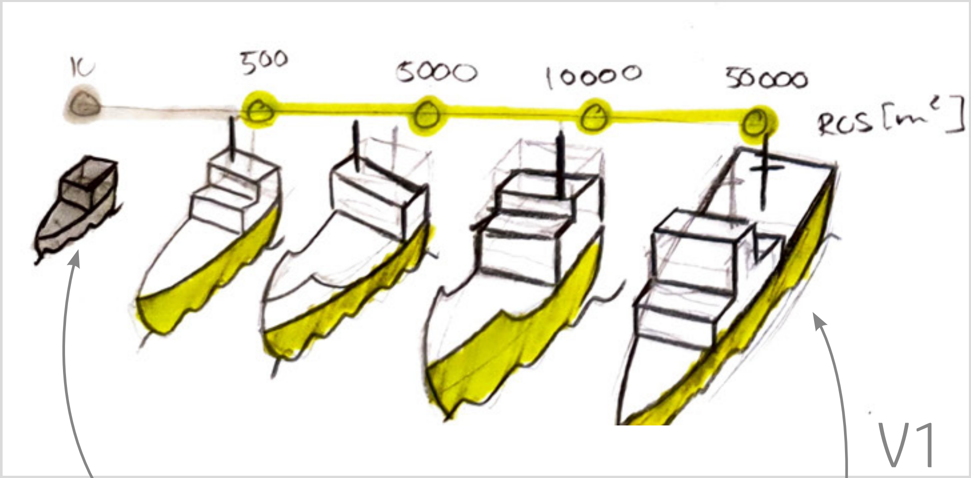
This sketch shows an idea that will let the navigator know which echoes are currently being suppressed. It is somewhat dependant on having objects nearby as reference. The basis of this idea is that the radar and ECDIS images will be compared, and if there are charted elements that should appear as echoes on the radar – but does not – they will be highlighted as red triangles on this display. In that way, the navigator gets informed if they are suppressing any charted echoes.

THE IDEA - VERSION 2

This version had many similarities with V1, but here the colour scheme was changed to match the rest of the sketches. Previously, the colors were not consistent throughout, thus confusing some of the participants in the sketch discussion. In addition, some explanatory text was added in the upper right corner to explain the symbols and colour coding.

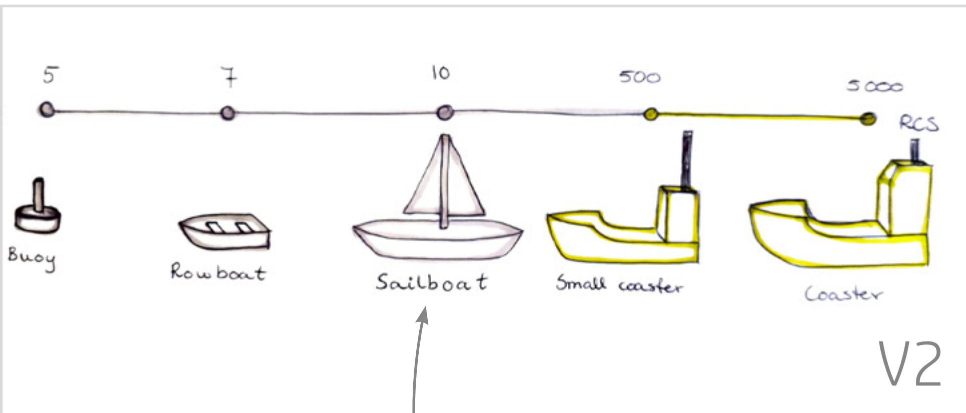
FEEDBACK

Seven out of eight navigators were positive to the idea. One navigator said that he was concerned that the maps were not always up to date, as they were updated once a week. He mentioned that there might be some buoys or markers that were either removed or added to the area, which the ECDIS was not always aware of. One mentioned that he was concerned that the entire screen would be covered in such alertness symbols, while two mentioned that they could use overlay functions today to get the same effect.



Grey icon for suppressed vessel

Green icon for visible vessel



Change of perspective

CONCEPT D - SENSITIVITY SCALE

THE IDEA - VERSION 1

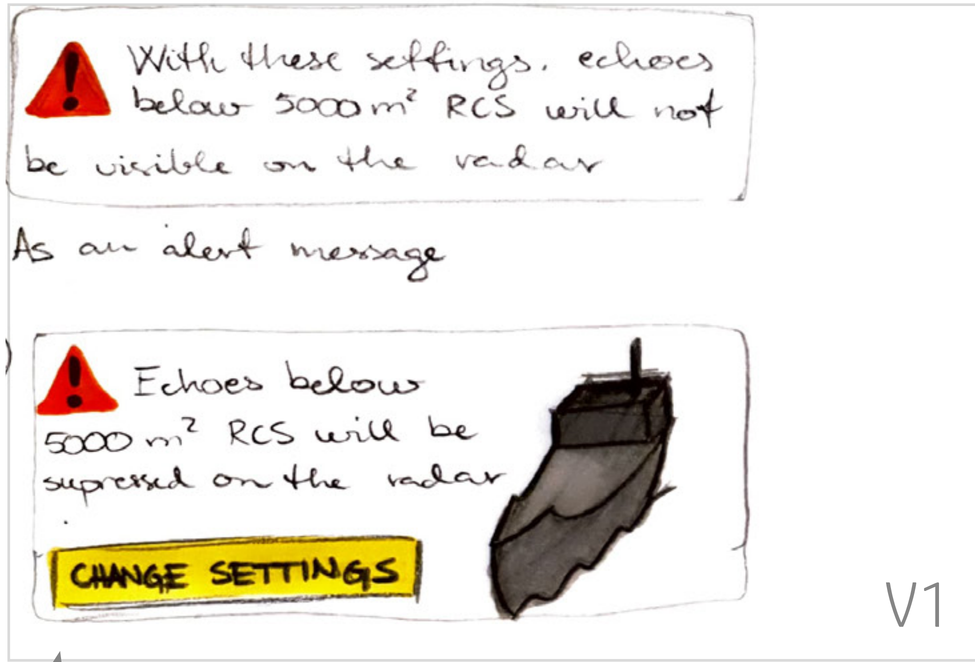
This idea builds upon concept C. Here, one will use the same principle to build a sensitivity scale that tells the navigator which echoes most likely appear on the radar and which ones will not. In that way, one can let them know which echoes they will suppress with these settings. This scale is shown in RCS (Radar cross section), a measurement of how much of the signal is being reflected back by the receiver (Knott et al., 2004). It is supplemented with illustrations of ships with the corresponding RCS values, to give the navigators a better idea of the scale of the visible and suppressed echoes.

THE IDEA - VERSION 2

This iteration altered some of the vessels to add a more nuanced scale, going all the way from a small buoy to a large coaster. In addition, the vessels perspectives were changed to a sideview, thus simplifying the silhouettes.

FEEDBACK

Six navigators were positive to the idea. One mentioned that they did not see the value if they already had the previous function. Others thought that this feature would be very helpful, as it can be difficult to imagine the real-life size of the echoes on the radar. Two people mentioned that the scale was somewhat unrealistic, as large vessels, like a coaster, would have AIS enabled anyway, and if you couldn't see their echoes, you probably couldn't see anything on the radar. Lastly, it became apparent that only one out of the eight navigators was familiar with the term "RCS".



Encourages to change settings

CONCEPT E - SENSITIVITY POPUP

THE IDEA - VERSION 1

This idea has many similarities with the sensitivity scale. Here, the navigator will get a notification telling them the size of the echoes they are suppressing. There are two versions here; one version that only lets them know the RCS of the object, and one version that shows them the RCS and an illustration of the kind of vessel they might be suppressing. It also gives them an opportunity and an incentive to change the settings via the button presented below the notification.

THE IDEA - VERSION 2

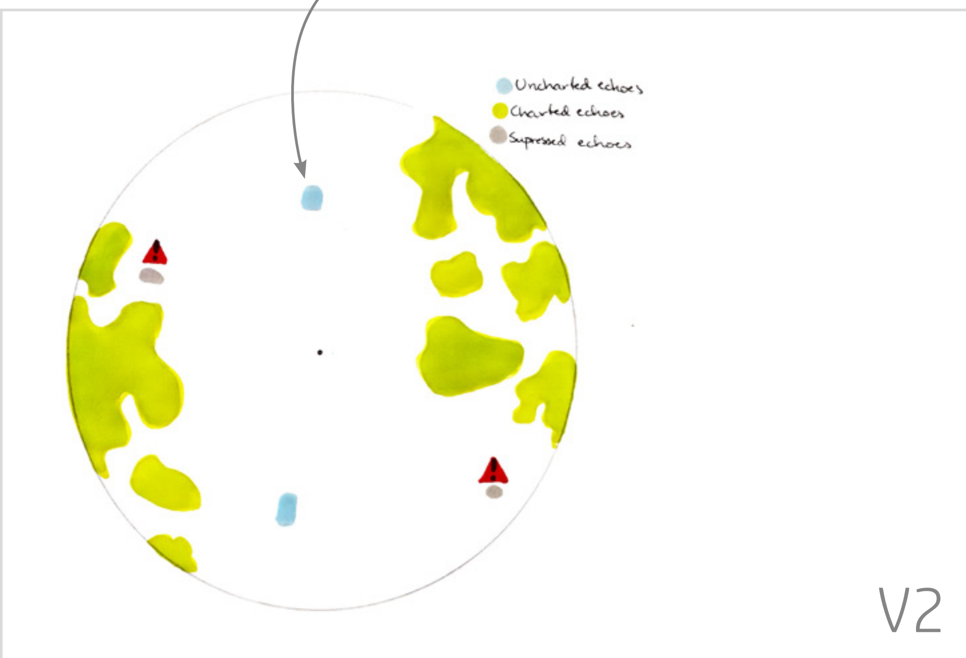
The second iteration had many similarities with V1. However, the second iteration showed all the vessel types that were being suppressed, and not just the size of the vessels one would be able to see on the radar.

FEEDBACK

Four out of eight navigators were positive to the idea. One mentioned that he was worried that it would “drown” in the sea of existing popups. Two others preferred the scale over this feature.

Uncharted echo

Updated color scheme



CONCEPT F - UNCHARTED ECHOES

THE IDEA - VERSION 1

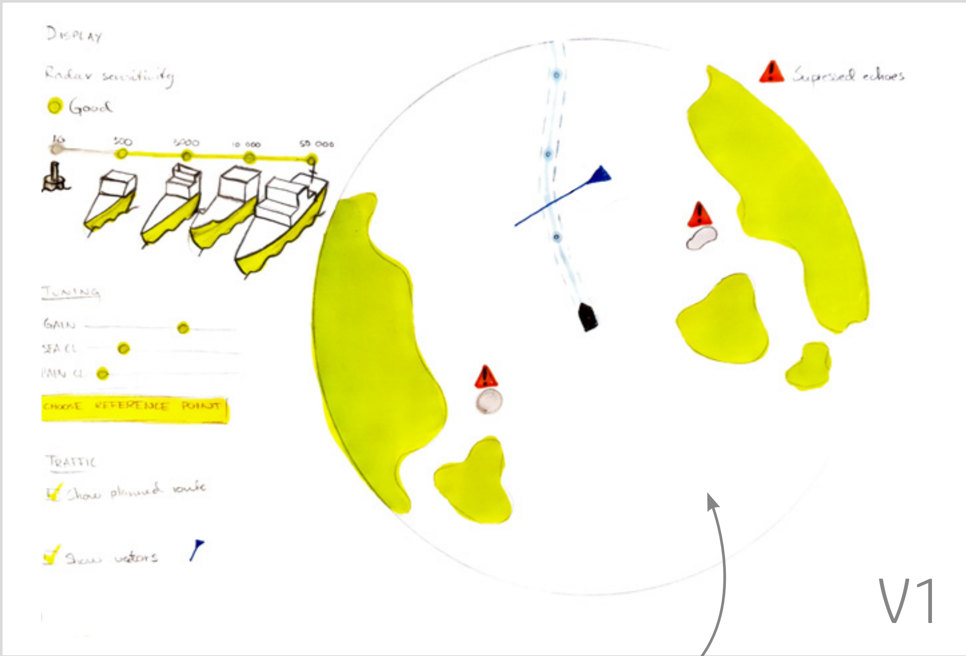
This idea compares the radar and ECDIS displays to see which elements correspond and not. However, instead of just showing the echoes that *should* be there, it also highlights the ones that should *not*. In that way, the navigator becomes aware of potential vessel echoes in the nearby waters. The suppressed echoes will be marked in a different manner, so that it is possible to differentiate the two.

THE IDEA - VERSION 2

The second iteration experienced the same changes as solution C, where the colour codes were updated to match the rest.

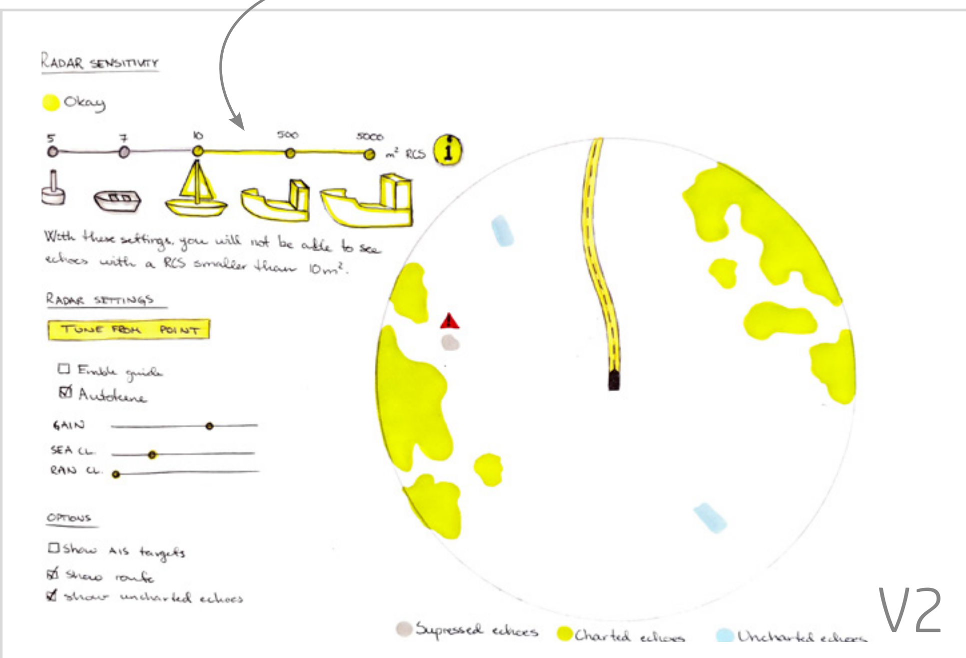
FEEDBACK

Five people though that this was a good idea. Some liked that the uncharted echoes had a different colour from the rest, as it made them more aware of these echoes. Two people were afraid that the display might get covered by a bunch of uncharted echoes, thus disturbing the map.



Combination of different concepts

New scale



CONCEPT G - COMBINATION OF SEVERAL CONCEPTS

THE IDEA - VERSION 1

V1

This sketch shows a combination of several ideas, put together into one single display. Here, one can see which elements correspond with the ECDIS and radar output, shown as green pieces of land etc. The grey icons with orange triangles above them visualize suppressed echoes that are charted on the ECDIS but not visible on the radar. In addition, one can see the ship itself and the plotted route, as well as AIS targets and their vectors. To the left, one can see the sensitivity scale that shows which echoes are being suppressed and not. In addition, one has the oppurtunuity to adjust the radar settings based on a reference point on the map. Lastly, there are some settings regarding the visbliity of the plotted route and AIS targets.

THE IDEA - VERSION 2

The second iteration shared many similarities with the original, but some of the elements were updated. For example, the color coding and scale was updated to match the new iterations.

FEEDBACK

The navigators highlighted different elements in the display. Five were positive to the display in general. One mentioned that the features belong in two different levels. For example, the map is vital and should be visible all the time to give them an overview. Meanwhile, one mentioned that the radar settings would probably be tuned once per shift or so, and did not need to be visible at all times.

GENERAL FEEDBACK

Table 8 shows a brief overview of the concepts and their reception.

CONCEPT	IDEA	POSITIVE
A	Tuning guide from reference point	7
B	Tuning guide with example image	5
C	Suppressed echoes indicator	7
D	Sensitivity scale	6
E	Sensitivity popup	4
F	Uncharted echoes	5
G	Combination of several concepts	5

Table 8. Main findings from the sketch discussions.

The feedback from the navigators made it apparent that three functions were preferred above the others. Specifically, A, C and D got a lot of positive feedback. The accompanying critique also touched points that could be solved without too much trouble. Solution B and G also got a rather positive reception, but solution B had some issues that were potentially quite difficult to solve. On the other hand, the issues with F would only be present in certain situations, for example at times with high traffic density. This feedback was later brought into a difficulty importance matrix and was used to consider which features to implement into the final prototype.

Location

Four people had some ideas regarding where these functions would be located. Three people mentioned that some functions could be implemented into the radar, like the scale, uncharted and suppressed echoes indicator. In addition, several navigators expressed some concern that the shipping companies might not want to buy another display, if these features were to be sold as a separate device.

RESEARCH MEETING

GOAL

A research meeting was scheduled with a person involved with the planning and deployment of navigational aids (buoys etc) along the Norwegian coastline. The goal of this meeting was to gather some insight regarding the RCS (radar cross section) of different objects, as such data could prove valuable to make the sensitivity scale function work. As this function would probably require a kind of RCS database or table, it was relevant to check whether this person knew of any existing records. In addition, the procedure of deployment and charting of new navigational aids was addressed, as the accuracy of the ECDIS charts had been a concern during the sketch discussions.

METHOD

The meeting functioned as a kind of semi structured interview, with some pre-planned questions. Notes were taken during the meeting, and the data was anonymized.

RESULTS AND CONSEQUENCES

During this meeting, it became apparent that they did not have a pre-existing database or list with the RCS of the different objects. This meant that his organization could not provide information that could form the data basis for the sensitivity scale function. This meant that one would have to put together such a database to make this function feasible.

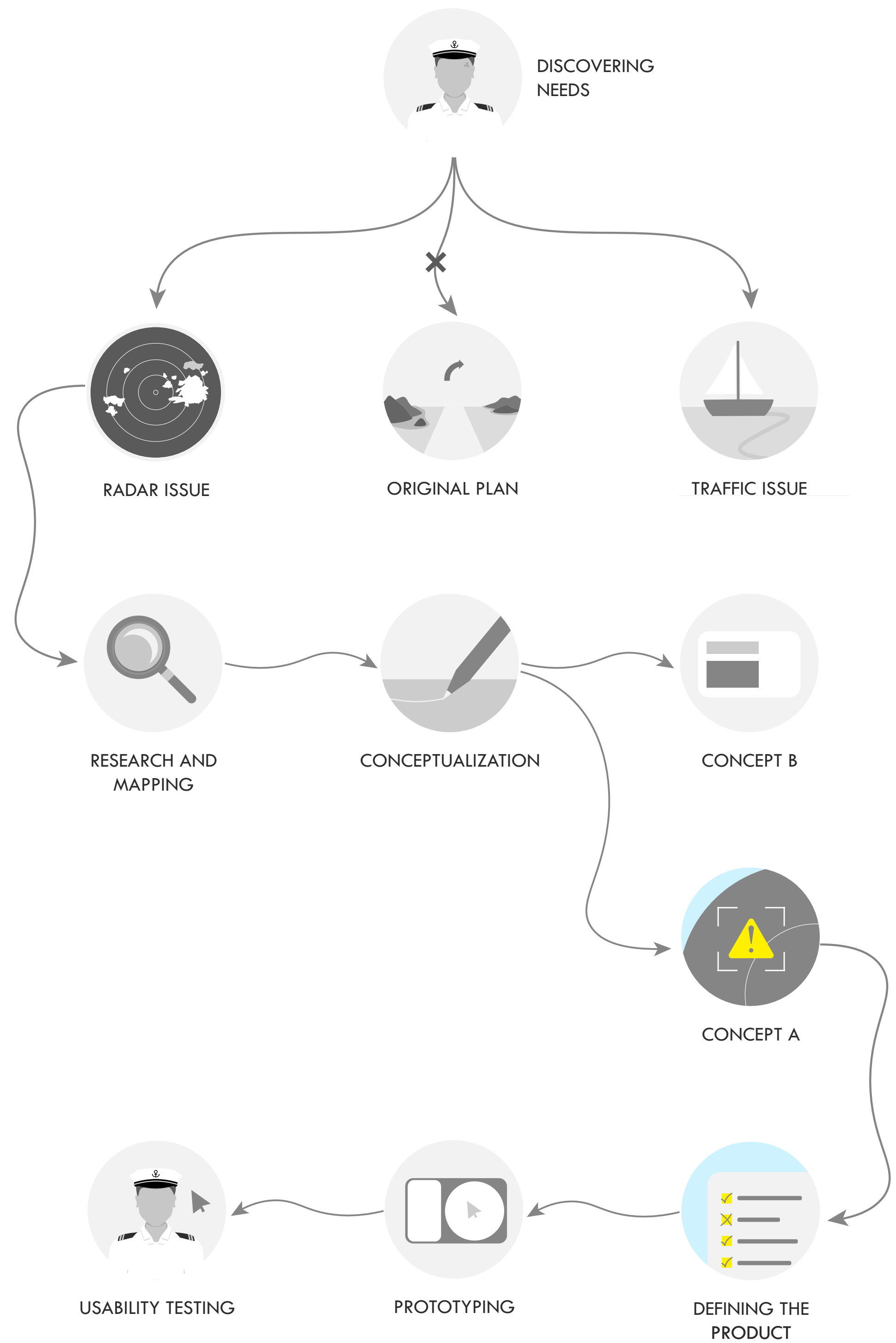
In addition, it was mentioned that registering new markers could be a lengthy process. In the worst case, it might take up to a month between the deployment of the marker until it would be registered in the map. However, they were working on digitalizing the process, which would reduce the processing time considerably.

These findings would have some consequences in regard to the product. The lack of an RCS database meant that such a table would have to be built from ground-up to make the sensitivity scale functional. Meanwhile, the different elements in the ECDIS charts would have to be assigned to a certain estimated RCS.

In addition, the lengthy registration process of new markers could create annoyances tied to some of the functions. For example, uncharted elements would be highlighted in a different colour than the rest. Thus, currently unregistered markers would be marked as uncharted echoes, and might distract the navigators from other, potential vessel echoes.

DEFINING THE PRODUCT

This chapter describes the choices made prior to the final prototyping. During this stage, it was decided which functions should be implemented as a part of the prototype, as well as when they should be present on-screen. Additionally, the prototype requirements were set and the basic structure was defined.



DIFFICULTY-IMPORTANCE MATRIX

GOAL

A difficulty-importance matrix was created to help decide which functions should be implemented in the prototype.

METHOD

This is a valuable tool used for prioritization and decision making (LUMA, n.d.). Each option is evaluated based on its importance to the user, as well as how difficult it is to develop and implement. After this estimation, one can place the options into the matrix and see where the options are positioned. As a rule of thumb, the options to the lower right will give the highest return of investment, and should thus be prioritized (LUMA, n.d.).

In this case, each function was evaluated based on its complexity. For example, solution A exploits an existing feature that is present in the radar today - the ARPA feature - where targets are plotted, and an alert is enabled if they disappear (Kjerstad, 2015, pp. 2-92). Thus, the difficulty of this feature was not deemed very high. However, as solution B had a range of possible parameters that might affect the radar image quality, it was deemed as a feature with a higher difficulty than the other options (Kjerstad, 2015, pp. 2-63). Their value was also estimated to decide their position on the importance-axis of the matrix.

RESULTS

Figure 9 shows the final matrix with the prioritized functions. Meanwhile, table 10 gives an overvew of the idea behind the concepts.

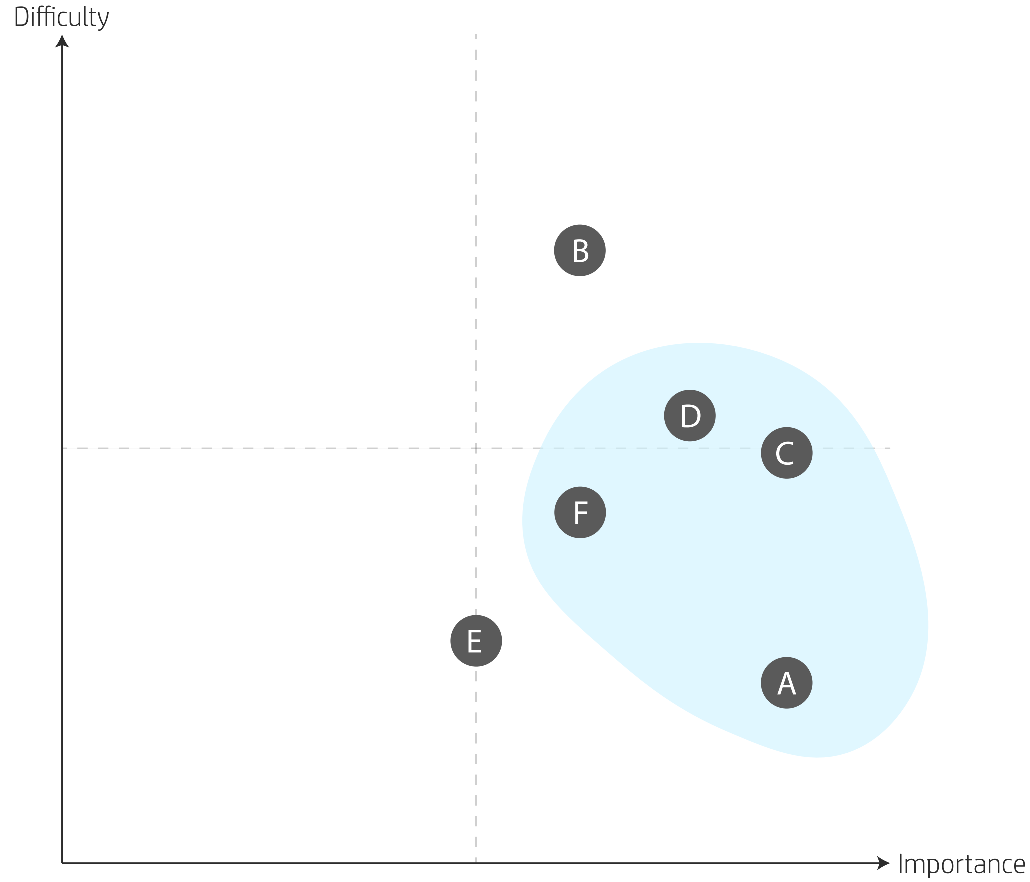


Figure 9. Difficulty-importance matrix.

CONCEPT	IDEA	POSITIVE
A	Tuning guide from reference point	7
B	Tuning guide with example image	5
C	Suppressed echoes indicator	7
D	Sensitivity scale	6
E	Sensitivity popup	4
F	Uncharted echoes	5
G	Combination of several concepts	5

Table 10. Main findings from the sketch duscussions.

DESIGN DECISIONS #2

CHOOSING CONCEPTS

The results from the analysis indicate that concept A, C, D and F would give the highest ROI. These functions were brought into the prototyping phaze, while the remainign functions were excluded from the final prototype. In addition, these chosen functions were included when defining the MVP (Minimum Viable Product).

LOCATION

It was important to decide whether these functions should be implemented as a part of the existing radar or become a part of a separate device.

Most of the functions were added to indicate the quality of the current radar settings, while the rest were tied to continuous monitoring of the echoes in the display. By integrating these functions in the radar, one would gather similar functions in one display. The integration of these functions would involve them as a part of the radar tuning process itself, and make them easily accessible to the navigator throughout. This could in turn ensure that the radar would be able to reach its purpose: to ensure safe navigation at sea.

On the other hand, making a separate device would have brought its own set of questions, some mentioned by the navigators during the sketch discussions. For one, where should this device sit? There is a risk that such a device would simply be placed at a rather random location at the bridge, with little to none concern regarding system design. Additionally, why should the shipping companies buy this separate device? It would have brought forth a list of questions and uncertainties.

The conclusion was that it would be most beneficial to include these functions into the existing radar display, due to their strong connection to the instrument, as well as the feedback from the navigators. However, there were still some unanswered questions. For example, would there be room for these solutions on the radar? One possible solution here would be to add them in a sort of widget window, which is present on radars like the NACOS Platinum from Wärtsilä (Wärtsilä, 2016b, p. 3). This question is discussed in more detail in the prototyping-chapter.

WORKFLOW DIAGRAM

GOAL

A workflow diagram was made to map the potential paths and pitfalls the users might encounter throughout their radar tuning.

METHOD

This process is closely tied to one of Nielsen's usability heuristics, as it mapped possible user errors and choices. Workflow diagrams map the branching patterns and choices the user might encounter. One can again use that overview to add relevant features where they are needed to prevent user errors (Nielsen, 1996, p. 1). In that way, it helped discover which features the final prototype should contain.

The use of workflow diagrams is a way of presenting a user's approach to a certain activity. Such a diagram presents which actions they perform, and in which order they do them. An alternative approach could have been to use user journey maps for the same purpose. However, such journey maps often follow one string of events, while the workflow diagram opens up for branching choices that the user might encounter. Thus, a workflow diagram was deemed as the appropriate method in this case (Preece et al., 2015, pp. 405-406).

RESULTS

V1

The first workflow diagram was used to map the users' actions today, much like the previous journey maps. It mapped a scenario where the navigator would adjust the radar settings, and how they might check the quality of those settings.

V2

The second workflow diagram was made as a part of a brainstorming exercise. This diagram shows how the navigator might interact with a radar with the chosen functions from the sketch discussion. It shows how the navigator might be alerted of poor radar settings, and how they are guided through the process of adjusting them. This diagram made it apparent which screens and functions should be included in the final prototype, and mapped potential user errors.

V3

Lastly, an extended version of the workflow diagram was made. This diagram was based on the previous version, with some alterations. In short, this diagram also mapped when the elements would appear on-screen. The functions would mainly be divided into three groups

- Instant – They would appear as a reaction to a certain action
- While tuning – They would appear during the adjustment of the radar settings
- At all times – They could be always present, as a feature for monitoring the situation

For example, the red indicator for the reference point would appear in an instant, and only when specific requirements were met. However, the sensitivity scale could stay on-screen as long as they were adjusting the settings. It might even stay on-screen during the sail, continuously telling them the state of the current settings. All these features could be incorporated in a widget-window, so that the navigator could choose when to have them on-screen. The findings from this diagram are listed i table 14 on page 109. They proved valuable during the later prototyping.

V1

INITIAL TUNING AND QUALITY CHECK (CURRENT SITUATION)

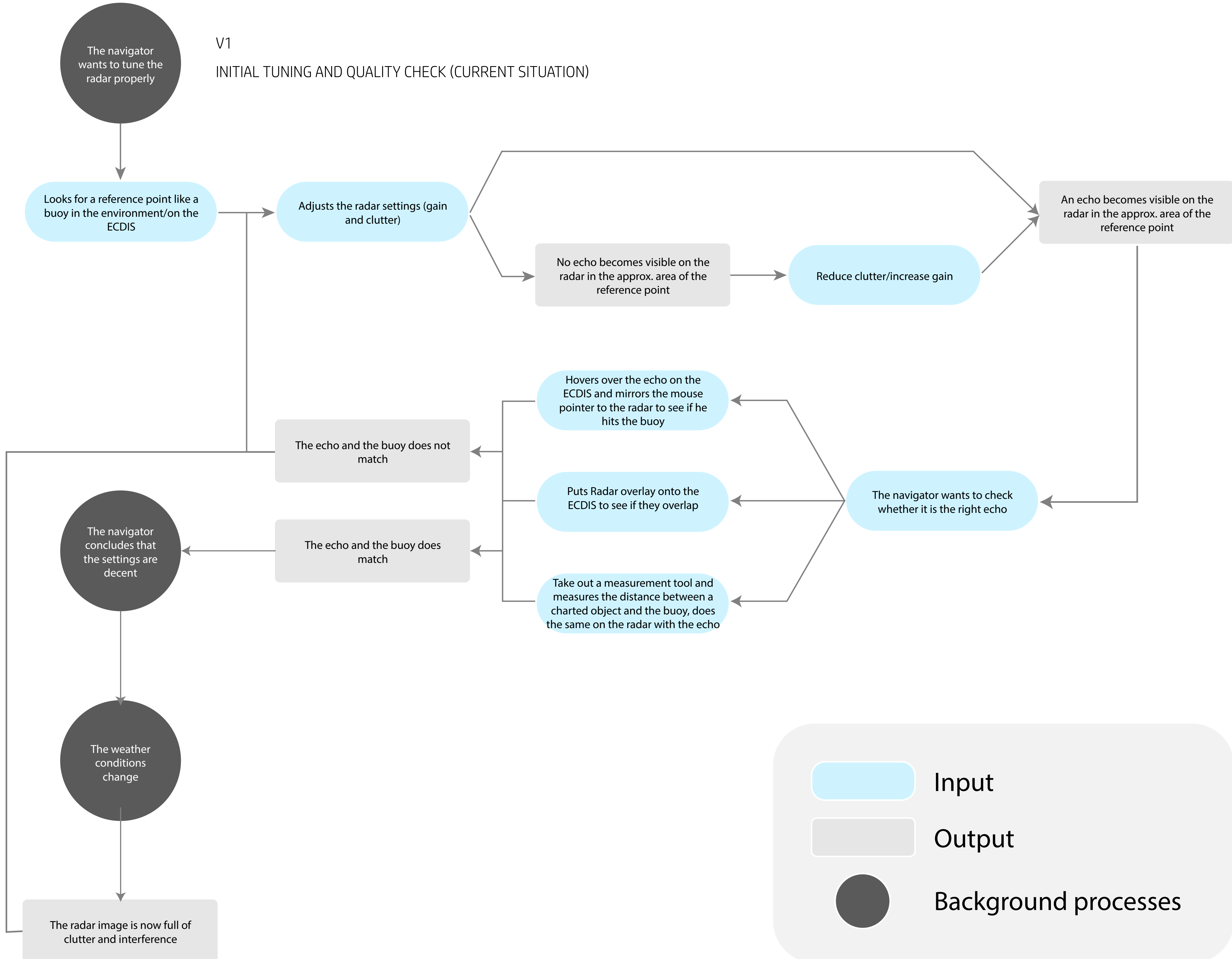


Figure 11. Workflow diagram for the normal radar tuning process.

V2

INITIAL TUNING AND QUALITY CHECK (WITH ADDED FUNCTIONS)

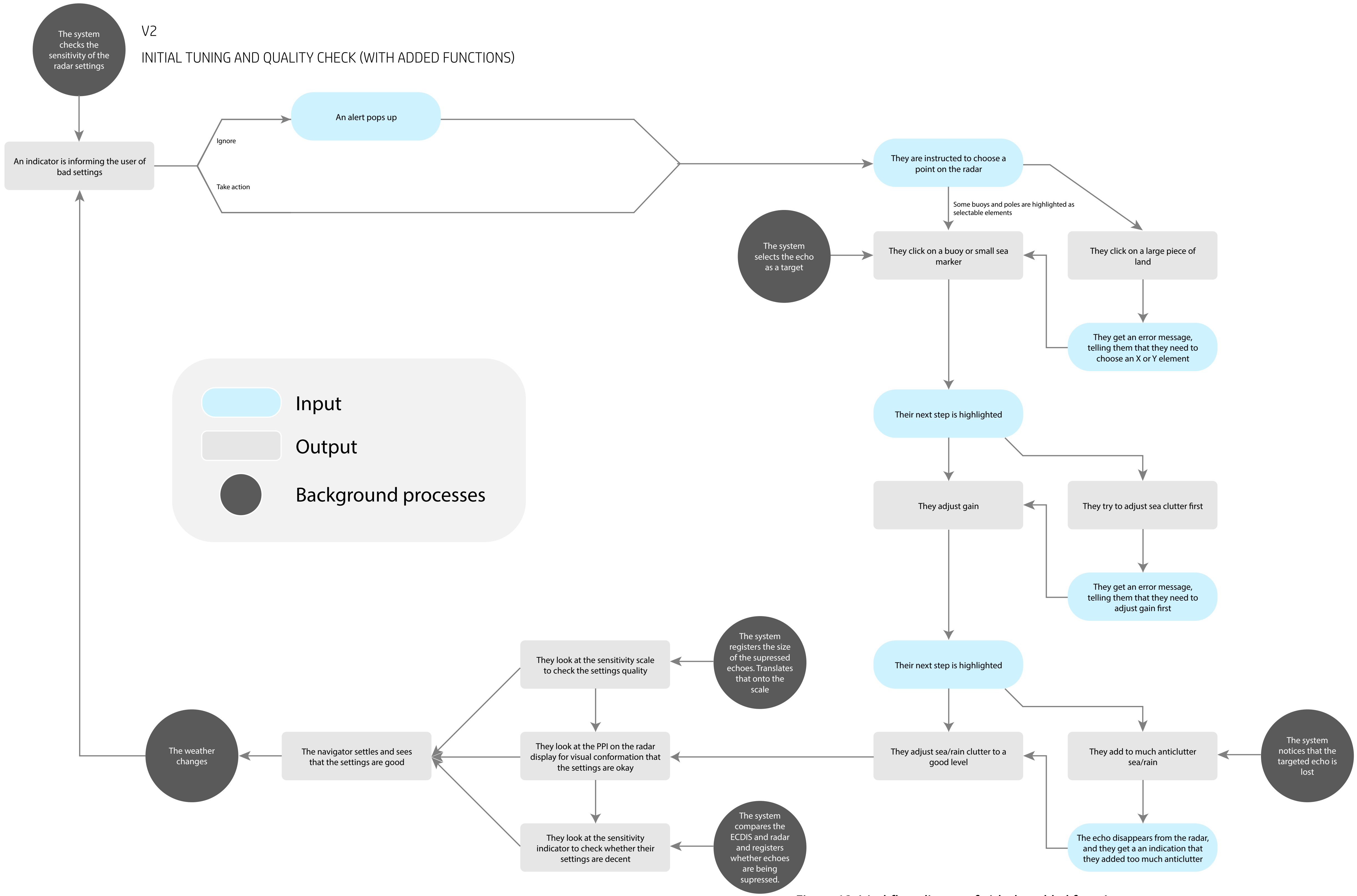


Figure 12. Workflow diagram fwith the added functions.

V3

INITIAL TUNING AND QUALITY CHECK (+FUNCTIONS AND APPEARANCES)

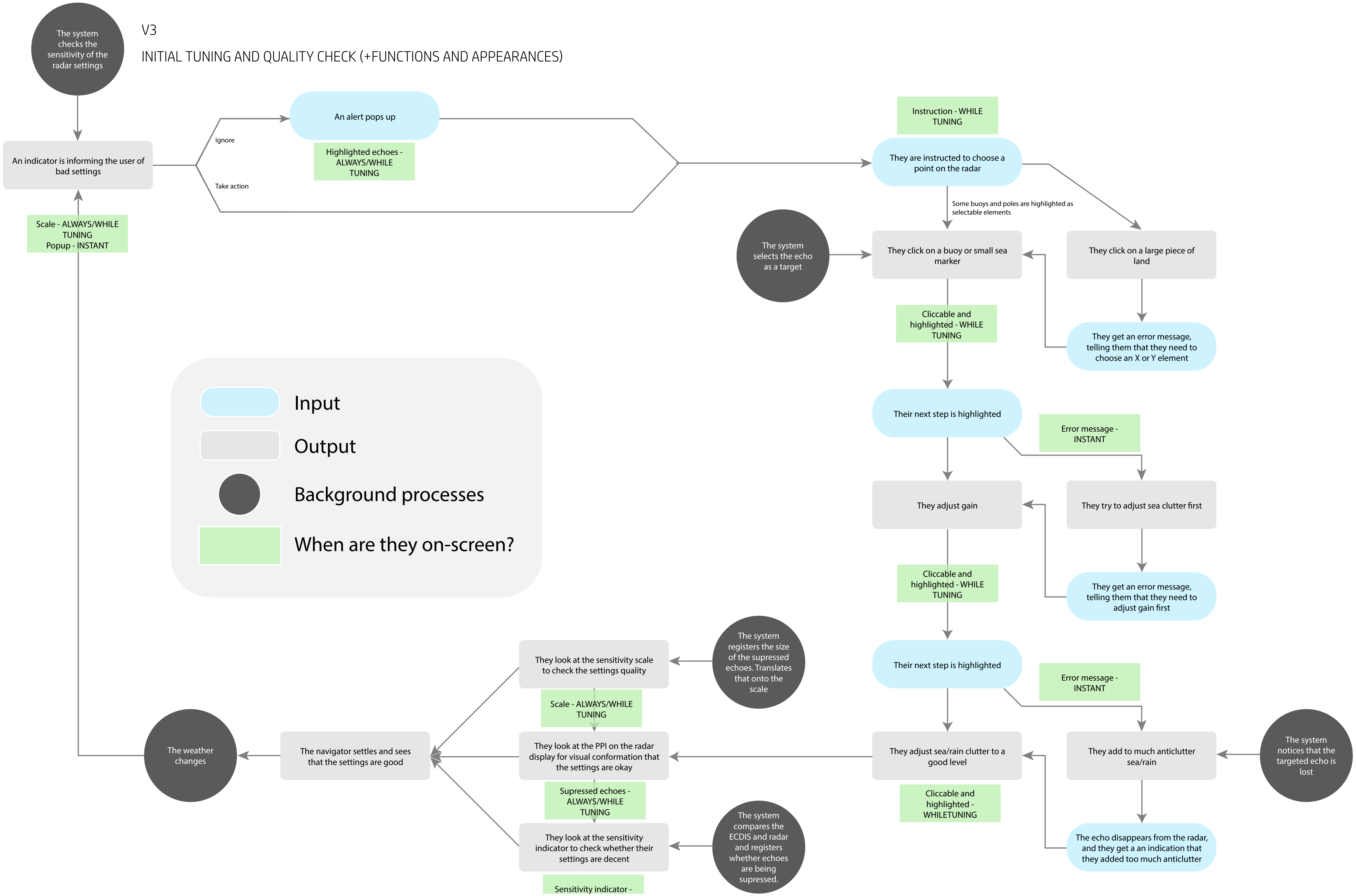


Figure 13. Workflow diagram with the functions and appearances.

RESULTS FROM V3

Tabe 14 and 15 show the main findings from the workflow diagram V3. They include an overview of the different functions and when they would appear on-screen.

FEATURE	ON-SCREEN (WHEN)
EXISTING FEATURES	
Auto-tune	At all times
Sea clutter slider	At all times
Rain clutter slider	At all times
Gain slider	At all times
PPI	At all times
Range slider	At all times

Table 14. Appearance of existing features.

FEATURE	ON-SCREEN (WHEN)
NEW FEATURES (AS A PART OF THE WIDGET)	
Sensitivity indicator	At all times
Sensitivity scale	At all times/while tuning
Popup, error	Instant
Highlighted suppressed echoes (in PPI)	Instant/while tuning
Flashing suppressed echoes (in PPI)	Instant
Tuning guide	While tuning/when enabled
Highlight potential reference points	While tuning
Highlight bad slider-setting	While tuning
Popup, success	When enabled
Map showing suppressed and uncharted echoes	At all times
Visibility switch for uncharted echoes in PPI	At all times
Visibility switch for suppressed echoes in PPI	While tuning/when enabled

Table 15. Appearance of new features.

DEFINING AN MVP

GOAL

An MVP (Minimum viable product) was defined to help prioritize and discover which features should be present in the final prototype.

METHOD

The difficulty importance matrix and workflow diagrams had made it apparent which features could be implemented into the radar, as well as when they should be present on-screen. However, it was necessary to define the functionality that should be present in the prototype. Thus, an MVP was defined, and a corresponding requirements list was developed.

Lenarduzzi & Taib defines an MVP as “a version of a new product, which allows a team to collect the maximum amount of validated learning about customers with the least effort”. (Lenarduzzi & Taibi, p. 115,2016).

RESULTS

As the goal of the user test was to check the usability of the main functions, it was not deemed necessary to make the entirety of the UI interactive. Thus, the main functions were prioritized and made the basis for the requirements list for the prototype.

The MVP would consist of a normal radar with five added functions:

- Tuning guide
- Tuning from reference point
- Sensitivity scale
- Mini map
- Anomalies list

RESULTS

Table 16 shows the requirements list for the prototype of the MVP.

REQUIREMENT	MUST	SHOULD	COULD
Adjusting radar settings (gain, sea clutter, rain clutter)			
The radar echoes change according to the settings	X		
The clutter dots increase or decrease in size and eventually fade if the settings are suppressing echoes		X	
The user can change the gain, sea clutter and rain clutter levels	X		
The setting levels change (visually) as they are interacted with	X		
Suppressed echoes in the PPI are highlighted on the mini map	X		
Corresponding suppressive settings are highlighted		X	
The suppressed echo is highlighted in the PPI		X	
The user can hide the “suppressed echo”-icon in the PPI	X		
Tuning guide			
The user can open a guide that will explain the approach to ensure decent radar settings (gain, sea and rain clutter levels)	X		
The user can choose a reference point to utilize throughout the guide	X		
The guide will inform the user of the main functions			X
Tuning from reference point			
The user can choose a reference point on the map	X		
The user can highlight possible reference points by hovering over them			X
The user can mark the chosen reference point by clicking it		X	
The icon of the reference point will change depending on the settings (visible/suppressed)	X		

Table 16. Requirements list for the MVP

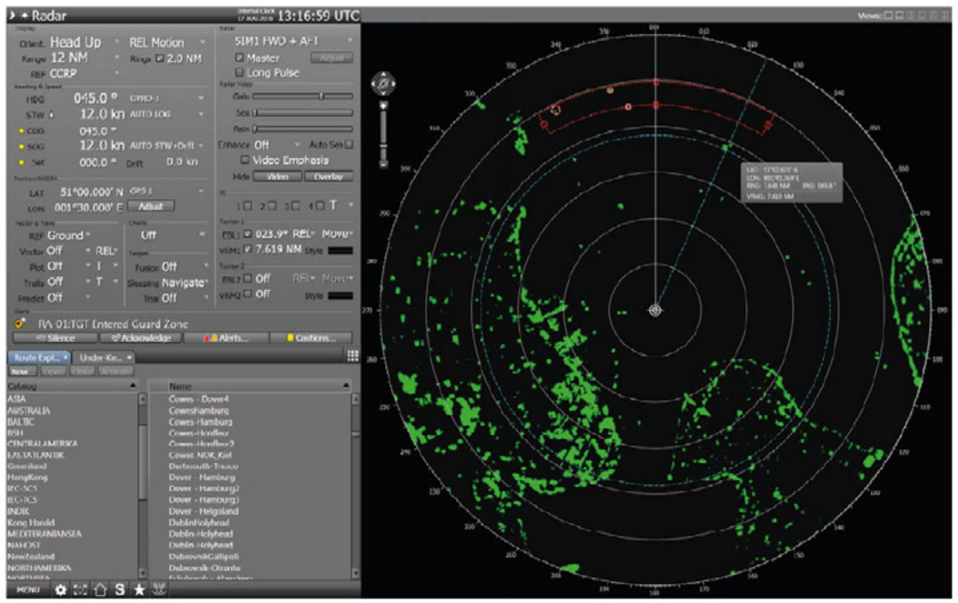
Sensitivity scale for reference			
The sensitivity scale is responsive and be affected by the radar settings	X		
The scale includes illustrations of relevant objects (buoy, small boat, fishing vessel, etc)		X	
The illustrations in the scale will change colour between grey and green depending on the settings	X		
Mini map			
The prototype contains a mini map in the corner showing the area that is visible on radar	X		
Suppressed echoes are marked in the mini map as a red triangle icon	X		
Uncharted echoes are marked in the mini map as a blue icon		X	
Charted echoes are marked in the mini map as green shapes that correspond to the chart data		X	
The users are able to highlight uncharted echoes in the PPI		X	
These uncharted echoes are marked with icons/markings in the PPI		X	
The user is able to enable/disable this function (button	X		
Anomalies list			
An anomalies list will be present in the widget-window		X	
It informs of the number of uncharted echoes		X	
It informs of the number of suppressed echoes		X	
It informs of the number of AIS targets		X	

Table 16. Requirements list for the MVP

FOUNDATION

UI

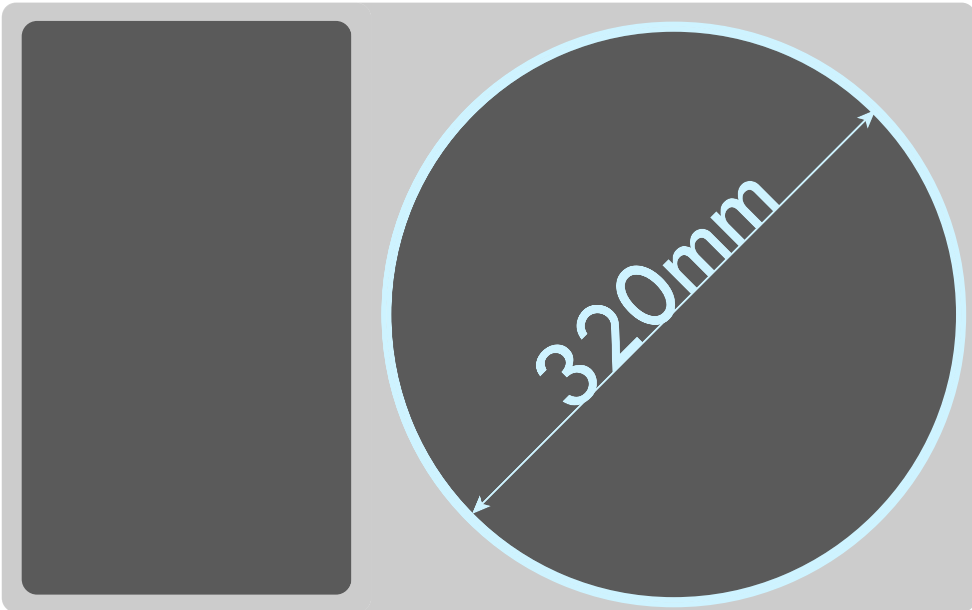
As the final prototype was supposed to resemble a real radar, its UI was based on an existing radar called “NACOS Platinum” from the Finnish manufacturer Wärtsilä. This UI includes a range of features, most importantly the PPI itself, the radar settings as well as alert functions and so on. In addition, this radar has a pre-existing widget window in the lower left corner; a flexible piece of the UI that can house different functions. Thus, it made sense to incorporate the developed functions into this widget window (2016b, p. 3).



From Wärtsilä NACOS Platinum [Radar display], by Wärtsilä Coroporation, 2016t, Wärtsilä (https://www.wartsila.com/docs/default-source/product-files/aut-nav-dp/ivc/brochure-o-ea-nacos-platinum.pdf?sfvrsn=789bae45_4). Copyright © 2016 Wärtsilä Corporation.

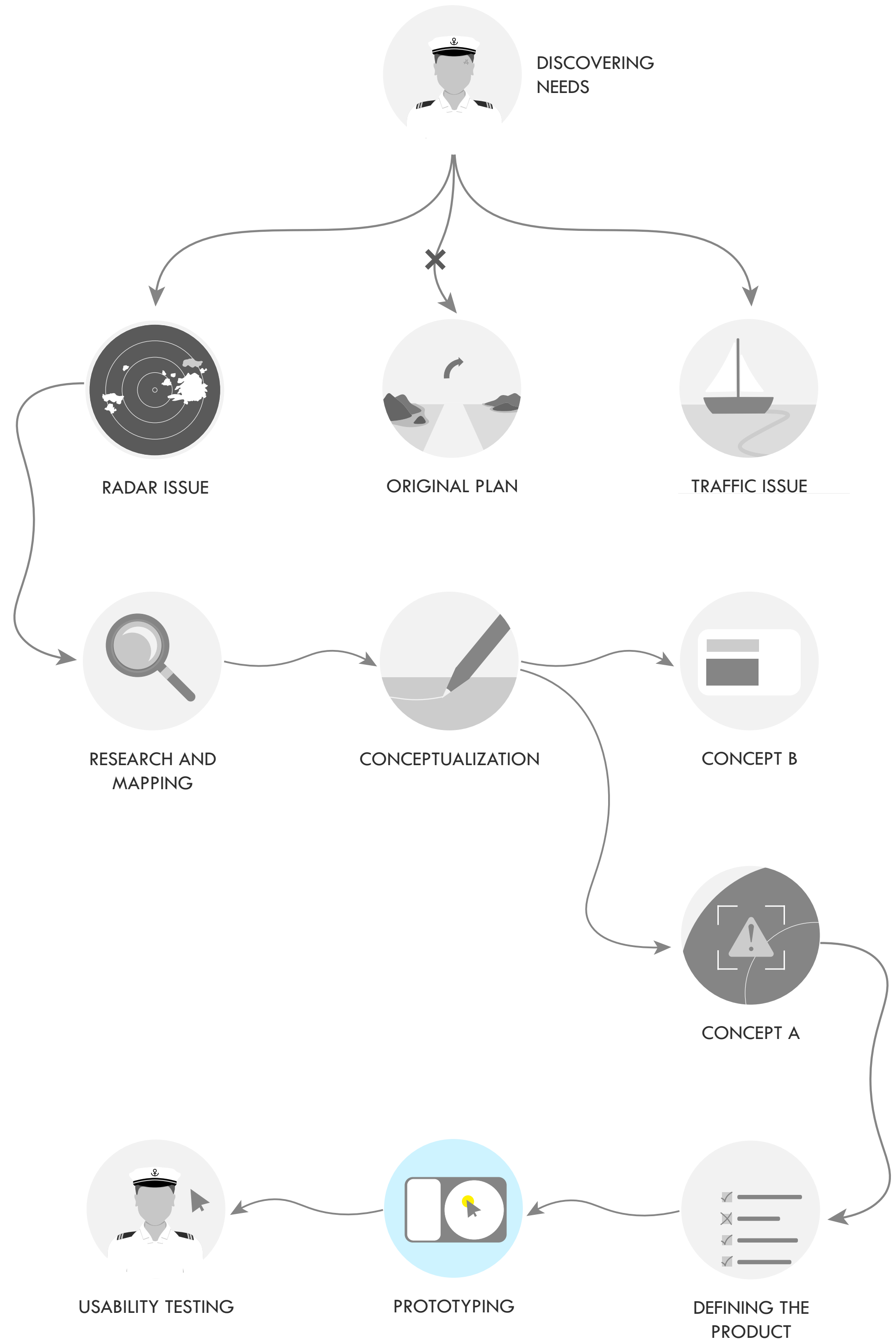
SCREEN SIZE

The screen size and ratio for the prototype was based on the Wärtsilä radar, as well as the IMO regulations for such displays. Realistically, the PPI would have a diameter of 320mm, to correspond to the IMO regulations (IEC, 2013, p. 184). This meant that the display would correspond to a 25-inch display (TVSizes, n.d.).   .



PROTOYPING

This chapter describes the final prototype and its features. Here, one can find thorough explanations of the added elements, as well as how the design principles were utilized throughout.



HIGH-FIDELITY PROTOTYPING

GOAL

A high-fidelity prototype was made to later test the effectiveness of the chosen functions. The final prototype is based on the requirements list for the MVP.

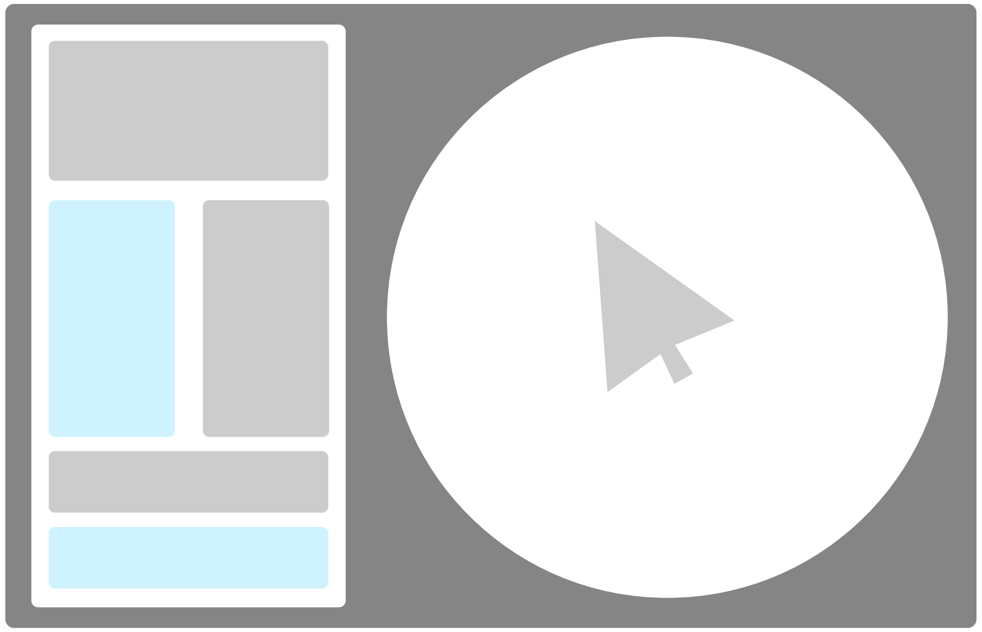
METHOD

There are a range of advantages and disadvantages with high-fidelity prototyping, compared to the less resource-consuming low-fidelity prototyping. These are listed below

HIGH-FIDELITY	LOW-FIDELITY
− Resource-demanding	+ Less resource-demanding
+ Focus on key aspects	+ Easy to make changes
+ Interactive	− Simplification of the real product
+ Feels like a finished product	− Inproper representation of some features
+ Improved realism	
− Can set high expectations	

(Preece et al., 2015, pp. 428-429)

High fidelity prototyping was deemed a much more suitable method for this step in the process, to see how the different functions would change the tuning process. The prototype was made in Figma, a tool commonly used for the creation of interface designs (Bracey, 2018).



RESULTS

The final prototype emulates a real radar, and lets the navigators adjust the radar settings like they do in real life. It lets them choose between two different help-functions:

- A tuning guide, that explains the added features and gives the user a step-by-step guide of which settings to adjust. This approach also includes the selection of a reference point, whose icon will change depending on the quality of the settings

- The option to tune only from the reference point. The user chooses the reference point and adjusts the settings without any guide. However, this path includes the same indicators as the guide, like the sensitivity scale and mini map.

Additionally, one can find these three features in the widget-window:

- A mini map, that highlights suppressed and uncharted echoes, as well as AIS targets. It also shows them the land contours, marked in green.

- A sensitivity scale, that gives them an indication of the size of the vessels that will likely appear on the radar. If they are suppressing buoys, for example, this icon will be greyed out on the scale

- An anomalies list, that gives them a brief overview of the anomalies present in the mini map. Additionally, it contains a feature that lets them highlight the anomalies in the PPI.

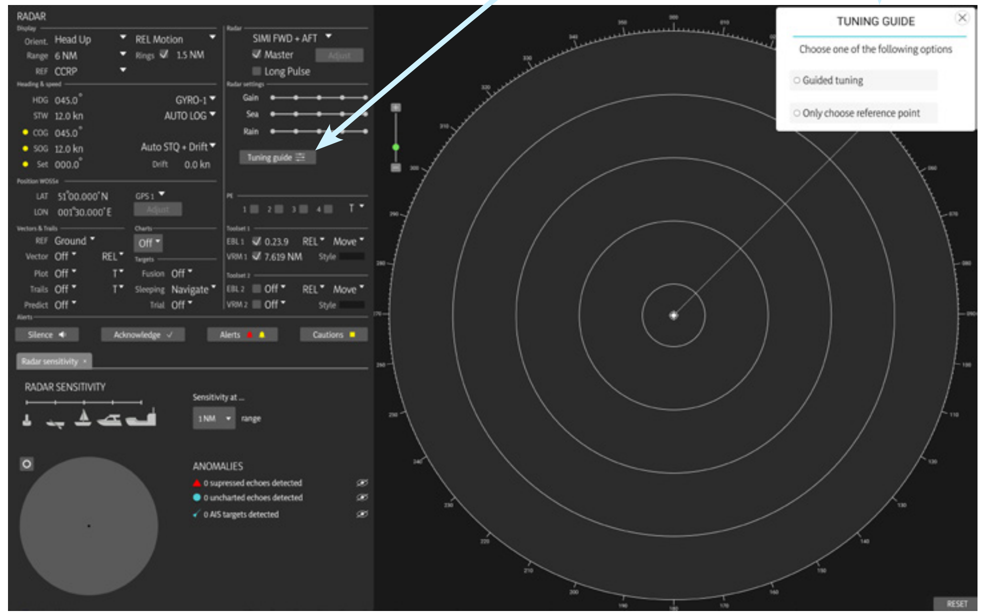
PROTOTYPE LINK

The link below leads to the final prototype.

https://www.figma.com/proto/f9sf4xzo258kTa70cFHrMu/Radar?node-id=276%3A106426&scaling=contain&page-id=116%3A81&starting-point-node-id=276%3A106426

If you click it, you will reach the startup screen of the prototype. First, make sure to choose ”fit to screen” in the upper left corner to make it fit your screen and to give it the right porportions.

Then, click the ”Tuning guide” button in the radar menu to the left. This leads to the two paths that were developed as a part of this project. You can either choose ”Guided tuning”, which will lead you to the tuning guide, or you can click the option ”Only choose reference point”, which will let you adjust the settings with more freedom.



REALISM

SHORELINE

The task of emulating a real radar proved to be a challenge. For one, the shoreline went through several iterations. The original shoreline was unrealistic, as the pieces of land appeared far too solid. The next iteration took inspiration from the Wärtsilä radar, and a screen dump was used as a reference. The land was now less solid and was made up from hundreds of dots of varying sizes. All these dots were placed manually to emulate the look of a real radar. However, on a real radar, the pieces of land would cast a radar shadow, meaning that the back of the shorelines should not be visible (Kjerstad, 2015, pp. 2-22). This was altered in the third and final iteration.

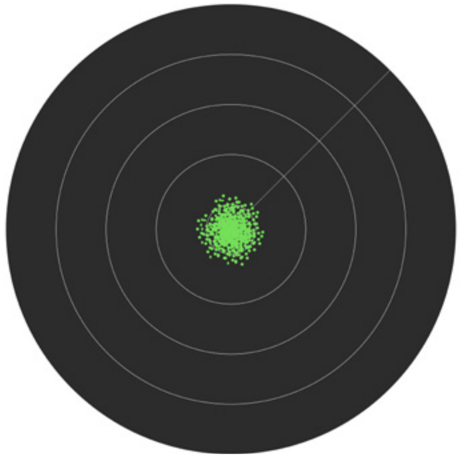
V1 - UNREALISTIC
Not enough detail
Too solid

V2 - UNREALISTIC
The ”back” of the shorelines should not be visible (due to radar shadow)

V3 - REALISTIC
Hidden parts of shorelines
Non-solid land

CLUTTER

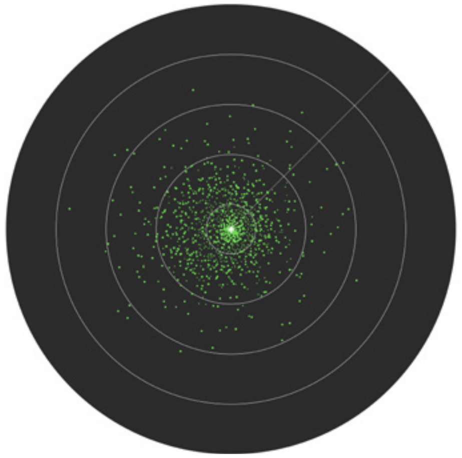
In addition, the emulated clutter was changed throughout the project. Originally, it consisted of rather large dots concentrated in the middle of the PPI. These were, however, too condensed, and too large to be realistic. Thus, it was decided to add more dots widespread across the PPI. There was also a higher density in the centre to emulate real sea clutter. However, this high number of objects would affect the performance in Figma and made the transitions between screens appear choppy and slow. Thus, it was decided to reduce the number of dots. The final version has kept the overall setup, with a concentration of dots in the centre and a random distribution through the rest.



V1 - UNREALISTIC

Not enough detail

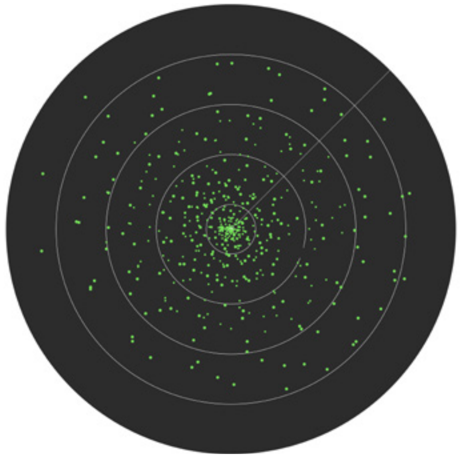
Too condensed



V2 - BAD PERFORMANCE

Too much detail

Slows down Figma



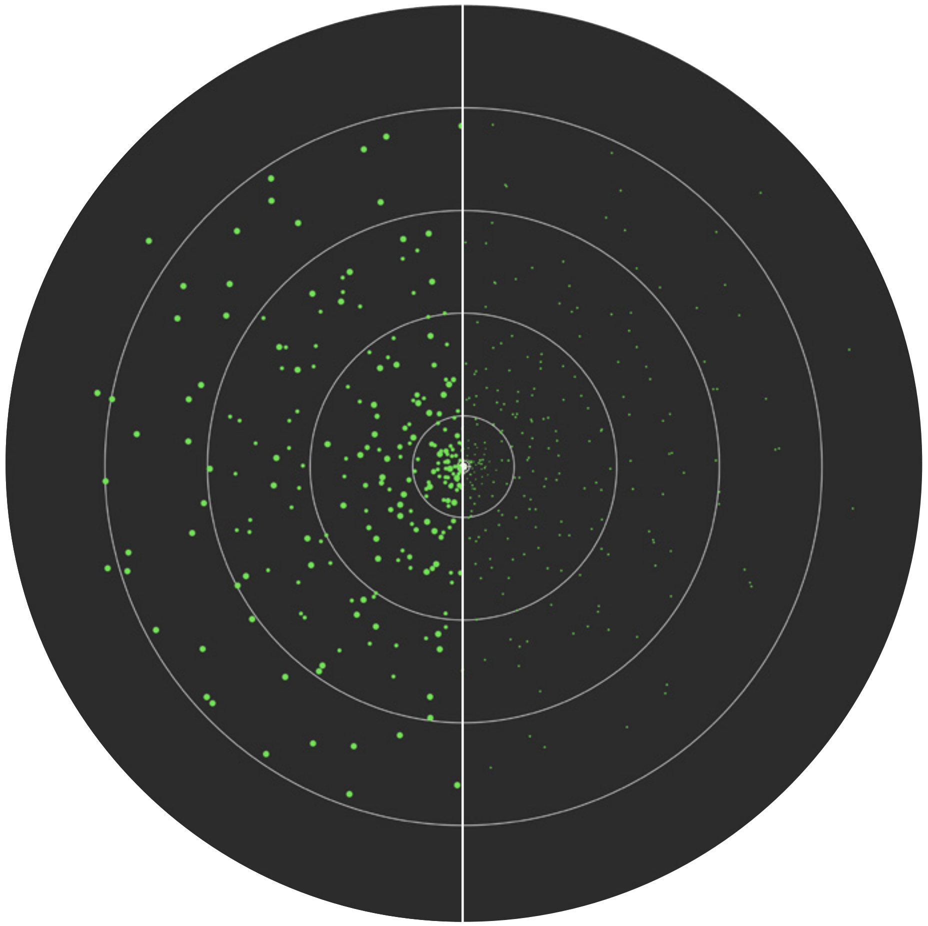
V3 - REALISTIC + GOOD PERFORMANCE

Sufficient detail

Good performance in Figma

CLUTTER BEHAVIOUR

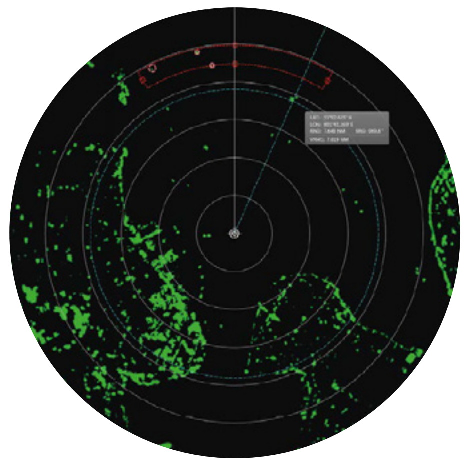
The size of the clutter-dots will change as the users adjusts the levels of anticlutter. The clutter dots shrink as these levels increase, and if the user adds a sufficient level of anticlutter, the dots will disappear entirely. Meanwhile, they will reappear and grow if the anticlutter levels are reduced. This behaviour is based on real radars, where the size of the noise changes depending on the settings.



RADAR COMPARISON

Below, you can see a comparison between the screen dump from the Nacos Platinum and the prototype.

PROTOTYPE



NACOS PLATINUM (REAL RADAR)

From Wärtsilä NACOS Platinum [Radar display], by Wärtsilä Coroporation, 2016t, Wärtsilä (https://www.wartsila.com/docs/default-source/product-files/aut-nav-dp/ivc/brochure-o-ea-nacos-platinum.pdf?sfvrsn=-789bae45_4). Copyright © 2016 Wärtsilä Corporation.

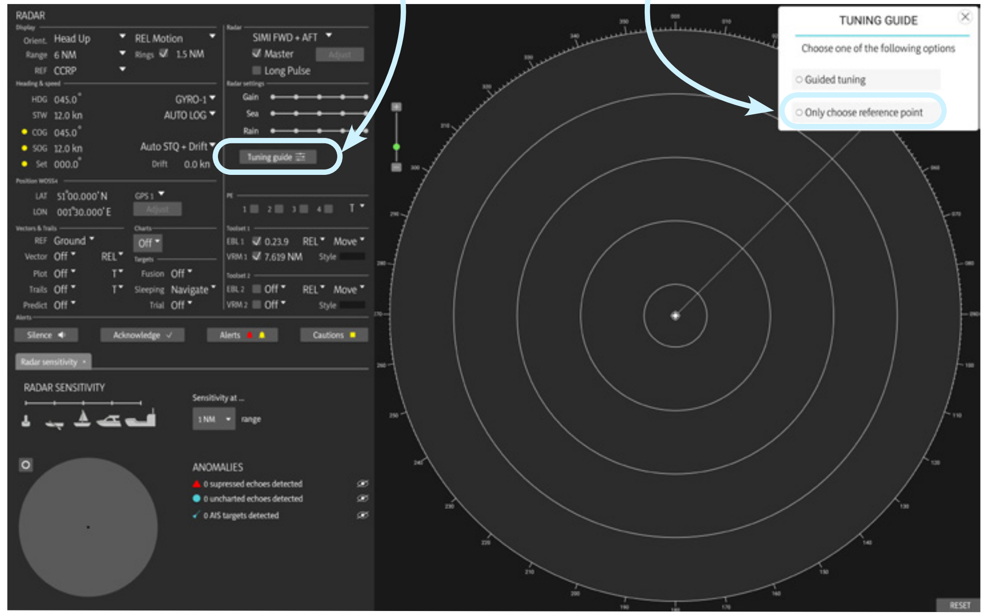
THE FEATURES

REFERENCE POINT

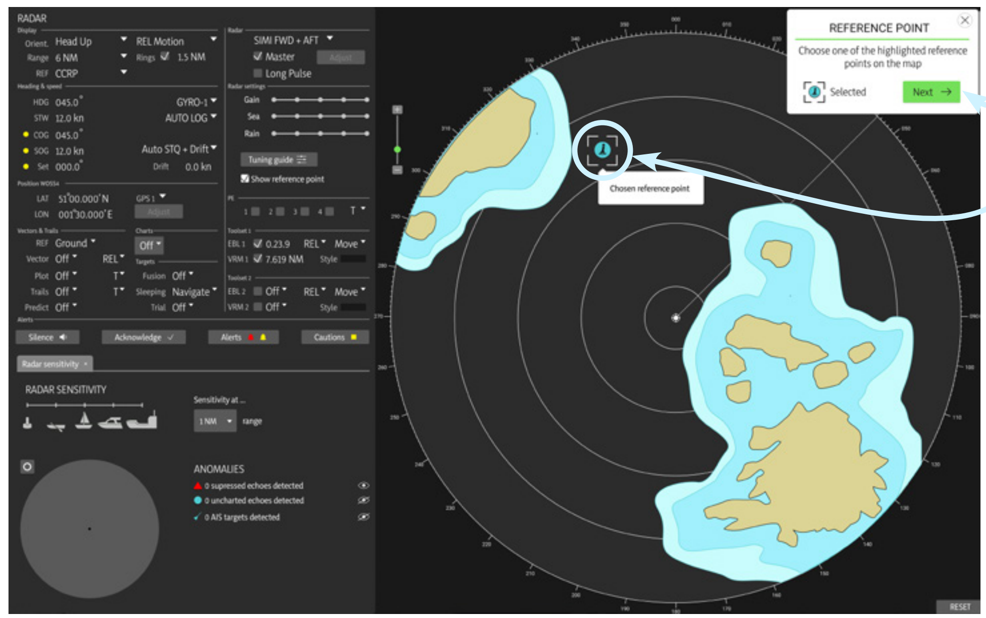
The reference point feature gives the navigator a lot of freedom during the tuning process. Initially, they are asked to choose a reference point in the map, but after this, they will receive no more instructions. They can adjust the settings as they please, but there are certain indicators telling them of the status of the reference point. For example, if the navigators adjusts the settings to a point where they are suppressing the reference point, the icon in the PPI will change from a green buoy to a red triangle. The icon changes again if they adjust their settings until the echo is visible again. If they hover over the icon in the PPI, they will either be notified that the echo is visible on the radar, or they are told that their current settings are suppressing the echo.

The next pages include a brief description of how to utilize the reference point feature:

1) Click the “Tuning guide” button in the menu and select “Only choose reference point” in the popup



2) Select one of the highlighted reference points in the map and click ”Next” in the popup



3) Adjust the gain, sea and rain clutter sliders until you are satisfied with the quality of the radar image. While tuning, make sure that the chosen reference point stays green.

4) If the reference point turns red at any point, adjust the highlighted slider until it turns green again.

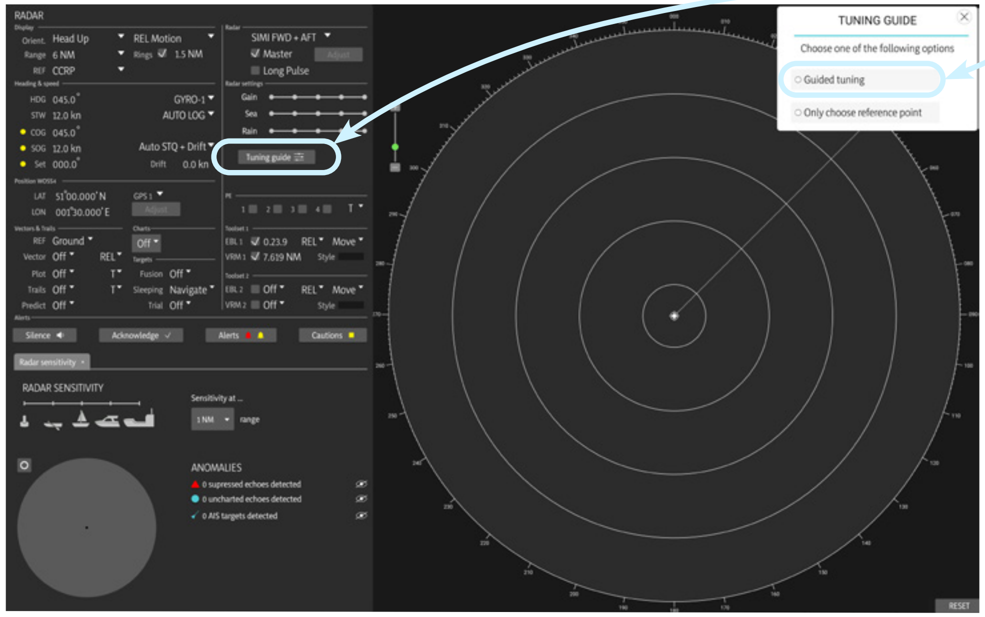
TUNING GUIDE

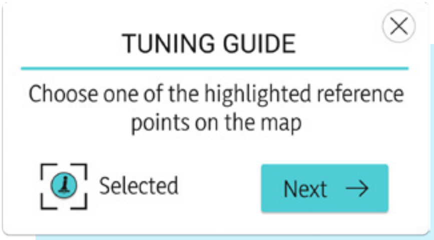
The tuning guide gives the navigator an introduction to the added features, and will guide them through the tuning process. This is a popup that appears in the upper right corner.

Initially, it will make them choose a reference point in the waters, exactly like when following the reference point-approach. Like in the previous example, the icon for the reference point changes if they suppress the echo from this object, and they are not allowed to proceed to adjust the next setting before they resolve this issue. In short, this tuning guide asks the user to perform specific actions in a certain order, and introduces them to the majority of the added functions.

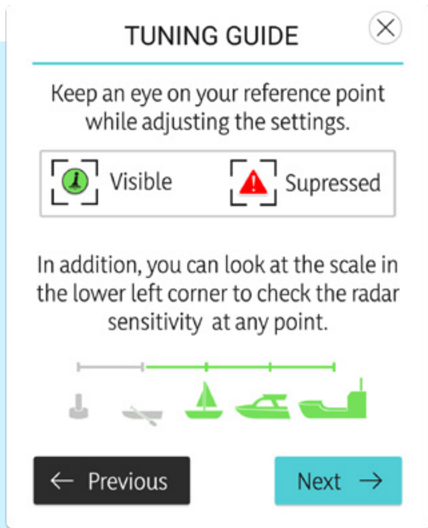
You can see a walkthrough of the tuning guide on the following pages. This overview shows the isolated popup, as the rest of the screen will remain the same as when utilizing the reference point approach.

1) Click the “Tuning guide” button in the menu and select ”Guided tuning” in the popup.





2) Select one of the highlighted reference points in the map and click "Next".



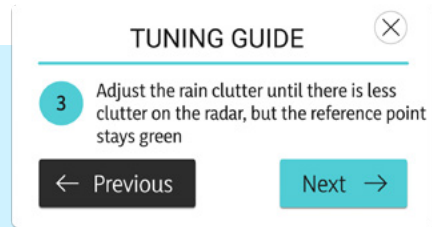
3) Read the popup and click "Next".

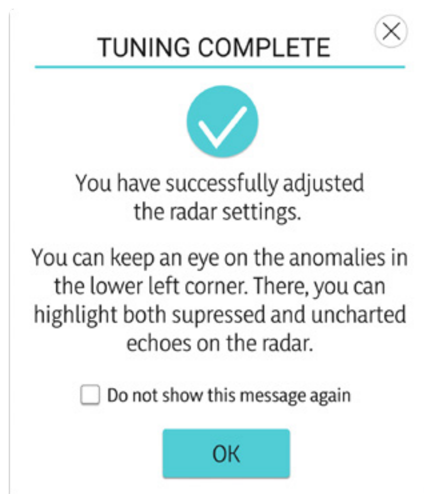
4) Adjust the gain settings until you can see clear echoes and some clutter. Make sure that the chosen reference point stays

green. Then click "Next".

5) Increase your sea clutter settings until there is less clutter in the PPI, but the reference point stays green. When you are happy with your settings, press "Next".

6) If necessary, change your rain clutter settings. Make sure that the reference point stays green. When you are happy with your settings, press "Done".





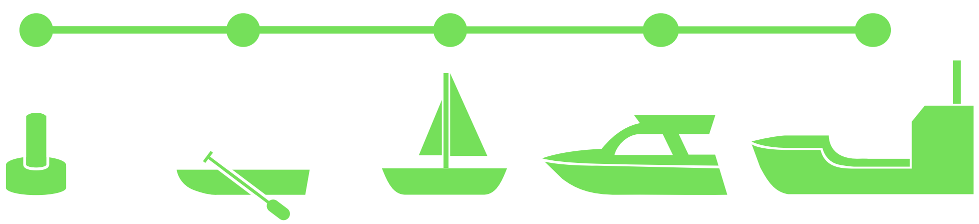
7) Read the popup and click "OK".

SENSITIVITY SCALE

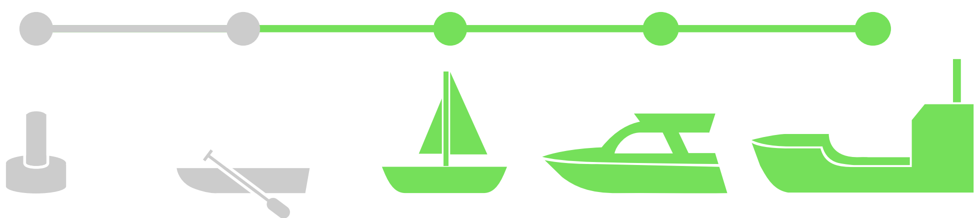
The sensitivity scale will change depending on the chosen radar settings. If the reference point – in this example a buoy – gives a visible echo on the radar, the scale stays green, indicating that echoes from everything from a small buoy to a large tanker are visible. However, if the user adjusts the settings until they suppress certain echoes, the corresponding illustrations will turn grey.

Below are some illustrations showing how the scale will be affected by the radar settings.

NO SUPPRESSED ECHOES

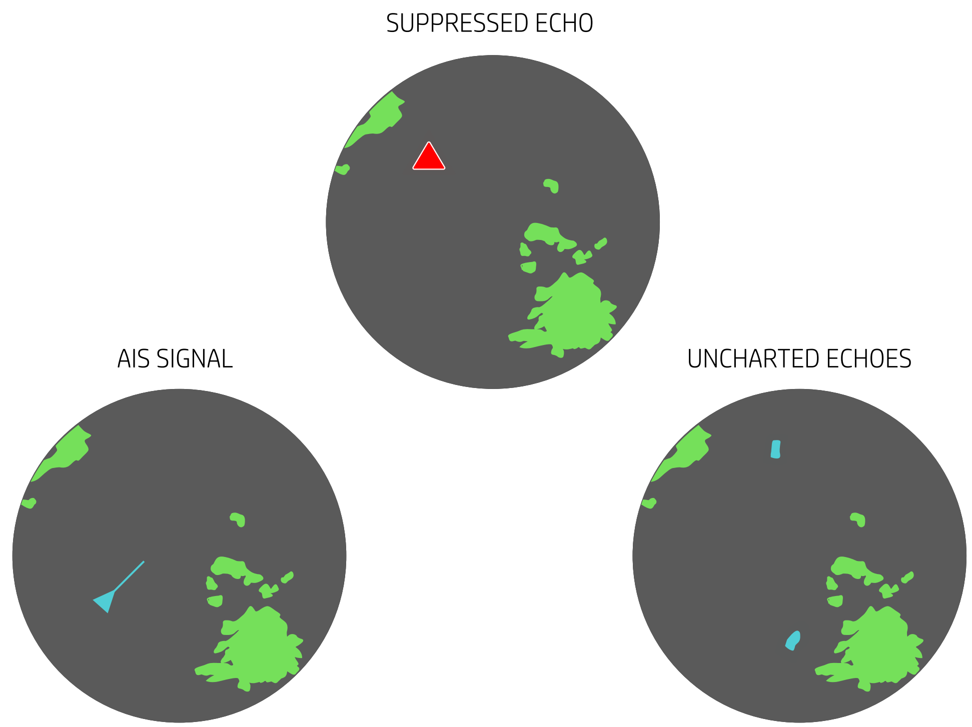


SOME SUPPRESSED ECHOES



MINI MAP

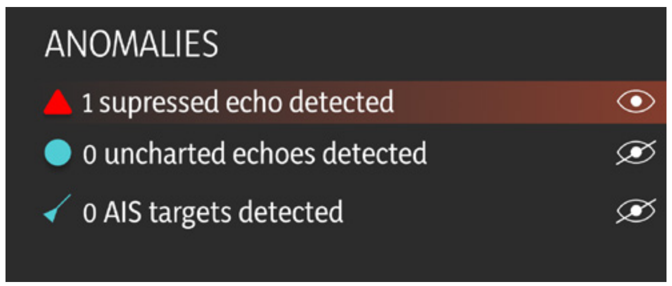
The mini map contains indicators of suppressed echoes, uncharted echoes and AIS targets in the surrounding waters. The suppressed echoes are marked as a red triangle in their position, to make the navigator aware of the issue and to inform them of which object is affected. Uncharted echoes are shown as blue objects in the mini map to differentiate them from the rest. Additionally, the AIS targets will appear as normally, as a triangle with a line defining the course of the vessel. Lastly, all the charted objects that give off echoes – as they are supposed to – will be marked with green in the mini map to indicate that these echoes have a decent quality. The illustrations below show the mini map in different situations



ANOMALIES LIST

The anomalies list gives the navigator an overview of potential points of interest in the nearby waters. For one, the system will alert the navigator if it detects uncharted echoes. These uncharted echoes can originate from other vessels or unidentified objects in the waters, which are not present in the charts. Meanwhile, the list will also notify them of suppressed echoes. For example, if the charts show that there is a buoy close by, but no echo from this appears in the PPI, the system will alert the navigator that there it has detected a suppressed echo. Lastly, this list also gives them an overview of detected AIS targets. The eye-icons next to the list let them show or hide the highlighting of these anomalies in the PPI. In that way, if the navigator wants to highlight uncharted echoes, they can click the eye-icon next to this point in the list to mark them in the PPI. The illustrations below show how the anomalies list might change throughout.

UNCHARTED ECHOES

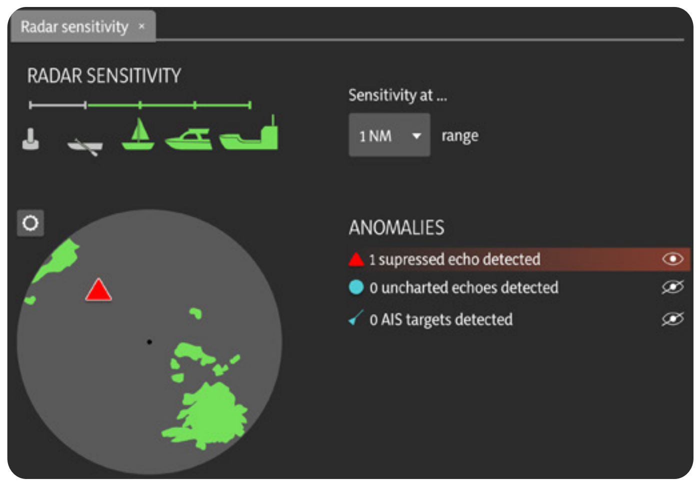


SUPPRESSED ECHOES

UTILIZING THE WIDGET WINDOW

The workflow diagrams made it apparent that some features can remain present on-screen. However, these features are situated in the widget window, which gives the navigator some flexibility in that regard. Consequently, the navigator can choose whether or not to utilize these features during their normal sail.

The mini map and anomalies list can quickly give the navigator an overview throughout the sail and show them the number and location of certain anomalies in the water. The navigator is then alerted if the system detects a new suppressed echo, for example, either by looking at the anomalies list or the mini map. Meanwhile, if new uncharted echoes appear, they can also quickly spot these through the same means. The feedback from the navigators indicate that this function can be valuable throughout the watch. Meanwhile, if the navigators are in need of a different widget, they can simply change tabs and hide these features from the screen. This approach ensures flexibility for the navigator and lets them prioritize the functions based on their needs.



LIMITATIONS

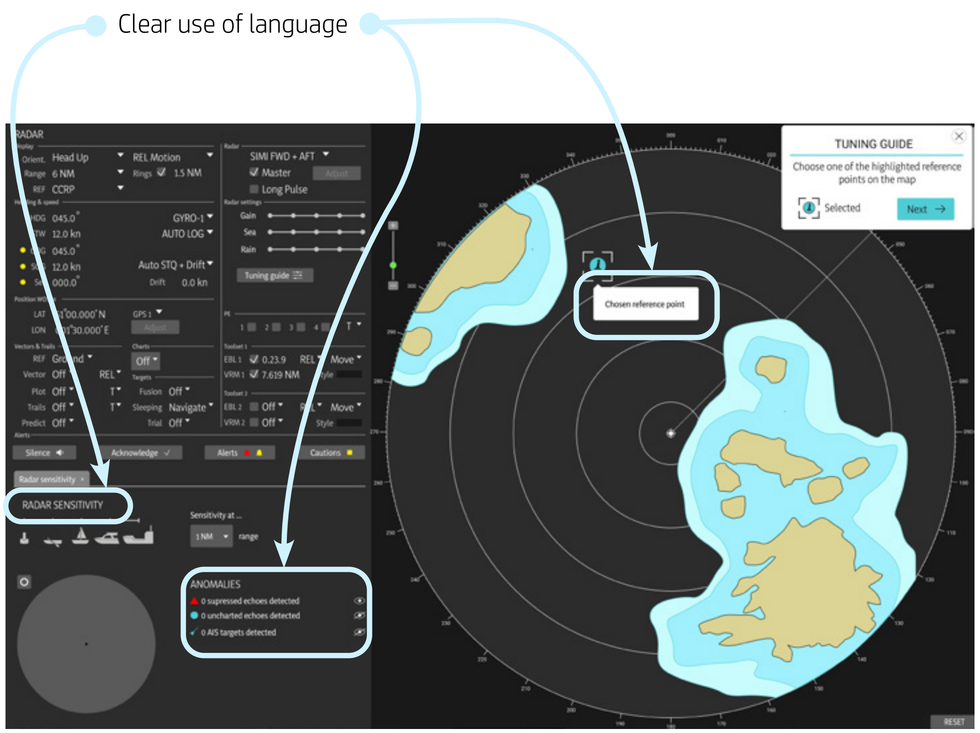
The final protoype is affected by certain limitations in Figma. After some trial and error, it became apparent that Figmas functionality did not support the use of sliders. Therefore, a compromise had to be made. In the end, the users would have to click between five different levels of gain, sea clutter and rain clutter instead of changing a set of sliders. Ideally, they should have been able to do more fine-tuning during the test, but this would have made the number of screens go up exponentially. With these five settings on each slider, it was already necessary to create 125 (5x5x5) different screens, each of them had to be manually altered to seem realistic to the user. Thus, doubling the number of steps, for example, would have brought that number up to 1000. As the connections between the screens would be added manually, the risk of bugs and errors would increase with the number of screens. Therefore, it was decided that five levels on each slider was sufficient for the test.

PROTOTYPE DESIGN

Nielsens usability heurstics were utilized during the development of the prototype. The following pages address how these were utilized throughout. (Nielsen, 1996, p. 1)

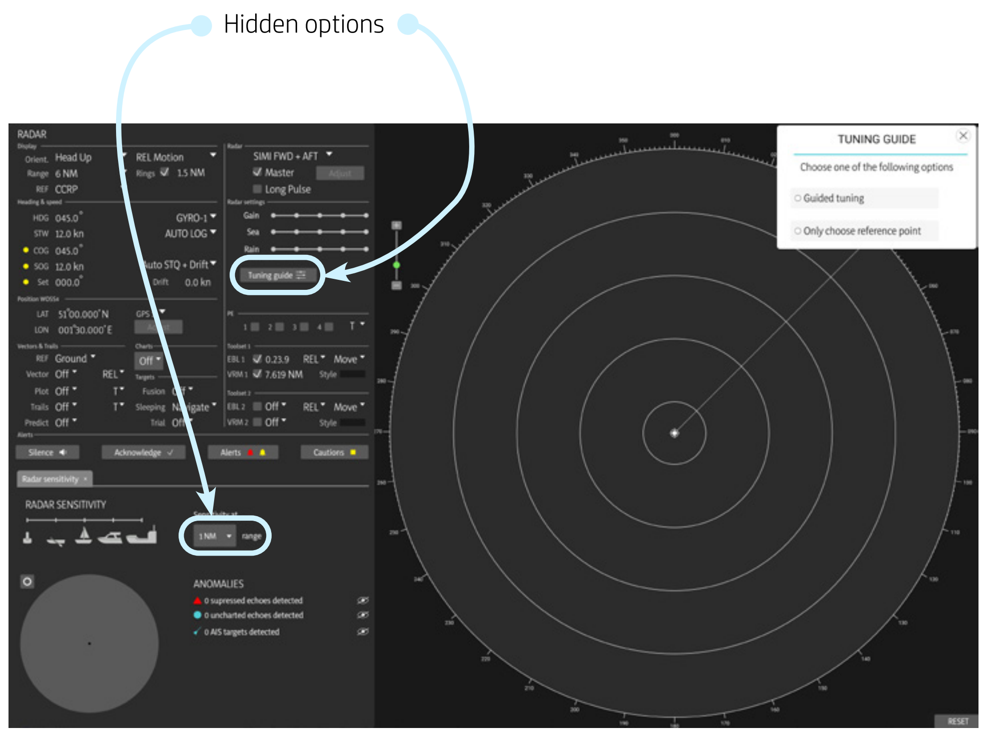
SPEAK THE USERS' LANGUAGE

Clear use of language has been a focal point during the development of the prototype. For example, the anomalies list should briefly explain the different features. The navigators already use the term "suppressed echoes", and are known with AIS targets. Meanwhile, the possible vessel echoes are called "uncharted echoes", to extenuate the fact that they are not charted on the map. Meanwhile, they could be other objects floating in the waters, and simply calling them "vessel echoes" would have been misleading.



MINIMIZE THE USER MEMORY LOAD

Some options are hidden from the main screen to reduce the number of elements the user has to memorize. For example, the tuning guide button opens a pop up with two options that the navigators must choose between. Meanwhile, the dropdown next to the sensitivity scale contains several options that are hidden to reduce the memory load.



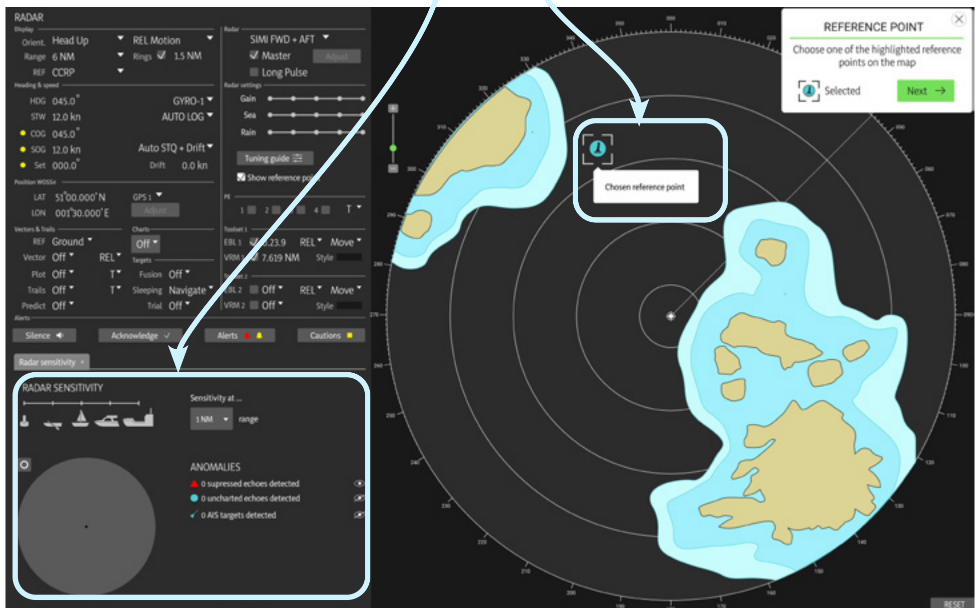
BE CONSISTENT

Consistency has also been a key focal point throughout the development. For one, the widget window will remain the same, with some slight variations. The same structure is present on each screen, but certain elements are highlighted or greyed out, while some elements might appear in the mini map. However, the overall structure will remain the same.

Similar functions includes the same steps to maintain a consistent setup. For example, both the guide and reference point feature makes the navigator choose a reference point in the map. These two approaches contain many similarities to improve the consistency of the prototype.

Overall structure remains the same

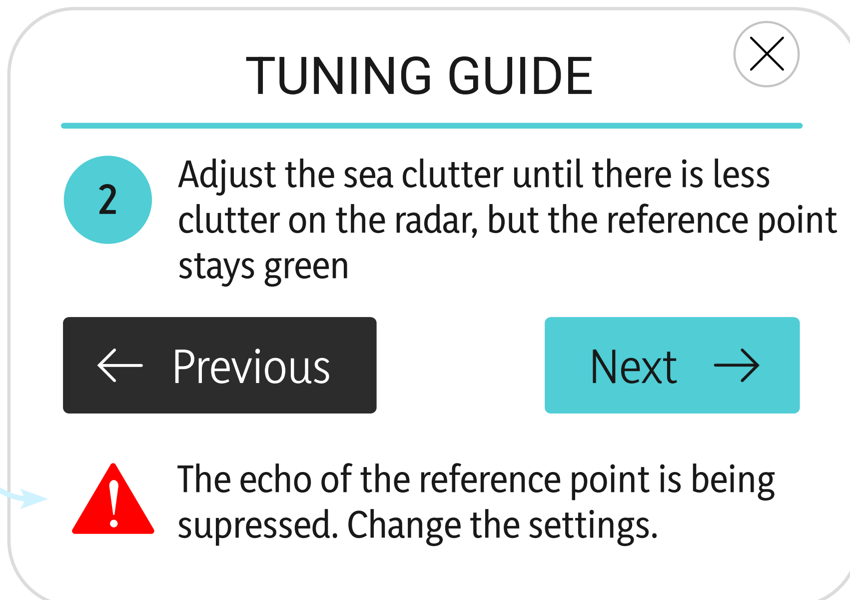
Same approach for tuning guide as well



PROVIDE FEEDBACK

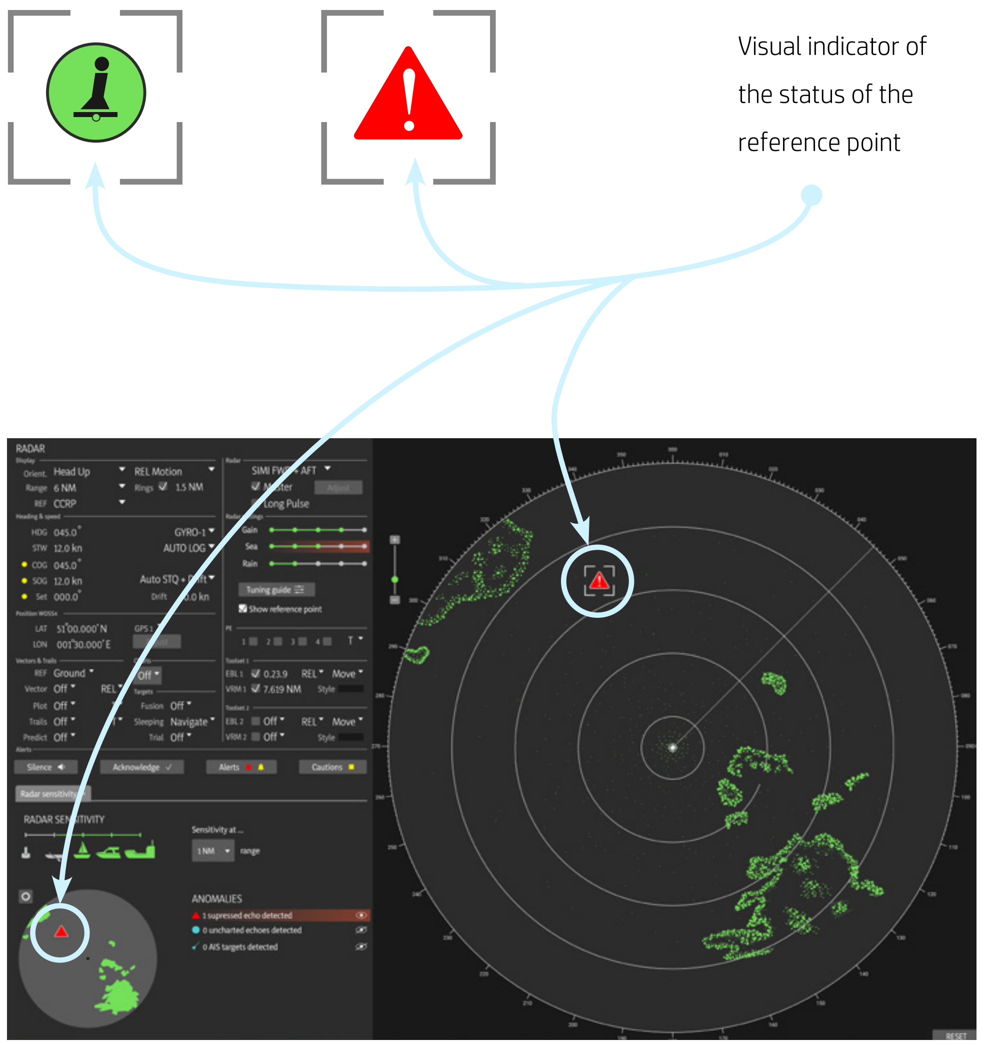
Continuous feedback is a key element in this prototype. This feedback comes in the shape of popups in the guide, for example. Meanwhile, if the navigator tries to proceed through the guide with insufficient radar settings, they are informed of this through an error message in the upper right corner. This alert makes them aware of the issue and informs them of the necessary measures.

They are informed of what is wrong and how they might fix it



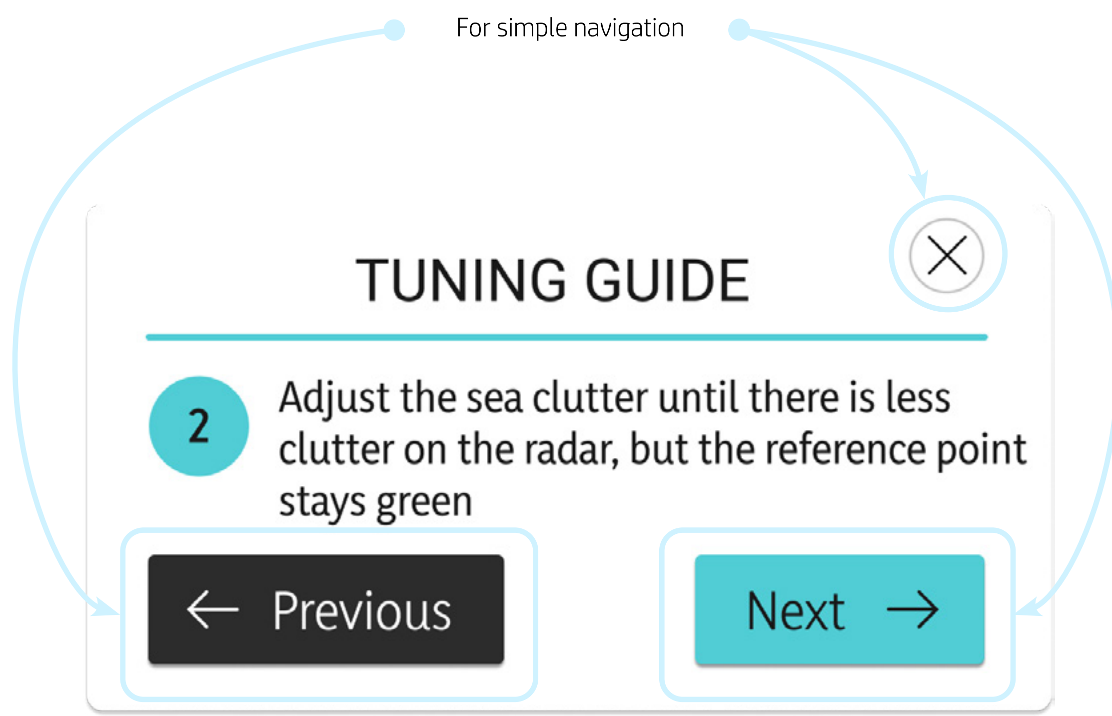
PROVIDE FEEDBACK

Another form of feedback is the icon for the reference point itself. This changes based on the quality of their radar settings. If this echo is being suppressed, the icon will turn into a red alert triangle. Meanwhile, if the echo is visible on the radar, the icon will remain green.



PROVIDE CLEARLY MARKED EXITS

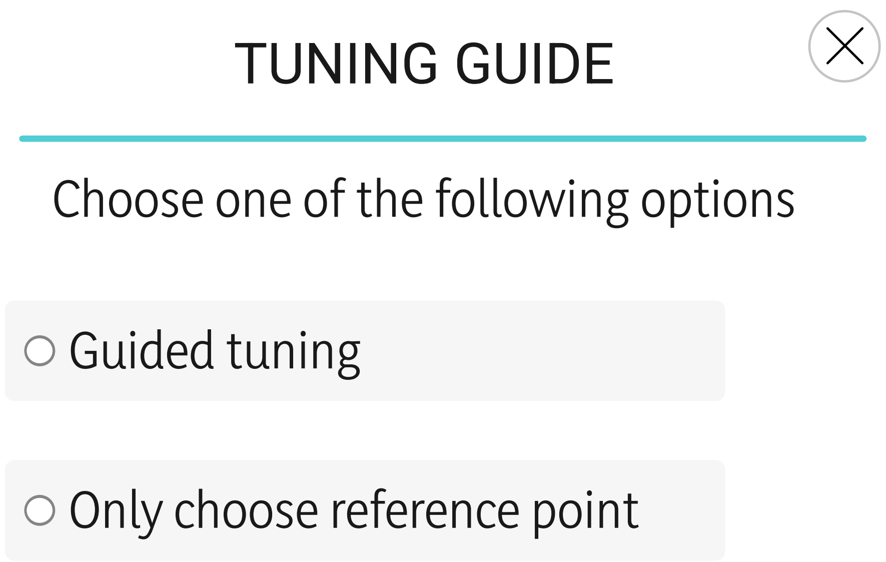
Certain elements have been added to ensure that the user can easily navigate back and forth in the prototype. For one, the guide contains buttons that lets them progress through the guide or to go back to the previous step. Additionally, they are able to exit the guide by clicking the cross in the upper right corner.



PROVIDE SHORTCUTS FOR ADVANCED USERS

The guide is designed for the novice user. Meanwhile, the reference point-path is designed for the more advanced user, and provides a kind of a shortcut to the function itself. This feature was added to ensure that the users do not have to click through the entire guide if they want to utilize the reference point feature.

Shortcut for the advanced user



USE PLAIN LANGUAGE FOR ERROR MESSAGES

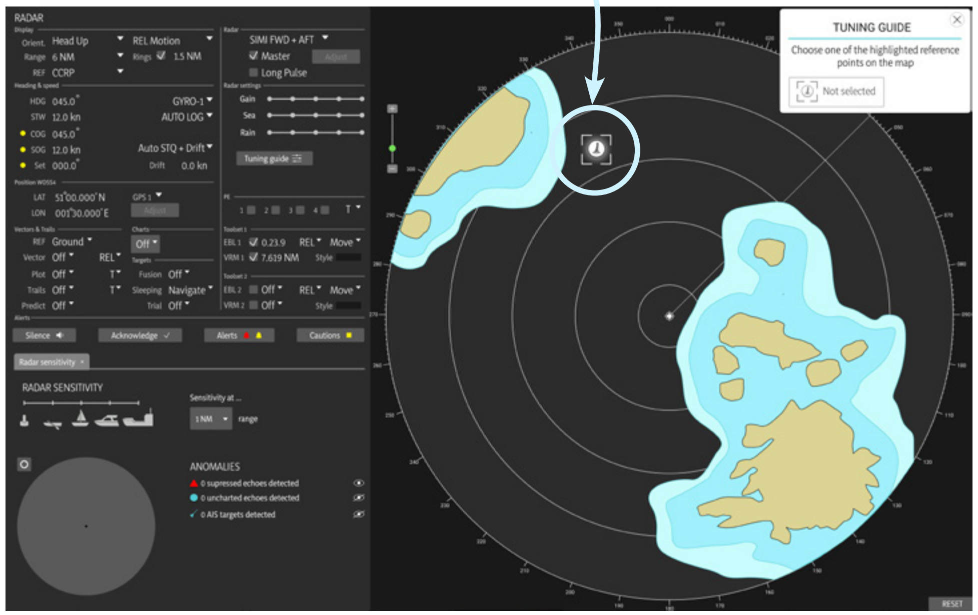
Error messages are utilized throughout the prototype. As mentioned, they are present in the guide if the user is suppressing charted echoes. Meanwhile, if the user hovers over the red icon for the reference point, they are notified that this echo is currently being suppressed due to their settings.

Clear information

PREVENT ERRORS

Error prevention has been a focus throughout the development of the prototype. For example, what would happen if the user tries to choose a piece of land or some other unfit object as a reference point? This was mentioned by a navigator during the sketch discussions. Certain means were added to prevent this. For ecample, user must choose between a selection of pre-defined reference points, to ensure that they do not select an object that is unfit as a reference point. The presented options are buoys or other objects which are suitable for the task.

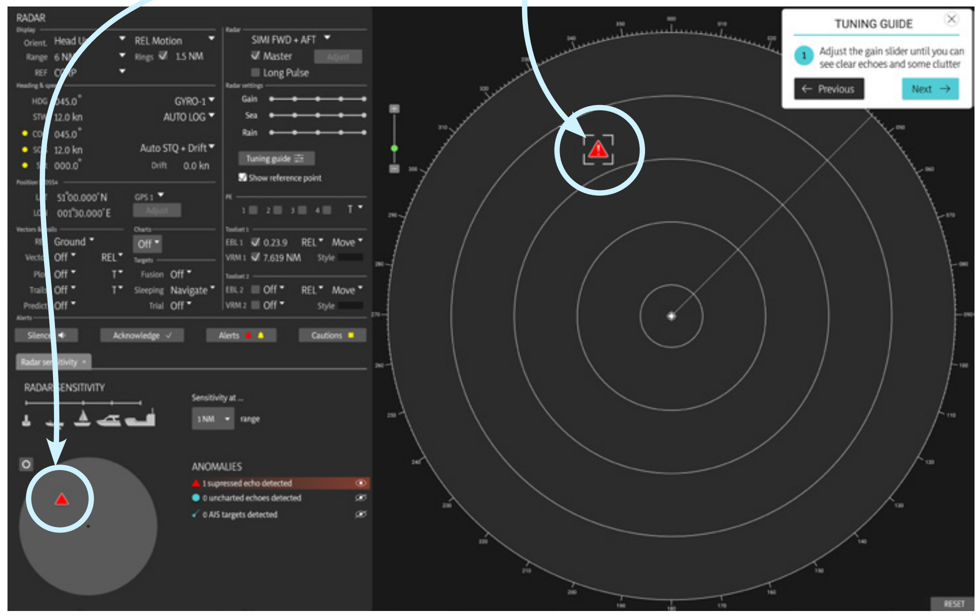
Possible reference point



USE OF COLOR

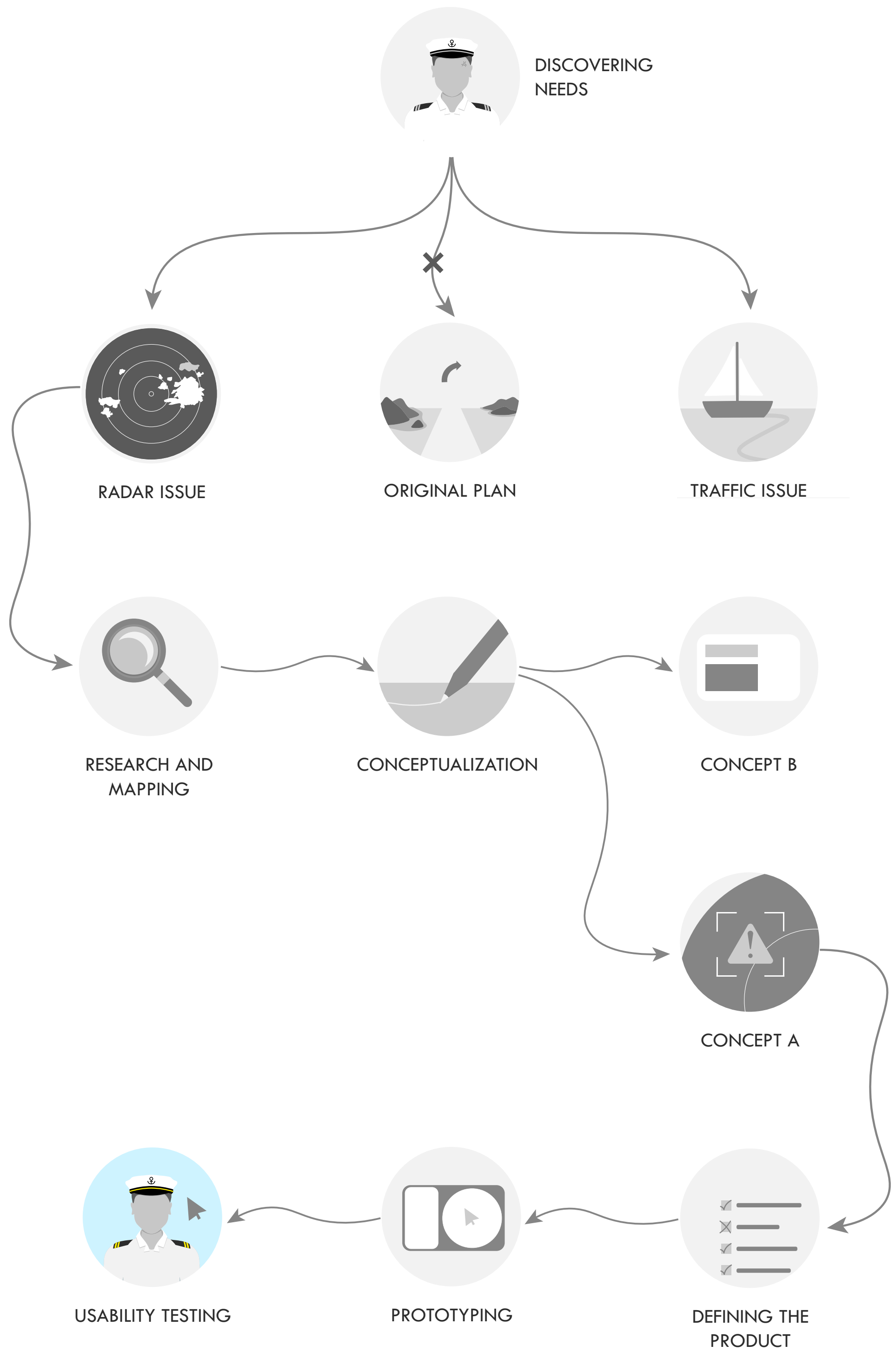
Highly saturated colors are utilized throughout the prototype, to attract the attention of the navigator. If the reference point is being suppressed, for example, the indicator in the PPI will turn bright red. This is similar to the alerts the navigators are already accustomed to.

Saturated colors for the alerts



USABILITY TESTING

This chapter revolves around the usability tests that were conducted close to the end of this project. The results from these tests and following analysis are also included.



PILOT TEST

GOAL

A pilot test was conducted to validate the test structure and prototype. Such tests can help uncover bugs in the prototype and show whether the interview guide and test setup are appropriate according to the goals of the test (Lazar et al., 2017a, p. 361).

METHOD

Pilot testing can be valuable in human centered design and can help pinpoint if the test setup is collecting the correct kind of data. In that way, one can early discover whether to make changes to the test setup or not (Lazar et al., 2017a, p. 361)

In this case, the pilot started with a short presentation. This was an introduction to the test format itself and the participant received some information regarding possible limitations of the prototype and the test structure. Then, they received a link to the Figma prototype and proceeded to share their screen via Teams. They were asked to adjust their radar settings to a level they were happy with, by following these steps:

1. Click the “tuning guide” button and tune choose one of the options.
2. Click the “tuning guide” button and tune choose the remaining option

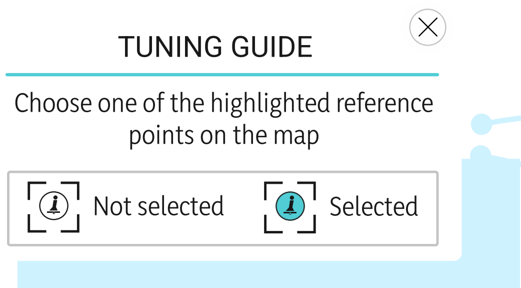
In that way, they tried out the two different options, but were able to choose the guide-option or the reference point-option first.

RESULTS

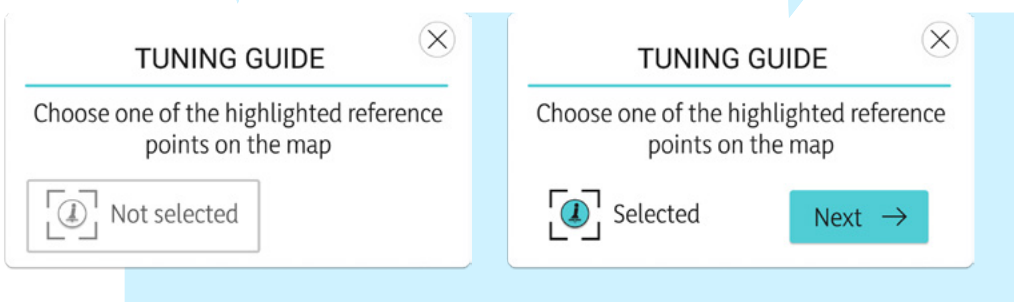
The pilot test provided valuable insight that were brought into the final testing. For one, some alterations were made to the planned interview guide. Addicionally, the prototype was tweaked based on the feedback from the test. These alterations are addressed on the following pages.

SELECT REFERENCE POINT

The user tried to press the reference point icons in one of the popups

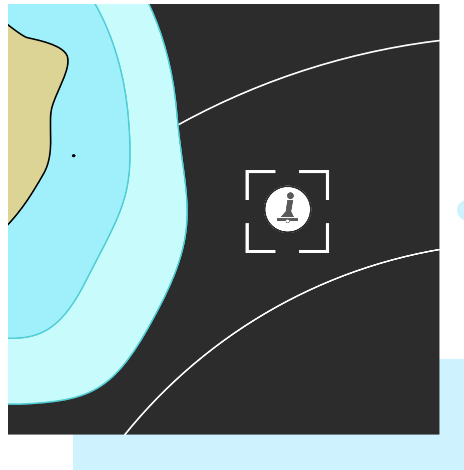


Made the icons “grey” to make it apparent that they were not clickable. Removed the “selected” icon until they had chosen a reference point in the map

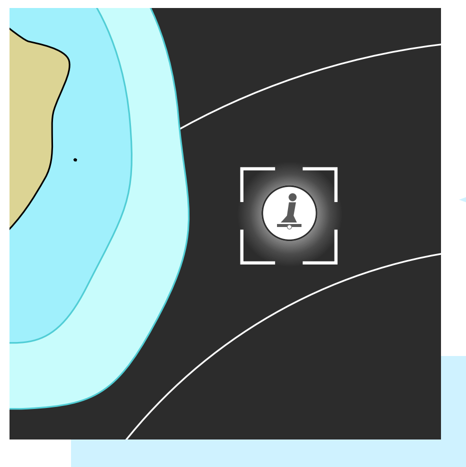


SELECT REFERENCE POINT

The user found it difficult to find the reference point in the map

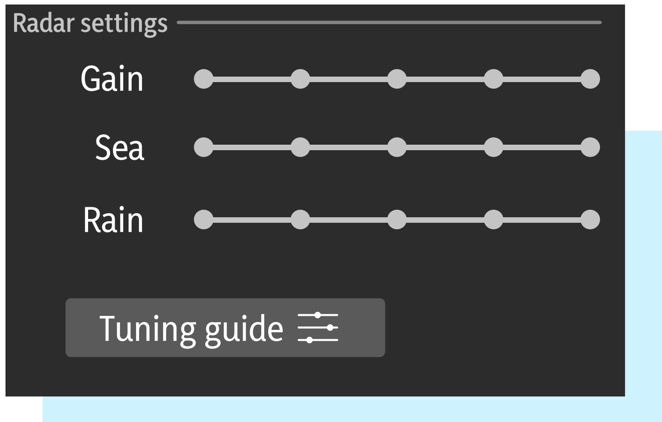


Highlighted and enlargened the reference point

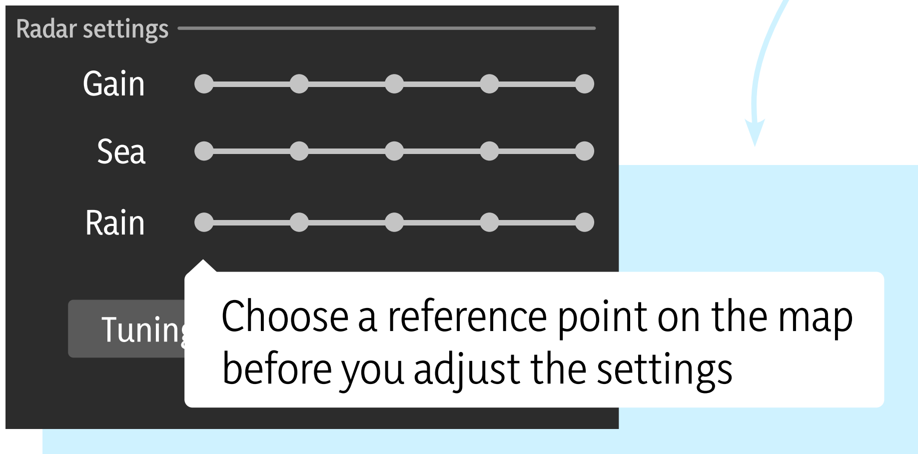


ADJUSTING GAIN

The participant tried to click and choose levels for gain, sea and rain clutter during the reference point selection process,

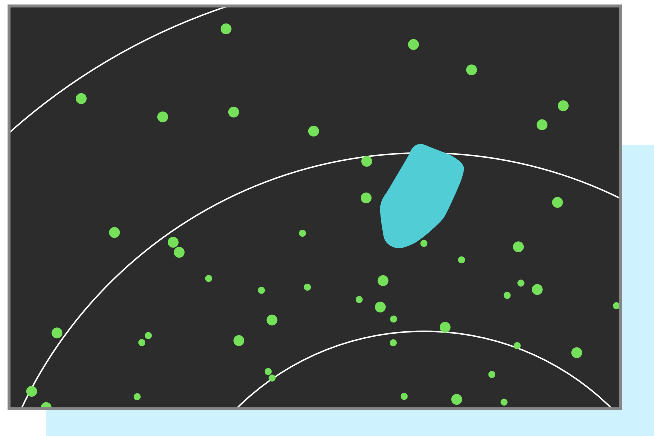


Added a popup that tells them that they cannot change these settings before a reference point is selected

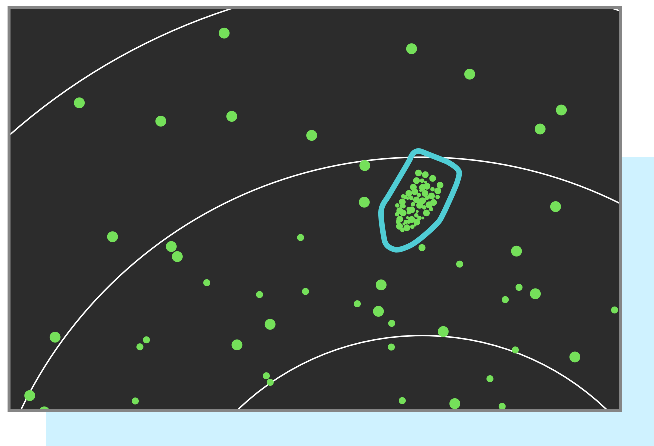


NOT REALISTIC UNCHARTED ECHOES

The participan discovered that enabling the visibility of the uncharted echoes on the radar would show some blue objects on the radar, and not actual echoes.



Swapped the blue shapes with actual echoes on the radar. Gave them a blue outline instead when clicking the visibility-button



FINAL USABILITY TEST

GOAL

Final tests were conducted to test the usability of the prototype. This was measured from the three key aspects of usability: efficiency, effectiveness and user satisfaction (ISO/IEC-25010, 2011, p. 11).

METHOD

Thus, most of the questions in the interview guide would focus on these three. In addition, some extra questions were added to investigate their interpretation of certain elements, like the mini map and scale in the lower left corner.

For clarification, effectiveness, efficiency and user satisfaction are defined as:

- Effectiveness is defined as "accuracy and completeness with which users achieve specified goals" (ISO/IEC-25010, 2011, p. 16)
- Efficiency is defined as "resources expended in relation to the accuracy and completeness with which users achieve goals" (ISO/IEC-25010, 2011, p. 16) where "resources" could be a measurement of time, for example.
- User satisfaction is defined as the "degree to which user needs are satisfied when a product or system is used in a specified context of use" (ISO/IEC-25010, 2011, p. 16)

Thus, an effective product would

- Give the navigator an indication of the quality of their current settings
- Give the navigator an overview of which echoes were visible and not
- Give the navigator an indication of how to improve their settings

Meanwhile, an efficient product would let them achieve this

- In a short amount of time
- With quite few actions and errors

Lastly, the user satisfaction would measure

- How pleased they were with the product
- To what degree they felt like it achieved the goals
- To what degree they would imagine themselves using the product
- Their thoughts regarding ease of use

Usability tests can help discover whether the interface fulfils its purpose and intended function. The users are often asked to perform certain tasks that will be utilized often in the developed interface. Their actions and approach are then observed and recorded. Meanwhile, it is normal to conduct a post-interview or hand out satisfaction questionnaires to measure the user satisfaction of the system. (Sharp et al., 2019, p. 501).

However, it is not always easy to know how many users should be included in said tests. Some agree that between five and twelve users are appropriate. Others say that a higher number yields better results, as it is based on more a larger portion of the user group (Preece et al., 2015, p. 525). In this case, it was decided to include seven users.

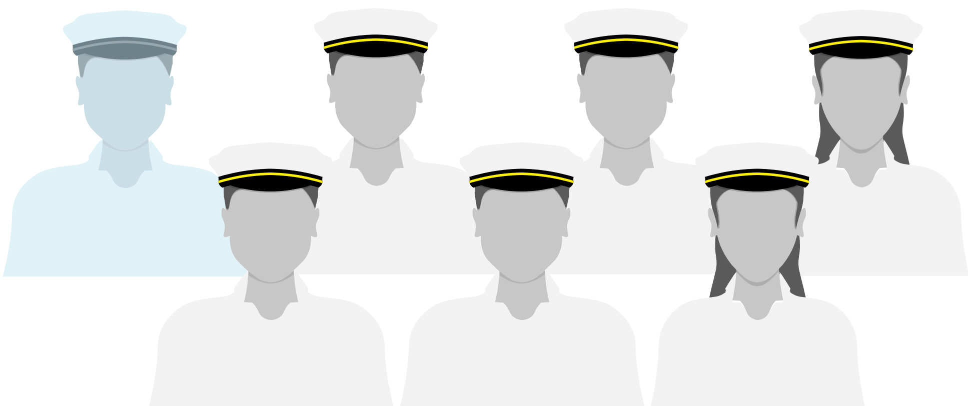
One technique commonly used in usability testing is the “thinking out loud”-technique, where the facilitator asks the participant to share their thoughts during the test. This approach can give valuable insight regarding the thought processes and opinions of the users (Preece et al., 2015, p. 524).

Lastly, there are several other methods that can be used to gather feedback on the user satisfaction of a product. One option would be to hand out user satisfaction questionnaires. However, this approach might not yield detailed feedback regarding their thought about certain aspects of the prototype. Thus, it was decided to do post-test semi structured interviews. This made it possible to gather qualitative data which could then be thoroughly analysed (Preece et al., 2015, pp. 259-260).

PARTICIPANTS

Seven navigators participated in the final usability tests. Six had previously participated in interviews and sketch discussions, which meant that they had some knowledge about the project.

One additional participant got to test the prototype, this time a navigator student with no prior knowledge of the project. Therefore, this participant received a brief introduction in advance of the test, where the goal and background of the prototype was explained. In addition, some questions were asked regarding their experience, age and thoughts about radar tuning in general.



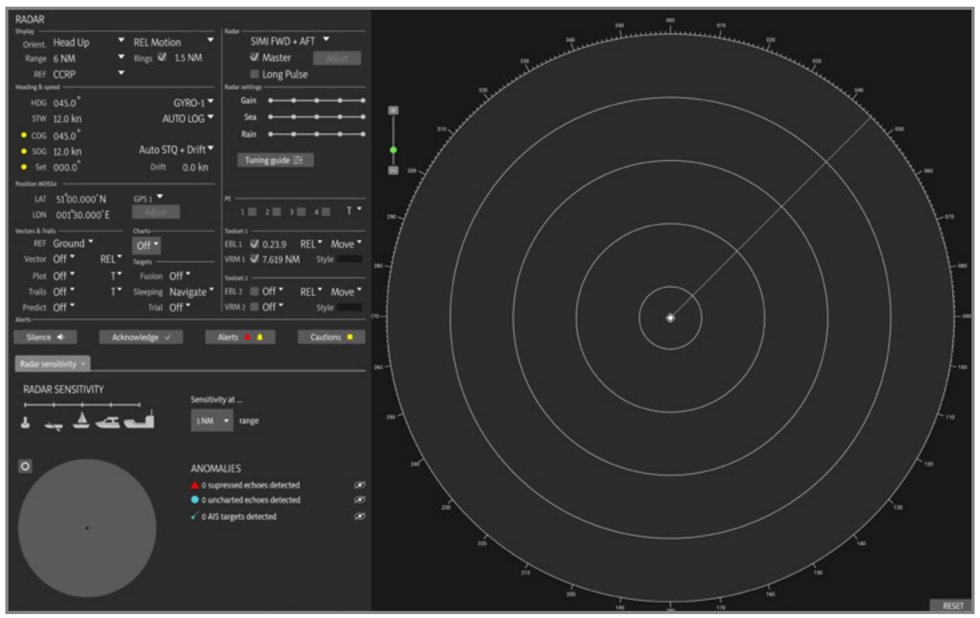
PRESENTATION

All the participants were met with a short presentation prior to the tests. This was an introduction to the test setup that also mentioned what was the focus of the test itself. Appendix D contains the slides from this presentation.

In addition, they navigators recieved a short recap of the principles and received a quick debrief regarding certain limitations of the prototype. Then, they received a link leading to the prototype itself and were asked to share the screen.

TEST

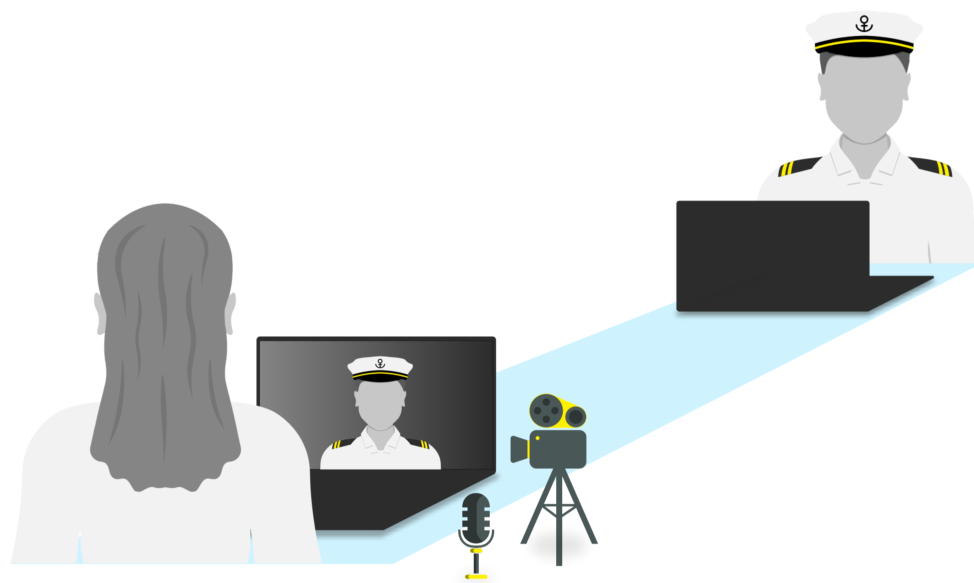
Once the navigators clicked the link, they would see the default screen of the prototype; a blank radar with all settings set to zero. Then, they were told to click the “tuning guide” button and tune choose one of the options. When they were happy with the quality of their radar settings, they were again told to click the “tuning guide” button. However, this time they were asked to click the option that they had not previously chosen. This approach made it possible to see which alternative they would choose on their first run.



INTERVIEWS

After the initial testing, the navigators participated in a semi structured interview regarding their experience during the user tests. The interview took place as soon as the test was finished. They still had access to the prototype, so they were able to go back and explain their thoughts about the different features.

See Appendix A for the interview guide that was utilized throughout these interviews.



QUALITATIVE ANALYSIS - SOURCES OF ERROR

GOAL

The execution of the usability tests was analysed to search for possible sources of error.

METHOD

This was done through In Vivo coding. This qualitative analysis followed the inductive approach, much like the analysis of the first interviews conducted in the project. In short, one would analyse the data in search for patterns without having a pre-formed opinion on the topic (Aljaroodi et al., 2020, p. 3; Lazar et al., 2017a, pp. 304-305).

The focus of the analysis was the execution itself. In short, one would sort through all the transcripts from the interviews and look for facilitator errors or other issues mentioned by the participants.

RESULTS

UNREALISTIC PROTOTYPE

The participants mentioned that some parts of the prototype seemed somewhat unrealistic. For example, the size of the vessel echoes was seen as way too large, compared to the range of the radar. In addition, the “ideal” level of gain at roughly 75% was seen as too high, compared to many other radars. This was also supported by the usability tests, where some participants tried to set it to 50% and proceed with that setting. In addition, some were a bit confused that they could not make the shore more dense-looking, as it would stay spotted no matter what settings they chose. On a real radar, this might be seen as an indication of too little gain. Several participants also mentioned that they were missing the opportunity to fine-tune the settings, as they could only choose between five levels.

As some aspects of the prototype were perceived as unrealistic, others were seen as rather “normal”, compared to a real radar. Some mentioned that the effect of the sea and rain clutter settings made sense, and that the features were quite recognizable.

Some participants encountered errors in the prototype, caused by some illogical connections between screens. This transported them back to a previous screen, and made them go through one step again.

FACILITATOR INVOLVEMENT

Sharp et. al has the following to say about usability testing: “The goal is to be unobtrusive and not to affect what people do during the evaluation” (Sharp et al., 2019, p. 505). However, there were two instances where this approach was not followed. For example, the participants were asked to click “the eye” next to a certain element in the anomalies list. Later, they were asked how they interpreted what just happened. This approach was quite leading and was therefore not given much weight in the final analysis. In addition, the facilitator answered two questions from the participants during the course of the seven usability tests. The facilitator confirmed their suspicion of the sensitivity scale and of how they would be alerted of new, suppressed echoes.

QUALITATIVE ANALYSIS - RESULTS FROM THE TEST

GOAL

This analysis was conducted to examine the results from the usability test. Such an analysis can help uncover whether the product reached the set goals or not.

METHOD

This was done through priori coding. This type of coding differentiates from the more emergent coding after the initial interviews, as it is based on existing theory and pre-set parameters (Lazar et al., 2017a, p. 309). In this case, the codes were chosen prior to the analysis.

The coding was done through several rounds. The first rounds focused on sorting the findings based on a set selection of parameters; effectiveness, efficiency, user satisfaction and understanding. Then, they were again sorted into subsections. Later, a round of "cleanup" was conducted, where each code was thoroughly examined to ensure that the data was sorted correctly. Lastly, the transcriptions were analysed once more, this time specifically to look for pressure points, critique and valuable comments regarding the potential issues discovered during the usability tests. This last sweep was done to try and prevent bias, and to make sure that no shortcomings were "hidden" from the final code.

The analysis focused on two different aspects from the usability tests:

- The participants' actions
- The participants' feedback from the interviews

The participants' actions would show how they approached the different tasks during the usability test. Analysing such findings is valuable, as it can discover potential pressure points or issues with the interface (Sharp et al., 2019, p. 501). In this way, one could measure the effectiveness and efficiency of the added functions. For example, if the majority of the users would encounter multiple error messages throughout, and struggle to move forward, this would indicate that the efficiency of the prototype was low. Meanwhile, if all of them were able to reach the optimal setting, this would indicate high effectiveness.

On the other hand, their feedback would say more about their understanding of the different functions, as well as the user satisfaction of the prototype. The interviews would let them elaborate and explain their thought process throughout, and this data could be analysed according to the set parameters.

These parameters were analyzed from a qualitative perspective, but the quantitative data was also included in the analysis. In that way, one could map how many of the participants understood a certain function, for example. Meanwhile, the qualitative perspective made it possible to extract their feedback from the transcripts to bring forth important nuances and comments.

The understandability, efficiency and user satisfaction of each function was considered as binary during the coding process. Certain criteria were set for each code, to decide whether it was successful or not. For example, the users was asked how they interpreted the functionality of each added feature. Thus, if their interpretation was in sync with the set functionality, they had indeed understood the function. In that way, this was a binary question. Meanwhile, if they reached good radar settings and did not encounter multiple error messages throughout, they walkthrough was considered “efficient”. Lastly, if they stated positive comments about a certain feature or mentioned that they saw it as valuable, and did not have critic remarks, they were deemed “optimistic” towards this feature, which indicated a good user satisfaction.

Understanding

- Did they understand the different features and their functionality?

Efficiency

- Did it require a lot of resources and effort to get decent settings?

User satisfaction

- Were they happy, unhappy, or indifferent to the functions?

However, the effectiveness of the different features was measured in a different manner. Each function was considered according to these four aspects:

Effectiveness

- Did they end up with good settings in the end, where they did not suppress any echoes?
- Did they know the quality of their settings?
- Did they know which echoes were visible on the radar with the current settings?
- Did they know how to change their settings for the better?

RESULTS - UNDERSTANDING

GUIDE

All the participants made it to the end of the guide with good settings. Five of them suppressed the echo at one point and tried to proceed, thus receiving an error popup telling them to change their settings. However, all of them adjusted the settings to a good level and proceeded to the next steps.

This shows that the guide was understandable and intuitive, as they followed the instructions and made it to the end with settings of a high quality.

REFERENCE POINT

Six out of the seven navigators adjusted the radar settings to the best possible quality. All the navigators followed the feedback from the reference point during the tuning process and understood its functionality. For example, shortly after suppressing the reference point echo, one of the navigators noticed the warnings and made the following statement: «Der. Og det har nå gått ned igjen. På en måte så jobber man mot, det er noe en kollega kaller «working to alarms», at man går opp, bruker alarmen som grenseverdi.»

> *[There. And now it has gone down again. In a way you are working towards – it is something a colleague calls "working to alarms", that you go up, and use the alarm as a limit] (Authors translation)*

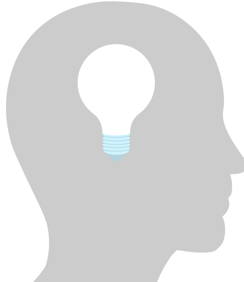
Lastly, one navigator was uncertain whether he had "hit the brief" after tuning from the reference point. When asked how he felt about the tuning from only the reference point, he put it like this:
"Nei, med den så vet jeg ikke helt om jeg traff mål egentlig. Jeg vet ikke om jeg traff oppgaven, for å si det enkelt."

> *[No, with that one, I am not sure whether I hit the goal exactly. I do not know if I hit the brief, to say it plainly.] (Authors translation)*

Meanwhile, when he was asked about the functionality of the red triangle icon for the reference point, he stated the following:
"Det vil nok betyr at du har hatt på så mye clutter at du har undertrykt det ekkoet.»

> *[I think it means that you have added so much clutter that you have suppressed that echo.] (Authors translation)*

This feedback shows that he understood the functionality behind the feature, but he was uncertain whether he had hit the brief. The comments from the navigator show that the reference point function was understandable and intuitive for the most part, but could benefit from some more feedback to keep the user "in the loop" of what was happening.



SENSITIVITY SCALE

Six navigators understood the functionality of the sensitivity scale. However, one navigator misinterpreted its function, and thought that clicking it would change the gain, sea and rain clutter settings above. Two others tried to click the scale, but when asked, they understood functionality behind this feature. One navigator explained its functionality as:
“Den indikerer hva du ser og hva du ikke ser»

[It indicates what you can se and what you cannot se.] (Authors translation)

These findings show that the sensitivity scale had a high degree of understandability regarding its function, but that some participants perceived it as interactive. This indicates that it could be beneficial to make some design alterations to make it appear less interactive, and to avoid confusion.

MINI MAP AND ANOMALIES LIST

All the navigators understood the functions and features involved in the mini map. They referred to the anomalies-list next to it and clearly distinguished the blue, uncharted echoes from the rest. This shows that these features were understood and clear in use.

RESULTS - EFFICIENCY

GUIDE

All the participants replied that the guide was easy to use, while some expressed that they were quite happy with its length and logic order. One navigator replied:
“Det var mye lettere enn radarene jeg er vant til, hvertfall. Det må jeg si.»

[It was much easier than the radars that I am used to. I have to say that.] (Authors translation)

Another mentioned:
«Jeg synes den var veldig logisk. Så, kort og grei egentlig.»

[I thought it was very logical. So, short and simple overall.] (Authors translation)

When examining their actions during their walkthroughs, some interesting findings emerged. Two of the navigators were highly efficient when clicking through the guide and did not encounter any error messages. Four others encountered an error message during their time with the guide, but quickly saw what had to be done to rectify it. These four did not encounter any more error messages after this. The last navigator encountered multiple error messages, in addition to a bug in the prototype during his initial walkthrough. However, on his second walkthrough, he encountered no error messages and was far more efficient.

These findings show that the tuning guide was efficient in use, as they all reached good settings without encountering many obstacles on their way.

REFERENCE POINT

The majority of the navigators went through the radar tuning from the reference point without much trouble. However, the navigator who chose to tune from the reference point before the guide, had this to say about this approach:
"Det var ikke vanskeligere, men det var litt mer trial og error, så man kan jo si at det var vanskeligere på den måten, men jeg synes de fungerte like bra, begge to."

> *[It was not more difficult, but it was a bit more trial and error, so one can say that it was more difficult in that regard. But I think they worked equally well, both of them.] (Authors translation)*

This was also supported by the observations from the test itself, when there were more "back and forth" adjustments of the settings, compared to the other tests. These findings show the learnability of the reference point feature, as the participants who has already encountered it were more efficient. All in all, the reference point feature was considered efficient based on the action and feedback from the usability tests.

SENSITIVITY SCALE, MINI MAP AND ANOMALIES LIST

The efficiency of these three features was not addressed during the analysis.

RESULTS - USER SATISFACTION

GUIDE

Six participants thought that the guide would only be used a few times, as an introduction to the different features. Three of them thought that new navigators would benefit more from this feature, compared to experienced navigators. One participant mentioned the following:
"Hvis jeg tenker tilbake som fersk navigatør, så kunne det ha vært et veldig bra hjelpemiddel»

> *[If I think back to when I was a green navigator, I think this could have been very helpful.] (Authors translation)*

However, one navigator had this to say about the guide:
"Det er jo ting som i utgangspunktet skal være basiskunnskapen hos en navigatør å få til, ikke sant. Så jeg tenker, det er greit å ha det, men jeg forventer at de skal gjøre det av seg selv."

> *[These things should be a part of the basic knowledge of the navigator, right. So, I think that it's okay to have this feature, but I expect them to do this on their own.] (Authors translation)*

Thus, he did not see great value in such a guide, as he saw this as a part of the basic skillset of all navigators. Meanwhile, the rest of the participants were positive to the guide, which shows that this feature had a high degree of user satisfaction.

REFERENCE POINT

The reference point feature had a high degree of user satisfaction, as five navigators were quite happy with the feature, and clearly saw the value. Meanwhile, the remaining two were also positive to the function, but did not think that it made much difference, compared to their current approach. One of these two also came up with the following statement:
«Men den gir jo en veldig tydelig indikasjon på når du har for mye clutter (anticlutter), og jeg har jo sett en del navigatører opp gjennom tidene som hadde trengt denne.»

> *"[But it is a very clear indication that you have too much clutter (anticlutter), and I have seen a fair share of navigators through my time that were in need of this.] (Authors translation)"*

However, three of the seven navigators mentioned that they missed a kind of a map or an ECDIS next to the radar. They did not fully trust the system and wanted to investigate the nature of this reference point. In short, they wanted to check whether it was a buoy, a small piece of land, etc.

This feedback shows that the reference point feature had a high degree of user satisfaction, and that the majority of the navigators saw its value. However, they wanted to check the nature of the reference point, as they did not fully trust the system.

SENSITIVITY SCALE

The sensitivity scale proved to have a high degree of user satisfaction, as six participants were positive to this feature and saw it as a good indicator of the quality of their settings.
"Ja, altså, sånn som den skalaen med disse fartøyene og bøyene og det. Det gir jo en annen visualisering av hva du legger merke til og hva du går glipp av, enn det man er vant til. Og for mange så tror jeg at det kan være veldig nyttig.»

> *"[Yes, like the scale with the vessels and the buoys. It gives a different visualization of what you notice and what you miss, compared to what you are used to. And to many people, I think this could be very useful.] (Authors translation)"*

The navigator student was especially fond of this feature:
«For de som er uerfarne så er den radar sensitiviteten (skalaen) der, den må jo være gull.»

> *"[For the inexperienced, I think that radar sensitivity (scale)... It must be gold.] (Authors translation)"*

However, one navigator had a more indifferent approach to this function and mentioned that she did not make much use of it throughout the test.
"Den glemte jeg bort helt og holdent - Det var mer interessant fra et designperspektiv.»

> *"[I completely forgot that. It was more interesting from a design perspective.] (Authors translation)"*

MINI MAP AND ANOMALIES LIST

Five of the participants saw the mini map as a helpful tool. One of the navigators stated the following:
[Den listen er fornuftig, og den der (minikartet) gir en kjapp visuell forståelse, «Okei, det er noe som ikke er i kartet da».»

> *[That list is sensible (anomalies list), and that one (the mini map) gives a quick visual understanding. "Okay, it is something uncharted".] (Authors translation)*

However, two participants did not think much of the mini map during their tests. One of these two did not see its value, and stated the following:
«Jeg vet ikke om den (peker på minikartet)... Den gir ikke så mye ekstra. Jeg tror det hadde holdt med den her (listen over anomalies) om man nå ville skille på ekkoene.»

> *[I do not know if that one... (points at the mini map) It doesn't add that much. I think it would suffice with this one (points at the list of anomalies) if you wanted to differentiate the echoes.] (Authors translation)*

The navigators were also positive to the anomalies-list in the lower left corner. They mentioned that it quickly gave them an overview of important remarks, like uncharted and suppressed echoes. This shows that the anomalies list and mini map had high degrees of user satisfaction, but that the mini map was not utilized to the same degree as the other features.

RESULTS - PREFERENCES

All the participants were asked whether they preferred to adjust the radar settings

- As on a normal radar, with no additional features
- With the help of the reference point (and no guide)
- With the help of the complete guide

The results from this question were quite varying. Three people would choose the reference point. One would follow the guide. One person would choose the guide or reference point but was not sure which one. The remaining two would either go for the normal radar, or they would tune with the help of the reference point. However, they would not use the reference point if they were not able to verify its quality, as they did not fully trust the system.

This feedback shows that the majority of the navigators mentioned the reference point feature as their preferred feature. This indicates that this has a high degree of user satisfaction.

RESULTS - EFFECTIVENESS

TUNING OUTCOME

All in all, the navigators reached the “optimal” setting five out of seven times when following the guide, not counting the participant who encountered the bug. The remaining two walkthroughs ended up with a more cluttered PPI, as they had lower levels of either sea or rain clutter, but the echo from the reference point was still visible.

Meanwhile, they reached the “optimal” setting six out of seven times, when tuning only from the reference point. The last outcome was also a decent setting, where the reference point echo remained visible.

These findings show that the guide and reference point functions were effective in use and helped the navigators reach good radar settings where they were not suppressing any echoes. This shows the value of the added indicators, as they would quickly make the navigators aware of bad settings.

QUALITY OF THE SETTINGS

Five of the seven navigators mentioned that they would use the reference point as an indicator of the settings-quality. Meanwhile, two navigators would use the mini map for the same purpose. Lastly, two participants mentioned that the sensitivity scale was a good indicator of the quality of their radar settings, as they could see which echoes would be visible and not.

However, three participants noted that the value of these functions was dependant on certain factors, like the situation at hand and the skillset of the navigator. One of them mentioned that they would not have much use of the functionalities in a scenario as the one presented on the radar in the test, but that it could prove valuable in other areas. One other navigator did not feel like the guide would be of much use to her, but rather saw it as an aid for new navigators. The navigator student who participated in the test was quite positive to the feature, supporting the idea to a certain degree. The last navigator mentioned that this was a part of the basic skillset of a navigator, and that they should be able to adjust gain, sea and rain clutter without the help of the guide.

As all of them reached good settings in the end, which shows that the functions made a difference and were effective in use. These comments show that the navigators utilized the different features throughout the tests, to get an indication of the quality of their settings. However, they did utilize different functions to reach the same goal.

WHAT IS VISIBLE

The findings from the analysis show five of the seven navigators specifically mentioned that they would use the reference point as an indicator, to see if this echo was suppressed or visible on the radar. Meanwhile, two of them also stated that they would look at the sensitivity scale for reference.

This feedback shows that the reference point and sensitivity scale were effective indicators that would tell the navigator whether any echoes were being suppressed in the PPI. Meanwhile, they would utilize the sensitivity scale to check whether all the objects were marked green, to ensure that their settings were decent, which shows that this was an effective feature throughout.

HOW TO IMPROVE THE SETTINGS

Three navigators mentioned how the different indicators could help them know when they added too much clutter. Two of them mentioned that they used the red triangle (the reference point) in the radar image as an indicator, whereas one of them would look at the red marking beneath the settings for reference. Meanwhile, the last navigator would use the sensitivity scale as an indicator.

These findings show that they would utilize different features to understand which settings should be adjusted. In short, these were effective indicators that would fulfill their intended purpose. The reference point turned out to be an effective indicator that would fulfil many needs, while the added features like the red marking were more specific in use and were not utilized to the same degree.

FUTURE WORK

The analysis of the usability tests made it apparent that there were some pressure points tied to the prototype. A set of altered or new design solutions were developed as possible solutions to these pressure points.

One could later test these new design ideas to see whether the added changes are an improvement or not. This could be a simple test with 2-3 participants, which is seen as an appropriate number of users for testing basic functions (Preece et al., 2015, p. 525).

The next pages introduce the found pressure points from the test, as well as their potential design solutions.

MORE FLEXIBILITY IN THE GUIDE

Three participants tried to change the gain settings at the “wrong” point in the guide, to see how the image would change. For example, they would try to increase the gain setting while they were adjusting the sea clutter, which was not supported by the prototype.

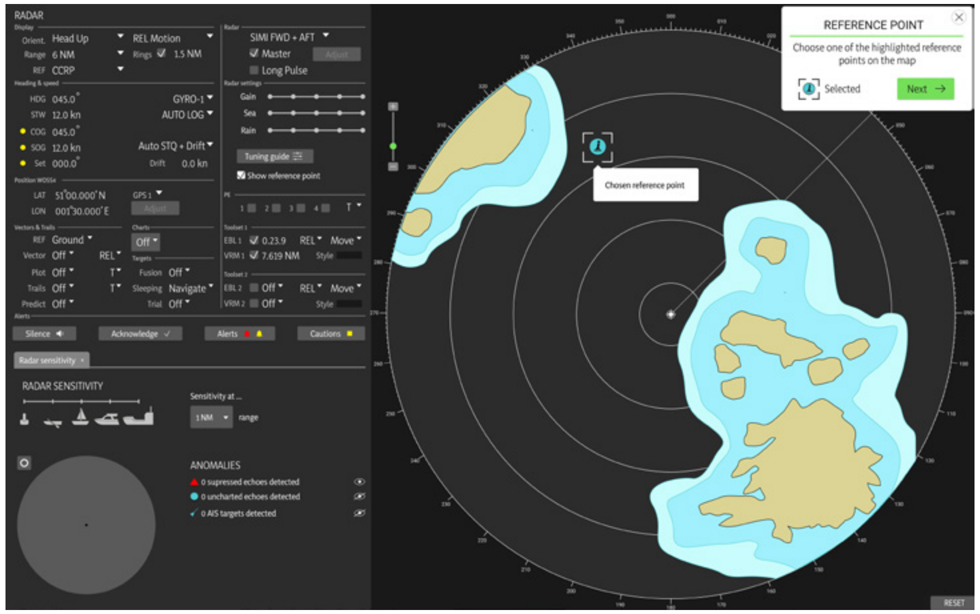
However, as there is often some “back and forth” during such radar tuning, it might be beneficial to make it possible to adjust the prior setting during the tuning guide. In this way, they receive a more fluent experience throughout and the guide becomes more flexible.

QUALITY OF THE REFERENCE POINT

Three participants were unsure of the quality of the reference point. In short, they were not sure what kind of object the system locked onto.

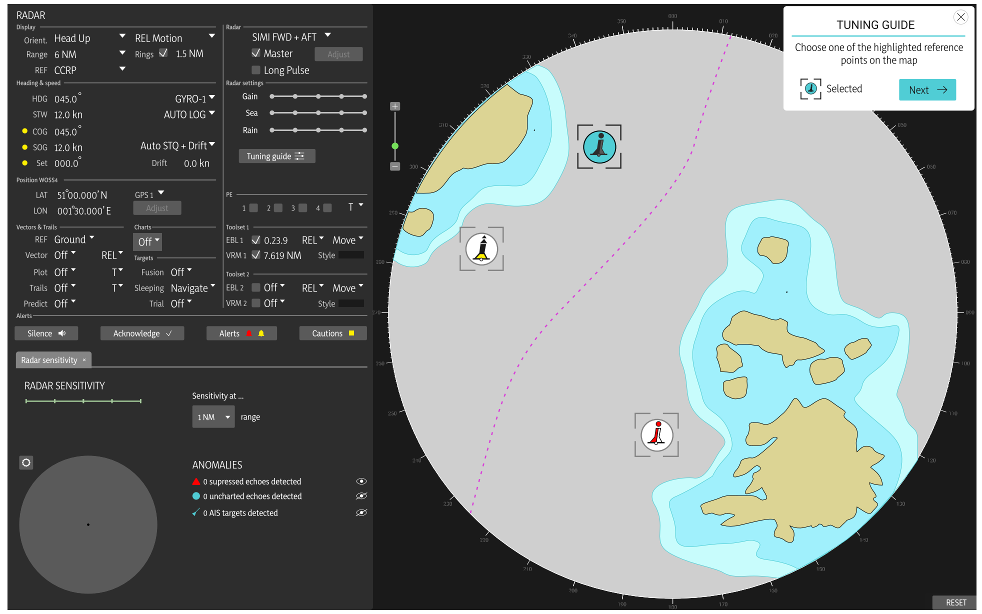
The reference point in the test had the same icon as a buoy, to indicate which type of object was chosen. However, this indicator was not sufficient to make them aware of the nature of the reference point.

PRESENT



Thus, some changes could be made. For example, the chart from the selection process can be changed to look more like a real map, by adding a bright background. This is standard on different charts. In addition, one can enlarge the buoy icons and make sure that they resemble their respective buoy types. This could make it easier for the navigators to know which of the buoys they are seeing outside will be the reference point.

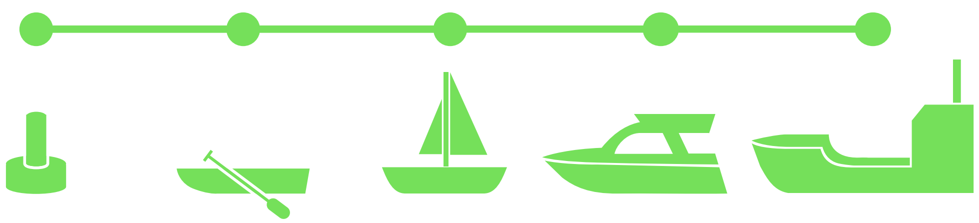
FUTURE



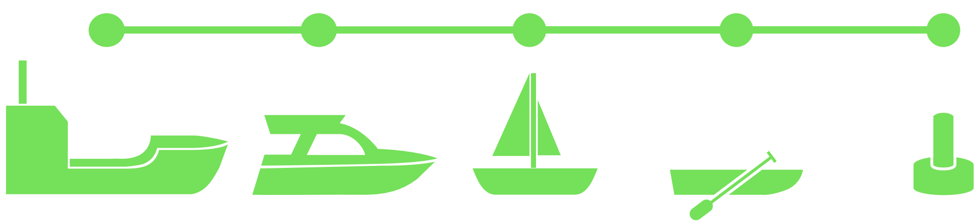
ILLOGICAL ORDER IN THE SCALE

One of the participants mentioned that it could prove beneficial to change the order of the vessels in the sensitivity scale. The argument behind this was that the smaller the echo, the higher the sensitivity. In that way, the navigator found it confusing that the scale ”increases” by moving to the left. Similar features often start from left and increase to the right, whereas this scale does the opposite. Thus, it makes sense to flip it.

PRESENT



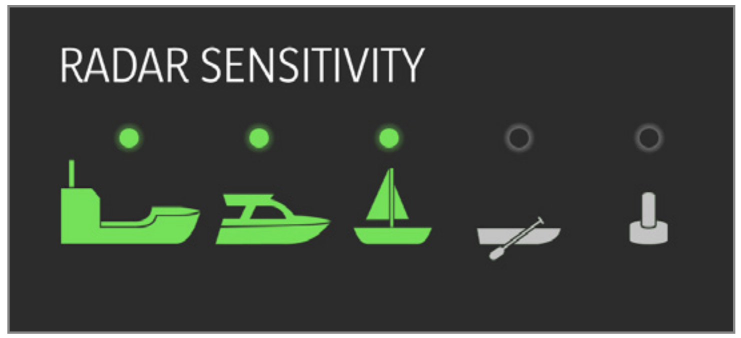
FUTURE

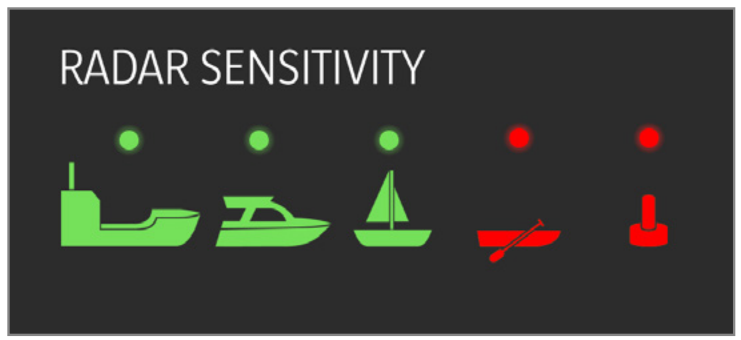


MISINTERPRETED THE SCALE

One participant misinterpreted the function of the scale. Meanwhile, two more participants tried to click it during their tests.

The sensitivity scale has many similarities with the gain, sea and rain clutter sliders, which are interactive. Thus, it is no wonder that several people tried to click it. To avoid this, one can make some small design changes, to indicate that it is not clickable. For example, one can add simulated lights above the vessels, much like the yellow dots further up in the menu. In that way, the scale will look more like an indicator instead of an interactive object. The suppressed elements can be red or grey, for example.

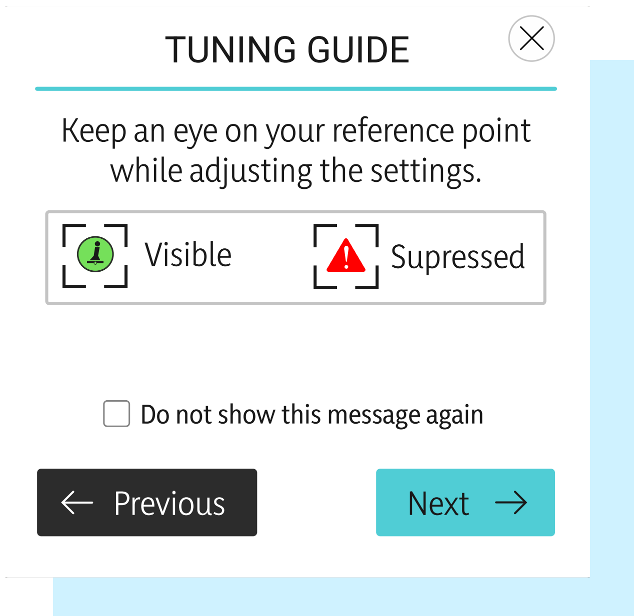




HOW TO PROCEED

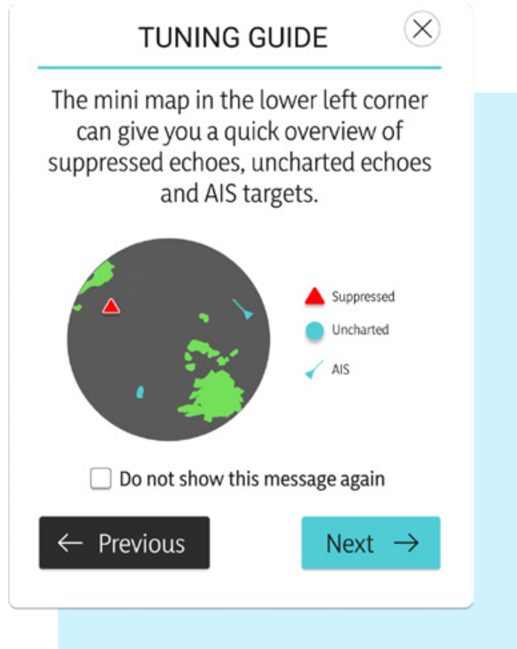
Three people had an idle period after they had chosen the reference point, before they started adjusting the settings on their own. This might indicate some insecurities regarding how to proceed when they were not being supported by the tuning guide.

To clarify the functionality of the reference point, one can add a popup once the reference point has been chosen. In that way, they get an indication of how to proceed and an explanation of what the different icons mean.



IGNORING THE MINIMAP

Two people did not notice the mini map during their tests. This might be caused by the fact that it was not directly involved with the radar tuning itself. However, it might be beneficial to make the navigators aware of this feature, as it can be utilized during normal navigation as well. One could implement it as a part of the tuning guide, so that the guide introduces the user to all the added functions. This will make them aware of the functionality of the mini map.



DISCUSSION

This chapter includes the main discussion. The validity of the results will be addressed, as well as the project outcome and future work.

VALIDITY

The validity of the results is dependent on a range of different factors. A number of these factors are listed below.

VALIDITY CHECK

For one, the validity check that followed the initial interviews validated certain findings, and disproved others. This check was done with the help of the previous interviewees, and the results showed that they encountered multiple challenges. It became apparent that radar tuning and unpredictable traffic were two big issues. This user involvement ensured that the project would be based on real, confirmed user needs and challenges.

LEADING QUESTIONS

Prior to the usability tests and following interviews, the interview guide itself was discussed with the supervisor to ensure that it did not include leading questions. However, during the final interviews, there were two instances where such leading questions were asked. These questions regarded the uncharted echoes, and whether the navigators thought it was a good idea to have an on/off switch for their visibility. As this was discovered during the analysis, it was decided to exclude these answers from the results. This exclusion did – however – not make a substantial difference, as all the remaining participants were positive to the feature. Meanwhile, this exclusion ensured that the results remained valid.

FACILITATOR INVOLVEMENT

In addition, the facilitator answered two questions during the usability tests, regarding the functionality of certain elements in the prototype. This could have skewed their answers in the final interviews. However, as this involvement was simply confirming their existing suspicions, it was not seen as a source of error that would affect the results.

PARTICIPANTS

The same navigators were included in both the initial interviews, sketch discussions and later usability test. This meant that they had prior knowledge to the functions they accessed during the test. Their previous involvement could – however – be a possible source of bias. Sharp et. al describes bias as "selecting a population of users who have already had experience with the new system and describing their performance as if they were new users" (Sharp et al., 2019, p. 515). The participants had previously seen sketches for most of the added functions and had their functionality explained during these sketch discussion. This involvement could be seen as a possible source of error. However, in the shipping industry, it is common that the navigators get training or an introduction to the functionalities of the systems when going on a new ship. For example, junior navigators will get such demonstrations from the existing mariners onboard (Baum-Talmor & Kitada, 2022, p. 7). Thus, their prior knowledge to the functions was not seen as a source of error in this project, but rather a factor to be aware of. In addition, the navigator student that participated in the usability test had no prior knowledge to the project and developed functions, and there was no apparent difference between their performance compared to the navigators who had been included from the start.

REPRESENTATIVE USERS

When conducting usability testing, it is important to include representative users to ensure that the results are valid (Lazar et al., 2017b, p. 274). In total, seven navigators tested the final prototype. Six were experienced navigators, while the last participant was a navigator student. It was decided that the navigator student should be included, as the product was aimed towards both experienced and inexperienced navigators. The fact that the participants were all members of the user group helps increase the validity of the results.

NUMBER OF USERS

However, the recommended number of users vary between sources. Lazar et al. mentions that five users is seen as an appropriate number of users, and that roughly 80% of the existing usability issues in a design could be found through these initial five. Others say that seven is a more appropriate number, and that a larger pool of participants is key to uncovering substantial usability flaws (Lazar et al., 2017b, p. 275). In short, this is a debated topic, but the key purpose of including these users is to uncover possible usability flaws. In that way, one could approach it from a different angle. As this project followed a qualitative approach, it was decided to not decide the number of participants based on the quantitative perspective. Instead, it was chosen to proceed with usability tests until the user feedback was somewhat consistent, where they would uncover many of the same flaws and issues. The final user test uncovered few new issues, and at that point, the participants responses supported each other. Thus, it was decided that seven participants were sufficient.

NON-REPRESENTATIVE ENVIRONMENT

The fact that the tests were done remotely was in one way convenient, but also had its drawbacks. For one, it is a non-representative environment, and meant that they did not have access to other instruments that they would normally use to cross-check the information on the radar. Some of the navigators mentioned that they missed having a chart to compare to the radar image, as they would have liked to check the terrain in the surrounding area to consider the quality of their radar image. All in all, this lack of additional instruments made the navigators somewhat uncertain of their radar, which might have affected the results.

REALISM OF THE PROTOTYPE

The main aspects of the prototype were described as realistic and the participants stated that it behaved like a real radar. On the other hand, several people mentioned that the ideal gain levels were artificially high, and that they missed the opportunity to fine-tune the settings. These aspects somewhat reduced the realism of the prototype. However, the main goal of the test was to see whether they would use the added features and whether these would help them during their tuning process. Thus, the comments regarding the levels of gain and lack of sliders were not seen as invalidating.

REPEATING THE TUNING GUIDE

One participant encountered a bug during the guided tuning. This bug sent him back one or two steps when they clicked a certain button. This led to some confusion, and he did not end up with settings he was happy with. Thus, he was asked to try the guide again, as the initial run had been compromised. His second guided tuning ended up being vastly more efficient than the first, and he did not encounter any error messages, unlike their first run. The fact that he went through the guide twice could have some effect, as he had prior knowledge of the functions and following steps. However, it was not seen as a source of error, as the other participants had free access to the prototype during the later interview as well and proceeded to test and click the different elements throughout.

NVIVO CODING

NVivo coding was used throughout the project, to increase the validity of the results and reduce the possibility of bias. This method let the data "speak for itself", as it was based on the transcriptions from the initial interviews, as well as the final usability tests. The use of such quotes increases the validity of the analysis and reduces the influence of a possibly biased researcher. These quotes made it easier to form an opinion on the results, as they clearly represented the thoughts of the participants. Additionally, several passes were done during the coding process, to ensure that no potential issues or flaws were missed. A second sweep was conducted after the initial coding, where the coder made sure to extract all possible instances of pressure points, critique or comments regarding issues in the prototype, and these were then added to the existing list of such pressure points and critique. This sweep was done to try and counteract potential biases from the initial coding.

OVERALL

The validity of the results was strengthened by the use of certain methods. For one, the validity check ensured that the perceived issues were correct. Meanwhile, the usability tests were conducted with representative users, and with a sufficient number of participants. Additionally, the prototype emulated a real radar to a sufficient degree, which let the user focus on the tasks during the tests. Lastly, the use of In Vivo coding helped protect the results from bias.

However, there is one aspect that might affect the results in some way: the fact that the usability tests were conducted in a non-representative environment. Thus, it could prove beneficial to conduct a few more usability test in a representative environment, to see whether it would reproduce the same results.

DID IT SOLVE THE PROBLEM?

The goal of the project was to develop a set of additional radar functions, that would make it easier for the navigator to adjust the settings to a decent level.

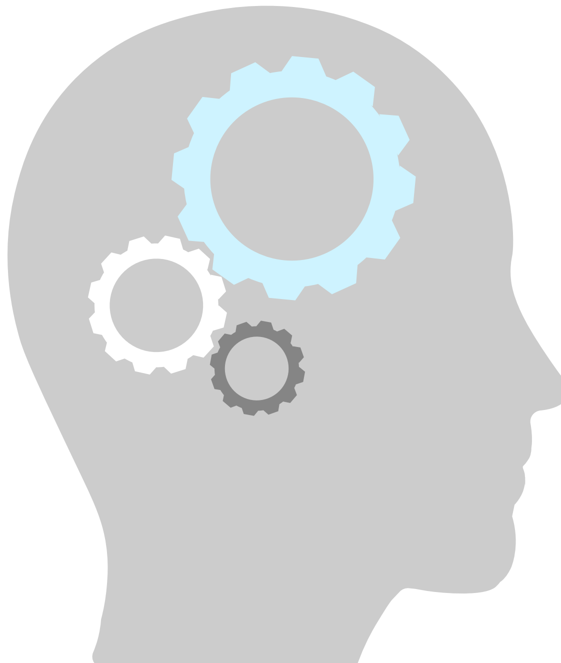
The functions should...

- Indicate which echoes are visible, and which echoes are being suppressed
- Indicate the quality of the current radar settings
- Indicate how one can adjust the radar settings to make suppressed echoes visible

Five functions were developed as possible solutions to the radar issue: First of all, the tuning guide, which introduces the added functionality and gives the navigator a step-by-step guide on how to adjust the settings properly. Secondly, a reference point indicator, which lets the navigator choose a charted elements in the map as a reference point and informs them of whether the echo from this reference point is being suppressed or not. Thirdly, a sensitivicty scale, that gives the navigator a visual indicator of which echoes are visible and which echoes are being suppressed. The fourth feature is a mini map, that highlights suppressed and uncharted echoes, to give the navigator a brief overview of their position. Lastly, the anomalies list, which lists up the present anomalies in the mini map and lets the navigator highlight these in the PPI itself.

UNDERSTANDABILITY

However, it was vital that these functions were transparent and easy to understand. The understandability of these features was adressed during the usability tests. The results from the tests show that the participants understood the functionality behind the added elements. However, one participant was somewhat unsure of the functionality of the scale, and another had some uncertainty regarding the reference point function. This indicates that these features are understandable, but not sufficiently intuitive. In that regard, it might be beneficial to add some feedback to counteract these uncertainties.



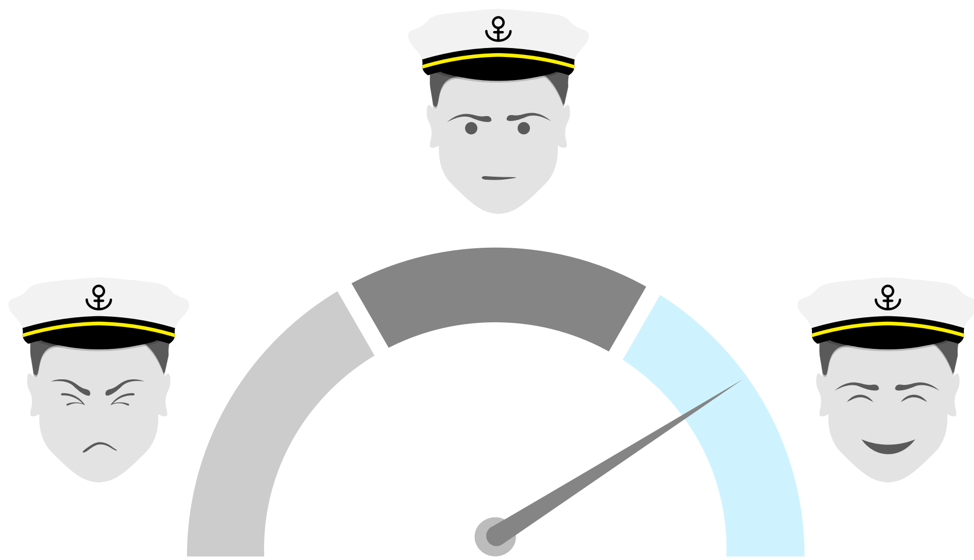
EFFICIENCY

Meanwhile, it was important that the added functions were efficient in use. The results from the tests showed that some of the navigators clicked through the tuning guide without encountering any issues, while others encountered one error message before proceeding. However, the majority of those who encountered such warnings did not face them again, as they adjusted their settings to a good level after this incident. The one navigator who encountered multiple error messages was affected by a bug that would make progression difficult. Thus, this instance was not seen as a sign of low efficiency.

These results indicate that the error messages in the tuning guide made the users aware of the issue. In that regard, it also increased their efficiency, as they made precautions to not encounter the same error again. They also utilized the reference point indicator to find the appropriate setting levels. These results show that the reference point feature made the tuning process more efficient.

USER SATISFACTION

The user satisfaction of the different features was also adressed during the analysis. Results from the tests show that the added features had a high degree of user satisfaction, and that most of the participants were positive to the guide, reference point and sensitivity scale. Additionally, one of the participants with a relatively indifferent approach to the reference point, still acknowledged its value to other navigators. This feedback confirms the value of this feature, but also makes it apparent that all navigators might not utilize it. Lastly, five partcipants were potisitve to the mini map, while two others had not thought much of this feature. However, the fact that two navigators did not pay much attention the mini map is not necessarily an indicator of low user satisfaction but could simply indicate that it was not a very prominent feature. One could for example include an introduction to the mini map in the tuning guide, to make the navigators aware of its functionality.



EFFECTIVENESS

QUALITY OF THE SETTINGS

One of the main goals in this project was to make the navigators aware of the quality of their radar settings. The results from the usability tests showed that both the reference point and tuning guide were effective indicators that would inform the participants of the settings quality. Each navigator reached good radar settings in the end, both when tuning from only the reference point, as well as the guide. This shows that the added features were helpful in this regard.

Additionally, the navigators that initially suppressed the reference point and encountered the error message, was made aware of the reference point feature and proceeded without suppressing it in the end. If they had tried to proceed with bad radar settings, this would indicate that the guide had a low effectiveness. However, all the navigators adjusted their radar settings to a good level before proceeding. This shows that the guide was effective in use and could prove valuable during normal navigation.

The usability tests showed that the reference point was also an effective indicator that would inform the users of the quality of their radar settings. Most of the participants utilized this feature throughout. The interesting thing about the reference point tuning is that it is a more independent kind of tuning, where the user can adjust the settings however they want without encountering such error messages. All the present indicators are – in this case – visual elements like red triangles and red markings. Thus, the fact that all seven navigators reached a level of good settings in this scenario, is quite interesting. It shows that the reference point helped them during their tuning process and made them aware of the quality of their settings. However, most of the navigators followed this approach after completing the guide. There is a chance that the users simply remembered the settings from the guided tuning, and thus knew the idea outcome of the tuning process. On the other hand, the one participant who chose to follow the reference point during their first walkthrough ended up with good settings, nonetheless. This indicates that the different features helped them throughout the tuning process.

Meanwhile, the scale and mini map were also effective indicators of the settings quality, but the participants did not utilize them to the same degree as the reference point feature.

VISIBLE ECHOES ON THE RADAR

The initial interviews showed that the navigators were uncertain whether they were suppressing echoes in the radar. Thus, one of the main goals in this project was to make features that informed them of which echoes would be visible in the PPI.

For one, the sensitivity scale was a feature aimed directly towards this purpose. During the tests, the navigators looked at this scale for reference to see which echoes were visible and not. This shows that the scale was effective in use and made them aware of which echoes were potentially being suppressed.

Additionally, the reference point turned out to be another effective indicator, as it informed the navigators of the status of their reference point echo. All the navigators used it correctly throughout the tests, and they all understood its function. They kept an eye on the icon in the PPI to check whether the echo from the reference point was visible or not, meaning that they used this feature as intended. These observations shows that the reference point was an effective indicator throughout.

HOW TO IMPROVE THE SETTINGS

The last project goal was to inform the navigator of how they could improve their settings to a point where they were not suppressing any relevant echoes. Certain indicators were added to the prototype to emulate such a function. Mainly, the ”responsible” setting was marked in red to indicate that the user should change this setting.

However, only one navigator mentioned the red markings below the settings, so one cannot say for certain whether this feature was effective or not. She did – however – see this as an indicator that she should change her settings. However, this was the only participant who mentioned this feature. The cause of this could simply be that the remaining navigators noticed other, more prominent changes, or that they did not notice the red markings. Either way, their approach was correct, and all of them ended up with good settings in the end.

Meanwhile, the reference point also turned out to be an effective indicator, that would let the navigators know how they could improve their settings. The feedback from the final usability test show that the users often looked at the reference point during their tuning, to see how their settings affected the icon. In that way, if they added more sea clutter, for example, they keept an eye on the reference point to see if it turned red. If they noticed that they were suppressing the echo, they knew that they had added too much sea clutter and would adjust their settings. This shows that the feature worked as intended, and was effective in use.

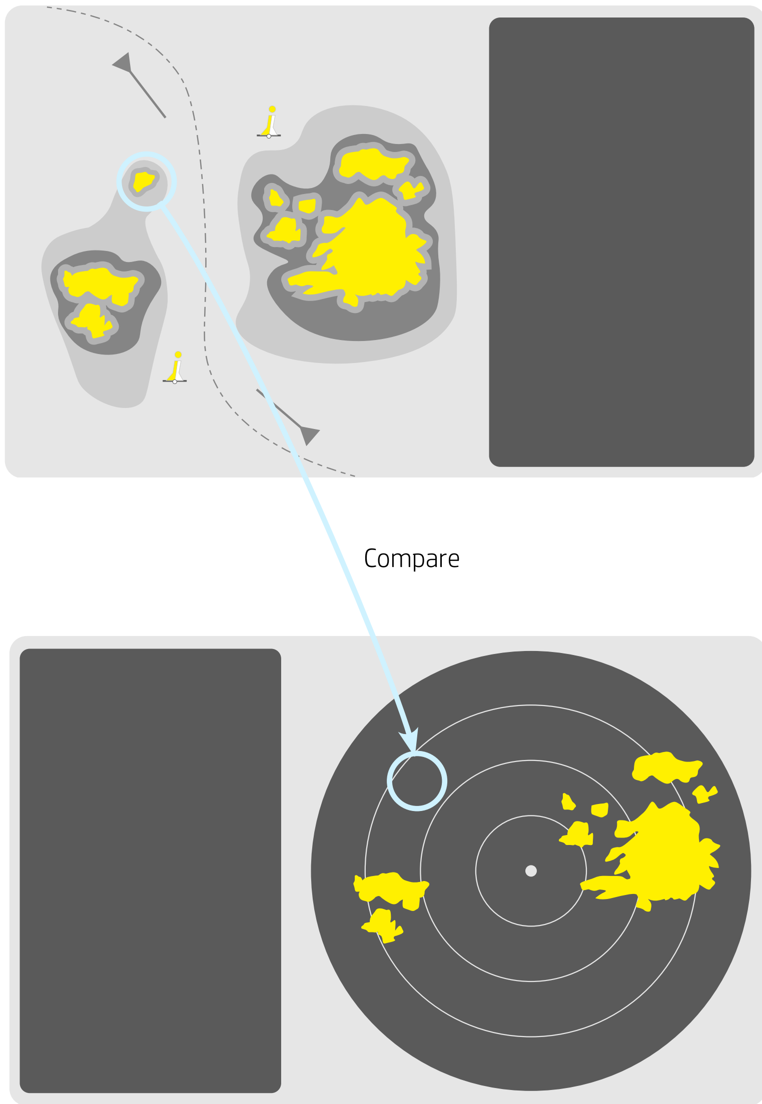
FEASABILITY

During the project, I wanted to develop features of a high degree of usability, but I also wanted to make sure that they were actually feasible in real life. Thus, I considered some of the logic behind the different features, based on the existing functionality of the navigational equipment.

REFERENCE POINT

For one, the ECDIS has a complete overview of which object should be present in the waters, should they be pieces of land, buoys or lighthouses (Kjerstad, 2015, pp. 2-149). Thus, the idea behind the reference point function is that the navigator will choose a rather small, charted element in the surrounding waters, for example a buoy. Then, the system will compare the radar image and ECDIS, to see whether this charted buoy gives an echo or not. Simply, if there is no concentrated echo output in the area where the buoy should be, it means that the echo is most likely being suppressed. Thus, one can use this comparison to set the "state" of the reference point to either green(visible) or red (suppressed).

Today, many radars have existing functionality that could be used to make this happen. For example, the automatic radar plotting aid (ARPA) which will detect moving targets in the area. This system will target certain echoes, which will give the navigator a notification "new target". Meanwhile, if that target is lost, they will get notified "lost target" (Kjerstad, 2015, pp. 2-92). This system proves that the existing technology is already present, and one could use many of the same principles to check the status of a reference echo.



MINI MAP

The mini map is based on the same principles as many of the other functions, where the ECDIS and radar output is compared in the system. In the same way that one can use the map to discover which elements *should* be there, one can also discover which objects should *not*. This is the idea behind the marking of the uncharted echoes, as these are not a part of the "expected" echoes, based on the data from the ECDIS. The map itself is simply taken from the ECDIS, but the objects have different colours, based on their type.

SENSITIVITY SCALE

Lastly, the idea behind the sensitivity scale is to use much of the same functionality as previously mentioned and use that to see which echoes are visible on the radar. Meanwhile, if the system notices that a buoy is being suppressed, the scale will indicate that it is not possible to see similar objects on the radar by making the buoy-icon grey. Meanwhile, if larger objects like beacons or lighthouses do not appear as echoes on the radar, the system will inform the navigator that larger, corresponding objects are being suppressed. This requires a kind of database with the estimated RCS (radar cross-section) of the illustrations on the scale, like the RCS of buoys, small fishing vessels and larger vessels. The development of such a database is discussed in the following section, "Future work".

VESSEL TYPE	ESTMATED RCS [m2]
Buoy	X
Fishing vessel (35 feet)	X
Small coaster(120 feet)	X

FUTURE WORK

ADDITIONAL USABILITY TESTING

The final prototype simulates a radar with the added functions, but it is not a functional product. Thus, some work would have to be done before it could be added to the market. For one, the usability tests discovered some issues with the current prototype. It could be beneficial to implement the suggested changes from the Prototyping-chapter, and conduct a few additional tests.

CONTACTING RELEVANT STAKEHOLDERS

The next step after such tweaking would be to present the idea to a company. The prototype itself was based on the radar from Wärtsilä, thus, it would make sense to present it to this company. There is already room on their radar for most of the added features, meaning that the design itself can rather easily be implemented as a part of the display. However, Kongsberg Maritime is another big actor in the maritime market, as they deliver complex solutions to many types of vessels. This is another relevant actor that could be contacted. In short, one could approach several companies and present the project and the prototype. However, as the prototype was developed with the Wärtsilä radar in mind, one would have to change the setup somewhat to make it fit into a Kongsberg-radar, for example.

MAKING IT WORK

Meanwhile, there is still some work to do in regard to the actual functionality of the different elements. For example, the sensitivity scale requires some additional work to function in a real-life setting. During the project, it was discovered that there is no concrete database containing the registered RCS of different vessels. However, there has been some research on this area which could be utilized in the development of such a database. It is possible to find the estimated RCS of certain elements, like some buoys, fishing vessels, coasters etc (Arctia, 2021a, 2021b; Williams et al., 1978). In short, one would have to assemble a database of the known RCS of certain kinds of vessels and use that to translate the data from the radar and database into the sensitivity scale.

Additionally, these features would have to be coded and implemented into an existing radar. This step would be initiated if the idea was picked up by a relevant company.

ADDRESSING THE OTHER DISCOVERED CHALLENGES

Lastly, future work could also revolve around the discovered issues from the initial interviews that have not been addressed throughout the project. The traffic issue presents a major challenge to the navigators, and it could benefit them if this was addressed in some way. Simply days before the delivery of this report, there were national news of an almost-collision between a cruise ship and a cabin cruiser in the Norwegian fjords (Emma Findenes Øvrebø, 2022). This extenuates the importance of addressing this issue.

CONCLUSION

This chapter contains the main conclusion.

CONCLUSION

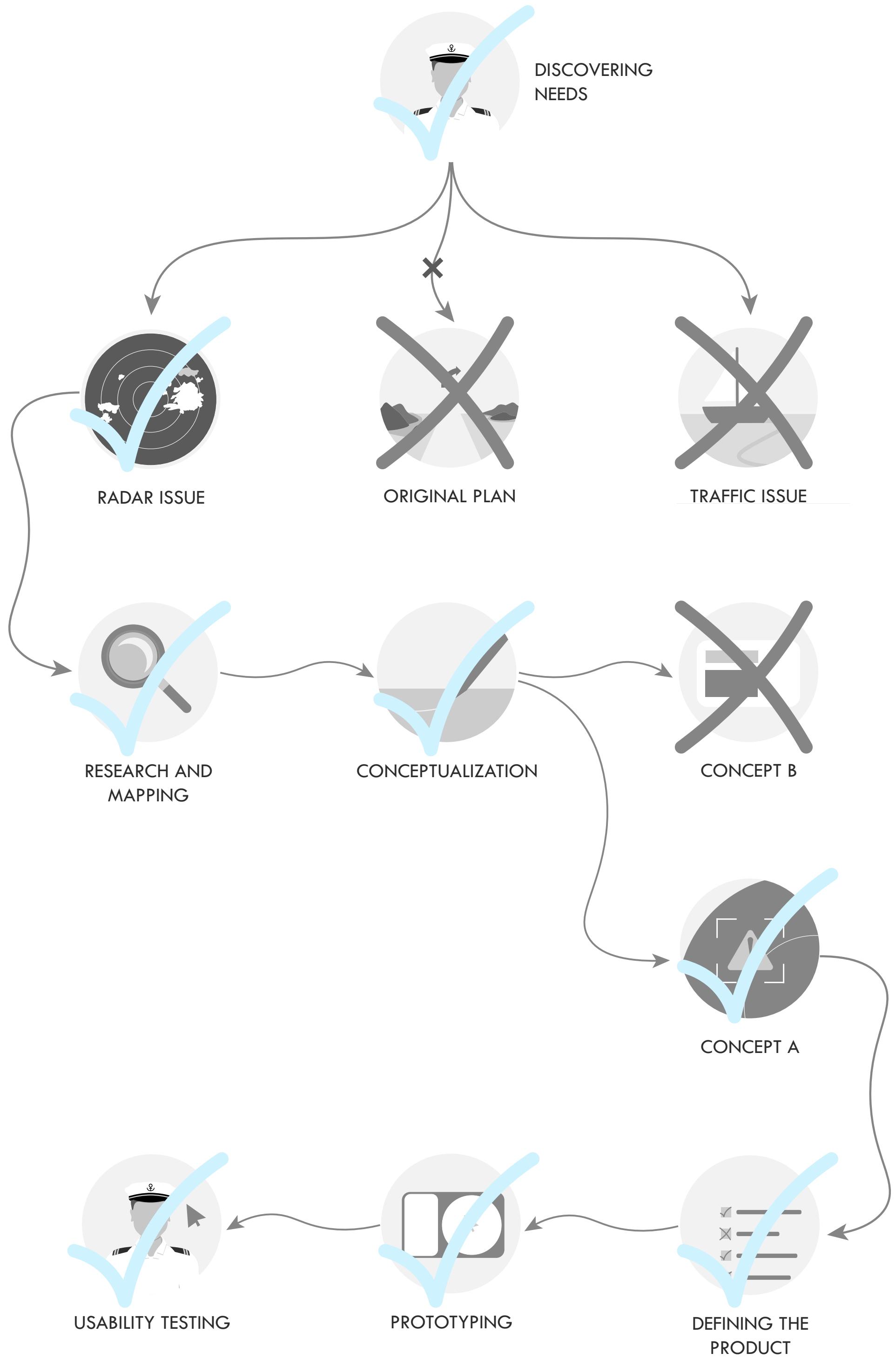
This project clearly shows the value of the human-centered design approach. The initial goal of the project was to develop a situational awareness display tied to Porathe's existing research. Meanwhile, the findings from the initial interviews made it apparent that the navigators are not in need of such a display, but encounter different challenges on a daily basis. It was decided to pursue the radar tuning issue, where the navigators struggle to find a balance during their radar tuning. On one hand, they want a clean-looking radar image, so that they can spot relevant echoes. On the other hand, if they filter out too much, these echoes will disappear from the screen. The consequence is that their primary tool for collision avoidance will not give an accurate depiction of reality, and can no longer ensure safe navigation.

A series of potential solutions were sketched out and shown to members of the user group. Their feedback was used to further iterate upon these ideas and later to extract the most valuable concepts. These were implemented into the final prototype, and tested on representative users. However, as the tests were done remotely, it could be beneficial to conduct similar tests in a more representative environment, to examine whether this would reproduce the same results.

Lastly, the findings from the usability tests were analysed and used to evaluate the prototype based on the key aspects of usability. The results from this analysis shows that the developed features have a high degree of understandability, efficiency and user satisfaction. In short, these features improved the usability of the radar tuning process.

EVALUATION

This chapter includes my evaluation of the project, as well as the process itself and the challenges I faced throughout.



THE PROCESS

This project has proven to be both educational, inspirational and challenging.

As the shipping industry is a rather unknown domain, I spent a lot of time trying to understand the approach and challenges of the navigators. I gathered insight through an initial literature search, but this proved to be insufficient to get a good understanding of their methods. Thus, I went to the vocational school for some hands-on experience, which proved to be quite valuable. Later in the project, when I was about to start sketching possible solutions for the radar-issue, I realized that I did not have a sufficient amount of insight into the problem. Thus, I decided to partake on another research trip, which gave concrete information on how to approach the issue. This made the conceptualization-phase easier and ensured that my sketches would be accurate according to the “correct” practice. In short, there was a lot of back and forth to ensure that I had a sufficient amount of insight to proceed to the next step. This was a valuable learning experience, and showed the value of good preparation and sufficient knowledge of the chosen domain.

Meanwhile, the feedback from the navigators was a great help throughout. It truly showed me the value of involving the users from the get-go, as their feedback drove it in a completely different direction than initially thought. If I had continued along the path of the situational awareness device, I may have ended up with a product that they had no use for, a product detached from the market and the needs of the users. This shows the value of the user-centered design approach, which I embraced throughout the project.

This project made me aware of the importance of an experienced and involved supervisor. Erik Styhr Petersen, my supervisor at NTNU, has shared his knowledge with me throughout and helped me navigate through an unknown domain. For this, I am very thankful.

THE PRODUCT

In the beginning of the project, I had a quite clear idea of the product I was going to create. However, as the project goal changed and went in the direction of the radar, I was uncertain of what kind of product I was going to end up with.

However, in the end, I stand here with a functional prototype that emulates a real radar to the point where the experienced navigators discussed it like it was functional. I am proud of the final product and happy with the feedback from the navigators.

The results from the final usability tests show that the added features helped the navigators throughout their radar tuning. They were positive to the new functions and utilized them throughout, and all ended up with good settings in the end. This strengthened my confidence that these features can make a real difference to the navigators, and proved the value of this project.

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APPENDIX A

INTERVIEW GUIDE - USABILITY TEST

1. Hvordan synes du det gikk å justere innstillingene ved hjelp av guiden? EFFICIENT

2. Var det enkelt, vanskelig? EFFICIENT

3. Hvordan synes du det gikk å justere ved hjelp av kun referansepunktet? EFFICIENT

4. Var det enkelt, vanskelig? EFFICIENT

5. Hvordan vet du om innstillingene er gode nå? EFFECTIVE

6. Hvordan var det å justere radarinnstillingene i denne testen, kontra på en vanlig radar, når du hadde disse ekstrafunksjonene til rådighet? EFFECTIVE

7. Hvis du skulle ha justert igjen, ville du ha... USER SATISFACTION

a. Gjort det på vanlig måte, uten noen form for hjelp

b. Justert kun ut ifra referansepunktet

c. Justert ved hjelp av guiden

8. Var det noen irritasjonsmomenter? USER SATISFACTION

9. Sammenlignet med en vanlig radar, var det lettere eller vanskeligere å vite om innstillingene dine var gode her? EFFECTIVE

Elementer

10. Hva synes du om minikartet nede i venstre hjørne? La du merke til det? USER SATISFACTION

a. Hva betyr de blå objektene på kartet? UNDERSTANDING

b. Hva betyr den røde trekanten på kartet? UNDERSTANDING

c. Trykk på øyet – hva synes du om en slik løsning (uncharted echoes markert på radar). USER SATISFACTION.

11. Hva tenkte du om skalaen? La du merke til den? UNDERSTANDING

a. Hva tror du den betyr? UNDERSTANDING

Til slutt

12. Var det noe spesielt du likte eller mislikte ved prototypen? USER SATISFACTION

13. Var det noe som var uklart eller noe du var usikker på underveis? USER SATISFACTION

APPENDIX B

CONSENT FORM - USABILITY TESTING

Vil du delta i forskningsprosjektet «Design av informasjonsdisplay på skipsbro»?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å utvikle et informasjonsdisplay til bruk på skipsbroen. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Prosjektet går ut på å utvikle et brukergrensesnitt til et display som gir navigatøren en oversikt over viktig informasjon om kommende farvann. Nærmere bestemt et radardisplay med ekstra funksjoner. Det blir en del kartleggingsarbeid for å undersøke hva grensesnittet skal inneholde.

I den sammenheng er det viktig å undersøke hvordan situasjonen er på broen i dag; om det nåværende oppsettet fungerer eller om det er noen rom for forbedring. Målet er at informasjonsdisplayet skal gi en bedre oversikt over situasjonen, derfor er det nyttig å vite hvor svakhetene ligger i dag.

Prosjektet utgjør en masteroppgave innenfor studieretningen Industriell design ved NTNU.

Hvem er ansvarlig for forskningsprosjektet?
NTNU er ansvarlig for prosjektet. Det kan også bli aktuelt å involvere NTNU Shore Control Lab.

Hvorfor får du spørsmål om å delta?
Du blir spurt om å delta siden du sitter på innsikt som kan komme til god nytte i prosjektet. Dette displayet skal utvikles for navigatører, og derfor er det viktig å involvere dere fra starten. Innspill fra deg kan nemlig gjøre det enklere å finne ut av hvor behovet ligger og hvordan man kan gjøre displayet så brukervennlig som mulig.

Hva innebærer det for deg å delta?

- Brukertest
  Hvis du velger å delta i prosjektet, innebærer det at du deltar i en brukertest over Teams. Det vil ta cirka en time. Du vil først få en kort introduksjon til prototypen og de tilknyttede funksjonene, før selve brukertesten begynner. Etter testen vil jeg stille deg noen spørsmål. Hvis det er greit for deg så vil jeg gjerne ta video- og lydopptak av intervjuet, slik at jeg enklere kan analysere resultatene i ettertid. Dersom dette ikke er ønskelig, vil jeg isteden notere underveis.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Personopplysningene vil være tilgjengelige for studenten (Julie K. S. Solberg) og veileder (Erik Styhr Petersen) ved NTNU
- Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data

Personopplysningene vil ekskluderes fra den endelige masterrapporten. Denne rapporten vil være tilgjengelig for offentligheten, og vil ta for seg metodene (intervju, brukertest osv), samt hovedfunn. Informasjonen i rapporten vil ikke kunne spores tilbake til deg.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er juni 2022. Etter dette vil alle personopplysninger slettes.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke. På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Masterstudent i Industriell design ved NTNU
  Julie Karine Schmidt Solberg
  Telefon: 970 94 481, e-post: jksolber@stud.ntnu.no
- Veileder ved NTNU
  Erik Styhr Petersen
  Tlf 45 401 16 494, e-post: erik.s.petersen@ntnu.no
- Vårt personvernombud
  Thomas Helgesen
  Tlf. 930 79 038, e-post: thomas.helgesen@ntnu.no

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Julie Karine Schmidt Solberg

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «Design av informasjonsdisplay på skipsbro», og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i brukertesten
☐ at det tas lydopptak av testen
☐ at det tas videoopptak av testen

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltaker, dato)

APPENDIX C

CONSENT FORM - INTERVIEWS

Vil du delta i forskningsprosjektet «Design av informasjonsdisplay på skipsbro»?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å utvikle et informasjonsdisplay til bruk på skipsbroen. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Prosjektet går ut på å utvikle et brukergrensesnitt til et display som gir navigatøren en oversikt over viktig informasjon om kommende farvann. Dette brukergrensesnittet kan være i form av et slags 2D/3D-kart som gir en mer fokusert oversikt enn dagens systemer. Det blir en del kartleggingsarbeid for å undersøke hva grensesnittet skal inneholde.

I den sammenheng er det viktig å undersøke hvordan situasjonen er på broen i dag; om det nåværende oppsettet fungerer eller om det er noen rom for forbedring. Målet er at informasjonsdisplayet skal gi en bedre oversikt over situasjonen, derfor er det nyttig å vite hvor svakhetene ligger i dag.

Prosjektet utgjør en masteroppgave innenfor studieretningen Industriell design ved NTNU.

Hvem er ansvarlig for forskningsprosjektet?
NTNU er ansvarlig for prosjektet. Det kan også bli aktuelt å involvere NTNU Shore Control Lab.

Hvorfor får du spørsmål om å delta?
Du blir spurt om å delta siden du sitter på innsikt som kan komme til god nytte i prosjektet. Dette displayet skal utvikles for navigatører, og derfor er det viktig å involvere dere fra starten. Innspill fra deg kan nemlig gjøre det enklere å finne ut av hvor behovet ligger og hvordan man kan gjøre displayet så brukervennlig som mulig.

Hva innebærer det for deg å delta?
- Intervju
  Hvis du velger å delta i prosjektet, innebærer det at du deltar i et intervju over Teams. Det vil ta cirka en time og du vil bli spurt om hvordan du går frem for å skaffe en god situasjonsforståelse når du navigerer, både på daglig basis og i spesielle situasjoner. Dersom det er greit for deg så vil jeg gjerne ta lydopptak av intervjuet, slik at jeg kan transkribere alt i etterkant og sørge for at den noterte informasjonen er så nøyaktig som mulig. Dersom dette ikke er ønskelig, kan jeg heller notere underveis og utelate alle personopplysninger.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.
- Personopplysningene vil være tilgjengelige for studenten (Julie K. S. Solberg) og veileder (Erik Stylhr Petersen) ved NTNU
- Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data

Personopplysningene vil ekskluderes fra den endelige masterrapporten. Denne rapporten vil være tilgjengelig for offentligheten, og vil ta for seg metodene (intervju, brukertest osv), samt hovedfunn. Informasjonen i rapporten vil ikke kunne spores tilbake til deg.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er juni 2022. Etter dette vil alle personopplysninger slettes.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke. På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:
- Masterstudent i Industriell design ved NTNU
  Julie Karine Schmidt Solberg
  Telefon: 970 94 481, e-post: jksolber@stud.ntnu.no
- Veileder ved NTNU
  Erik Stylhr Petersen
  Tlf 45 401 16 494, e-post: erik.s.petersen@ntnu.no
- Vårt personvernombud
  Thomas Helgesen
  Tlf. 930 79 038, e-post: thomas.helgesen@ntnu.no

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:
- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Erik Stylhr Petersen *Julie Karine Schmidt Solberg*

Julie K. S. Solberg

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «Design av informasjonsdisplay på skipsbro», og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i intervju
- ☐ at det tas lydopptak av intervjuet

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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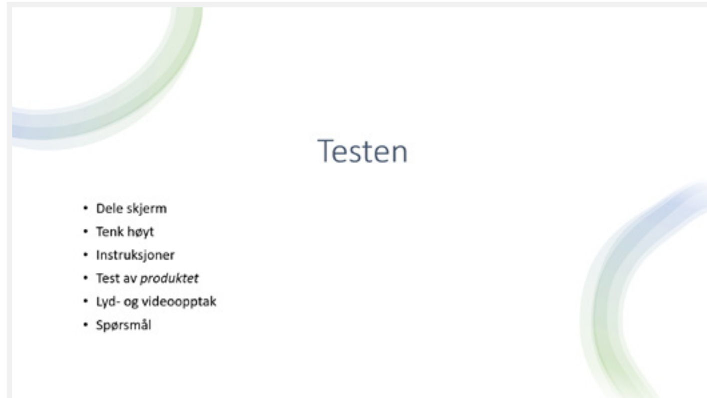
(Signert av prosjektdeltaker, dato)

APPENDIX D

PRESENTATION FROM THE USABILITY TESTS




Prototypen
• Radar med ekstrafunksjoner
• Kombinasjon av ulike skisseforslag


Viktig info
• Alt er ikke interaktivt
• Begrensninger ved programvaren
• Klikk for å justere gain, sea clutter osv
• Fokuser på radar-tuning


Spørsmål?