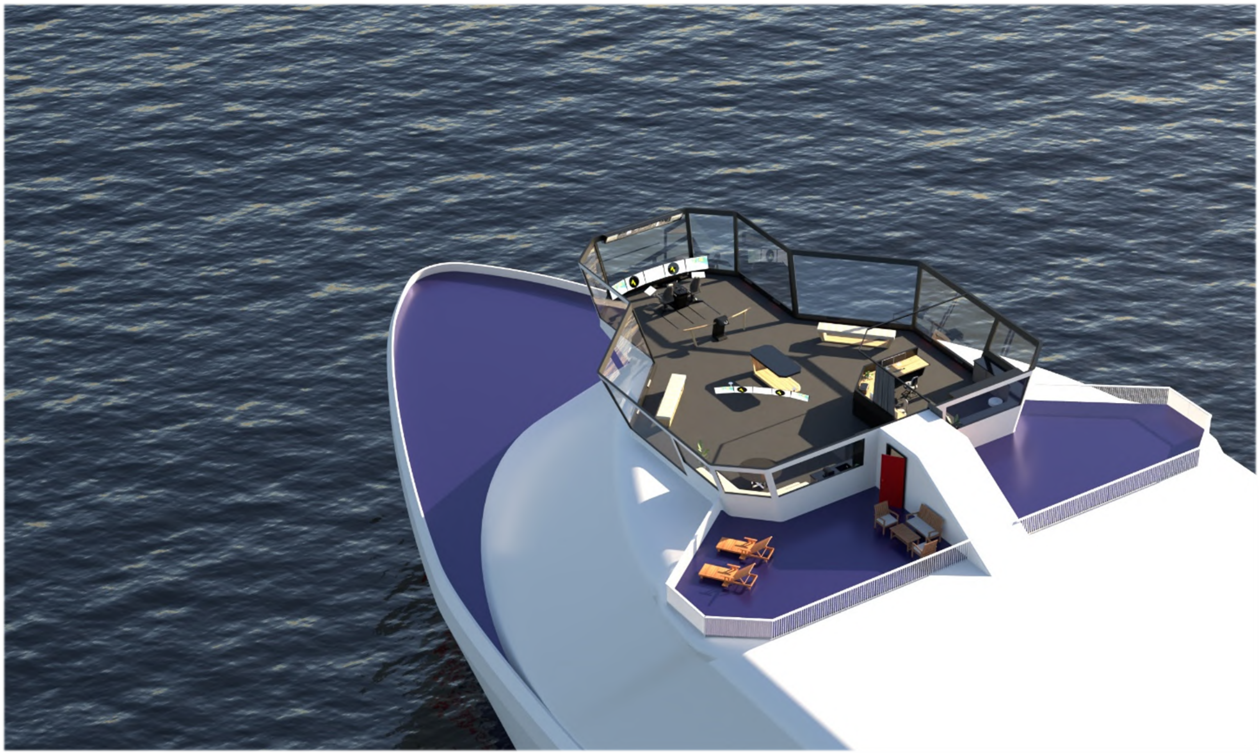

Designing the Future Ship Bridge

A vision for the future ship bridge on large passenger vessels with a focus on ergonomics, interactions, and the physical work environment

Master's Thesis in Industrial Design Engineering

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DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

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Abstract

The thesis aimed to propose a vision for a future ship bridge design for large passenger vessels. The bridge vision was to satisfy requirements regarding physical layout, ergonomics, and user-centered design while incorporating the latest technological advancements and considering how more advanced automation might affect bridge design in the future. The project was meant to complement an ongoing UX-research project at ABB.

The project was initiated with a comprehensive data collection phase involving interviews and multiple field studies of bridges on passenger ships, where the users and the context could be observed. The collected data was analyzed and subsequently transformed into design guidelines. The project proceeded with an iterative ideation phase consisting of idea development, concept development, user evaluations, and lastly the visualization of the final bridge vision.

The resulting bridge vision offers a slim, centrally located bridge with a protruding cockpit while also incorporating a spacious workspace design featuring open surfaces and large windows. The bridge provides an almost uninterrupted view all around the horizon with flat, top-out inclined windows to minimize reflections and refractions. The windows can also be dimmed to protect the crew from light distractions and heat. The layout of the bridge includes a central navigation station, a large widescreen setup, an overhead display, an administrative area, and a break area. The T-shaped central control table houses ship control equipment and two multifunctional touchscreens with adaptable card interfaces. The seats offer a flexible working position with the ability to sit, stand, or walk. Smart camera systems replace physical wing bridges, allowing the navigators to have all controls in one place. Finally, a smartwatch provides internal communication tools and health monitoring features to all crewmember onboard the bridge.

Keywords: Bridge design, user-centered design, ergonomics, workspace design, UX, HMI

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Lastly, we would like to thank the Marine Academy at Chalmers and all those who helped us access and utilize their bridge simulators. We extend our special thanks to those who participated in our concept evaluation, whose feedback provided us with critical insights into the feasibility and efficacy of our ideas.

Contents

Introduction

01

In this chapter, the context of the project is introduced by presenting the background, aim, objectives, demarcations, and report structure.

1.1 Background

Onboard large passenger vessels, the bridge serves as a vital nerve center for navigation, control, and communication. It is a complex socio-technical and multifaceted environment, incorporating a multitude of interactive systems that are designed to facilitate the safe and efficient operation of the ship (Meck et al., 2009). The primary objective of the bridge systems is to enable the captain together with other bridge staff to assess the surroundings of the ship and take appropriate actions to control its movement. This involves constantly monitoring a range of factors, including weather conditions, sea state, traffic, and the ship's position relative to its intended course. This complex environment results in human error being the main cause of 75-96% of all maritime casualties (Rothblum, A. 2000).

Many ship bridges today look remarkably similar to ship bridges from many decades ago (Meck et al., 2009), with improvements in safety and efficiency mostly being added as new technological solutions while failing to recognize the whole bridge as a system (Lützhöft, 2004). According to Grech et al. (2019) as much as a third of all maritime accidents are caused by inadequate design of the equipment onboard, meaning that holistic and systematic innovation in the field is much overdue. Mark Bull (2021) describes the current situation as: if ship bridge designers would instead design cars, pedals would be found in the back, instruments on the front passenger side and light switches under the arm rest, etcetera. He ends the statement with *"Yes take it from me, navigation bridge design is that bad!"*.

With growing maritime trends in automation, digitalization, and standardization, new ship bridge designers will have more factors than ever to consider when designing for the future. Attempts at completely redesigning the bridge for the future have resulted in very futuristic concepts where the final concept seems to focus more on the implementation of trending new technologies than a realistic user-centered, and systematic redesign where all parts of the bridge are considered (Lurås, 2016); (Rolls-Royce, 2016).

With that mentioned, in order to design a user-centered ship bridge of the future, both physical and cognitive ergonomics will have to be considered and the user needs will have to be well understood. This master thesis project worked together with a User Experience (UX) team at ABB and explored the physical layout of the bridge, implementations of innovative technologies, and how automation can play a role in the design of future ship bridges.

1.2 Aim

The project aimed to propose a vision for a future ship bridge design for large passenger vessels. The bridge vision should satisfy requirements regarding physical layout, ergonomics, and user-centered design while incorporating the latest technological advancements and considering how more advanced automation might affect bridge design in the future. Thus, the purpose of the project was to contribute to the field of naval bridge design by inspiring future product development processes.

The future visions delivered by the end of the project should be within 5-10 years into the future. The project and deliverables produced should stay at a holistic level and would focus on the whole bridge as a product rather than the design of specific tools, systems, or interfaces. The context that was to be examined and designed for was large passenger vessels on shorter to medium-length routes of approximately 2-15 hours.

1.3 Objectives

The objective of the project was to deliver visual concepts in the form of rendered pictures of the bridge design, videos showcasing the intended functionality of the bridge, as well as 3D CAD models. Interactive 3D models of the bridge were also to be explored, with the possible addition of experiencing the bridge vision in a VR environment.

1.4 Demarcations

Due to the visionary nature of the project, the examination of naval regulation documentation was deemed beyond the project scope due to the complexity and restrictions it could impose on the bridge vision and was therefore only included for a limited amount of design decisions.

1.5 Report Structure

Below the structure of the report is described by presenting each chapter together with a short description.

Chapter 1: Introduction

In this chapter, the context of the project is introduced by presenting the background, objectives, demarcations, and report structure.

Chapter 2: Summary of Final Result

This chapter presents a short summary of the final bridge vision developed during the project. This is done to facilitate the reading of the following chapters, where the development process of the final bridge is described. A more detailed description of the bridge vision is presented in chapter 7.

Chapter 3: Theory

This chapter introduces the theory utilized throughout the project. This is done by first presenting the Literature Review, which describes the literature examined and used, including Existing Ship Bridge Design, Future Developments, Emerging Trends and New Technologies, and Physical Ergonomics. That is followed by the Method Descriptions, explaining the methods used in the project, as well as how they contributed to the results.

Chapter 4: Implementation

This chapter provides a detailed account of how the final design concept was developed to achieve the intended goals. A comprehensive overview of the implementation process is presented, including the software and hardware tools used, as well as the data collection methods and processing techniques employed.

Chapter 5: Results from Field Studies

In this chapter, findings from the field studies carried out in the project are presented. First, the bridge layouts of the ships visited are described, followed by a thorough review of the problems identified from the bridges, and lastly, a summary of the identified problems is listed in bullet points.

Chapter 6: Resulting Design Guidelines

In this chapter, the design guidelines identified and stated during the project are presented. The guidelines were developed with the data collected in the Discover phase as a basis, thoroughly described in chapters 4.2 and 4.3. The guidelines were divided into eleven groups Shape and View, General Layout, Information Gathering, Physical Ergonomics, Buttons, Screens, Cameras, Light Conditions, Social Aspects, Communication, and Aesthetics.

Chapter 7: Design Results

In this chapter, the final ship bridge design is presented in detail. The bridge design is divided into the areas Shape, General Layout, Cockpit, and Back Bridge, and the chapter ends with a summary of the design results. The initial ideas and concept iterations leading up to the final design are further presented in Appendix A-E.

Chapter 8: Fulfillment of Design Guidelines

This chapter describes the final bridge's fulfillment of the design guidelines. The chapter is divided into the same eleven groups as the design guidelines, namely Shape and View, General Layout, Information Gathering, Physical Ergonomics, Buttons, Screens, Cameras, Light Conditions, Social Aspects, Communication, and Aesthetics. How the bridge design takes the guidelines into consideration are described for each group.

Chapter 9: Discussion

This chapter discusses the entire project from different perspectives. It starts with discussing the methodology, including the scope of the project, the design process, the field studies, and the user groups. That is followed by discussions regarding environmental, societal, and ethical considerations, other use scenarios, differences from previous work, and recommendations for future work.

Chapter 10: Conclusion

In this chapter, conclusions from the project are presented as bullet points.

Summary of Design Results

02

This chapter presents a short summary of the final bridge vision developed during the project. This is done to facilitate the reading of the following chapters, where the development process of the final bridge is described. A more detailed description of the bridge vision is presented in chapter 7.

2.1 Shape

The shape of the final bridge vision combines the advantages of having a protruding cockpit with the big and open surfaces usually found on a much larger bridge while still staying slim, see Figure 1. The angles of the diagonal windows perfectly line up with the central navigator positions, minimizing the blocking of the view because of window poles, while also allowing a 260-degree, almost uninterrupted forward-facing view. The windows in the back of the bridge combined with the bridge's raised-up location allow for a good view towards the stern of the ship, providing an almost 360-degree view of the horizon. The window surfaces are flat, faced toward the navigators, and have a top-out incline to minimize both light refractions and reflections. All window panels on the bridge can be dimmed in bright conditions thanks to an electrochromic layer. Furthermore, instead of having physical wing bridges, the bridge has all controls in one place while smart camera systems provide views of the sides and stern of the ship as well as a bird's eye view.

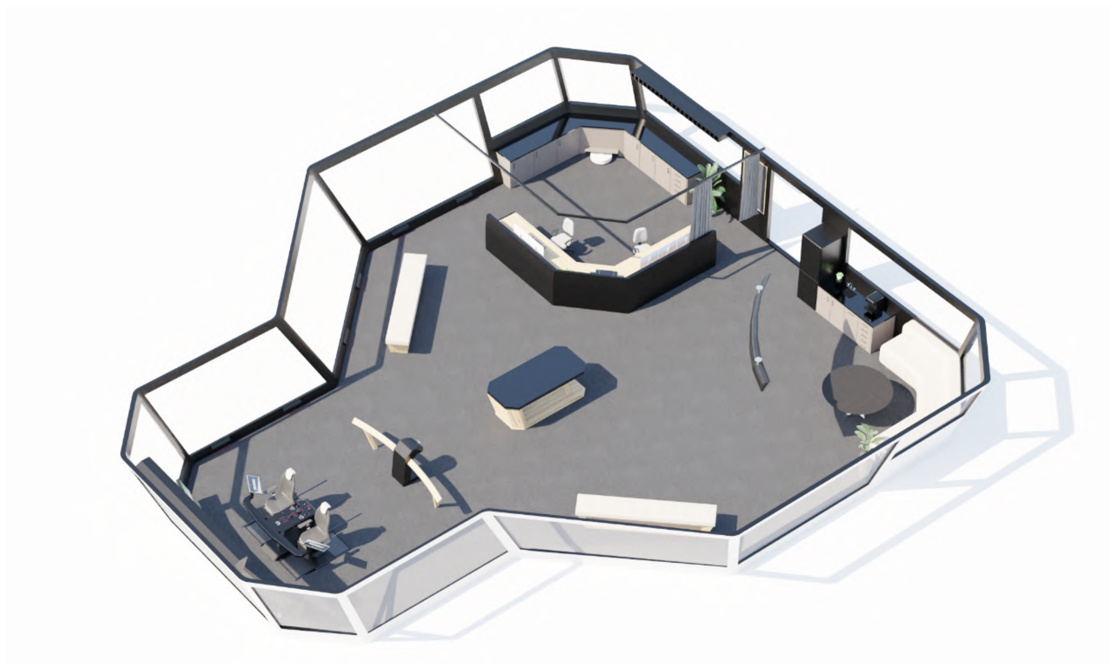

Figure 1: The shape and layout of the final bridge vision.

2.2 Layout

The layout of the bridge vision provides an open and spacious workspace while still providing everything needed for future operations as seen in Figure 1. The navigation station is located centrally in the protruding cockpit while everything else is located further back on the bridge, only separated by the manual steering station with integrated bench railings that creates a semi-enclosed social area at the front of the bridge. Two large diagonally placed benches allow the lookout to move between the two sides of the ship, creating a more mobile role that helps to keep an eye on the entire horizon. The bridge also has a large break area for coffee breaks and the daily morning meetings, while still allowing the staff to stay in the loop of the navigation thanks to the overhead monitory display. A large administrative area is also located in the back of the bridge with all equipment needed such as computers, printers, and storage. Thanks to the low height of this area, the backward visibility can remain uninterrupted.

2.3 Cockpit

The cockpit is arguably the most important part of the bridge vision and can be seen in more detail in Figure 2. The T-shaped central station in the middle of the cockpit houses all essential equipment for controlling the ship in physical form between the two navigation seats. On each side of the central station two multifunctional touch displays are located, providing a combination of digitalized systems previously seen as physical panels and completely new features optimized for future ship navigation. These are all arranged in an easy-to-use and modifiable card configuration. The widestrip, located at the bottom of the front windows, provides the navigators with the most essential systems, such as the radar, ECDIS (Electronic Chart Display and Information System), and conning display, right in front of them with minimal impact on the forward view. The control table, touchscreen, and widestrip can be seen in Figure 3. The overhead display shows the most vital information more condensed and in bigger fonts, allowing for information gathering simply by a quick glance. Thanks to its positioning near the top of the window it remains visible from almost all parts of the bridge and does not impact the forward visibility.

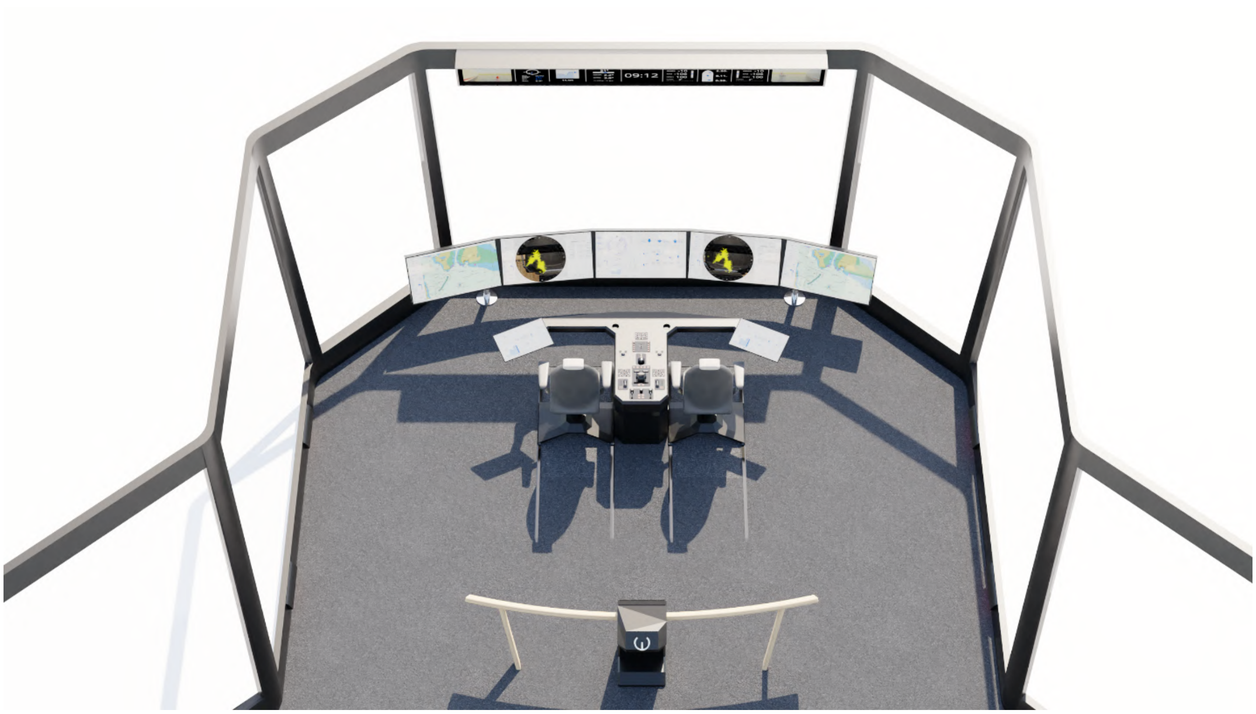

Figure 2: The protruding cockpit area of the final bridge.

Figure 3: The central station showing the control table, the two touchscreens, the widestrip, and the treadmills.

2.4 Working Position

The two main navigation seats are designed to allow for maximal flexibility, providing the navigators with the possibility to sit in both upright and slightly reclined positions with an integrated footrest. The seats can also be moved backwards to allow working while standing or even while walking, thanks to the treadmills hidden under the floor underneath the chairs, that could be turned on.

2.5 Smartwatch

A specially designed smartwatch provides the crewmembers with smart features such as internal walkie-talkie functions and a smart health monitoring system, in which the crewmembers can track their physical movement and level of alertness. The smartwatch will also warn the navigator with alarms if the alertness is too low and there is a risk of falling asleep.

Theory

03

This chapter introduces the theory utilized throughout the project. This is done by first presenting a literature review, which describes the literature examined and used. That is followed by method descriptions, explaining the methods used in the project, as well as how they contributed to the results.

3.1 Literature Review

The literature examined throughout the project is presented below. The chapter consists of Existing Ship Bridge Design, Future Developments, Emerging Trends and New Technologies, and Physical Ergonomics.

3.1.1 Existing Ship Bridge Design

Understanding the design of existing ship bridges was considered to be essential for the project and was therefore part of the literature review. How the crew operates the ship and what roles exist on the bridge was also investigated, because of the large impact this could have on the design of the bridge. Finally, ergonomic bridge design guidelines were investigated as a means to help in specific design decisions.

Current Bridge Design

A modern bridge is equipped with a diverse array of systems, both digital and physical. The most critical of these is the navigation equipment such as the radar and ECDIS (Electronic Chart Display and Information System), which provides real-time information on the ship's location, speed, heading etcetera. This information is displayed on multiple screens located around the bridge, allowing the crew to stay informed and make correct decisions about the ship's course. In addition to the digital navigation equipment, the bridge also features a range of physical controls and displays. These include button layouts for various systems, such as the ship's engines and steering, as well as traditional nautical instruments like binoculars and compasses (Chopra, 2020).

Naval Roles

The crew on a bridge consists of several members with different roles. Hederstrom (2016) describes the roles on the bridge of a large cruise ship as follows:

- Operations Director/Captain – Highest ranking, has an overview of the bridge and the navigators.
- Navigator – Navigates the ship along the intended course.
- Co-Navigator – Monitors and supports the navigator and cross-checks actions.
- Administrator – Manages administrative tasks such as alarms and paper maps.
- Lookout – Maintains visual and audible lookout around the ship and reports to the navigator.
- Helmsman – Executes steering orders.

Ergonomic Bridge Design Guidelines

American Bureau of Shipping, ABS (2018) has released a document containing guidance on ergonomic bridge design with recommendations that range from how certain alarms should be designed to preferred viewing angles. Some examples of guidelines that were considered are presented below:

- The height of readable characters should be at least 3.5mm times the reading distance in meters and the width should be 0.7 times the character height.
- The horizontal immediate field of view is limited to 70 degrees with the preferred viewing area being the most central 30 degrees. Including head movement this field is increased to 120 degrees, and both head and eye movement makes it closer to 200 degrees. This is where all important equipment should be located.

- Interior colors should not be too bright, minimize reflections and reduce the contrast between interior and exterior.

3.1.2 Future Developments

A significant amount of research has already been conducted in the field of ship bridge design. Many of the research projects stem from big corporate players within the maritime market such as Rolls-Royce or Kongsberg as well as universities with a strong maritime connection such as Oslo School of Architecture and Design (AHO). One example of a research project from AHO is the Ulstein bridge vision project as described by Lurås (2016), which aimed to develop a user-centered vision for what the future of bridges on offshore vessels could look like. The result of the project was a very minimalistic vision where the ship was controlled from a small table, with all necessary controls, in combination with large screens and digital projections of the front windows. The user-centered and conceptual design approach of the Ulstein bridge vision project consisted of 12 designers spending over 1800 hours on field studies and initiating multiple patents (Kristiansen, 2014).

Other researchers have also investigated the use of advanced technologies in bridge design, such as Augmented Reality (AR) and Virtual Reality (VR) implementations as well as automation to the point of remote controlling the ship from the shore. One example of this high-level automation is the research project Rolls Royce Advanced Autonomous Waterborne Applications (Rolls-Royce, 2016). In the videos resulting from the project, ship operators can be seen controlling a fleet of ships from a shore control center with the help of AR, smart drones, and holographic projections. Researching similar projects provided important inspiration during the initial stages and allowed the project to build on earlier work rather than doing the same work again.

3.1.3 Emerging Trends and New Technologies

Because of the visionary nature of the project, future trends within the maritime industry as well as in other industries needed to be understood to predict what these trends can lead to in the future.

Digitalization

One way of predicting future trends within the marine industry was to look at other similar industries. The prevailing trends toward digitalization can be clearly seen in the automotive industry, as evidenced by the rapid replacement of traditional physical buttons with digital touchscreens. However, this transition presents challenges, such as the potential difficulty in locating and using certain controls, which could increase driver distraction and errors (Ng et al., 2017). Digitalization is rapidly increasing within the maritime field as well, where an increased number of systems are being replaced with digital screens (Bjørneseth et al., 2020). This literature helped decide what systems on the bridge could be replaced and combined into the digital touchscreens and what systems should be kept in their physical form.

Standardization

Another emerging trend is the standardization of digital systems. Ocean industries concept lab (OICL), a research group at AHO, who also was behind the Ulstein Bridge vision, has designed a multitude of design systems intended to improve standardization. The open-source design framework OpenBridge4.0 (OICL, 2023) provides standardizations for all digital systems on a bridge ranging from individual icons to suitable color schemes for all times of the day. OICL has also designed an open-source design framework for both

AR and VR applications called OpenAR and OpenVR for advanced maritime operations (OICL, 2023). Taking standardization into account, the OpenBridge4.0 design framework was used and inspired all digital interfaces in the bridge vision. Furthermore, physical buttons and engine controls were designed to be similar to currently used systems, to follow already established mental models.

Autonomous Drive

Autonomous drive is a highly relevant topic and a rapidly increasing trend in the transportation industry today and will likely continue to be as the technology advances over the next decade. One Sea (2022) proposes a standard for defining levels of automation within the maritime industry that range from level 0 which is manual control up to level 5 which is fully autonomous and unsupervised driving. There are similar classifications within the automotive industry such as the Society of automotive engineers' standard of six levels of automation J3016_202104 (SAE, 2021), but One Sea's system was referred to when talking about automation. Modern passenger vessels today have autopilot systems with the possibility to keep a certain speed and heading of the vessel and can also be synchronized to the ECDIS to allow the autopilot to follow a route laid out in the voyage plan (Raunek, 2021). Automation within the maritime industry today, therefore, resembles level two automation according to One Sea's scale, depending on the state of the equipment onboard the ship. The future scenario in which the bridge vision was to be used, was a predetermined scenario where autonomous systems were assumed to be more advanced in comparison to today's systems, and therefore one level higher according to One Sea's 6 levels of automation within the maritime industry (One Sea, 2022). Thus, if modern passenger ships currently use level two autopilot systems, ships in 5-10 are assumed to use level three autopilot systems. This literature was used when arguing for certain design decisions that included allowing for more monitory tasks onboard the bridge and the implementation of new systems such as the smartwatch.

New Technologies

Some technologies researched for this project, due to their possible implications on a future bridge, were Augmented Reality (AR), Virtual Reality (VR), electrochromic dimmable windows, and OLED screen technology.

Electrochromic windows offer the possibility to dim a window surface by applying s small current to an electrochromic surface or glaze on the window. The advantages of the technology for residential applications are being researched and both visual and thermal advantages have been found (Sibilio et al., 2016). In other words, by utilizing electrochromic windows, both the visual light levels and thermal levels of a room can be controlled. This was found to be potentially useful for the bridge context.

OLED technology is a screen technology currently implemented into consumer devices such as smartphones and televisions, but the uses for the technology could offer potential advantages on a ship bridge. OLED offers a significantly higher contrast ratio between bright and dark parts of the screen in comparison to for example LCD technology (Damara et al., 2012). This allows black parts of a screen to appear completely dark by not emitting any backlight.

3.1.4 Physical Ergonomics

Since the project aimed to mainly focus on the physical design of the bridge, physical ergonomics was seen as an important area to further research. This mainly included how different working positions affect the health and wellbeing of people in a workspace.

Working Position

Since work on a modern ship bridge can be more or less sedentary it was important to understand the impact of different working positions. Buckley et al. (2015) recommend that workers in sedentary occupations should spend between 2-4 hours of their working day doing light activities such as standing or walking. Following these recommendations and implementing an alternating sitting-standing routine can according to a study by Gibbs et al. (2017) increase energy expenditure slightly, up to 100 kcal during the day, adding up to a significant public health advantage over time. Similarly, both Dunstan et al. (2012) and Smith et al. (2018) found health advantages and possible treatment and prevention of chronic and cardiovascular diseases by combining sitting and standing in everyday work environments. Daily physical activity can also, according to Hansen (2016), improve stress resilience, well-being, alertness, and maybe even intelligence. In conclusion, the literature shows clear advantages of alternating between sitting, standing, and walking as a means to introduce more daily physical activity. This literature was considered when designing the bridge as a workspace and especially the working positions for the cockpit.

3.2 Method Descriptions

In this chapter, the methods used in the project are briefly described, as well as how they contributed to the results.

3.2.1 Double Diamond

The Double Diamond design process provides a structured framework that promotes both divergent and convergent thinking, guiding problem-solving and innovation. It consists of four stages: Discover, Define, Develop, and Deliver. In the Discover phase, the primary focus is on understanding the problem space, exploring possibilities, and gathering insights. During the Define phase, the gathered information is synthesized, key challenges are identified, and a clear problem statement is established. The Develop phase centers on idea generation, refinement, prototyping, and iterative design solutions. Finally, the Deliver phase involves the implementation and execution of the selected solution. By following the Double Diamond approach, designers can effectively nurture creativity, exploration, and decision-making throughout the design journey (Design Council UK, 2023).

3.2.2 Literature Review

A common method for obtaining background information and describing the current state of knowledge in a project is to conduct a literature review. A literature review can contain different types of sources, such as previous project documentation, manuals, handbooks, textbooks, scientific publications, etcetera (Bligård, 2015). The literature reviews carried out in the project helped to get an initial understanding of ship bridges and their context as well as reading up on previous maritime vision projects.

3.2.3 Benchmarking

Benchmarking is a method for systematically comparing one’s operations with competitors' or other industries’ operations with the purpose to learn from others. The goal of benchmarking is to translate this knowledge into insights and effective improvements that can strengthen one’s operations (Metodbanken, 2018). Benchmarking was used in the project to explore and analyze existing bridge designs, including real bridges, bridge simulators, and more visionary projects of future bridges.

3.2.4 Interviews

A basic method of collecting user data is to conduct interviews. Interviews provide a deeper understanding of users' thoughts and reasoning, beyond their actions. Interviews can be structured, semi-structured, or unstructured. Structured interviews involve preparing questions in advance, while unstructured interviews are more discussions about a topic. In semi-structured interviews, there is an overall structure with specific topics to cover, but the discussion can be more fluid. Structured interviews are suitable for collecting quantitative data, while unstructured interviews are more suitable for collecting qualitative data (Bligård, 2015). Interviews were conducted continuously throughout the project to collect qualitative data from experienced ship bridge users.

3.2.5 Observations

An observation is a method aimed at understanding a user's situation without influencing the user's behavior. Thus, to understand not only what users say they do, but what they do in practice. Observations are done so that the researcher studies the sequence of events that is in focus, either in a real-use situation, in the field or an arranged experimental situation in a lab (Bligård, 2015). Several user observations were carried out in the project. The observations were done in a real ship bridge context and the goal was to complement orally mentioned aspects from the interviews with observed ones.

3.2.6 KJ-Analysis

KJ, after Jiro Kawakita, is an analysis method for compiling a large amount of data. The method is implemented so that the results from the data collection are written down on paper notes, with only one data per note. When all the data is written down, similar notes are grouped together and finally each grouping is named. The method is bottom-up based, meaning that it starts from a detail level and then expands to a whole (Bligård, 2015). The KJ-analysis was used in the project to analyze data collected from the interviews and observations, which was later converted to design guidelines.

3.2.7 Brainstorming

Brainstorming is an idea-generation method used to get as many ideas out as possible. The method involves freely discussing solutions and ideas within a specific problem area. By building on each other's ideas, new completely different ideas can come up, which otherwise would not have been thought of. Neither positive nor negative criticism is allowed during brainstorming since the method aims for quantity over quality, and all ideas must be treated equally (Bligård, 2015). Brainstorming was used in the early ideation phase of the project. The design guidelines were used as a basis for the brainstorming and the goal was to get as many ideas as possible.

3.2.8 Braindrawing

Braindrawing is a variant of brainstorming where sketching is used instead of discussion. The focus of brainstorming is to stimulate creativity and generate as many ideas as possible. Neither positive nor negative criticism is allowed. Braindrawing works so that the participants sketch their ideas on paper, around predetermined areas, for a certain time. When the time is up, the papers can be passed on to the next participant who then continues sketching the existing ideas or is inspired to sketch completely new ones

(Wikberg-Nilsson et al., 2015). The ideation phase included several braindrawing sessions to get a wide scope of ideas but at the same time get some quality on them.

3.2.9 Prototypes

A prototype is a variant of a model that is used to concretize a concept. Prototypes can be used as a communication tool to show results to users or other stakeholders but can also be used to stimulate understanding and learning by exploring design options, testing functions, and evaluating solutions. The use of prototypes can take place in all phases of the process (Bligård, 2015). In the project, prototypes were built to explore different bridge shapes and layouts.

3.2.10 Mood Board

A mood board is a compilation of, for example, images, colors, photos, and materials, which together describe a mood, feeling, message, etcetera. A mood board is used to communicate thoughts and style in ethical design and thus frame idea generation and development work. The mood board can also be used to describe the user, use, and surroundings (Bligård, 2015). In the project, interior design mood boards were used to get user feedback on colors and materials to be used on the bridge. The mood boards can be seen in Appendix F.

Implementation

This chapter provides a detailed account of how the design process was carried out to achieve the intended goals. A comprehensive overview of the implementation process is presented, including the software and hardware tools used, as well as the data collection methods and processing techniques employed.

4.1 Design Process

The project was divided into four phases: Discover, Define, Develop, and Deliver (see Figure 4), similar to the double diamond approach to product development as described in chapter 3.2.1. The Double Diamond product development method was considered to be well-suited for this project for several reasons. Firstly, the approach prioritizes user-centric design, placing the needs and preferences of the ship's crew at the forefront of the design process. Secondly, the exploratory nature of the Double Diamond approach enables the exploration and experimentation of various ideas and concepts. Furthermore, the Double Diamond framework embraces both divergent and convergent thinking, fostering a balanced and dynamic approach to the project. In the early stages, divergent thinking encourages the generation of a wide range of innovative ideas and possibilities for the ship bridge vision, including exploring diverse design concepts and emerging technologies. As the project progresses, convergent thinking helps narrow down and refine these ideas into a more focused and feasible vision. This iterative combination of divergent and convergent thinking promotes creative exploration and enables the consolidation of the ship bridge vision. The Discover, Define, Develop, and Deliver phases of the project are presented in more detail in the following chapter including the methods and activities conducted for each part of the process.

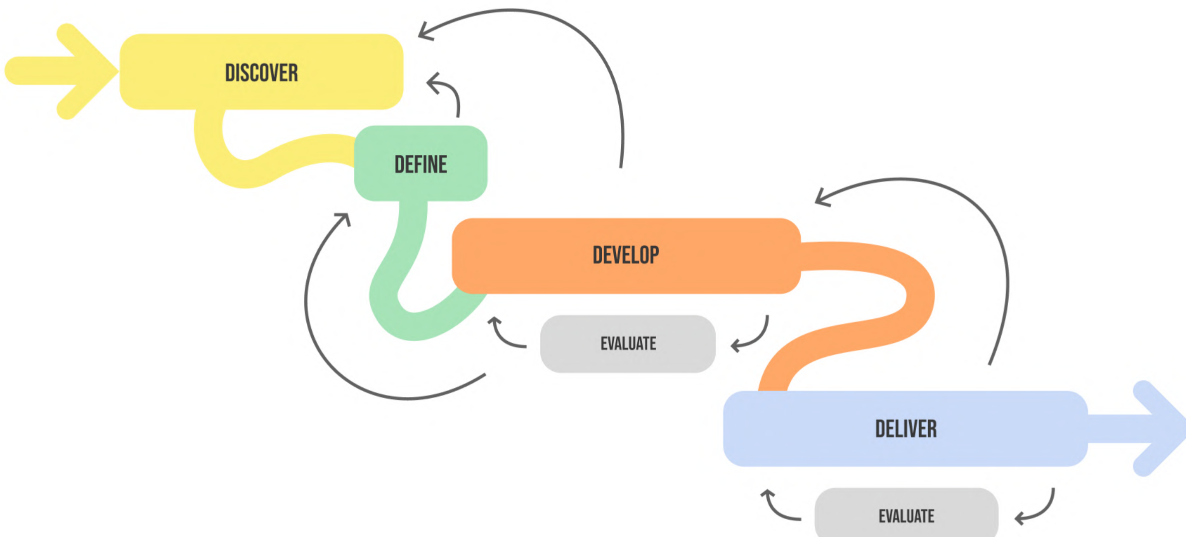

Figure 4: Illustration of the design process.

4.2 Discover

The first part of the design process was the Discover phase. This was done to understand the context of ship bridges, the users, and potential problems. This phase aimed to make a thorough list of design guidelines to be used as a base for the ideation phase. The Discover phase is presented below, divided into theoretical studies and empirical studies.

4.2.1 Theoretical Studies

Literature Review

The first step in this process was to carry out a literature review (see method description in chapter 3.2.2) by reading previous research within the maritime field. This was done to get an initial understanding of vessels, ship bridges, and their context as well as to see what similar vision projects have resulted in. The research mostly consisted of scientific papers, articles, and YouTube videos.

Analyzing Field Study Material

To further understand the context of ship bridges, findings already conducted by the ABB UX team were analyzed. This was done not only to understand the big picture of ship bridges but also to see what general problem areas there were in existing bridges. Taking part in those findings also helped to shape and decide the preliminary scope of the project.

Benchmarking

Throughout the project benchmarking (see method description in chapter 3.2.3) was done to see what existing bridge designs there are today. The benchmarking included literature as well as YouTube videos and covered both old, new, and futuristic bridges. This gave both knowledge and inspiration to the project.

4.2.2 Empirical Studies

Discussion with Professors

A formal discussion was conducted with two professors at nautical studies. The focus of the discussion was how users will interact with higher automated systems and the goal was to get an expert's opinion on what automation may look like on a future ship bridge. This provided insights into how automation might affect bridge design in the near future.

Field Study Stena Jutlandica

The first field study was carried out on the bridge of the passenger ferry Stena Jutlandica. The primary goal of the field study was to experience a ship bridge in a real context for the first time. The trip was an ordinary trip from Gothenburg to Frederikshavn and then back again. The departure from Gothenburg was 15:45 and the arrival back in Gothenburg was 23:10, which allowed experiencing the context in both daylight and darkness. The field study included open discussion and individual interviews (see method description in chapter 3.2.4) with the crew members, as well as observations (see method description in chapter 3.2.5) of both the bridge layout and the crew using and interacting with it.

Field Study Stena Danica
A second study visit was conducted on the passenger ferry Stena Danica. The trip was an ordinary trip from Gothenburg to Frederikshavn and then back again. The departure from Gothenburg was 9:15 and the arrival back in Gothenburg was 17:20, so the whole visit was in daylight. Danica had not been updated as recently as Jutlandica, and therefore Danica had an older bridge design. The goal of this field study was to see what the older design looked like, and what similarities and differences there were. The field study included, as in the first visit, observations of the bridge layout, open discussions, and individual interviews with the crew members.

Field Study Stena Carisma
A third study was carried out on the highspeed catamaran ferry Stena Carisma. At the time of the field study, the ship had not been in traffic for the past ten years, therefore, the field study visit was conducted when the ship was in port. The reason for visiting Carisma was because it had a more modern bridge than Jutlandica and Danica. The bridge also did not have wing bridges and instead utilized cameras to be able to see the sides of the vessel. Since the ship was in port, all the systems were not turned on and could not be observed when used. However, the general layout of the bridge was studied. One former captain of Carisma was interviewed throughout the visit.

Field Study Bridge Simulator
A further study visit was conducted at Chalmers University of Technology, where a full-scale ship bridge simulator, complete with all necessary navigation systems, was tested. The purpose of the visit was to gain a deeper understanding of the use of a bridge, to get a chance to try the simulator and to examine the equipment more easily in use without being in a critical situation at sea. During the visit, one former captain with many years of experience was also interviewed and shown some early concepts.

Interviewed People During the Field Studies
Table 1 presents a list of all interviewed people during the field studies including their rough age and recent naval role. Most interviews were semi-structured while some were more unstructured. The interview questions used during the field studies are presented in Appendix H.

Naval role	Age (years)
Captain	50-60
Navigator	40-50
Navigator	50-60
Co-navigator	20-30
Lookout	50-60
Captain	50-60
Captain	50-60
Navigator	50-60
Co-navigator	20-30
Lookout	30-40
Captain	50-60

Table 1: List of interviewed people during the field studies.

4.3 Define

To get a clear overview of the data collected during the Discover phase, the data was sorted, analyzed with the KJ method, and combined into a list of design guidelines that could be used as a base for the ideation phase. Below, this is described in more detail.

4.3.1 KJ-Analysis

To analyze data from the field studies, the KJ method was used (see method description in chapter 3.2.6). Findings from the interviews and observations were put on digital post-it notes in the program Figma. The data included problem areas, well-functioning aspects, possible improvements, and new ideas etcetera. The post-it notes were divided into clusters with notes dealing with similar aspects, see Appendix G. Each cluster was given a name summarizing the notes in that cluster. When all the data from the field study were managed, complementing data from the UX team at ABB was added to the clustering. Those notes were colored grey to distinguish them from the other notes and are not included in the Appendix.

4.3.2 Design Guidelines

After the analysis, the data was converted into a list of design guidelines, see chapter 6. This was done by analyzing the individual clusters in the KJ-analysis and writing down design guidelines that would solve the issues, consider the recommendations, and keep the positive aspects of all notes in each cluster. The groups from the KJ clustering were kept to get a clear structure of the guidelines, illustrated in Figure 5. It was a total of 20 different groups. The guideline list was iterated and updated several times during the project.

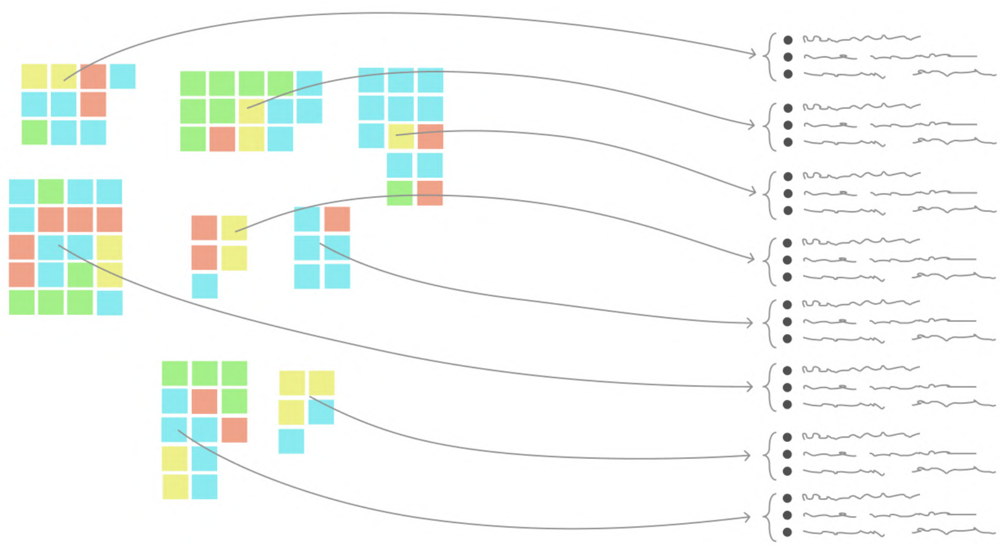

Figure 5: Illustration of how the design guidelines were based on the KJ-analysis

4.4 Develop

When a general knowledge regarding the context of ship bridges had been achieved and the design guideline list had been done, the develop phase was initiated. Figure 6 demonstrates the progression of the Develop phase, from an initial stage of diverse ideas to the completion of a refined concept, including all the intervening stages of the process. The individual stages: ideation, idea development, concept development, concept evaluation, and user evaluation, will be further explained in this chapter.

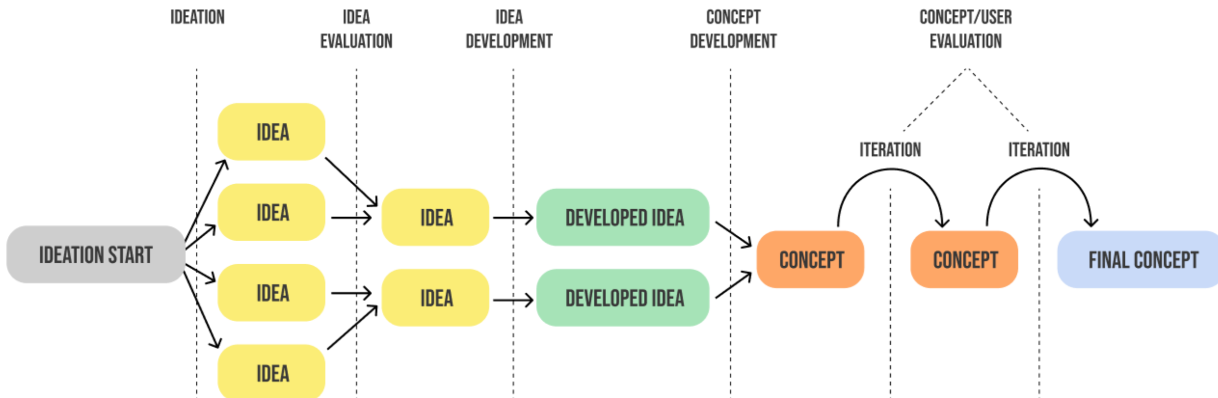

Figure 6: The ideation and evaluation process from ideas to the final concept.

4.4.1 Ideation

Brainstorming

The first part of the ideation consisted of brainstorming (see method description in chapter 3.2.7). To make the brainstorming structured, different sessions within different areas were conducted. The areas were the same as the eleven groups from the guideline list, namely: Shape and View, General Layout, Information Gathering, Physical Ergonomics, Buttons, Screens, Cameras, Light Conditions, Social Aspects, Communication, and Aesthetics. The goal of the brainstorming was to get as many ideas as possible, in other words, the focus was on quantity. Some initial ideas from the brainstorming sessions are presented in Appendix A.

Braindrawing

Another ideation method carried out was braindrawing (see method description in chapter 3.2.8). The same areas as in the brainstorming were used, and both new and old ideas were included in the sessions. The goal with the braindrawing was also to get a wide scope of ideas but at the same time get some quality in the ideas. Sketches from the braindrawing sessions can be seen in Appendix B.

Future Trends

Since the visionary nature of the project, future technologies and opportunities had to be taken into consideration. Such research was done in the benchmarking, but it was also part of the ideation. Trends in different industries and contexts were explored and then converted into ideas for the design of the bridge vision.

Physical Prototypes

A physical prototype of the front of a ship was built with a system of magnetically interchangeable bridges (see Figure 7). This allowed for rapid prototyping of new bridge shapes as well as testing how they would function on a ship. A total of nine different bridge shapes were built and tested on the physical ship prototype. The ship and the bridges were built in a scale of 1:50. A set of 3D-printed human figures and furniture were also created to test how the shape of the bridges would affect possible layouts.

Figure 7: Physical ship model with interchangeable bridges and the 3D printed layout pieces.

Blender

The 3D modeling tool Blender was used for digital rapid prototyping, mainly for experimenting with different shapes, angles, and windows of the new bridge. Thanks to its use of subdivision modeling, changes to an existing object could be easily done by moving individual edges or points after the object was originally shaped.

Figma

Figma was also used for rapid prototyping, but with parts that did not have to be modeled in 3D. For example, the layout of the bridge and placement of equipment in the cockpit were experimented with in Figma. Another part of the bridge that was ideated in Figma was the indicators for engine controllers.

4.4.2 Idea Evaluation

The initial ideas were continuously evaluated throughout the project. One part of the idea evaluation was a presentation held for the UX team at ABB. This was done early in the ideation phase, where the idea space was quantitative rather than qualitative. The goal was to discuss the ideas and get input on which ideas to focus on and which ideas could be eliminated. Around 70 ideas were presented within the eleven areas: shape, general layout, view, wing bridge, night mode, tiredness, physical ergonomics, autopilot, social aspects, communication, and information gathering. The discussions from the idea presentation in combination with the interviews and field studies allowed the 70 ideas to be narrowed down. Which ideas were kept, and which ideas were discarded together with the reasonings behind them are presented in Appendix C.

4.4.3 Idea Development

To get more thorough conceptual ideas, the early ideas from the ideation were further developed. Here the focus was on quality rather than quantity, so more time was spent on each idea than in the ideation phase. The initial ideas were the basis, but new ideas were still allowed. The development process of early ideas and related design decisions are presented in Appendix D.

4.4.4 Concept Development

After the idea development, the ideas were still solitary ideas within different areas, and therefore, in this step, the ideas were combined into one bridge concept. The concept was developed by first choosing the fundamental ideas, for example, shape, and layout, and then building further with ideas that correspond with the other ideas, and so on. The concept building was constantly iterated during the development. To build the concept, a mix of the programs Blender and Figma were used. The concept was iterated three times before ending up as the final concept and all iterations and design decisions that shaped them are presented in Appendix E.

4.4.5 Concept Evaluation

To be able to assess how the developed concepts could be improved, evaluation was carried out continuously throughout the process. Below the different approaches used to evaluate the concept are described.

User Discussions

One part of evaluating was to talk to users. Whenever possible during the project, ideas were shown and discussed with ship bridge users. Since users were met at different times throughout the whole project, the quality differed of the ideas and concepts that were evaluated. Some ideas were orally presented, some in sketch format and some in the form of more finalized CAD renders.

Blender Evaluation Sessions

Another evaluation method used in the project was the 3D modeling and visualization tool Blender. This was not only used to model the concept but could also be used to evaluate and compare ideas and concepts with each other. A feature found to be useful in Blender was the possibility to place a camera with the Field of View (FOV) adjusted to mimic human eyesight exactly where the user would sit and therefore be able to see what the user would see.

VR Evaluation Sessions

In addition to Blender, VR technology was used to assess the proposed concepts iteratively, see Figure 8. By utilizing both a VR headset and hand controllers, a virtual version of the bridge could be visited, and the placement, size, and reachability of the components could be assessed. This allowed for the iterative refinement of the proposed design to ensure that it effectively addressed user needs and provided an optimal physical workspace for the users. VR systems that were used for concept testing were the Oculus Rift and the HTC Vive pro.

Figure 8: VR session evaluating the bridge concept.

4.4.6 User Evaluation

Upon the completion of the development phase of the new ship bridge design, the final concept was evaluated with users. The primary goal of the user evaluation was to assess whether the design guidelines had been effectively translated into the design of the new ship bridge. To conduct the evaluation, a PowerPoint presentation was created to showcase the ship bridge with rendered pictures from a CAD model. The presentation provided an in-depth exploration of the new design, highlighting the key features, ideas, and specifications of the ship bridge. To ensure the representation of all aspects of the design, some ideas that were not fully visualized were presented through digital sketches. It was important to ensure that the digital sketches were understandable and clear enough for evaluation. During the evaluation process, the users were given the opportunity to provide feedback on areas that they deemed inadequate or require further refinement. Additionally, the users were encouraged to express their opinions on the overall interior design, by evaluating seven different mood boards (see Appendix F) representing different design directions when it comes to colors and materials to be used on the bridge. Table 2 presents a list of the interviewed people during the concept evaluation including their rough age and recent naval role.

Naval role	Age (years)
Captain/Lector	50-60
Captain/Lector	40-50
Navigator/Lector	30-40

Table 2: List of participants in the concept evaluation phase.

4.5 Deliver

Lastly, the final concept was to be refined and visualized. This chapter explains the steps taken to successfully finalize and deliver the bridge vision.

4.5.1 Refinement of Final Concept

After the completion of the user evaluation process, the collected feedback was thoroughly analyzed to identify any shortcomings or areas requiring improvement in the design concept. The analysis process involved a detailed review of the feedback provided by the users, with an emphasis on identifying commonalities across the feedback. Modifications to the final concept were later done based on the results from the final user evaluation and all changes are presented in Appendix E.

4.5.2 Visualization of Final Concept

To visualize the final concept, Blender was utilized allowing for an immersive visualization of the concept with realistic lighting and a dynamic ocean environment. A ship was also modeled in Blender allowing for the bridge to be placed in the right context. Prefabricated 3D models and materials from BlenderKit (2023) were used for visualization of the final concept under the Royalty free and CC0 license offered by BlenderKit. The interfaces for the screens used on the final bridge were inspired by the OpenBridge (2023) design system. Furthermore, to better communicate the intended vision, animated video material was also created using Blender. The video material provided an engaging and dynamic visualization of the design, showcasing the functionality of the bridge and its various components.

4.6 Guide for Presentation of Results

In the following chapters 5-8, all results will be presented in four different stages. Firstly, the objective results from the field studies will be presented together with the identified problem areas in chapter 5. Secondly, the resulting design guidelines based on the data from the field studies and interviews will be presented in chapter 6. Third, the final bridge design vision will be presented in detail in chapter 7. Lastly, chapter 8 will describe how the bridge vision fulfills the developed design guidelines.

Results from Field Studies

05

In this chapter, findings from the field studies carried out in the project are presented. First, the bridge layouts of the ships visited are described, followed by a thorough review of the problems identified from the bridges, and lastly, a summary of the identified problems is listed in bullet points.

5.1 Bridge Layouts

Below, an objective interpretation of the bridge layouts found on Stena Jutlandica, Danica, and Carisma are presented and visualized. The layouts are based on pictures and videos taken during the field studies and might differ slightly from the real layouts.

5.1.1 Stena Jutlandica

Stena Jutlandica was built in 1996 and is roughly 182 meters long and 28 meters wide (MarineTraffic, 2023). The bridge has a cockpit-style arrangement with most controls centered around two central navigator seats (see Figure 9). Almost all systems are within reach of these two seats except for the two wing stations and a computer and an old map table behind the cockpit area. In between the computer and map station, a manual wheel was located, however, this was never used during the field study and was mainly present for regulatory reasons. One of the wing stations was briefly used to control the ship when docking and undocking in Gothenburg as well as in Frederikshavn, otherwise the ship was controlled from the two seats in the cockpit. The bridge also included storage for maps, flags, and emergency items such as an old morse code machine. A break area with a table a couch and some chairs were located in the back next to the door to the administrative room.

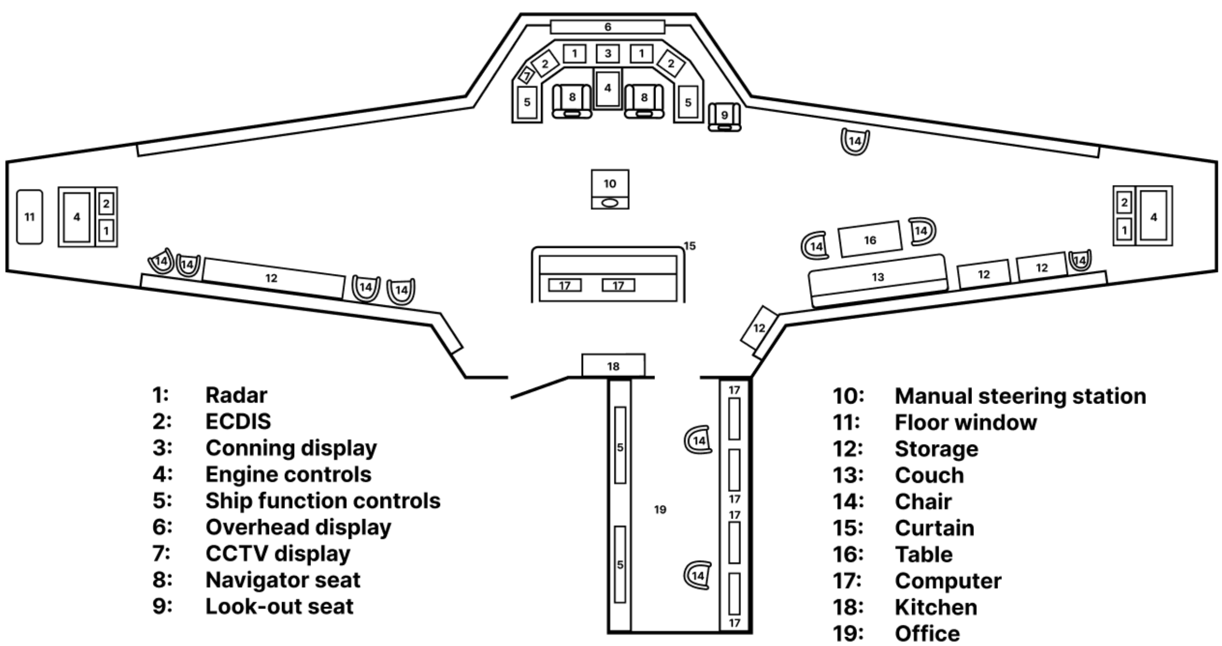

Figure 9: Illustration of the layout of the bridge onboard Stena Jutlandica.

5.1.2 Stena Danica

Stena Danica was built in 1983 and is roughly 155 meters long and 28 meters wide (MarineTraffic, 2023). The bridge on Stena Danica (see Figure 10) had a similar cockpit style arrangement to Jutlandica with some major differences. The biggest difference was the relative spreading out of equipment compared to Jutlandica where almost everything was reachable from the two navigator seats. On Stena Danica, some mimic panels and anchor controls were instead located behind the cockpit on two large panels connected to two old map tables. The wing stations were rotated 90 degrees and facing forward instead of the inward-facing wing control stations of Jutlandica and also lacked radar screens. The bridge also offered a break area with a couch and a small kitchen area with a sink, fridge, and coffee machine. The manual wheel station was almost identical to that on Jutlandica. An office was located in a room connected to the bridge via a door in the back in which the captain could spend time on administrative tasks.

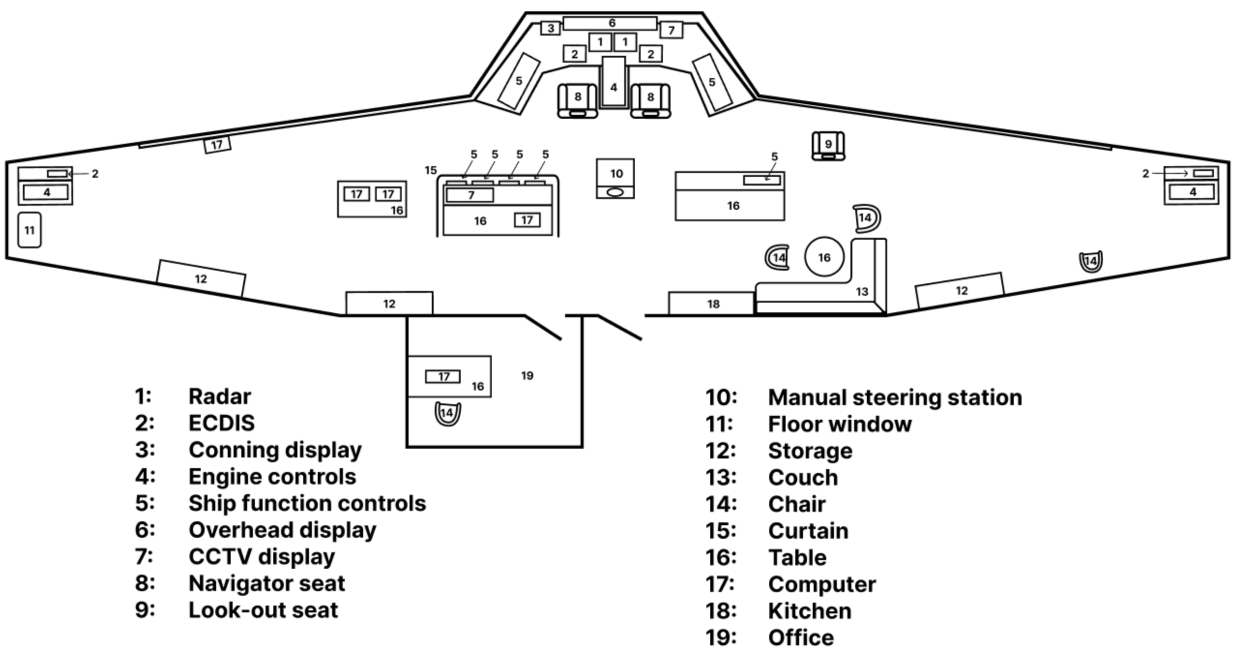

Figure 10: Illustration of the layout on the bridge onboard Stena Danica.

5.1.3 Stena Carisma

Stena Carisma was built in 1997 and is roughly 90 meters long and 30 meters wide (MarineTraffic, 2023). The bridge on Stena Carisma differs a lot from the bridges on both Jutlandica and Danica, mainly when it comes to the overall shape and contents of the bridge (see Figure 11). The bridge also utilizes a cockpit-style arrangement with all controls centered around two main seats but lacks the kind of physical wing bridges normally found on large passenger vessels. Instead of wing bridges with separate control stations, CCTV cameras displaying images to the overhead display were used when the navigator needed to view the side of the ship when departing or mooring in the harbor. The bridge also houses the engine control room taking up a large percentage of the available space on the bridge. Furthermore, tables for office supplies and computers and a small kitchen and break could also be found on the right side of the bridge. It became clear that the bridge was revolutionary and futuristic when Carisma was built back in 1997 and even though the design is now more than 25 years old, it still holds up pretty well today according to some of the interviewed former crewmembers.

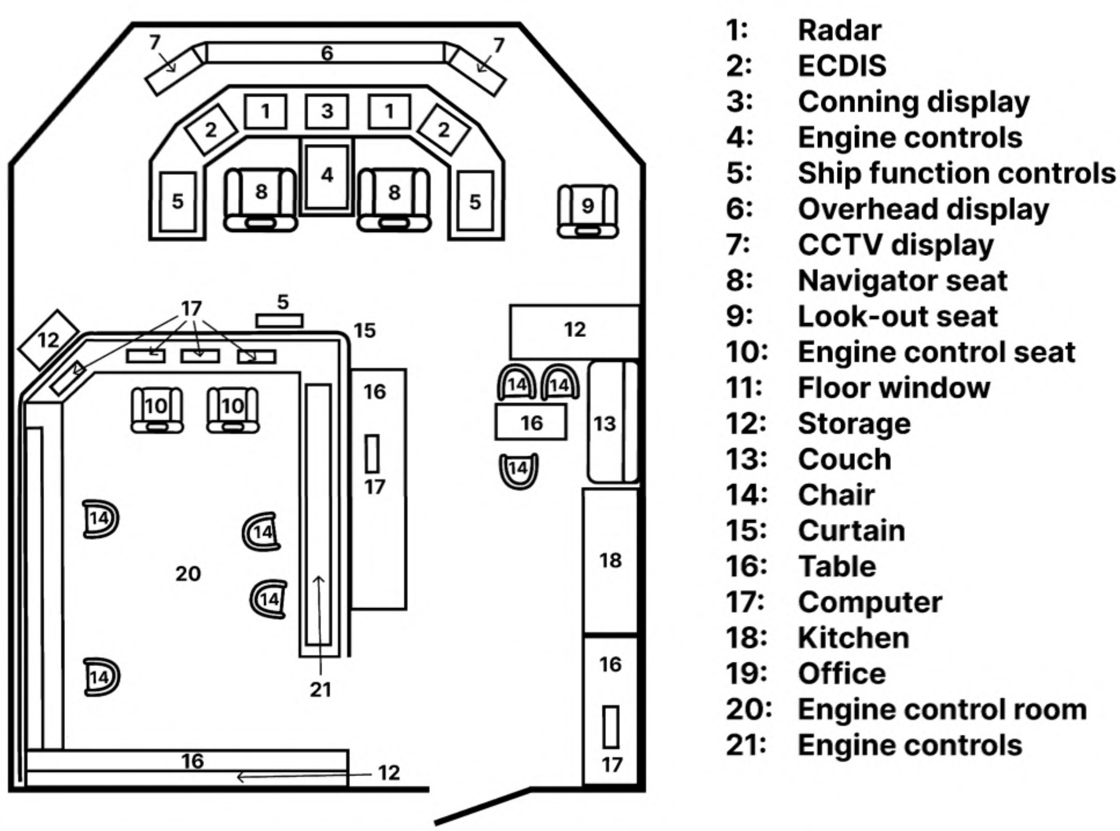

Figure 11: Illustration of the layout on the bridge onboard Stena Carisma.

5.2 Identified Problems

After the three field study trips to Jutlandica, Danica, and Carisma and conducting interviews with many of the crew members onboard, different problem areas could be identified. Below, those problem areas are presented.

5.2.1 Old Design and Unintuitive Placements

Many of the issues found on the bridges that were visited stem from the long lifetime of ship bridges and naval regulations. For example, Stena Danica has been in operation for more than 40 years. New technologies have been implemented over the years, but the overall shape and layout were not designed for modern operations. New tools and digital systems are added wherever space could be found, and old ones are removed leading to many unintuitive placements. One example could be seen on the wing bridges on Stena Danica where the main engine controls were located far away from the indicators showing engine Revolutions per minute (RPM) and propeller pitch. Similarly, the rudder indicators are not located where the rudder controls are (see Figure 12). The intuitiveness was also pointed out by the crew when discussing the placement of instruments on the bridge.

Figure 12: The unintuitive placements found on the wing bridge onboard Danica.

5.2.2 Light Conditions

During departure from Gothenburg onboard Jutlandica, the setting sun provided a very bright environment on the bridge. The temperature increased and blinders were used to not get blinded by the sun. These blinders were made from a thin plastic film that was mechanically lowered to cover the windows. During the interviews, it became clear that the blinders are not sufficient enough and the crew sometimes has to use sunglasses in combination with the blinders. During the night, bright floodlights, and navigation lights from further back on the ship would shine through the back windows on the bridge disturbing the navigator's night vision and focus.

5.2.3 Sedentary Work

The visited bridges were mainly designed for being used in a seated position, some with the ability to move the chair backward and work from a rather crowded but standing position. During long shifts on the bridge, especially at night, the crew expressed problems staying awake and alert when sitting still in their chairs. This would also be worsened by the shift structure where they were working for one week straight and then had 1-2 weeks off leading to even more tiredness during the last days of the working week. The chairs also lacked good enough footrests for the extended time they were used, leading to the users instead making use of tables and the edges of navigational equipment as footrests which in itself lead to limited visibility of the screens (see Figure 13).

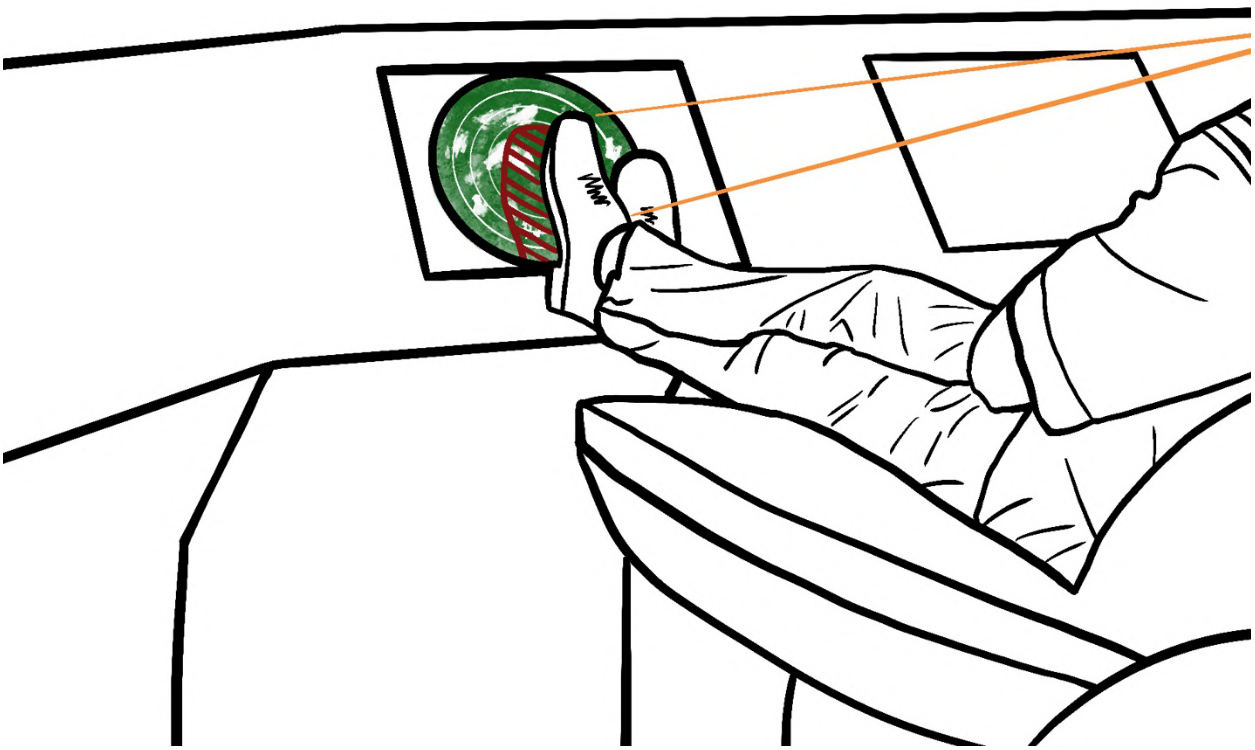

Figure 13: The lack of good footrest leading to compromised visibility of navigational equipment.

5.2.4 Poor Reachability and Lack of Standardization

Even though the systems onboard were found to be more or less centered around one central cockpit, reachability was not good enough to allow the navigators to reach all equipment from their seats. The best reachability could be found on Stena Jutlandica and Stena Carisma, where a majority of the equipment was reachable from the two main seats, while on Stena Danica much more equipment was placed further back or to the sides of the bridge. The reachability of the cockpit on Stena Jutlandica was further analyzed and can be seen in Figure 14, from the perspective of the navigator in the left chair. Green represents equipment that is easily reachable and/or readable while yellow is not as easily reachable and/or readable, but still possible. Finally, red resembles equipment not reachable for the navigator sitting in the left chair. Looking at the figure it becomes clear that much of the equipment is either yellow or red, thus forcing the navigator on the left to get out of his chair to use the equipment or ask a college to use the unreachable equipment instead. Moreover, the figure does not illustrate all other equipment found further to the sides of the bridge or the wing bridge stations. Many of the crew members that were interviewed expressed a will to be able to reach all necessary equipment from their chairs, many referring to cockpits found on airplanes.

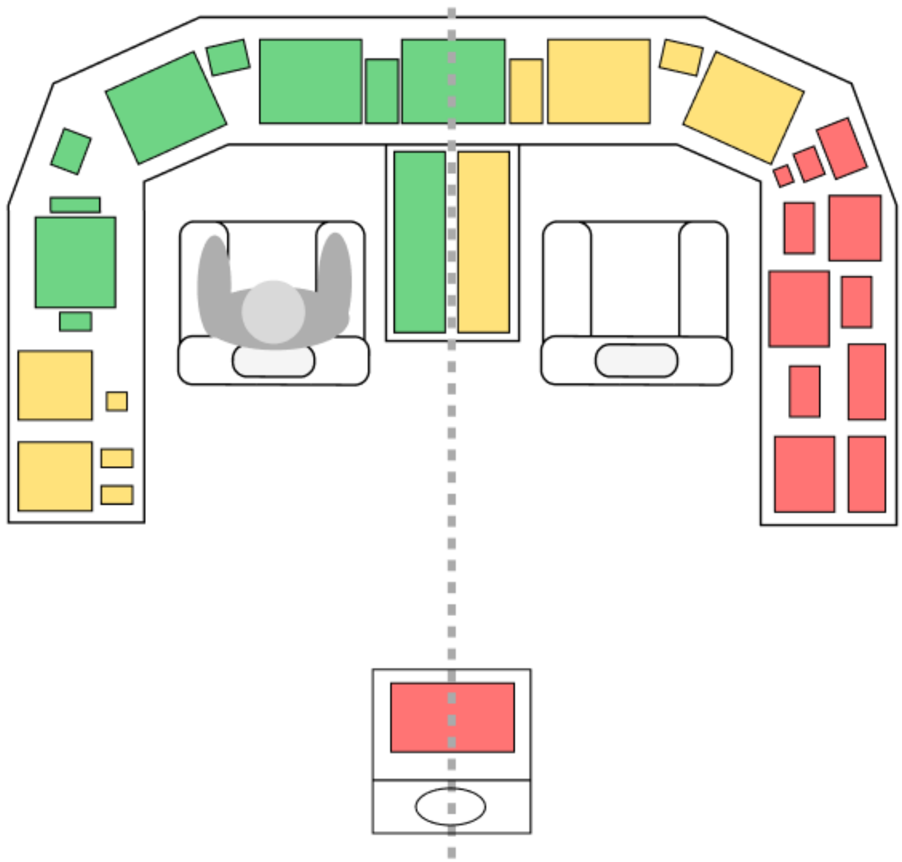

Figure 14: Illustration of reachability in the cockpit area on Stena Jutlandica.

5.2.5 Poor Dimming Functions

During night operations onboard the bridge, all systems, and buttons that emit light had to be dimmed manually by the crew in order to preserve night vision, which could be a process that took upwards of 20 minutes. Since all equipment is not manufactured by the same company the process to for example dim a screen can be very different from system to system, ranging from turning a physical knob next to the screen to diving deep into the settings to reach a digital dimmer slider. Some buttons and screens did not have a dimming function leading to the crew having to use cardboard pieces and taped plastic covers to cover the bright light (see Figure 15). Almost all interviewed people expressed the lack of a sufficient and easy-to-use dimming system as one of their main issues with the current bridge design. It was also found that screens that used a black background during the night still emitted disturbing backlight due to the usage of old LCD panels.

Figure 15: Plastic light cover for a button panel.

5.2.6 Crammed Workspace

The three visited bridges had a varied level of crowdedness with Jutlandica feeling the most open and airy, Carisma the most crammed, and Danica somewhere in between. Some of the interviewed crewmembers also stated that their dream bridge would be more open and spacious and consist less of the big and chunky systems that take up much of the space today.

5.2.7 Makeshift Solutions

On the visited bridges some makeshift solutions were found that had been implemented as a result of poor design or lack of better systems. One example could be seen on Jutlandica where a lever had gotten a welded extension to make up for the fact that the captain needed to use the lever behind his back while looking out over the water (see Figure 16).

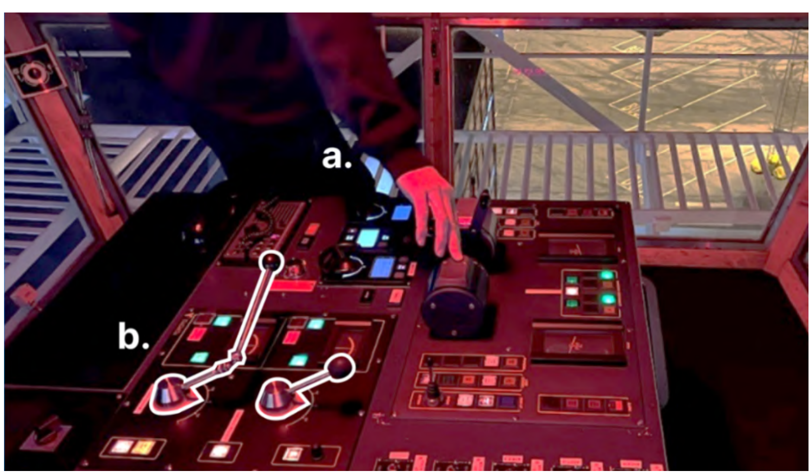

Figure 16: The captain using engine controls behind his back (a) and makeshift lever extension (b).

Another example could be seen when mooring the ship where tape pieces on the windows were used together with a concrete block on the mainland to know the position of the ship during the last stages of mooring, seen in Figure 17.

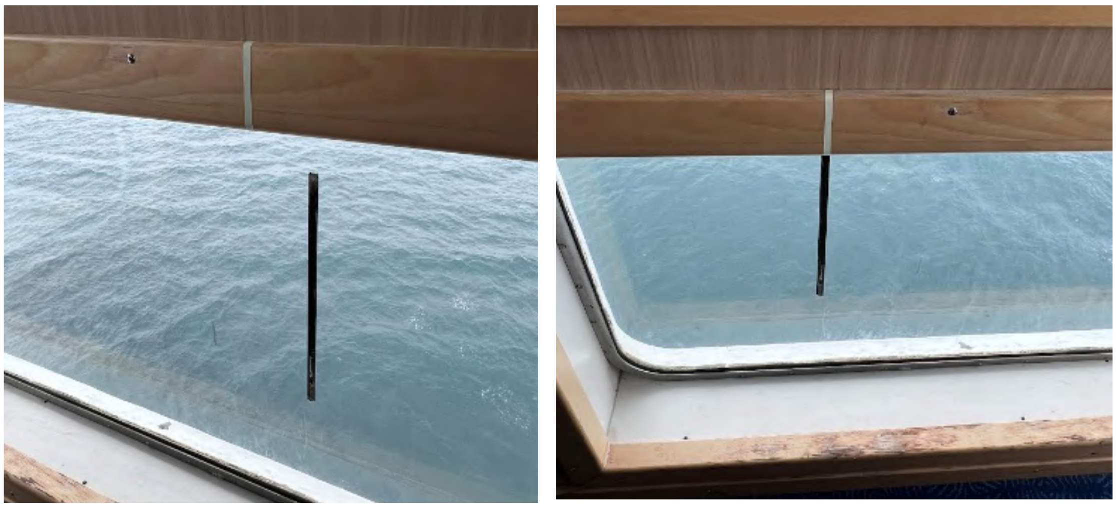

Figure 17: Tape on windows to help with mooring.

Moreover, physical homemade signs were placed in front of the navigators to help them remember that the stabilization fins are extended since they have to be retracted when in port (see Figure 18). This was done because the controls for the stabilization fins were located behind the navigator seats and thus far out of their Field of View (FOV). Other makeshift solutions found were wooden cup holders and binocular holders screwed into the side of the control table, also seen in Figure 18.

Figure 18: Fin reminder sign (left) and makeshift cup holder and binocular holder (right).

5.2.8 Lack of Integration

Since different systems onboard the bridges were manufactured by many different manufacturers the lack of communication between the systems often became an issue. Two interviewees separately described a situation in which they had to walk around the bridge trying to carefully listen to where an alarm came from because each system had its own alarm systems and sounds. Another consequence of the lack of integration was that several systems tended to display the same information, leading to information overflow for the user. As an example, the radar manufacturer wanted to show heading and ROT (Rate of Turn) values, to offer the best possible product. So did the EDCIS, the overhead, and the autopilot manufacturers as well, leading to the same information being displayed in up to 15 different places right in front of the user. The lack of integration also led to a lack of intuitiveness between systems. For example, some maps displayed north towards the top of the display while other maps displayed the heading of the vessel towards the top of the display, while a third chose to display north to the right of the display. When it comes to both internal and external communication on the bridge the lack of integration results in upwards of 10 different phones and radios having to be used for different situations.

5.2.9 Limited Visibility

By utilizing a cockpit-style arrangement that protrudes from the rest of the bridge, both Stena Danica and Jutlandica managed to achieve a forward-facing view of at least 180 degrees. However, the vertical degree of visibility was rather limited on all three visited bridges due to large and bulky equipment in combination with a low ceiling height. The narrowest field of vertical visibility could be found on Stena Carisma, where it was limited to only around 20 degrees (see Figure 19). Other visibility issues could be seen on Danica where poles between windows were placed right in front of each of the two navigator seats, leading to a disturbing factor affecting the view.

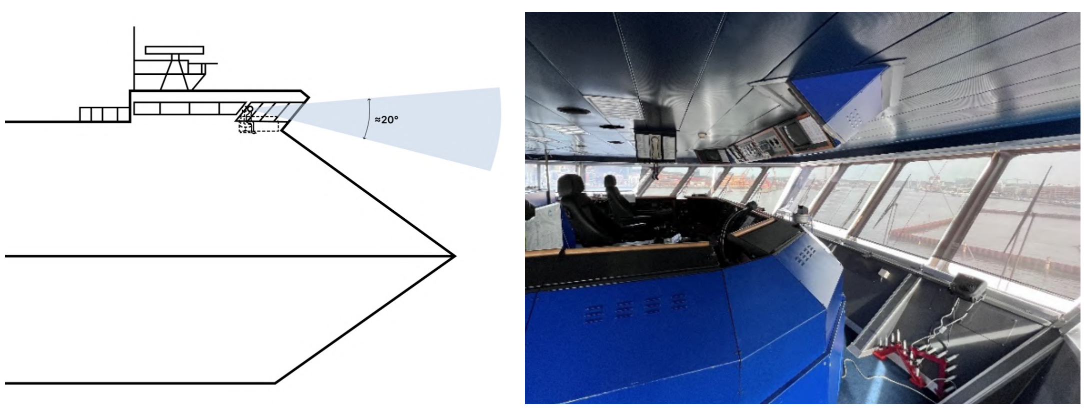

Figure 19: Illustration of the limited vertical visibility on Stena Carisma.

5.2.10 Limited Flexibility

On all three visited bridges the lookout had a permanent seat located to the right of the two central navigator seats, sometimes even outside the cockpit area. When two navigators or one navigator and the captain were on the bridge this was where the lookout would sit. However, the off-center position of the seat did not allow for the lookout to fulfill their role of keeping watch all around the horizon at all times. One interviewee also stated that the lookout should have a more mobile role rather than just sitting in their seat.

The central cockpit area was also found to act as a hub for social interactions on the bridge, because of the constant present of at least two crew members there. This led to the other rest of the crew also wanting to socialize near the cockpit. However, none of the visited bridges offered any type of seating for the additional people, leading to them leaning against navigation equipment or the back of the navigator chairs instead.

5.3 Summary of Identified Problems

After conducting field study trips and interviews with crew members aboard Stena Jutlandica, Danica, and Carisma and analyzing the collected data, the identified problems can be summarized into the following bullet-points.

- Outdated layouts and unintuitive locations of controls and indicators.
- Inadequate blinds when the sun is low and disturbing lights from the ship at night.
- Fatigue and alertness issues during long shifts due to primarily seated work positions and lack of proper footrests.
- Inconsistent equipment placement and a desire for better efficiency and standardization.
- Time-consuming manual dimming of equipment with varying processes and the need for makeshift light covers.
- Varying levels of crowdedness, with a preference for more open and spacious layouts.
- Makeshift solutions for poor design, such as lever extensions and homemade signs.
- Communication and integration challenges between different systems onboard.
- Information overflow.
- Restricted vertical visibility due to bulky equipment and low ceiling height.
- Off-center and permanent lookout position and inadequate seating options near the cockpit.

Resulting Design Guidelines

06

In this chapter, the design guidelines identified and stated during the project are presented. The guidelines were developed with the data collected in the Discover phase as a basis, thoroughly described in chapters 4.2 and 4.3. The guidelines were divided into eleven groups Shape and View, General Layout, Information Gathering, Physical Ergonomics, Buttons, Screens, Cameras, Light Conditions, Social Aspects, Communication, and Aesthetics.

6.1 Shape and View

- The bridge should provide a mostly uninterrupted forward view of at least 180 degrees from the navigator's point of view.
- Independent of the location on the bridge, a good view of the surroundings should be available.
- Backward visibility should be possible.
- Windows should minimize reflections and refractions.

6.2 General Layout

- All navigational equipment should be possible to use from a central place.
- The layout should allow for the navigator to walk up close to the front window.
- The placement of equipment should be intuitive, well thought out, and easy to understand.
- The placement of equipment should follow the users' mental models.
- The bridge should provide space for personal items such as a coffee mug, smartphone, and binoculars.
- Interfaces and physical systems should make use of available standardization.
- The design should allow for easy upgradability.
- The bridge should allow for manual operations when wanted/needed.
- All systems on the bridge should be able to cooperate and communicate.
- The bridge should allow the crew to walk out on deck.

6.3 Information Gathering

- The most important information should be placed in front of the navigators.
- Vital information should always be visible without disturbing the view.
- All important information should be easily accessible.
- The bridge should display information effectively without causing information overflow.

6.4 Physical Ergonomics

- Regularly used buttons and screens should be put in an ergonomic relaxed position.
- The working position should be adjustable for both sitting and standing.
- The bridge should allow for daily physical activity while working.
- The bridge should prevent tiredness.

6.5 Buttons

- Buttons should provide feedback on whether they are on or off in all light conditions.
- Buttons should communicate their function in all light conditions.
- The layout of buttons should make it easy to use them without looking.
- The most vital navigational and control systems should be physical equipment.

6.6 Screens

- Screens should use OLED technology to improve night vision.
- Screens should be easily viewable from different working positions.
- Screens should be designed to minimize disturbing reflections.
- Screens should be visible and usable in all light conditions.
- The contents on screens should be easily interacted with when necessary.
- Text size should be sized after the viewing distance from the screen.
- The use of screens should be justified.

6.7 Cameras

- The bridge crew should be able to monitor exterior and interior parts of the ship.
- Exterior cameras should prevent salt and dirt on the lens.
- Exterior cameras should be usable in all weather conditions.
- Cameras should support the navigators' specific tasks when needed.

6.8 Light Conditions

- All equipment with screens and/or light-up buttons should be easily dimmable.
- Local dimming functions should be available, to dim individual screens and systems.
- A central dimming function should be available dimming all screens and light-up buttons.
- The bridge should provide an area where normal light can be used without disturbing the navigators during the night.
- The light level inside the bridge should match the light level outside the bridge.
- All lights and buttons should be designed to preserve night vision.
- All screen interfaces should have modes for different light conditions.
- Sun protection should be available and easily adjustable.
- Sun protection should have different levels of sun pass-through.

6.9 Social Aspects

- The bridge design should allow for social interactions.
- The bridge should allow for a personal workspace.
- The bridge should allow for different manning levels.
- Working on the bridge should be stimulating.

6.10 Communication

- The bridge should allow for easy communication between crewmembers.
- The bridge should allow for easy communication with the passengers.
- The bridge should allow for easy communication with other ships.

6.11 Aesthetics

- The bridge should have a uniform design, both in shape and color.
- The bridge should have an airy and open feeling.
- The bridge should not be overflowing with things.
- Matte and dark colors should be used.

6.12 Implementation of Guidelines

The design guidelines were used as a starting point when developing the final bridge design, presented in detail in chapter 7. Moreover, how the guidelines were taken into consideration in the design and whether the final bridge fulfilled them or not, can be read in chapter 8.

Final Design Results

07

In this chapter, the final ship bridge design is presented in detail. The bridge design is divided into the areas Shape, General Layout, Cockpit, and Back Bridge, and the chapter ends with a summary of the design results. The initial ideas and concept iterations leading up to the final design are further presented in Appendix A-E.

7.1 Shape

The shape of the bridge vision can be seen in Figure 20 incorporating the benefits of a protruding and slim cockpit, while also having large, open surfaces usually found on much larger bridges. The geometrical advantages of the shape, window placement, and functionality, as well as colors and materials, are further presented below.

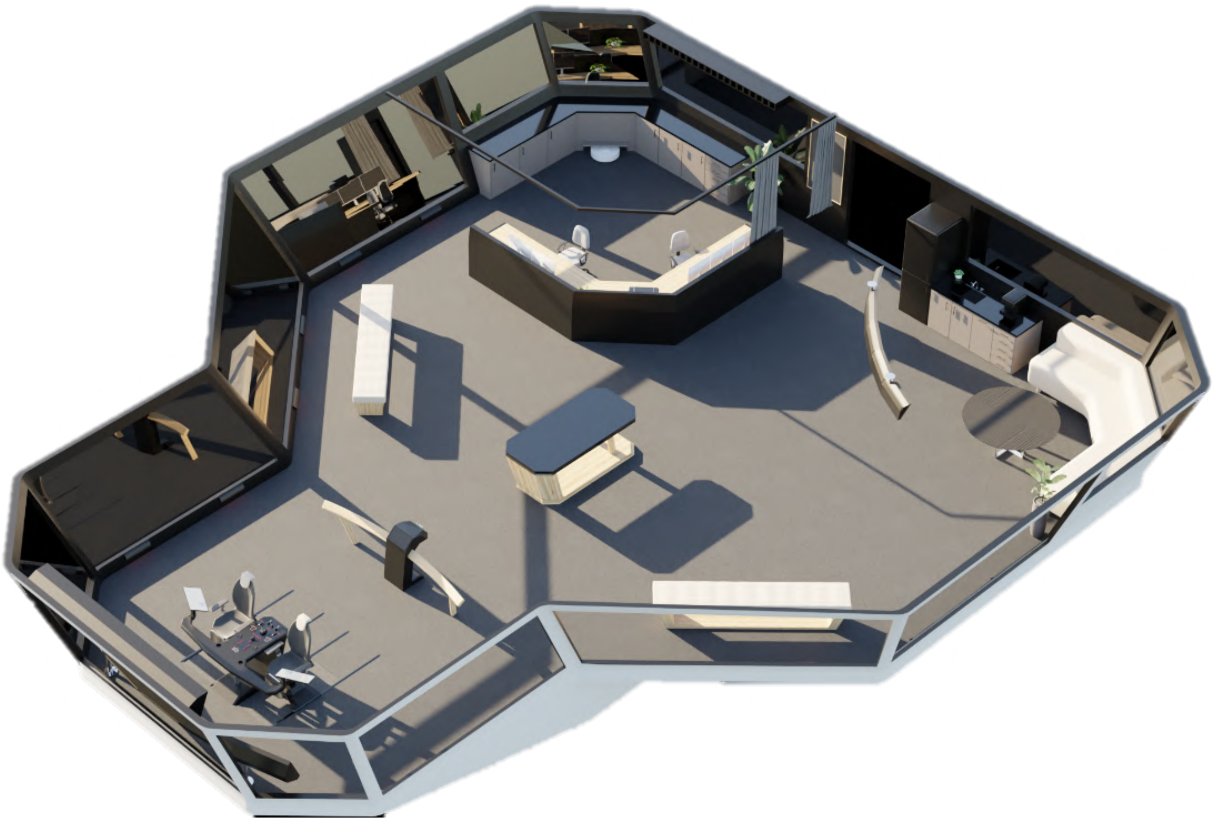

Figure 20: Overview of the final bridge vision.

7.1.1 Geometry

The bridge is 15 meters wide and 18 meters long with the cockpit taking up half of that width, at 7,5 meters wide. The ceiling height is 2.8 meters which creates an open and airy workspace for the crew while also allowing for large floor-to-ceiling windows, maximizing the view of the sea. The diagonal windows connecting the cockpit with the rest of the bridge are angled at 45 degrees to perfectly align with the central navigator positions which reduces the obstruction of the view due to window poles (see Figure 57 in Appendix E). Additionally, the shape of the bridge together with the protruding cockpit allows for a nearly uninterrupted 260-degree forward-facing view through the cockpit windows, illustrated in Figure 21. The raised-up location of the bridge on top of the ship, coupled with the windows in the back, offers a good view toward the stern of the ship. This results in a close-to-360-degree horizon view with the only part blocking the view being the small staircase leading up to the bridge, illustrated by the white part in the circle in Figure 21. Additionally, all corners on the bridge are designed with a chamfer of 45 degrees which avoids tight corners while also matching the two large diagonal windows creating a coherent overall design.

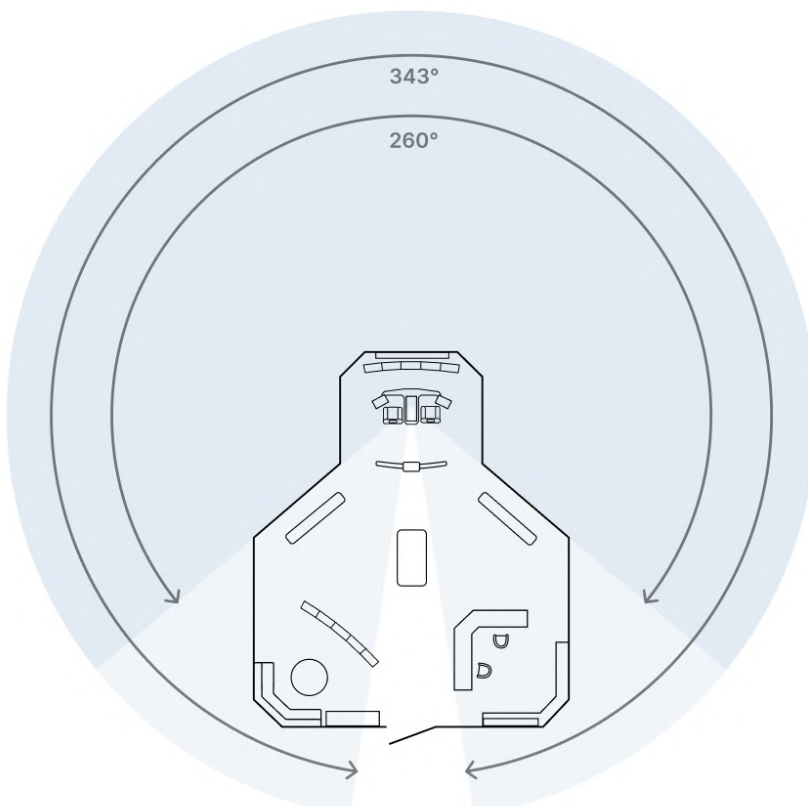

Figure 21: Illustration of the horizontal visibility from the cockpit.

7.1.2 Wingless Design

By removing the physical wing bridges the bridge vision allows for more efficient operations. This is because the navigators have all controls, both physical and digital at the same place, all within reach at all times, thus removing the need to for example transfer the controls out to a wing bridge control station and physically walk there to retake control of the ship. The safety also benefits from adopting the wingless approach since the navigators always get visual feedback from both sides of the ship thanks to the smart camera systems. By removing the need to transfer controls between three different control stations housing the same functionalities, the navigators know that the control units in the cockpit always are active. This would make accidents like the one described by ATSB (2023) impossible to occur. In special situations, if the crew needs to look down towards the waterline, the doors in the back of the bridge could be used to walk out on the deck where an outside area with railings acts as an emergency wing bridge, see Figure 22. The wings could also be used as a break area to get fresh air and sunlight.

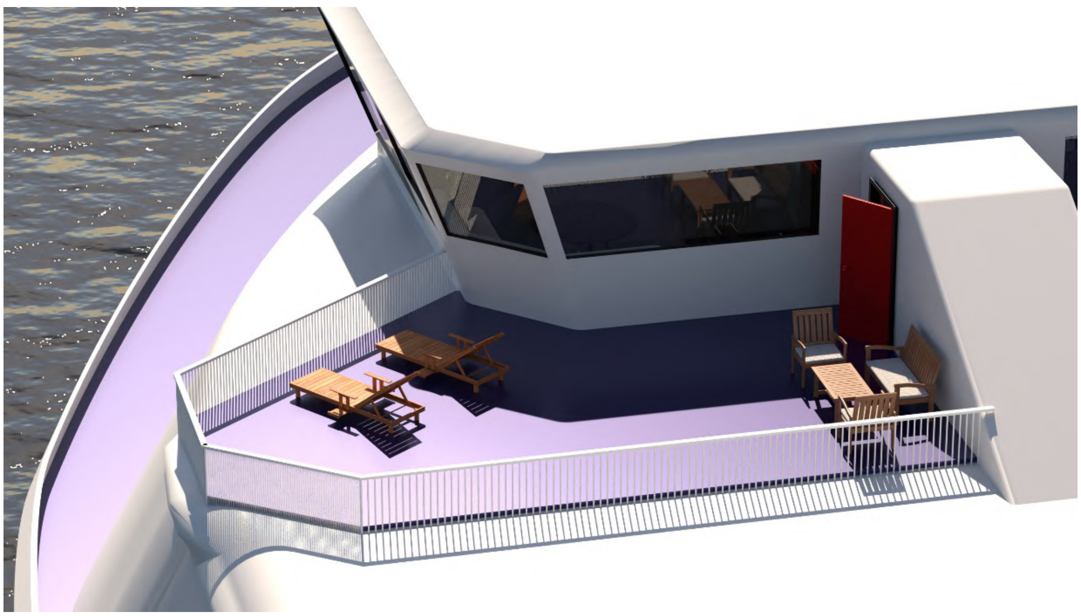

Figure 22: The outside area and door leading into the bridge.

7.1.3 Windows

The window surfaces are designed completely flat and directed towards the navigators to minimize refractions that stem from looking through thick planes of glass at either an angle or if the glass is bent. The windows are additionally designed with a top-out incline of roughly 20 degrees to minimize light reflections from the sun as well as dirt build up on the window surfaces, while also complying with SOLAS regulations of a top-out incline of 10-25 degrees (IMO, 1974). All windows around the bridge can be electro-chromatically dimmed, which has several uses to improve working conditions for the crew. Firstly, the windows can be dimmed when the sunlight is bright and disturbing, as shown in Figure 23. This avoids the navigators from getting blinded by the light and allows them to not have to rely on using sunglasses. The dimmed windows also reflect the heat from the sun and prevent the bridge from overheating. Additionally, the feature can be used in dark conditions to block distracting external ship light from entering the bridge from the rear of the ship and affecting the navigators' night vision. This can be done by dimming only the rear windows. The windows can be dimmed in different transparency levels depending on how bright the disturbing light is. Physical controls to dim the windows are placed on the central station, see figure 36 in chapter 7.3.6. Here the users can control what windows to dim and how transparent the dimming should be.

Figure 23: Dimmable windows used to block bright sunlight coming from the left.

7.1.4 Colors and Materials

The bridge uses a dark and toned-down color palette with a base in the dark grey carpeting that also creates a dampened sound space on the bridge. The furniture on the bridge is made from a combination of matte black surfaces, black and beige leather, walnut wood, and stainless-steel details. The kitchen furniture and storage both have a toned-down beige color. The ceiling on the bridge has a dark matte color to avoid any reflections of the roof in the front and side windows. The color palette used on the bridge helps minimize the contrasts between the inside of the bridge and the dark ocean environment outside of the bridge which was a recommendation from ABS (ABS, 2018) while still following the results from the Mood Boards (see Appendix F).

7.2 General Layout

The layout is designed to provide the crew with open surfaces and a spacious workspace that still incorporates everything needed in situations ranging from nominal conditions to emergencies. The layout of the bridge vision can be seen in its entirety in Figure 24, with the entrance being located by a staircase at the center back. The cockpit is located towards the front in the narrow protruding part of the bridge only separated from the rest of the bridge by the manual steering station and the bench railings connected to it. This allows the crew to enter and exit the cockpit from both sides and allows walking through the cockpit area uninterrupted.

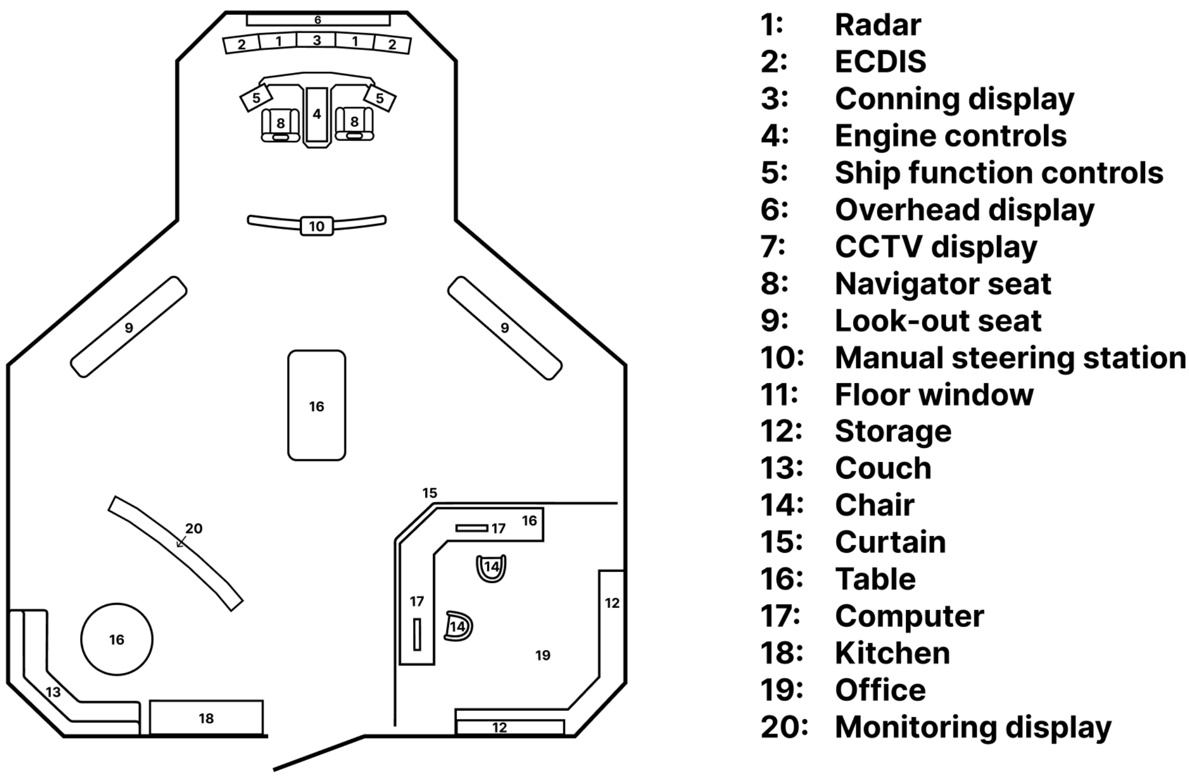

Figure 24: The layout of the final bridge with all the different areas listed.

Two large benches are located by the diagonal windows. These can be used by any crewmember but are mainly designed for lookout operations, by providing large uninterrupted views of both sides of the ship through the large windows. Centrally located in the middle of the bridge is a large multi-use collaboration table that can be used for standup meetings, route planning, and other tasks requiring a large open work surface. Its location also allows the crew to walk past it on any side without blocking any passageways on the bridge. In the back of the bridge towards the starboard, a large and functional office space is located, with a combination of storage space for equipment such as flags, emergency equipment, cleaning equipment, and desk space for computers and printers. Towards the port side in the back of the bridge is a comfortable and functional break and kitchen area, offering seating in the form of a couch and chairs, a large table, a refrigerator, a coffee machine, and a sink.

7.3 Cockpit

The cockpit area, see Figure 25, in the front of the bridge, consists of two main navigation seats and a central control table including all physical controls and two multifunctional touchscreens connected to it. Five screens can be found in a widescreen configuration in the very front of the cockpit, the widestrip, that in combination with the overhead display, located near the top of the front windows, provide all data needed to the navigators. Below, all parts of the cockpit are described in detail.

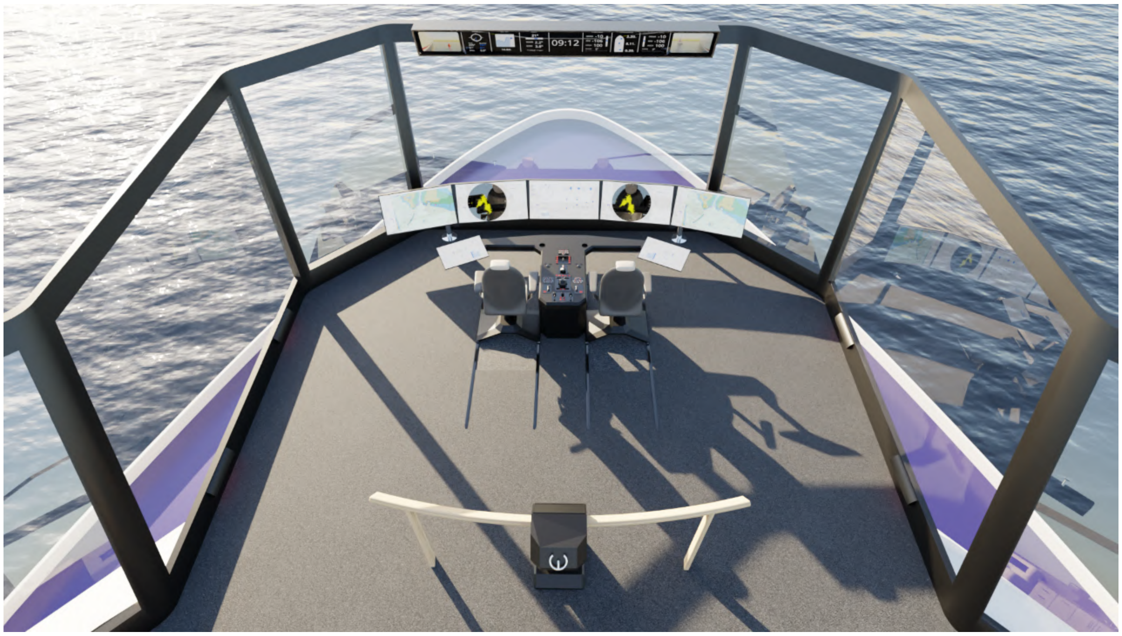

Figure 25: Rendered picture of the cockpit area on the bridge vision.

7.3.1 Control Table

The T-shaped central control table, see Figure 26, provides the navigators with all essential physical equipment for controlling, well within reach from both seats thanks to its narrow width of 60 cm. Towards the front of the table, the sides protrude outwards, creating the T-shape by connecting to the two touch displays located on each side. The table area between the central table and the touch displays functions as space for personal items such as smartphones, coffee mugs, and binoculars. The entire table can be adjusted in height to compensate for different body heights. The shape of the table also resembles the entire cockpit by having the same 45-degree chamfers and the same top-out incline of 20 degrees.

Figure 26: The central control table.

7.3.2 Touchscreens

The touchscreens, see Figure 27, located on each side of the central table offer a combination of digitalized systems, previously seen as physical panels, as well as completely new features optimized for future ship navigation, all arranged in an easy-to-use and modifiable card configuration. The interfaces shown on the touchscreens are based on OpenBridge4.0 (OICL, 2023). The screens are thoughtfully placed allowing easy and effortless reachability to all corners of the display, from both a seated and standing position. The angled position towards the side of the Field of View (FOV) of the navigator when looking forward, does not take away any focus from the most important systems such as the radar, EDCIS, and conning display, located right in front of the navigator. Some examples of features previously seen as physical panels, which are now implemented into the touch screens, are exterior lighting mimics and controls, exterior and interior door mimics, and cargo deck controls. By integrating bridge systems into the touchscreens new opportunities emerge, like the ability to show advanced graphs of fuel consumption or weather patterns and how they affect each other, as well as autopilot decision support and recommendations, bridge lighting and dimming functions, etcetera. All in the same place. The touchscreens also include a comprehensive alarm center where the navigators can see and interact with all incoming alarms. The card configuration of the interface allows for personal modifications while still providing the option for predetermined home screens, for those who want it to look the same every time. The cards host different applications, and their position and size can be easily adjusted for different needs. As well as showing multiple cards at once, applications can be opened in full-screen mode when more information is needed.

Figure 27: The starboard touchscreen with an exemplified card interface.

7.3.3 Camera Systems

The bridge vision utilizes a smart camera system to provide supportive views of the surrounding of the ship. Cameras showing the side, the stern, and the front of the ship help the navigator with overtaking and seeing other obstacles. With the addition of a bird's eye view camera, shown in Figure 28, an overview of the ship and its closest surroundings can be seen, which supports when mooring or navigating through tight passages. This is done by combining views from cameras all around to ship to achieve the illusion of a drone view. From the bird's eye view camera, the ship's current speed and ROT (Rate of Turn) can be shown as an overlay, helping the navigator to make precise movements while avoiding any obstacles reliably, by showing the reality with minimal delay and no drifting errors. The figure also shows lines on the ship that when lined up with the same lines on land, means that the ship is perfectly positioned in port. The other camera views as well as all settings for the camera systems are located as an application on the touch displays. This allows control of what cameras to show while also providing a larger picture than on the overhead display, to make even small details in the water clearly visible.

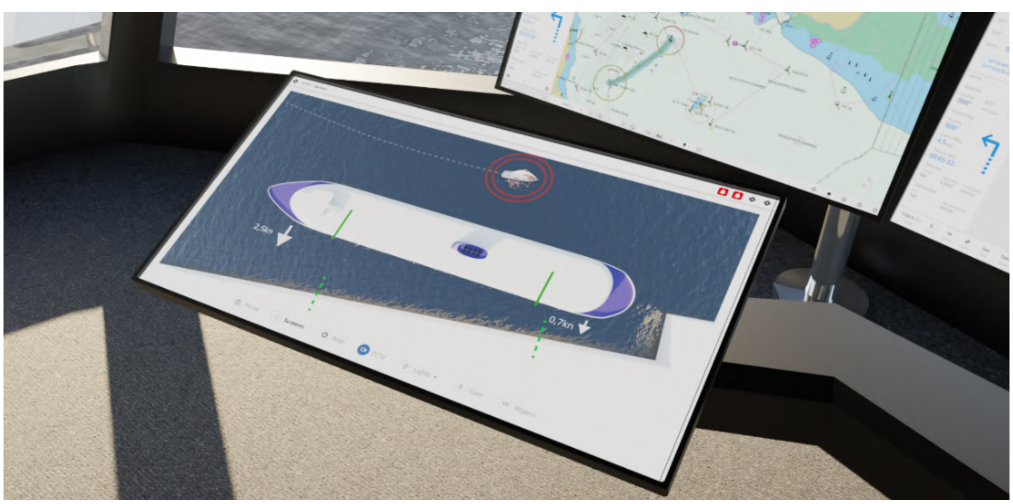

Figure 28: The bird's eye view camera shown on the left touchscreen.

The exterior cameras have automatic cleaning systems including small waterjets and wipers that also can be activated from the camera view on the touchscreen if needed, allowing the cameras to operate in most weather conditions and both salt and fresh water. Since the ship relies on cameras to view the sides of the ship, redundant cameras that can be activated in the case of a camera failure are available.

7.3.4 Widestrip

The widestrip, seen in Figure 29, consists of five screens separated by thin bezels in a large bent widescreen configuration, providing the navigators with the most essential information such as two radars, two ECDIS systems, and a central conning display. As Figure 30 shows, the widestrip is thoughtfully placed right within the navigator's immediate field of view when looking forward, with the radar screen in the preferred field of view for the navigator (ABS, 2018).

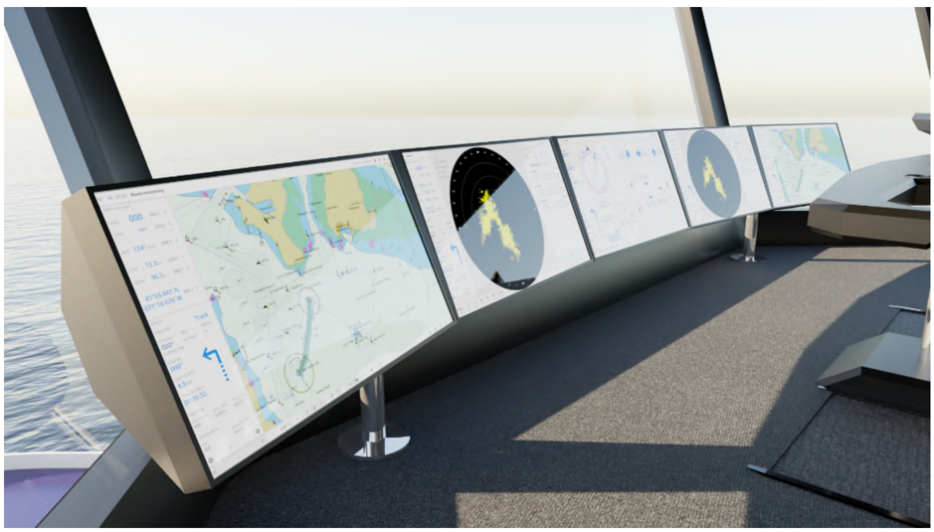

Figure 29: The widestrip on bridge vision.

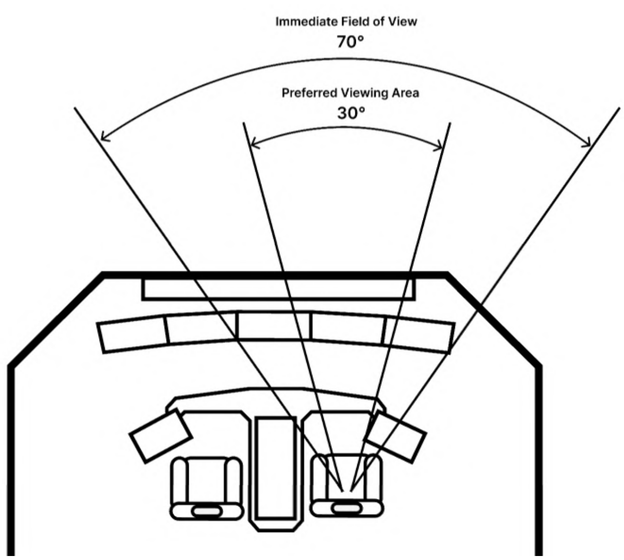

Figure 30: Illustration of how screens on the widestrip align with the navigator's field of view.

By placing the widestrip close to the bottom of the window, it is clearly and comfortably visible for the navigator with minimal impact on the forward vertical visibility, allowing roughly 30-degree vertical visibility from the navigator seats, as can be seen in Figure 31. The information on the widestrip can be easily customized from the touch display, allowing navigators to personalize what is shown on the widestrip, while still offering predetermined standard configurations. The interfaces shown on the widestrip are based on OpenBridge4.0 (OICL, 2023) and are designed with a character height of a minimum of 7mm to make characters readable from 2 meters which is roughly the distance between the navigators and the widestrip (ABS, 2018). A mouse pointer can be used to interact with information on the widestrip as well as for highlighting and showing things to each other. The screens used in the widestrip as well as the touch displays and overhead display utilize OLED technology which allows the black pixels to be turned off completely during the night, minimizing the interruption of the navigator's night vision due to backlighting.

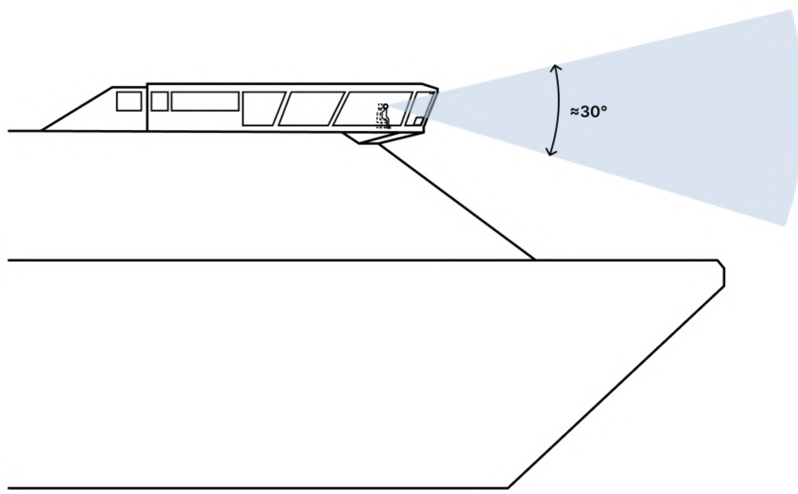

Figure 31: Illustration of the vertical visibility from the navigator seats.

7.3.5 Overhead Display

The overhead display, seen in Figure 32, is a screen providing a more condensed variant of vital navigation for example time, heading, ROT, wind speed, etcetera, in bigger font than on the widestrip, enabling information gathering through a quick glance. The icons and text on the interface shown on the overhead display are based on OpenBridge4.0 (OICL, 2023). The display is placed from the ceiling near the top of the front window of the cockpit, meaning it does not impact the forward view. Another purpose of the overhead display is to provide crew members with information regardless of where they are on the bridge, which is not possible with either the widescreen or touchscreen. The overhead screen does this thanks to its elevated position and big fonts.

Figure 32: The overhead display with navigation information and live camera feeds.

The overhead display also acts as the ship's side-view mirrors by showing live camera feeds from the two sides of the ship in a natural location towards the side of the navigator's FOV, as can be seen in Figure 33. Those cameras are part of the smart camera system utilized to provide supportive views of the surrounding of the ship. Cameras showing the side, the stern, and the front of the ship help the navigator with overtaking and seeing other obstacles. Settings for the overhead display cameras are found in a card on the touchscreens.

Figure 33: The starboard side camera view shown on the overhead display.

7.3.6 Physical Equipment

The central control table in the cockpit includes physical equipment, controls, and buttons used for different tasks on the bridge. Figure 34 shows the placement of the equipment including main engine controls, bow/stern thruster controls, autopilot controls, rudder controls, communication devices, window controls, dimming controls, and mouse wheels.

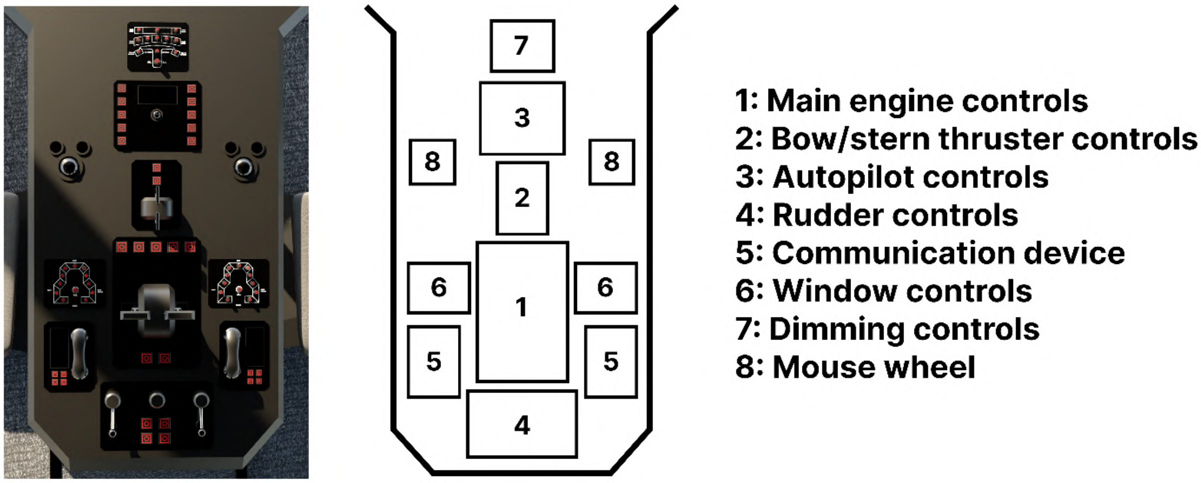

Figure 34: The arrangement of central station with all equipment listed beside.

At the very top of the central station, a group of dimming controls is placed to allow the navigators to adjust the brightness of all light-up equipment, represented by number 7 in Figure 34. The dimming control hub allows the users to quickly and easily dim the equipment needed, all from the same place. To arrange the knobs intuitively, they are placed in a layout representing the equipment in the cockpit with outlines of the overhead, widestrip, and central table together with descriptive text beside the knobs, as seen in Figure 35. This helps the user to fast and reliably get a glance at what knob controls what equipment. Additionally, all dimming settings can also be accessed from the touchscreen.

Figure 35: The dimming control hub.

On each side of the central station, number 6 in Figure 34, controls for dimming the windows are located, shown in Figure 36. As for the dimmable equipment control, the arrangement of the knobs is outlined and complemented with text. The outline here describes the placement of all windows on the bridge, helping the user to fast and reliably get a glance at what knob controls what window. Dimmable windows are further described in chapter 7.1.3.

Figure 36: The right-side controls for dimming the windows.

Furthermore, on each side of the table, number 8 in Figure 34, a mouse ball and two buttons are placed. They are used to interact with the widestrip and can also be used as a pointer for highlighting and showing things to colleagues. They are mainly designed to be used when standing, since the same controls are placed on the armrest of the seat, to be easily accessible when sitting, described more in chapter 7.3.8.

All steering equipment needed is placed on the center station with the autopilot controls placed at the top of the center control to be slightly separated from the manual steering controls below. A similar autopilot control is also placed on the armrest of the navigator seat, to be accessible when sitting, described in chapter 7.3.8. Behind the autopilot the stern and bow thruster controls are placed together, since they are often used at the same time, and are turned horizontally, to align with the ship's thrusters. Behind the thruster controls, the main engine controls are placed with the levers turning vertically, in the engine direction, and lastly, two rudder control levers are placed in the back, on each side, as the rudders are placed on the ship. This creates an intuitive setup of the controls as they are both placed and oriented in the same way as the corresponding parts of the ship they control. The engine controls are also designed to have integrated indicators located near the physical lever itself, see Figure 37. This allows the user to see necessary indicator values when looking at the equipment in addition to what is shown on the conning display.

Figure 37: The main engine controls with indicators above.

All buttons and levers that belong to each other are placed together with a framed plate that separates them from other equipment, making it easy to distinguish which buttons belong to what equipment. The frame plates also allow for the equipment to be easily removed and replaced by new equipment in the future. To give the users feedback on whether a button is on or off, two designs are made. Firstly, each button has two positions, up and down, where up is off and down is on. This gives a quick overview of the buttons in bright light conditions. In dark light conditions, the feedback is given by having a red outline that lights up when the button is pressed down, that is, when it is on. Also, the function of each button is communicated by having a red light-up icon on all buttons as well as a small text description.

Two identical multifunctional communication devices are placed on each side of the table, easily reachable from each of the navigation seats marked as number 5 in Figure 34. These devices combine the functionalities of VHF radios, internal communication, intercom, etcetera, into one single system. The communication devices are also compatible with the wearable smart watches, further described in chapter 7.3.10.

7.3.7 Reachability

The cockpit is designed around easy reachability of all equipment as can be seen visualized in Figure 38, with the navigator sitting in the left chair. Green represents equipment that is easily reachable and/or readable, yellow is not as easily reachable and/or readable, but still possible, and finally red resembles equipment not reachable for the navigator sitting in the left chair. As can be seen, not all equipment is green and thus not easily reachable and/or readable, however, all equipment marked with either yellow or red are duplicates of equipment also available as green-marked equipment for the navigator in the left chair. Therefore, all equipment is easily reachable and/or readable for both navigators.

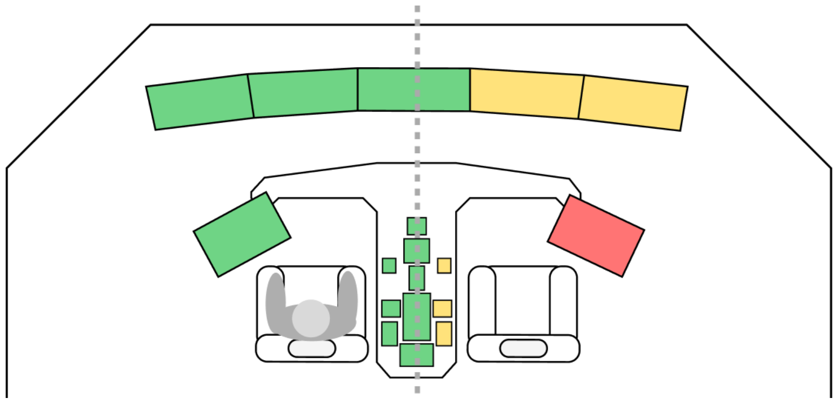

Figure 38: Illustration of reachability in the cockpit on the bridge vision.

7.3.8 Working Position

The cockpit is designed to allow for different working positions, thanks to the adjustable table and the navigator seats. The seats are movable both vertically and horizontally with an adjustable sitting pad, back, arm, and headrest, and the addition of an integrated footrest, to allow for full customization of the working position. The most used equipment, which was found to be autopilot controls and a mouse and buttons, are placed at the front of one of the armrests, allowing for system interactions, and controlling the ship without needing to lean forward, see Figure 39. At the front of the other armrest, the controls for the chair can be found.

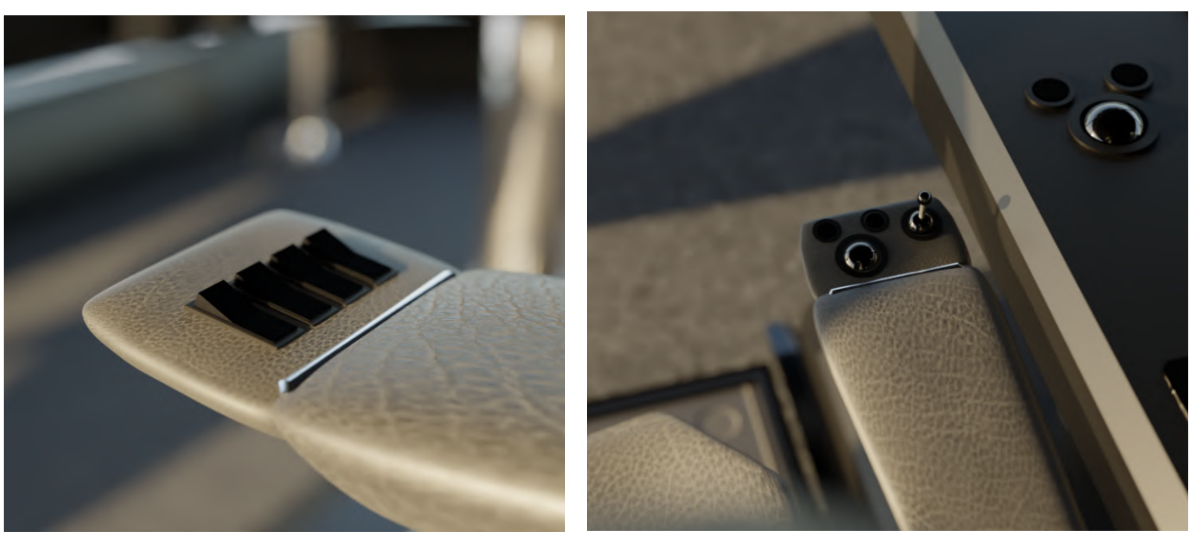

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Figure 39: The controls on the outer armrest and inner armrest respectively.

Furthermore, the seats can be moved away backward to make space for a standing working position. To still be able to use the equipment placed on the armrest when standing, the same buttons are also placed on the central station. To further make the design as intuitive as possible, the buttons on the armrest and the buttons on the central station are placed on the same side of the navigator. This means that the left navigator seat has the controls on the right armrest while the right seat has the controls on the left armrest, see Figure

40. Finally, the navigators also have the possibility to walk on the bridge while monitoring autonomous systems, thanks to the treadmill placed underneath a hatch in the floor. By using the treadmill, the navigators can get more daily physical activity and thus stay more alert, while still doing their job.

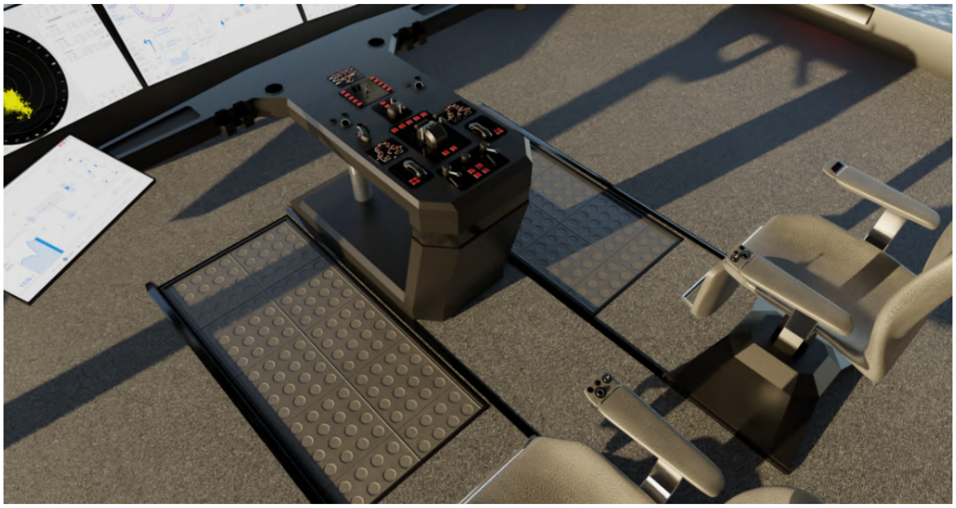

Figure 40: The workstation with the chairs pulled back and the treadmills activated.

7.3.9 Manual Steering Station

Furthest back in the cockpit area, the manual steering station is located, consisting of a physical wheel and some basic system indicators, see Figure 41. Towards the front of the manual steering station, less frequently used equipment such as GPS (Global Positioning System) and AIS (Automatic Identification System) boxes can be placed. In that way, they are still near the navigator seats, if needed. The manual steering station can be used by the helmsman to manually steer the ship in tight passageways or in the case of any system failure, which is needed for regulatory purposes even though that might change in the future. On both sides of the manual steering station, two slanted wood railing is placed in a forward bending arc. The railings provide the crew with a leaning spot while talking to or assisting the navigators in the main seats, and also create a semi-enclosed social area in the front of the bridge.

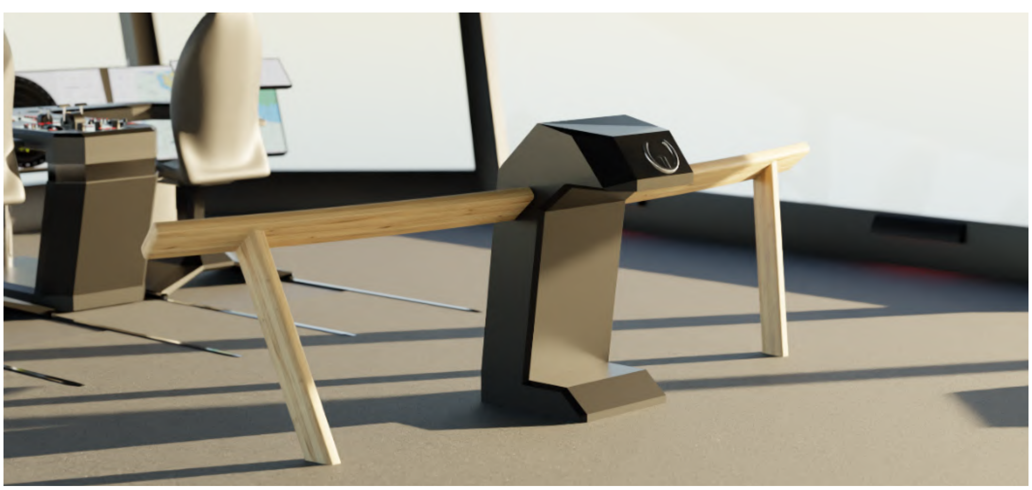

Figure 41: The manual steering station with the bench railings.

7.3.10 Smartwatch

The smartwatch is a wearable supportive equipment used to improve the work of the navigators. The two main functions are the communication- and alertness system, showcased in Figure 42. The system covers both internal and external communication as well as passenger messages. In that way, no matter where on the bridge the crew is, they always have communication accessible in one place. The alertness system helps the navigators to stay alert and not fall asleep. By tracking, for example, heart rate and movement, the watch can analyze and warn navigators that are about to fall asleep. The alertness system also includes physical activity tracking. This means the users can follow their daily activity and get encouraged to get their steps in.

Furthermore, the smartwatch could also be used in the future for alarming/calling the navigator to the cockpit when the autopilot needs human attention, in a level 4 or higher autonomous system according to One Sea's levels of automation (2022).

Figure 42: The smartwatch with exemplified communication and alertness interfaces.

7.3.11 Night Mode

The bridge vision allows the user to turn on night mode when it is getting dark outside. This means that all buttons in the cockpit become dimmed and that all digital interfaces on the widestrip, touchscreen, and overhead display change to the night palette based on the OpenBridge (2023) design system, see Figure 43 and Figure 44. The night mode setting uses dark colors that are easy on the eye and keeps the brightness to a minimum to help the navigators keep their night vision. Other lights on the bridge are tuned off except for dimmed red lights near the floor to show the outline of the bridge for safety and evacuation purposes.

Figure 43: The inverted interface shown on the touchscreen, with the widestrip in the background.

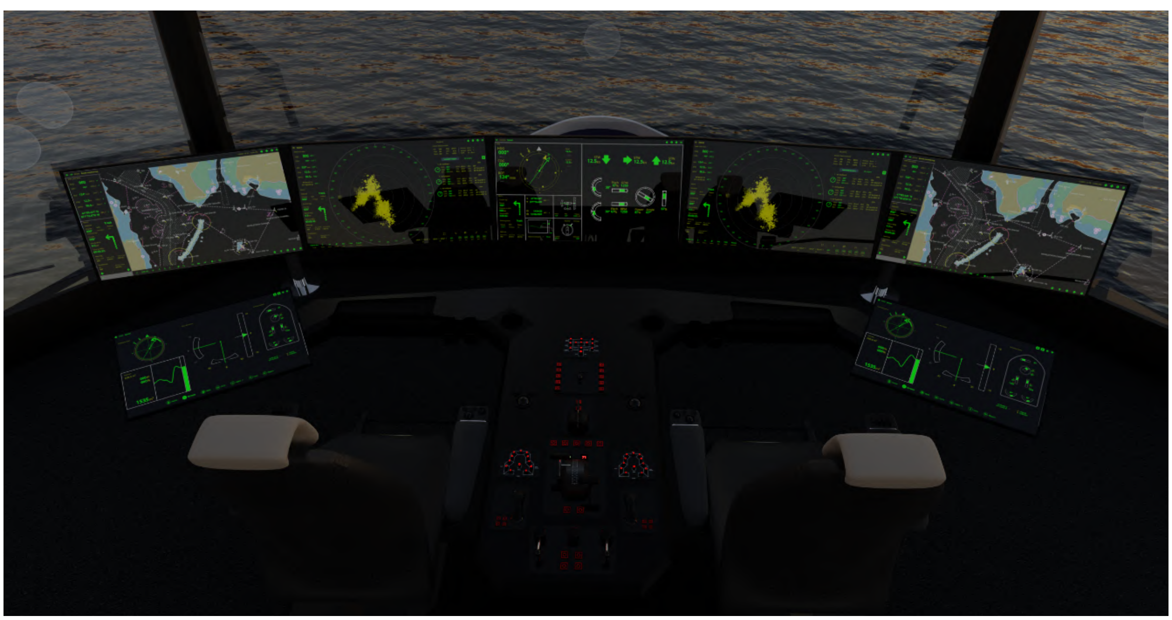

Figure 44: The cockpit at night

7.4 Back Bridge

The back bridge refers to everything behind the manual steering station that separates the cockpit from the rest of the bridge. The individual areas of the back bridge are presented below.

7.4.1 Lookout Seats

Instead of having a stationary seat for the lookout, the bridge allows the lookout to be more of a mobile role. This means that the lookout has a greater chance to see the entire horizon and be more aware of traffic and other obstacles on the sea. Two benches are placed on either side of the bridge along the big diagonal windows to allow the lookout to sit down as well, see Figure 45. The benches are designed to be low in height to not obscure the view since they are located close to the windows. The lookout benches are designed with the same top-out inclination of 20 degrees to match the design language of the bridge.

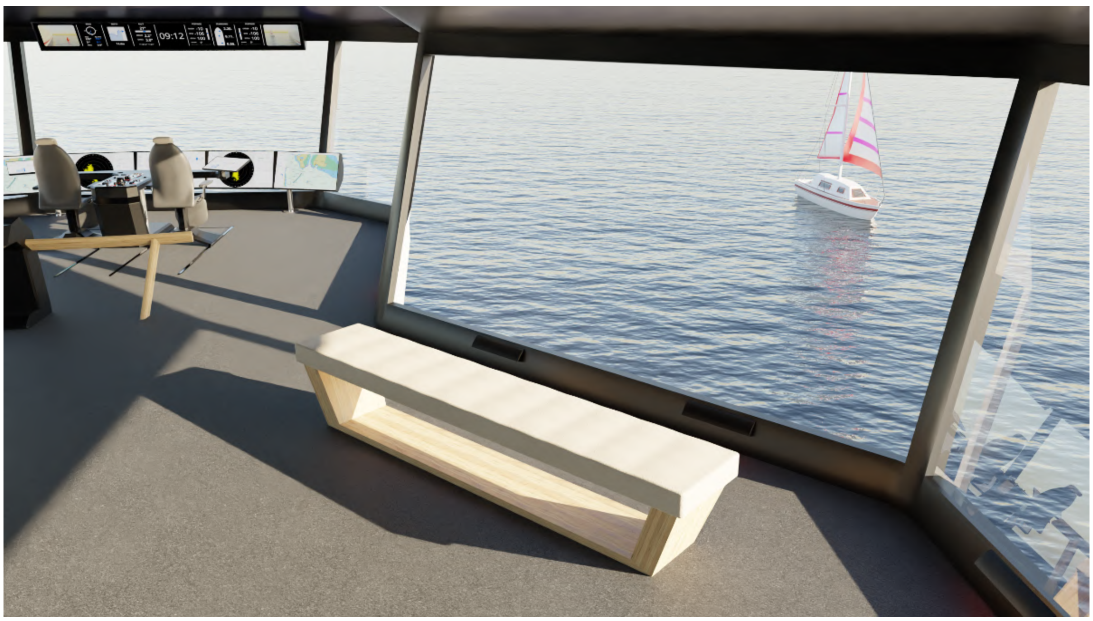

Figure 45: The starboard lookout bench.

7.4.2 Collaboration Table

The collaboration table, seen in Figure 46, located centrally on the bridge behind the manual steering station, acts as an open work surface for route planning, discussions, meetings, and emergency planning. The large surface fits physical maps or fire safety plans to be rolled out onto and the absence of any furniture in the near vicinity around the table makes navigating around it easy and provides a natural location for stand-up meetings to be held in circles around the table. The shape of the collaboration table resembles the shape of the cockpit with 45-degree chamfers and the same outward leaning angle as the cockpit has, also similar to the central control table. The shape of the table also provides storage possibilities underneath the table for larger items such as boxes or backpacks.

Figure 46: The collaboration table.

7.4.3 Break Area

Every workspace needs a place for taking a break. The break area provided on the final bridge vision is located in the back towards the port side, see Figure 47. Here, the crew can take coffee breaks, have shorter morning meetings, and just relax for a moment. Here a kitchen is located, equipped with a fridge, sink, storage, and a coffee machine, complemented by comfortable seating options including a couch, chairs, and a large table.

Figure 47: The break area of the bridge with the monitoring display shown from behind.

The entire break area is designed to be low in height to not block the view from the cockpit towards the port side stern of the ship. The break area also allows the crew to stay in the loop of the navigation, thanks to the arc-shaped monitoring display located in the ceiling, as seen in Figure 48. In the future when autopilot systems are more advanced, this could allow for one or both navigators to go and grab a coffee during calm conditions while still being able to keep an eye on what the ship is doing.

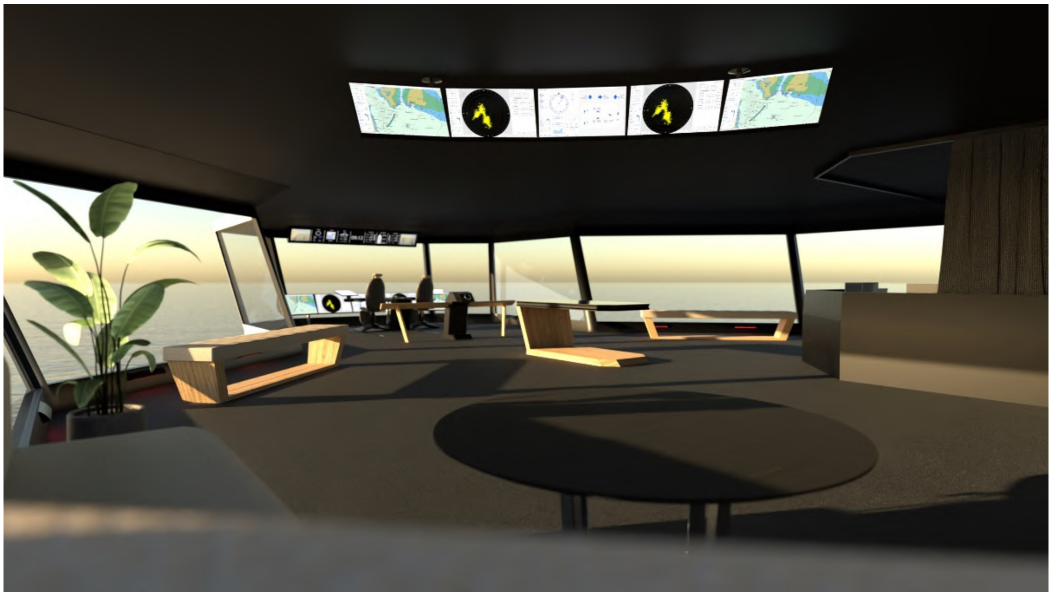

Figure 48: The view from the break area including the monitory display.

7.4.4 Administrative Area

With more advanced autopilot systems controlling the ship in the future, more time could be spent on administrative tasks on the bridge. The office space located towards the starboard in the back of the bridge, see Figure 49, is designed to not interrupt the backward visibility by keeping the highest point below the back windows. Administrative tasks can be conducted here, day or night, without affecting the navigators at the front thanks to the retractable curtains that keep light pollution from the computers inside the office area at night, while also not interrupting the backward visibility during the day when the curtain can be kept open. The back of the tables facing the rest of the bridge also functions as available wall space for hanging up signs and items that might be needed due to the closed-back design of the office space.

Figure 49: The administrative area of the final bridge.

The administrative area is also equipped with storage for safety equipment, flags, redundancy systems, cleaning supplies, etcetera. The flag storage is located neatly above the back windows near the ceiling while the other storage shelves stretch the entire back corner of the administrative area with a large open surface on top to temporarily place items. Located furthest down in the diagonal corner of the storage shelves, an automatic vacuum cleaner station is placed, where the bridge's cleaner robot goes to empty its bins and charge after spending the ship's off-duty hours keeping the bridge clean.

7.5 Design Results Summarized

The design resulted in a ship bridge vision offering a slim bridge with a protruding cockpit which also incorporates a spacious workspace design, featuring open surfaces and large windows. The bridge provides a mostly uninterrupted view all around the horizon with flat windows to minimize reflections, and all windows can be dimmed to protect the crew from light distractions and heat. The layout includes a central navigation station, a large widescreen setup, an overhead display, an administrative area, and a break area. The central control table houses ship control equipment and two multifunctional touchscreens with an adaptable card interface. The seats offer a flexible working position with the ability to sit, stand, or walk. Smart camera systems replace physical wing bridges, allowing the navigators to have all controls in one place. Finally, a smartwatch provides communication tools and health monitoring features to all crew onboard the bridge.

In conclusion, the bridge vision presented in this chapter was developed with the design guidelines as a basis together with complementary technologies and user-centered design. How the guidelines were fulfilled is described in chapter 8 and further discussions about the final bridge design are brought up in chapter 9.

Fulfillment of Design Guidelines

08

This chapter describes the final bridge vision's fulfillment of the design guidelines. The chapter is divided into the same eleven groups as the design guidelines, namely Shape and View, General Layout, Information Gathering, Physical Ergonomics, Buttons, Screens, Cameras, Light Conditions, Social Aspects, Communication, and Aesthetics. How the bridge design takes the guidelines into consideration are described for each group.

8.1 Shape and View

With its shape and the protruding cockpit, the forward view for the navigator is 260 degrees, which is more than the guideline of at least 180 degrees. Two other guidelines determined were to have a good view of the surroundings of the bridge and also allow for backward visibility. The new bridge fulfills both guidelines thanks to its open layout together with the windows along the bridge, giving a close-to-360-degree horizon view. Finally, the guideline about minimized reflections and refractions is fulfilled by having outward-leaning windows and none of them being bent in any direction.

8.2 General Layout

The design of the cockpit with the central station, including physical controls, touchscreens, and wide strip, fulfills the guideline that all navigational equipment should be possible to use from one central place. Two guidelines regarding equipment were that the placement of equipment should be intuitive, well thought out, and easy to understand and that the placement should follow the users' mental models. This is accomplished through several design decisions, described in detail in chapter 7.3. Furthermore, the frame plates grouping controls and allowing for equipment to be easily removed and replaced by new equipment in the future fulfills the guideline that the design of the bridge should allow for easy upgradability.

Another guideline was that the bridge should provide space for personal items such as a coffee mug, smartphone, and binoculars. This is fulfilled thanks to the table area between the central table and the touchscreens, where these kinds of items can be placed.

Thanks to the thin design of the widestrip and its placement on the floor, close to the window, it allows the navigator to walk up close to the front window, which was a guideline. Furthermore, the physical steering equipment is kept on the new bridge, including the physical steering wheel. This fulfills the guidelines that the bridge should allow for manual operations when wanted/needed. Another guideline was that the bridge should allow one to walk out on the deck, which is possible thanks to the two doors placed just behind the entrance.

Since the bridge vision uses OpenBridge's (2023) interface systems in all screens, it fulfills the guideline that the bridge´s interfaces should make use of available standardization. This also means that all systems are linked to each other and with that, the guideline that all systems on the bridge should be able to cooperate and communicate is fulfilled.

8.3 Information Gathering

Two guidelines were to place the most essential information in front of the navigators as well as to always provide vital information without disturbing the view. Those guidelines are fulfilled in the bridge vision through good vertical and horizontal visibility, the wide strip, the touchscreens, and the overhead display. The wide strip always shows the most vital information for the navigators and its placement gives the navigator a good window view. The touchscreens together with the overhead display provide the navigators with all other valuable information.

Two other guidelines presented were that the bridge should display information effectively without causing information overflow and that all valuable information should be easily accessible. Those guidelines are fulfilled by the balance of visible and hidden information on the bridge, some information is always visible while a greater proportion of information is hidden and could be found on the touchscreens. Having the engine indicators located by the engine controls is another way the bridge displays information effectively and with easy availability.

8.4 Physical Ergonomics

The screens and equipment on the bridge vision are carefully placed to be easily reachable and usable in a good working position. By putting the touchscreen further to the side, the most commonly used buttons on the armrest of the chair, and the other physical controls on the center console to the right, all important equipment can be used from the navigator seat. Together this fulfills the guideline that regularly used buttons and screens should be put in an ergonomic relaxed position.

Another guideline was that the working position should be adjustable for both sitting and standing. The bridge vision fulfills this by making the chairs movable backward and the table height adjustable. In addition, identical buttons to the ones put on the armrest are placed on the center console, to make those buttons reachable when standing. Two more guidelines were that the bridge should allow for daily physical activity while working and that the bridge should prevent tiredness. These guidelines are achieved both by the treadmill, the navigators can walk and work at the same time, which is good both from an activity and alertness perspective.

8.5 Buttons

One guideline regarding buttons was that they should provide feedback on whether they are on or off in all light conditions. In daylight, this is accomplished by the fact that each button has two positions, up and down, where up is off and down is on. In dark light conditions the guideline is accomplished by having a red outline that lights up when the button is pressed down, that is, when it is on. Furthermore, another guideline was that all buttons should communicate their function in all light conditions. This is fulfilled by having a red light-up icon on all buttons together with a small text describing its function.

Two more guidelines regarding buttons were that the most vital navigational and control systems should be physical equipment and that the layout of buttons should make it easy to use them without looking. This is fulfilled by carefully deciding what systems to have as physical buttons and what can be placed on the touchscreen, but also by a well-thought-out and intuitive placement of the physical equipment.

8.6 Screens

All screens on the bridge utilize OLED technology, meaning that the black pixels are turned off during the night and minimize the interruption of the navigator’s night vision, which was a guideline. Another guideline was that screens should be easily viewable from different working positions. This is fulfilled both by the widestrip screen’s arc placement, which angles the screens inward and the overhead display’s placement in the ceiling, which makes it visible from further away. Moreover, by designing the widestrip interface with a character height of a minimum of 7mm to make characters readable from 2 meters, the guideline that text size should be sized after the viewing distance from the screen is fulfilled. Another guideline was that the contents on screens should be easily interacted with when necessary. This is achieved by having a mouse and buttons for the widestrip placed both on one armrest and on the central station. One more guideline regarding screens was that the use of screens should be justified. This is accomplished by careful consideration of which equipment is placed on screens and which is kept as physical equipment on the central control table.

8.7 Cameras

Two guidelines regarding cameras were that the bridge crew should be able to monitor exterior and interior parts of the ship and that cameras should support the navigators' tasks when needed. This is achieved with the smart camera system providing supportive views of the surrounding of the ship, including the side, the stern, the front, and a bird's-eye view camera showing an overview of the ship and its closest surroundings.

8.8 Light Conditions

By having the office space in the back port side corner of the bridge, with curtains to screen off the rest of the bridge, the guideline to provide an area where normal light can be used without disturbing the navigators during the night, is fulfilled.

Three guidelines regarding light conditions were that local dimming functions should be available to dim individual screens and systems, that a central dimming function should be available to dim all screens and light-up buttons, and that this should be done easily. This was achieved thanks to the physical dimming knobs placed on the central station, which provide the wished features in an accessible and easy way without having to dig far into any settings.

The bridge vision has a feature to allow dimming all the windows on the bridge, with different transparencies, to block sunlight. This fulfills two guidelines, namely that sun protection should be available and easily adjustable and that it should have various levels of sun pass-through.
Another guideline regarding screen interfaces was that they should have modes for different light conditions. This is fulfilled by using OpenBridge's (2023) interface systems which have four modes: bright, day, dusk, and night.

Another guideline regarding light conditions was that the light level inside the bridge should match the light level outside the bridge. This is fulfilled partly by having only dimmed lamps on the bridge, allowing the inside light level to depend on the sunlight from the outside. The bridge also offers automatically dimmed equipment that adjusts the light level on screens and controls depending on the outside light level. This also fulfills the guideline that all lights and buttons should be designed to preserve night vision, together with the design of the buttons and the dim controls on the central station.

8.9 Social Aspects

Regarding social aspects, one guideline was that the bridge design should allow for social interactions. This is fulfilled both by placing the two navigation seats beside each other, making it easy to discuss and collaborate, but also thanks to the standing bench, allowing crewmembers to comfortably join the cockpit area and socialize. The standing bench further contribute to allowing for different manning levels by making it possible for more crewmembers to collaborate and help with the navigation, which was another guideline.

Furthermore, one guideline was that working on the bridge should be stimulating. This is fulfilled by the social possibilities mentioned above, but also by including the crew in the navigation, even when the automation level is higher. This is thanks to the possibility of steering the ship manually, but also by allowing the crew to follow and analyze information about the performance on the touchscreen.

A further guideline determined was that the bridge should allow for a personal workspace, which is accomplished with the two identical navigator workstations providing one radar, ECDIS, and touchscreen per navigator, allowing for personalized settings and adjustments.

8.10 Communication

By allowing the navigators to communicate with crewmembers, passengers, and ships via the smartwatch the three guidelines regarding communication are fulfilled. Moreover, the central phones give the navigators an additional possibility to communicate with crewmembers, passengers, and other ships from one multifunctional device.

8.11 Aesthetics

With a predefined interior design style, the bridge fulfills the guidelines of a uniform design, both regarding shape and color, and the colors should be matte and dark. Moreover, with a well-thought-out and space-efficient bridge layout, the bridge fulfills the guidelines that the bridge should have an airy and open feeling and not be overflowing with things.

8.12 Summary of Fulfillment

To summarize, most of the guidelines were taken into consideration when developing the final bridge and were thus also fulfilled by its design. However, the following three guidelines were not fulfilled by the design but were still considered to be important when designing a bridge:

- Screens should be designed to minimize disturbing reflections.
- Exterior cameras should prevent salt and dirt on the lens.
- Exterior cameras should be usable in all weather conditions.

Reflections were not looked into since that was considered to be too specific and thus too difficult to execute successfully for the project scope. However, when using screens, for example, the touchscreens, reflections have to be investigated since that could be a possible risk of errors. Moreover, how exterior cameras should prevent dirt and be used in different weather conditions was also considered to be too specific. With that mentioned, since the cameras in the final bridge design replace physical wing bridges, they have to be reliable and safe to use in all situations, and therefore such aspects are still important to be considered when designing a bridge.

Discussion

09

This chapter discusses the entire project from different perspectives. It starts with discussing the methodology, including the scope of the project, the design process, the field studies, and the user groups. That is followed by discussions regarding environmental, societal, and ethical considerations, other use scenarios, differences from previous work, and recommendations for future work.

9.1 Methodology

Discussions regarding the methodology and processes used throughout the project are presented below.

9.1.1 Project Scope

As mentioned in chapter 1.2, the project and deliverables were supposed to stay at a holistic level and focus on the whole bridge as a product rather than the design of specific tools, systems, or interfaces. This wide scope has minted the entire project and has been challenging throughout the process.

First, in the Discover phase, which was done to understand the context of ship bridges, the users, and potential problems and improvements, a challenge was to know how deep and thorough the understanding had to be. As mentioned above, the project should not focus on specific tools or systems, but to design an improved future bridge, including tools and systems, such things still needed to be understood. With that mentioned, it was occasionally complicated to draw a line between what to include in the Discover phase and what could be ignored, without losing too much important information.

In the Develop phase the wide scope both came with advantages and disadvantages. The advantages were that the ideation allowed for many diverse ideas that had the potential of improving several different aspects of the ship bridge and that the project could be directed into areas where the greatest improvement possibilities were found. However, the wide scope which resulted in various ideas also resulted in less qualitative and elaborated ideas, with a bridge design that included many diverse ideas rather than a few specific ones.

Thus, the wide project scope has not only affected the understanding and ideation of the project but consequently also the final result. All details of the bridge could not be thoroughly understood and redesigned, which could result in unexpected flaws in the design of the bridge vision and the interplay between various parts and systems, that could not have been predicted.

9.1.2 Design Process

As presented in chapter 4 the process of the project was divided into four phases: Discover, Define, Develop, and Deliver, with some iterations between the phases. However, the phases ended up fading into each other more than initially thought as parts of the Discover and Define phases kept being added upon far into the Deliver phase. The Develop phase was supposed to be the biggest part of the project which it ended up being, slipping far into the Deliver phase, thus leaving less time than expected for the final visualizations.

However, the chosen design process still worked quite well for this type of project. The big Develop phase made it possible to include both new ideas based on the guidelines, and futuristic technology ideas based on benchmarking and literature reviews of existing solutions. At the same time, the Develop phase was implemented differently from what was initially planned. Firstly, the future technology ideas were involved earlier in the ideation than thought. The plan was that ideas from the guideline ideation should first be thoroughly developed and that future technologies should complement those ideas. Nevertheless, future technology ideas were implemented much earlier in the ideation and became a greater part of the Develop phase than first thought. The reason for this was that the guidelines determined were mostly based on current problems and improvements found on existing ships, and therefore, if the final bridge were to be built mainly with ideas from the guidelines, the bridge would indeed cover existing problems but lack the futuristic perspective.

Another change in the process was done in the concept development in the Develop phase. The first intention was to build at least three total concepts with different ideas in each concept. The plan was that this would allow for many diverse ideas to be kept to the user evaluation and that the best ideas, regardless of which concept they came from, could then be built into the final concept. However, one concept was instead gradually built up from the best ideas identified throughout the process. The reason for this was that all ideas were so linked and depending on each other that the concepts would become less coherent and thus be hard to evaluate for the users if done as first planned. The concept was instead developed by first choosing the fundamental ideas, for example, shape and layout, and subsequently building it further with ideas that correspond with the other ideas, and so on.

9.1.3 Field Studies

An aspect that could have affected the validity of the project´s results is the field studies. The field studies in the project were limited to Stena Line's fleet departing from Gothenburg. This resulted in the most modern ship visited being Stena Carisma, which was built in 1997 (Marine Traffic, 2023) meaning it was more than 25 years old in 2023. Therefore, it can be argued that certain identified problem areas, and consequently the following design guidelines, already might have common solutions on more modern passenger vessels. This became clear during the user evaluations where interviewees mentioned that some of the ideas proposed already have been implemented *"pretty much everywhere"*. Some of the interviewed people recommended visiting, for example, a modern fishing vessel as a field study trip to be able to observe a well-thought-out and modern bridge. On the other hand, one can argue that by visiting older ships, a more thorough understanding can have been gained, since more problems were found that wouldn't have been found on a more modern ship. Consequently, if only modern ships were visited, some problem areas could have been missed since they did not exist on such ships, which later could risk the final bridge design missing vital aspects.

The project also consisted of only roughly 35 field study hours compared to for example the Ulstein project which resulted in over 1800 field study hours (Kristiansen, 2014). This difference likely affects the understanding of the context of the bridge and the different scenarios that can occur ranging from all possible weather conditions, different manning levels, and demanding situations that do not occur on a daily basis and was thus not observed on the field studies conducted for this project. The field studies were all conducted during the spring of 2023 meaning that other seasons could reveal problem areas not observable during spring.

At the same time, the field studies carried out still strongly contributed to the whole project and improved the conditions for achieving the aim. Without the field studies, the understanding of the context and the users would not have been at the same level that it was. Consequently, the guidelines, ideation, and also final bridge design would also have been affected negatively.

9.1.4 User Group

The people interviewed during the field studies and evaluation sessions were a rather homogenous group of Swedish men, mostly around 50 years old, opening up the possibility for gender, age, physical ability, and cultural biases affecting the collected data. The stated opinions and observed usage on the bridge do therefore not necessarily represent the industry as a whole. Furthermore, differences between the age of the interviewed groups were found, namely that, the younger the interviewees, the more open they were to new ideas and big changes to the bridge. Therefore, it can be argued that the bridge vision might have been affected into being more traditional and conservative than other similar vision projects, due to the average age of people interviewed, being relatively high. With that mentioned, a more diverse but also larger user group, including users with different sexes, backgrounds, and experiences, would have been desired to get a wider perspective, and hence also a more validated final bridge design.

9.2 Environmental, Societal, and Ethical Considerations

Firstly, from an environmental and sustainability perspective, the small and central design of the bridge vision offers the possibility to create a more aerodynamic ship design since the lack of physical wing bridges would remove drag otherwise created by the bridge. Although this aerodynamics might only affect a small percent of the total fuel consumption of a ship, an improved aerodynamic design would still help save significant amounts of fuel over time.

Although materials and production of the bridge were aspects not taken into consideration within this project, the impact of the design decisions could still offer a more sustainable usage of the bridge. One example is the applications on the touchscreens made possible due to full system integration that could show graphs of fuel consumption and compare it to previous journeys. Smart voyage planning applications could encourage the crew to plan and execute a voyage with fuel efficiency in mind.

Cultural and ethical differences will likely affect how well a bridge design is perceived and how usable it is. One example of this was that the manual steering station on Stena line's vessels here in Sweden is largely unused since the navigators simply turn on autopilot only minutes after leaving port, while in other countries like England, the manual steering wheel is operated by the helmsman on the captain's orders until the ship is out on open waters before the autopilot is enabled, as told by one of the interviewees. Another cultural difference could be the minimalistic design language used for the bridge vision that is largely interpreted as aesthetic and luxurious here in Scandinavia, while in other countries, different preferences could lead to the overall aesthetics of the bridge vision not being as well interpreted.

When it comes to Design-for-all aspects, the main seats are designed to be adjustable in both height and inclination allowing for a comfortable seated working position independent of body height. By designing the entire central control table to also be adjustable in height, the standing working position can also be adjusted for different body heights. However, one issue would arise if for example the navigator and co-navigator would both want to work in a standing position while being significantly different in height since the adjustments in table height affects both navigators and therefore cannot be individually adjusted. Since the chairs can be moved backward the central workstation could work well with a wheelchair user if needed, this would also be helped by having all controls and camera views available without moving around on the bridge. GDPR guidelines were followed throughout the project when taking pictures and interviewing users during the field studies and user evaluation sessions. Only basic information such as their naval role and rough age was kept for the report while all other personal information gathered was deleted at the end of the project and was thus not passed along to anyone.

9.3 Other Use Scenarios

Although the bridge vision was designed for large passenger vessels on short-medium length routes the ideas proposed could still offer advantages for bridge design on other types of vessels. One example could be for short-distance freight ships where the bridge is located towards the back of the ship making the use of wing bridges less advantageous since the bridge already offers good backward and forward visibility. On the other hand, there might also be certain ideas that would not fit very well in other scenarios. One example of this could be for large and long-distance container ships where the relatively small size of the workspace combined with the lack of physical wings would not fit well with the long timespan of trips and not allowing for easy pick-up and collaboration with port pilots.

9.4 Differences from Previous Work

The bridge vision proposed differs from previous research done within the field of future bridge design with a larger focus on the physical workspace and less focus on futuristic technologies. Although this might have been affected by the relatively short time span into the future that this project aimed to design for, it could also be a sign that some technologies that initially seemed interesting like AR and VR do not offer enough advantages in the technology's current state that would make them worth implementing. The bridge vision is also designed to be fully operational for manual operations as well as more autonomous operations including increased monitoring tasks for the crew members. By doing this the bridge vision became more realistic and easier to implement in the near future compared to other vision projects aimed for much further in the future.

9.5 Recommendations for Future Work

As discussed before, the wide scope of the project together with the arguable restricted amount of time, resulted in a holistic visionary design where the quality of details has been limited. With that mentioned, complementary work where all parts of the bridge could be further developed in detail would make the whole bridge more integrated. Below, different future work possibilities are discussed to improve the final bridge design.

To begin with, more field studies would need to be conducted to gain a deeper understanding of the context, including visiting a larger variety of bridges and during more hours. More people would also need to be interviewed to get a significant database of experiences and issues of current ship bridge designs.

Another way forward would be to build a 1:1 prototype of the ship bridge, especially the cockpit area, in order to test how the size and placements of things correlate in the real world. Physical ergonomic evaluation tools could be used to assess the ergonomics of the working positions in the cockpit. The VR evaluations carried out in the project gave a first insight into such understandings, but by building a real prototype other aspects like feeling and using the controls could be verified.

Moreover, the digital interfaces on the widestrip, touch displays, and the overhead screen would need to be more thoroughly designed and prototyped, including the full intended functionality. Having interactive interface prototypes could be used in further user tests by for example testing the interfaces on the full-scale bridge prototype, to assess how the digital and physical aspects cooperate.

Ship bridge regulations were decided to not be included in the scope of the project and were therefore not considered for all parts of the bridge. Thus, further development would have to include current and future regulations if they were to be produced. This means that some parts of the final bridge design, and certain technologies, might need to be severely altered to get approved for maritime use in the near future. At the same time, the reason for excluding regulations was because that was considered to risk to limit the project's innovative thinking, due to old regulations. Thus, as the industry develops the regulations also need to be developed, meaning that such futuristic ideas might be covered by the regulations in the future.

9.6 Achievement of Aim and Purpose

Overall, the final result addresses the aim of the project well. It covers the stated aspects regarding physical layout, ergonomics, and user-centered design, and includes technical advancements as well as considers future advanced automation. The project can hopefully also contribute to the field of naval bridge design by inspiring future product development processes thanks to the pictures and videos visualizing the bridge vision.

Conclusion

10

In this chapter, conclusions from the project are presented as short and summarized bullet points.

The conclusions from the project were that:

- The bridge on large passenger vessels is a highly complex socio-technical environment that requires a thorough understanding to be designed for.
- Ship bridges would benefit from a systematic redesign with a focus on user-centric design and futureproofing by designing for upgradeability.
- Replacing wing bridges with advanced camera systems can lead to increased safety and efficiency if the systems are easy to use and reliable in all conditions.
- A protruding cockpit design with screens placed near the top and bottom of the front windows will lead to improved vertical and horizontal visibility.
- With autopilot systems becoming more advanced in the future, bridge design will have to adapt by focusing on designing for more monitory roles and how to keep vigilance and alertness high.
- Designing a bridge with flexible working positions and allowing the crew to get daily physical activity while working can improve the crew's health, well-being, and alertness.
- Implementation of new technologies in ship bridge design needs to be justified and thus offer a clear advantage over current systems.
- Changes in user behavior, and its effect on safety and efficiency, as a result of new design solutions, need to be considered when designing a ship bridge, for example when moving physical equipment to digital screens.
- Even though ship bridge users sometimes have a "if it works, why change it?" mentality, when shown solutions that address their needs, they are generally open to change.

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Appendix

12

A: Initial Ideas

Below, some of the most relevant initial ideas are further presented and divided up into ideation categories. The ideation phase resulted in around 70 ideas within eleven different areas. Sketches from the early ideation sessions can be seen in Appendix B.

Shape

The shapes that were developed in the rapid prototyping phase for the physical ship model ranged from bridges that were similar to the ones found on Stena's vessels today, to two floored, 360-degree circular bridges. Four of the bridges developed utilized physical wing bridges while the other six took the other approach eliminating the need for physical wing bridges. The angle of the windows was also experimented with as well as the bend of the window panels.

General Layout

Another topic ideated about was the general layout of the bridge. This included ideas like modular/portable controls, having a smaller bridge, designing the bridge for only one central navigator, a worktable for the co-navigator/lookout, controls on the side of the chair, and designing for increased monitoring. Office area were explored if it should be included in the bridge layout or if it should be located in a separate location close to the bridge.

View

Ideas about how to allow the best view possible for the users of the bridge were brought up. Things from how the bridge shape should be designed and how to compensate for worsened visibility during night or bad weather, as well as how disturbing sunlight can be avoided, were discussed. Examples of ideas were cameras for complementing the view, AR to show other ships or other objects when the eye can't see them, digital AR screens, drone-style camera views, and dimmable windows.

Wing Bridge

For the wing bridge, different ideas about applications on the wings were discussed. Examples of wing bridge ideas were circular glass wing stations similar to spaceships seen in movies, rotatable control stations allowing the navigator to always have the controls in front, portable control, all glass wings, and the use of geofencing.

Night Mode

To allow the navigators to keep their night vision during dark working hours, different ideas were discussed. Examples were dimmed backlight buttons, buttons with red backlight, automatic light sensors adjusting the interior lighting to the exterior light conditions, buttons with physical feedback, only keeping the cockpit dark with a cockpit curtain, keeping the whole bridge dark, dimmable windows to block disturbing light and inverted interfaces.

Tiredness

Tiredness covers ideas about how to keep users alert during their work. Ideas include, among others, alertness monitoring with eye tracking/wristband, allowing for sitting, standing, and walking, radio/TV/games and interesting AR information pop-ups.

Physical Ergonomics

Here the goal was to make the workplace as ergonomic as possible for the users. Ideas covered having controls on the seat, again allowing for both standing and sitting, having easy-to-reach controls, having some sort of footrest, and having a walking treadmill.

Autopilot

Automation was a topic ideated to find possibilities to improve the work for the users. Examples of ideas brought up were smart engine systems that start/stop engines themselves and can adjust depending on wind or current conditions, autopilot modes (fuel efficient, fastest, stable ride, etcetera), allow the navigator to easily follow the autopilot and take over the control, AI to discuss decisions and visualization of how the Autopilot is thinking all the time.

Social Aspects

Social aspects of the bridge were discussed to improve the working environment. Here ideas like physical/digital games, allowing for small talk between the crew, monitoring sofas, and easy communication with other ships, were brought up.

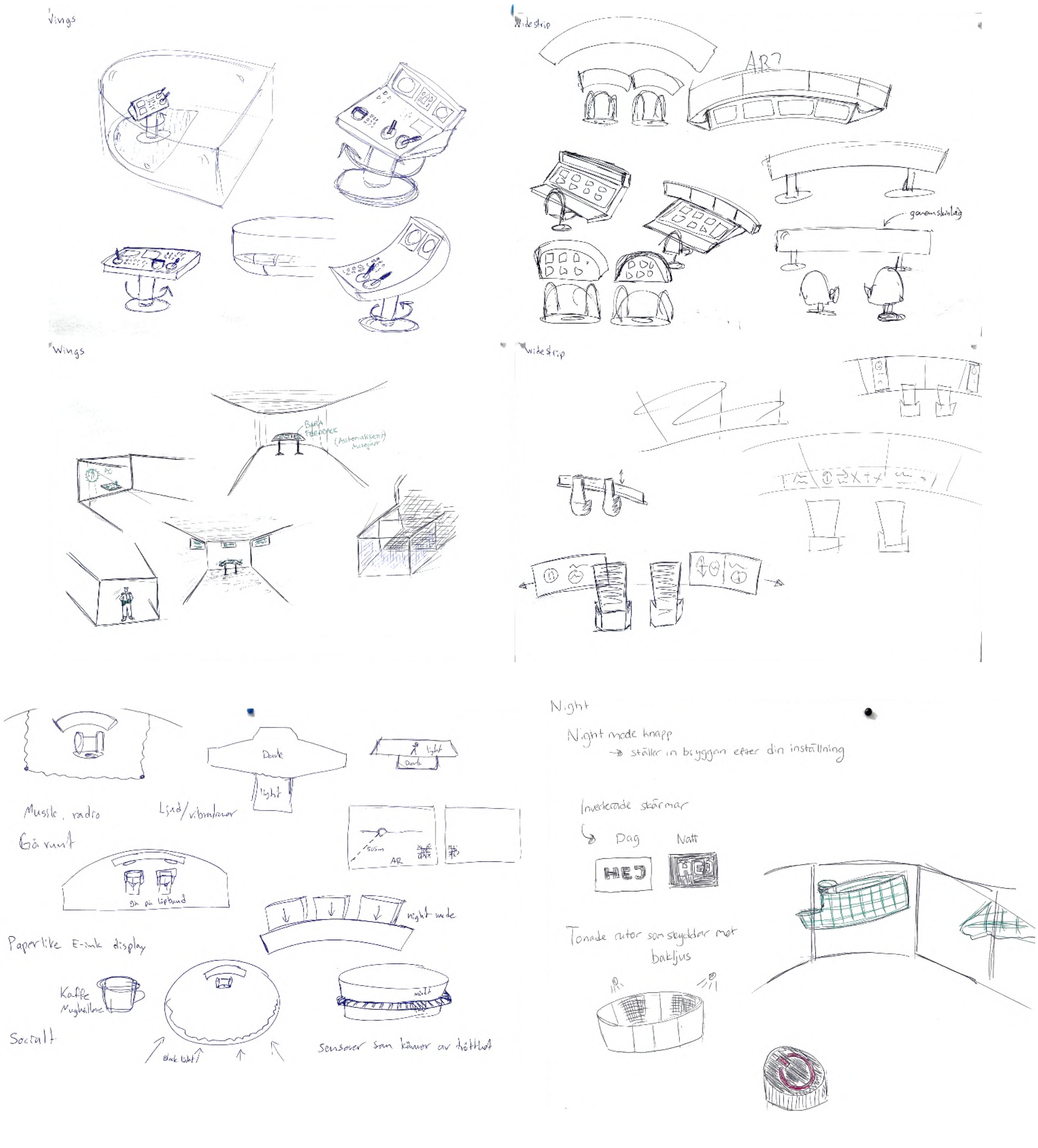
Communication

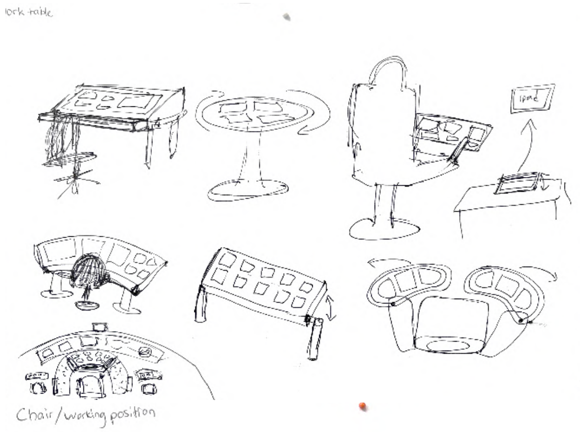
Communication was another topic that was ideated. Examples of ideas were hands-free headsets, a car phone system with speakers and microphones in the roof, smartwatch communication, one central communication device, and graphical communication with other vessels.

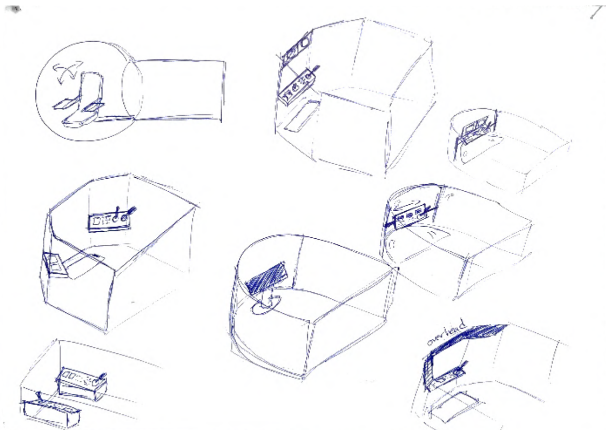
Information Gathering

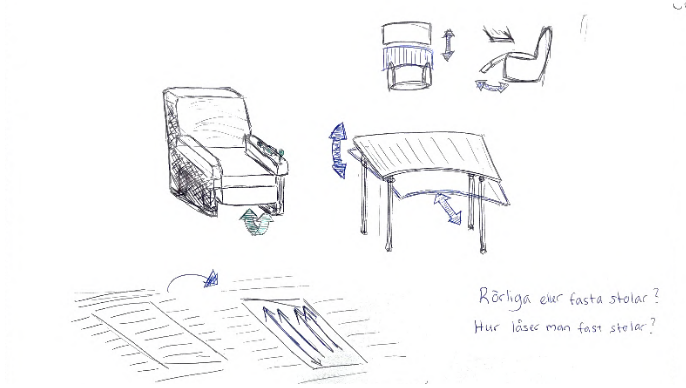
This topic covered how users should gather important information in the best way possible. Examples of ideas were window projection, heads-up display, overhead screens, screens inside window/transparent screens, retractable/extendable screens, holograms, and wristband/smartwatches.

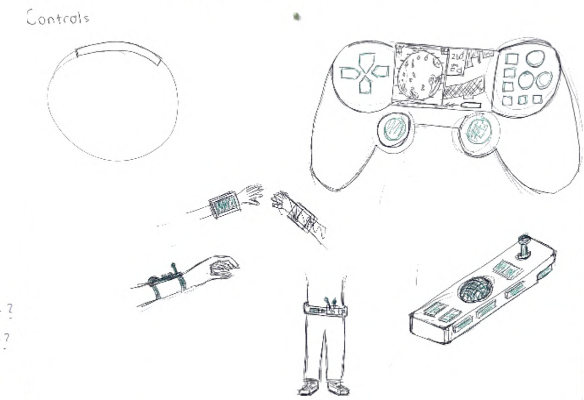
B: Sketches of Initial Ideas

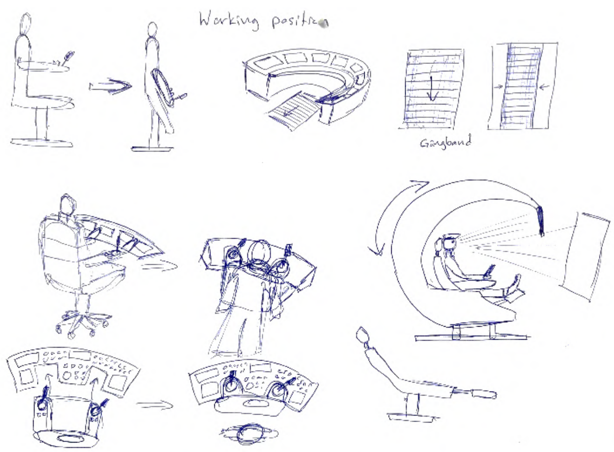


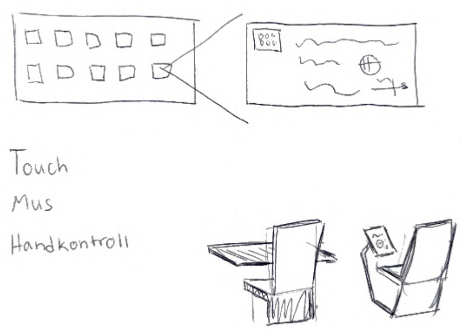

Ipad
Chair/working position


overhead


Rörliga eller fasta stolar?
Hur låser man fast stolar?


Controls


Working position
Gångband


Touch
Mus
Handkontroll

C: Idea Evaluation and Selection

Which ideas that were chosen to develop further, and which that were chosen not to develop, and why, are presented below. The division into eleven areas from the initial ideas was kept.

Shape

Three different shapes were chosen for further development including a raised-up 360-degree bridge, a small and central rounded cockpit, and a more traditional shape with wing bridges and a small protruding cockpit part with all rounded corners. The windows were decided to either have an outward leaning angle between the recommended values of 10-25 degrees (IMO, 1974), to avoid reflection from the sun but also to minimize dirt to build up on the windows, or to have an inwards leaning angle to provide a sleeker and more aerodynamic design. This was to be further explored before making a final decision.

General Layout

Portable Controls

An early idea for the steering equipment of the ship was to have portable controls. The advantages discussed were that by having a portable control the navigator could always bring the equipment wherever and in that way always be ready to steer the ship if needed. In addition, when sitting in the seat the control would still be easy to reach. However, this idea was not chosen to proceed with for two main reasons. The first one was that, in a future where automation is even further used, the steering equipment might not be as important to always have with you. The other reason was that, when having portable steering controls (not at least in a critical stressful situation), and the position of the control is not perpendicular to the ship bridge, the navigator risks losing orientation and make errors.

One Central Navigator

Another initial idea was to have only one central navigator station. All the bridges visited and seen during the project had been built with a double-seat station, but it was always only one navigator steering the ship. The intention with this idea was therefore to design a bridge that was optimized for the one navigator steering the ship, to give that person the best conditions regarding view, controls, and systems. This idea was yet not chosen to develop further. The reason was that for the visioned future, at least two crew members would still work very closely on the bridge, and by optimizing for only one navigator their collaboration risked being negatively affected, both regarding social and functional aspects.

Office Area

The administrative area was chosen to be kept on the bridge instead of having it at a separate location in close proximity to the bridge. This was in order to allow the navigators to have the ability to conduct administrative tasks while still being somewhat in the loop of what is going on at the bridge. The shapes that were chosen to be further developed also had enough space available to allow for an office area on the bridge without making it too crowded.

Wing Bridges

Whether to keep wing bridges or not was iterated back and forth with advantages and disadvantages and different user opinions. The foremost advantages with wings were that they always show reality with no delay and that it was nice to have the possibility to walk out on the wings. The disadvantages were that with wing cameras the wings lose their function and that when steering at the wing the control must manually be changed from the central station to the wing station, which can be problematic and cause errors.

Additionally, during interviews at the field studies it was understood that crew members who have operated the wingless bridge on Stena Carisma found it to be flawless with the use of cameras, allowing them to remain in a central position at all times. As mentioned above, the presence of bridge wings also poses a potential issue of having to navigate between, and transfer control between three different control stations on the bridge, leading to confusion and in some cases accidents. One recent example of an incident that occurred was when the captain wrongly believed that he had control of the ship at the port wing control station, when in fact the control was still at the central cockpit in manual mode, leading to an accident (ATSB, 2023). Furthermore, eliminating physical wings would give the bridge a more futuristic and captivating appearance, and with expected technological advancements in the next decade, it is believed that the technology will have matured enough to permit the adoption of a wingless approach, especially considering that it already worked back in 1997 on Stena Carisma.

View

Since the bridge wings were decided to be removed from the future bridge design, cameras complementing the wings' function had to be further looked into. That included cameras on the sides of the ship, to see obstacles beside the ship, cameras from above to simplify docking, but also additional cameras to get a good overview of other parts of the ship. Dimmable windows were also decided to be further developed, since it was found to have the potential to solve several problems, including sunlight, disturbing backlight, and heat. AR ideas were not chosen to proceed with. Although eye tracking technology paired with AR projection on the windows would make it possible to for example outline other ships in the near vicinity, this would only work with one person at a time since the AR projection cannot be adjusted for different people's eye positions at the same time. Therefore, the technology will likely not be mature enough to work in the way wanted only allowing for stationary AR projections or requiring the crew to use some kind of wearable equipment when being on the bridge. The other reason was that the benefits and need for AR solutions were not found to be as strong as initially thought. Since things generally move rather slowly compared to, for example, the automotive industry, the navigators were found to have plenty of time to look down at a normal screen. In total, the risk of disturbance and confusion in implementing AR seemed to be greater than the advantages of using it. However, the use of AR-enhanced camera views shown on normal physical screens was still considered an interesting alternative.

Night Mode

The idea to use backlighted buttons at night to make them visible was kept, but with the reminder that it risks affecting the navigators' night vision. Buttons with physical feedback were also kept since it potentially could simplify the usage of buttons during the night without any effect on the night vision. About whether to keep the entire bridge dark during the night or to design a place where bright light could be used, both ideas were kept. The reason was that this wanted to be further investigated and tested out in digital models, to see the advantages and disadvantages of the different solutions. Dimmable windows to block disturbing light and inverted interfaces were both chosen to be further investigated, with the reason that they could help to maintain night vision without affecting any of the navigators' tasks.

Tiredness

Initial tiredness-related ideas included using radio, TV, or games to keep the navigator alert. However, those ideas were not developed further because they were considered to risk getting too much of the navigators' attention. On the other hand, the ideas to allow for sitting, standing, and walking positions were kept. The reason was that those, unlike the others mentioned above, still allow the user to be fully focused on their task but at the same time help them to stay awake. The wristband tracking idea was also kept since it had the potential to both track and warn the navigator if they were about to fall asleep.

Physical Ergonomics

As mentioned regarding tiredness, the ideas to allow for sitting, standing, and walking positions were kept. That did not only make the navigators alert but could also improve their physical ergonomics and health. The footrest idea was also decided to be further looked into. The reason was that so many of the navigators observed in the field studies put their feet in a place where they covered important information, so a better solution for that wanted to be investigated.

Autopilot

During the early ideation, several ideas about automation feedback features and interfaces were discussed. However, since this was not the focus of the project, those ideas were not further looked into but were assumed to be more advanced in the future.

Social Aspects

As mentioned in Tiredness, ideas about games were considered to risk getting too much of the navigators' attention. That also applies to social aspects, and therefore such ideas were eliminated. However, the idea of allowing small talk between the crew members was further taken into consideration as it has social advantages while keeping the attention of the navigators. Monitoring sofas were also kept because it allowed the co-navigators to take a break and still be in the loop of what the ship is doing.

Communication

Hands-free headsets and car phone communication were ideas that were eliminated in this step since they did not seem to have any great advantages compared to the existing solutions. Also, graphical communication with other vessels was eliminated because it was not considered to be the focus of the project. Instead, the smartwatch and "one central communication" ideas were further looked into. They both seemed to have potential and be a more easy and efficient way to communicate than the existing ways.

Information Gathering

There were many initial ideas within information gathering, but several of them were eliminated in this step. Window projections were initially discussed with the advantage that certain important information could be projected onto the windows and that the navigator could thus always keep the eyes on the sea. However, that idea was eliminated because there were many other possible places to put the information, and also that the need to always keep an eye on the sea was not as critical as first thought due to the relative slow speeds at sea. The same reasoning also applied to heads-up displays and screens inside windows, which were neither further investigated. Nor the retractable/extendable screens or hologram ideas were developed. Those ideas were eliminated since they were not considered beneficially useful in the bridge design. The smartwatch idea was found to have the potential in improving information-gathering tasks for the crew members and was therefore chosen to be additionally developed.

D: Idea Refinement and Development

After the idea evaluation phase, the remaining ideas had to be further developed before incorporating them into a coherent concept. The process and design decisions that went into refining the ideas are presented below, divided up into the same ideation categories as used above.

Shape

The chosen shapes were further developed as digital models in Blender based on the physical models created in the initial ideation phase. Three different shapes were built in this step with two of them having variants of the windows, outwards and inwards leaning, as can be seen in Figure 50. The first shape had no wings but an open and spacious floor plan to allow all equipment and furniture needed without making it feel crammed. The second bridge had a smaller protruding cockpit station and rounded wing bridges, while the third shape was a two-floored bridge, with a raised 360-degree top floor, allowing for different task focuses on the different floors.

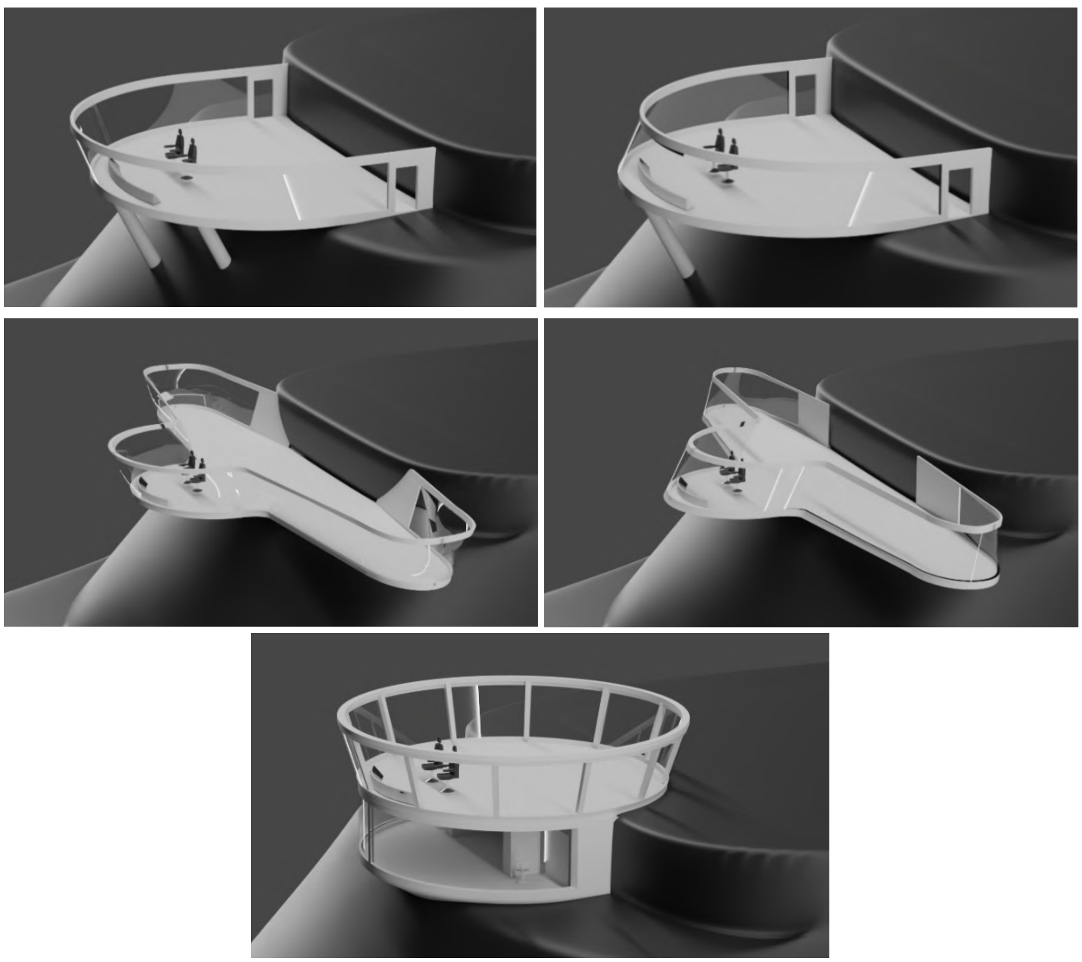


Figure 50: Evaluation of bridge shapes in Blender.

After evaluating the shapes with the help of cameras mimicking human FOV placed in the navigator seats, the first shape was chosen with the version that had outwards leaning windows. The reason why the second shape was ruled out was that it created places where the wing bridges interrupted the view from the protruding cockpit and also since it was deemed too similar to bridges visited during the field studies, with the only change being the rounded corners. The third shape was chosen not to be further developed since the new space created by dividing the bridge into two floors will likely not be needed in the future, as the amount of crew members is likely reduced as autonomous driving systems become more advanced. The top-out inclined windows were chosen to take further since they offered more advantages, like minimizing reflections and dirt build-up as well as allowing the crew to walk up close to the windows to get a good view of the bow of the ship.

Layout

The design of the new layout was done after deciding the shape of the bridge due to the very big impact the shape has on the layout. It was however decided to be based on the layout recommendations from the American Bureau of Shipping, but not being completely limited to the exact location of certain workstations (ABS, 2018).

Central Station and Chairs

The central control station was first designed as a rectangular table with two large touchscreens on each side, facing the navigator with an upwards leaning angle as seen in Figure 51. The most used controls, such as a mouse and basic autopilot equipment, were placed on the armrests on each chair while the rest of the physical controls were thought to be placed on the table in between the seats. The chairs were initially designed as generic office chairs with no special features.

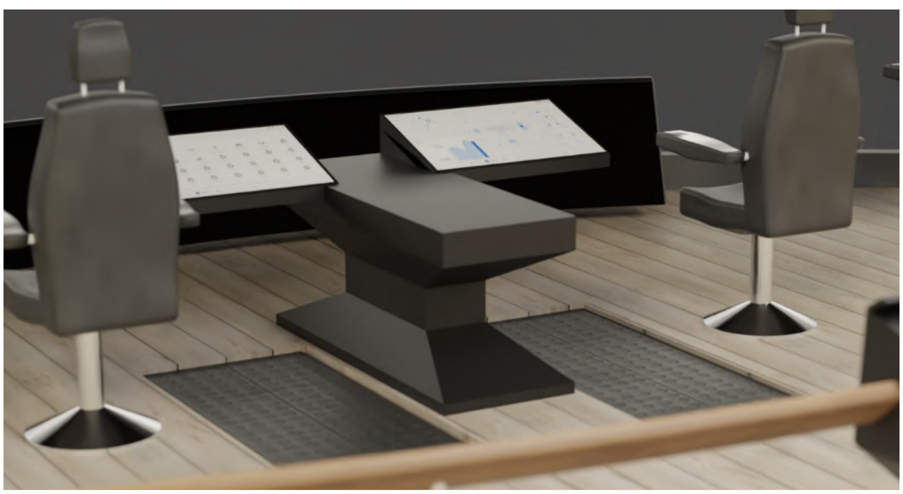


Figure 51: The initial central control table and chairs.

Touchscreens

The touchscreens were designed to utilize a card system where apps could be opened simultaneously and adjusted in size according to the user's needs or situational needs. An example of how the interface could look was developed in Figma since it would be needed to evaluate the touchscreen with users, but since the design of specific interfaces was outside the project scope the entire functionality and interactivity of the interface was not further looked into. Visual objects such as icons and colors were taken from the OpenBridge4.0 design framework to utilize available standardization and speed up the digital prototyping process (OICL, 2023).

Physical Equipment

Although the aim of the project was not to develop specific tools or interfaces some overarching ideas for the engine controls were develop. This was done since the engine controls had such a large effect on the design of the central control table and the bridge, but also because many problems with possible improvements were found during the field studies. Figure 52 shows how the engine controls and indicators were developed in Figma. The ideas were evaluated with users during the first user evaluation session and the last design labeled "Frame 10" was the most liked and therefore implemented in the final concept.

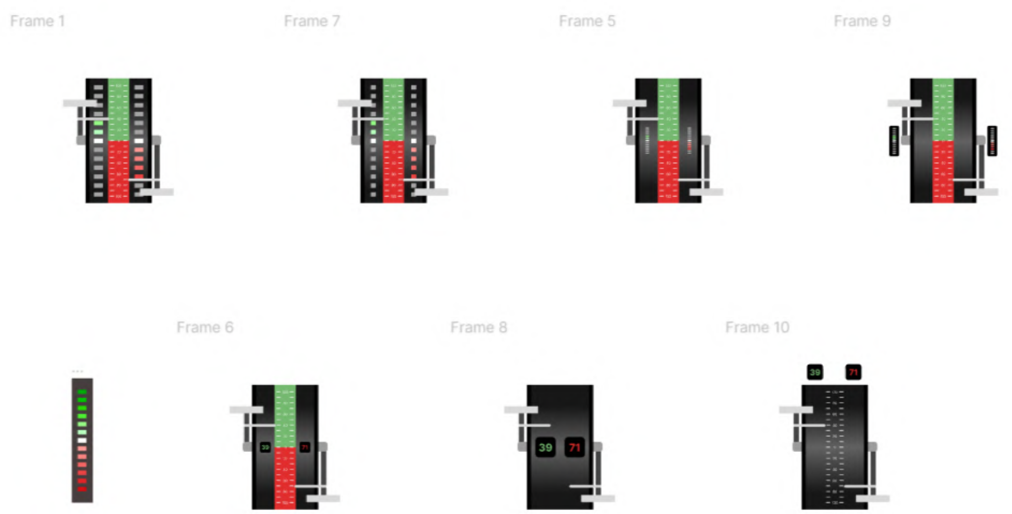


Figure 52: Engine indicator development in Figma.

Widestrip

A large bent widescreen was designed to be placed on the floor at the very front of the cockpit, seen in Figure 53. The borderless screen would allow applications such as the radar, ECDIS, and conning display to be showed anywhere on the big wide screen.

Figure 53: The first widestrip.

Smartwatch

The idea of using a smartwatch as an equipment to improve the work for crewmembers was iterated many times during the project. Initially, the smartwatch was discussed to be applied to several tasks on the bridge, including many different navigator apps. The user was thought to be able to see things like the radar, ECDIS, compass, etcetera, but also other ships' movement, cameras of the own ship, and managing alarms to mention some examples. In Figure 54, some of that ideas are shown, with the interfaces made with OpenBridge's (2023) design as a basis.

Figure 54: Initial smartwatch ideas.

E: Concept Building and Iteration

The developed ideas were combined into a coherent concept that was subsequently evaluated and iterated two times until ending up as the final concept presented in detail in chapter 7. The changes made during the evaluations and iterations are presented below.

First Iteration

The first concept that, seen in Figure 55, combined the centrally located shape with outwards angled and rounded windows stretching almost all around the bridge. At the central front part of the bridge, the control table with the two main seats could be found. The chairs were designed to slide backwards, revealing treadmills allowing for working while standing up or even walking. The two touchscreens were placed right in front of the two seats implementing the digital prototype of the card system. The widestrip was placed on the floor with the addition of an overhead display located near the ceiling. Behind the central control station, a manual steering station was placed, with two long railings offering the ability to lean on something while standing behind the navigators, creating a social area near the front of the bridge. In the back towards the port side of the bridge a break area was located, with a rounded corner couch, a table, and a small kitchen area. On the starboard side in the back a dedicated office area was placed, with one wall and one curtain that could be closed to preserve night vision, by keeping the rest of the bridge dark. Two outside areas with couches were combined with the functionality of having an outside wing station that could be used in situations when cameras would be insufficient. A smartwatch incorporating a multitude of different features was also to be worn by the crew.

Figure 55: Layout of the first bridge concept.

Second Iteration

The first bridge concept was evaluated during the field study to the bridge simulator at Chalmers. Together with those findings and the further insights gathered until this time in the process, the bridge concept was iterated. Below, the changes made in this iteration are described.

Shape

The first decision taken was to not have large bend windows on the bridge. The reason for this was to avoid light refractions that could give a misleading view and therefore be disorienting for the navigator, which was the main cause for a collision in the past (Marine Accident Investigation Branch 2017). Therefore, the shape was completely reworked for the second iteration. The small and central bridge idea was kept from the first iteration but the physical outside wings were removed. This was due to opinions from the concept evaluation. A variety of shapes were then created in a rapid prototyping session, using Blender. Figure 56 shows two different shapes evaluated in the second iteration. The shape on the right was chosen to be kept and further developed, mainly because of two reasons. The first reason was that the closer to the side windows the navigator seats are located, the better the view towards the sides of the cockpit. Secondly, a lesser amount of protrusion is needed to avoid the ship from interrupting the view when standing further back towards the sides of the cockpit, marked in red in the figure. The top-out inclination of the windows allowed the navigators to look out the windows head-on with minimal refractions. 45-degree chamfers can be seen all around the shape providing good diagonal visibility while still keeping all glass surfaces completely flat, minimizing refractions.

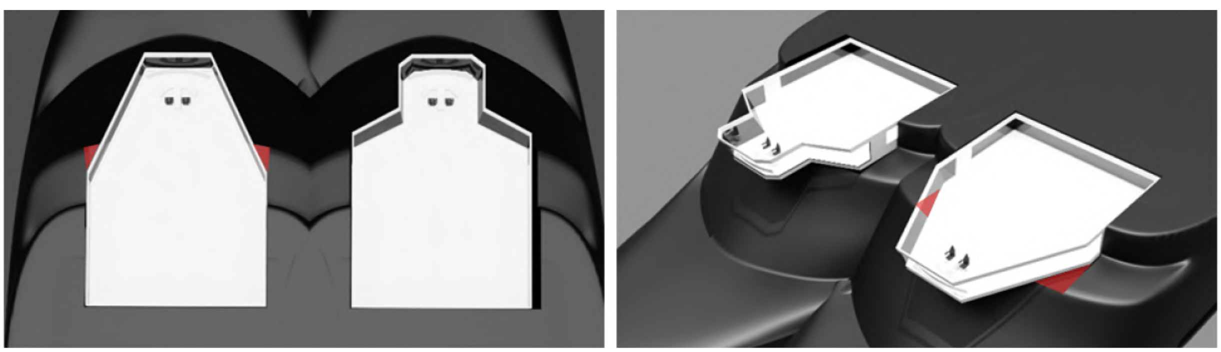


Figure 56: Two bridge shapes evaluated for the second iteration of the final concept.

Another advantage of the chosen shape was that it minimizes the angles in which poles between individual window panels would interrupt the view. The diagonal windows were angled perfectly to align with the central navigator positions, which reduced the obstruction of the view due to window poles. Figure 57 shows the bridge vision side by side with another shape, similar to the shape in the first concept, and their respective uninterrupted viewing angles. Looking at the images it is clear that side visibility becomes largely affected by the long bend, since the window poles appear much closer together towards the sides from the navigator's point of view. Taking this into account a protruding cockpit was chosen to be further developed into a complete concept to provide the best possible forward and side visibility.

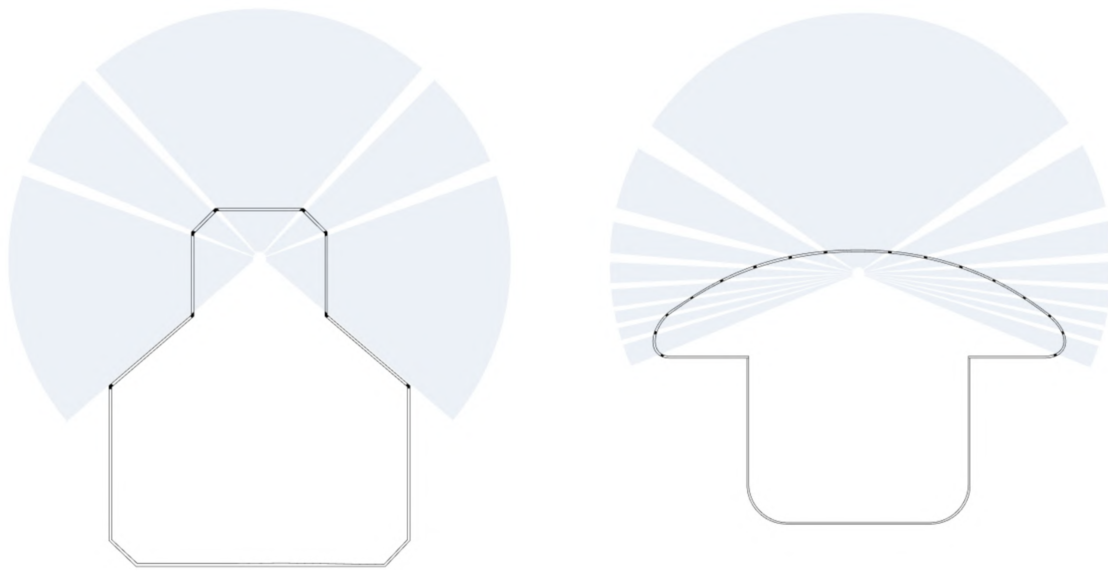


Figure 57: Illustration of how different shapes and window placements affect visibility.

Layout

The layout in the second iteration remained mostly the same with the main difference being the removal of the enclosed office that was replaced with a simpler office desk centrally located behind the manual steering station. This was done since the permanent office would interrupt the close to a 360-degree view of the horizon that the bridge could otherwise achieve. The railings on the manual steering station were also significantly shortened to better fit in the new narrow cockpit part. The second iteration of the layout can be seen in Figure 58.

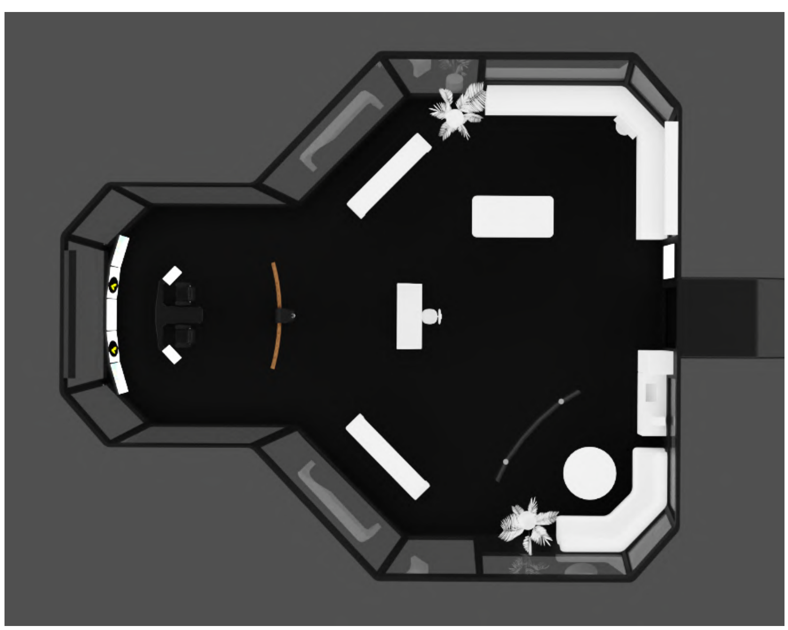


Figure 58: The second iteration of the layout.

Touchscreens

The evaluation showed that the users seemed to like the touchscreen and thought it could be useful. However, one user meant that because the display was placed in the center of the navigator's view, it felt like the most important equipment in the cockpit. Since the displays include primarily supportive- rather than vital information, they were not the most important equipment and were therefore decided to be moved to the side of the navigator. They were instead placed on the outside of the navigator's seat not to cover the view of the widestrip. In Figure 59, the two different placements are shown.

Figure 59: The changes made on the touchscreens, with the before-image to the left and the after-image to the right.

Widestrip

The widestrip was reworked into utilizing flat display surfaces instead of curved surfaces to avoid light reflections. The new widestrip instead consists of 5 individual displays oriented in the same widescreen arrangements with minimal bezels in between. This also creates a more redundant system since if one display would break the rest of the displays can still be used, instead of relying on a large singular display.

Smartwatch

After discussing the smartwatch ideas with users, many of the applications that previously were presented on the smartwatch were eliminated. The reason was that the use of the smartwatch was not found to be needed in such tasks. The users meant that they would never use the smartwatch to, for example, look at the radar, when they had a much bigger radar on the screen in front of them. Another drawback with the smartwatch was that the interface was so small that the information shown either would not be seen or would have to be so few it became useless. However, the users still liked the idea of the smartwatch and thought two applications could be useful, namely communication and alert system, see Figure 60. The communication system would include both internal and external communication as well as passenger messages. In that way, no matter where on the bridge the crew were, they always had all communication accessible in one place. The alert system would help the navigators to stay alert and not fall asleep. By tracking, for example, heart rate and movement, the watch could analyze and warn navigators that were about to fall asleep.

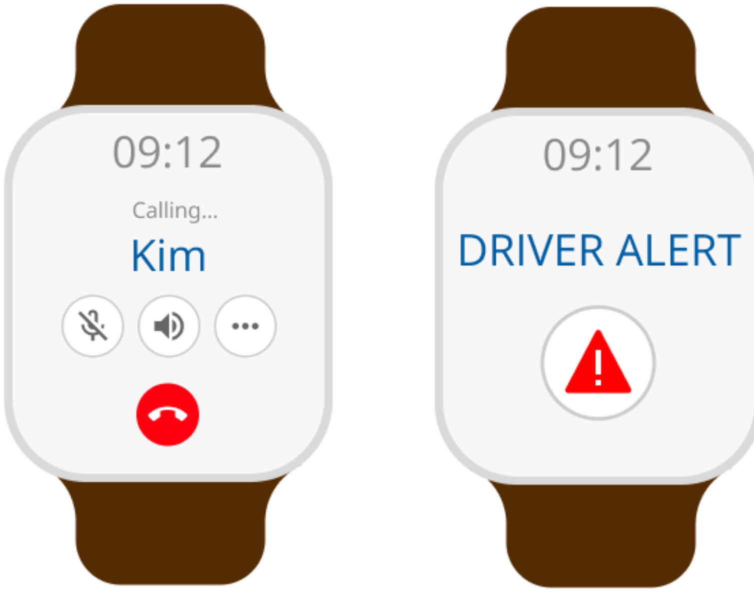


Figure 60: Illustration of the redesigned smartwatch functionalities.

Third Iteration

The second iteration was evaluated during the user evaluation. The changes done for the third and final iteration of the final concept are presented below.

Shape

The shape of the bridge was overwhelmingly appreciated. The only changes made were the positioning and size of several windows that were iterated during a VR evaluation session to further improve backward visibility and the results of the changes, seen in Figure 61 and Figure 62.

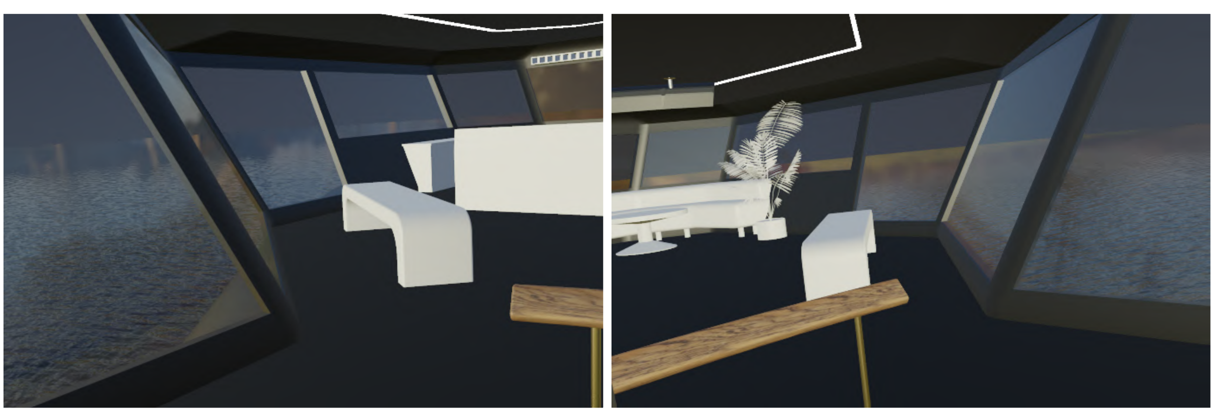


Figure 61: Backwards visibility before the changes.

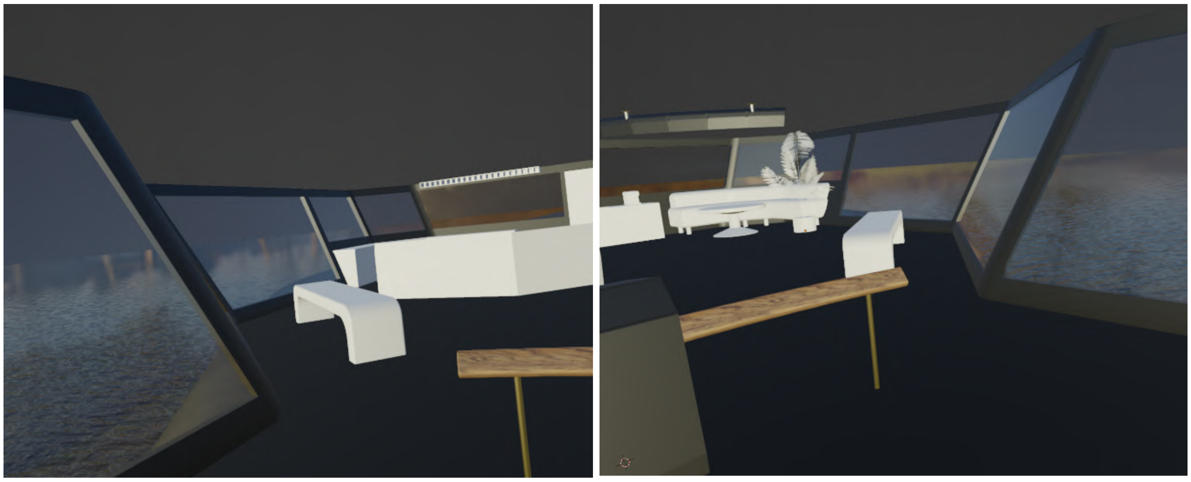


Figure 62: Backwards visibility after the changes.

Layout

During the concept evaluation phase, one common criticism was the rather large distance between the navigator seats and the Widestrip where the Radar, ECDIS, and conning can be found. During a VR evaluation session, this issue was also examined and the entire front of the cockpit including the Widestrip was moved closer to the central station. The distance from the user to the displays, therefore, shrunk from 2.8 meters to 2.2 meters. During the same VR evaluation session, the touchscreens were found to obstruct the view of the ECDIS display when sitting down. The screens were adjusted accordingly. The changes can be seen in Figure 63.

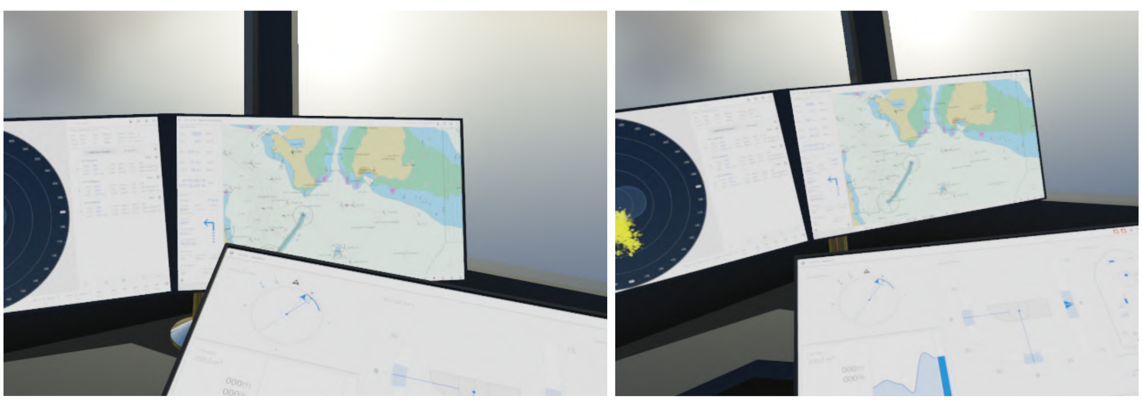


Figure 63: Before and after the rearranged touchscreen location shown in VR.

Other criticisms that surfaced during the concept evaluation were the limited desk space available on the bridge vision, due to the rather small computer desk, as well as the very limited wall surface area available. A rearrangement of the layout resulted in a bigger L-shaped administrative area with curtains that could be extended during the night. The back of the L-shaped desk also functioned as an area where signs and other wall-mounted objects could be placed. The changes done to the layout can be seen in Figure 64. The large open collaboration table was also moved to a central position in the middle of the bridge.

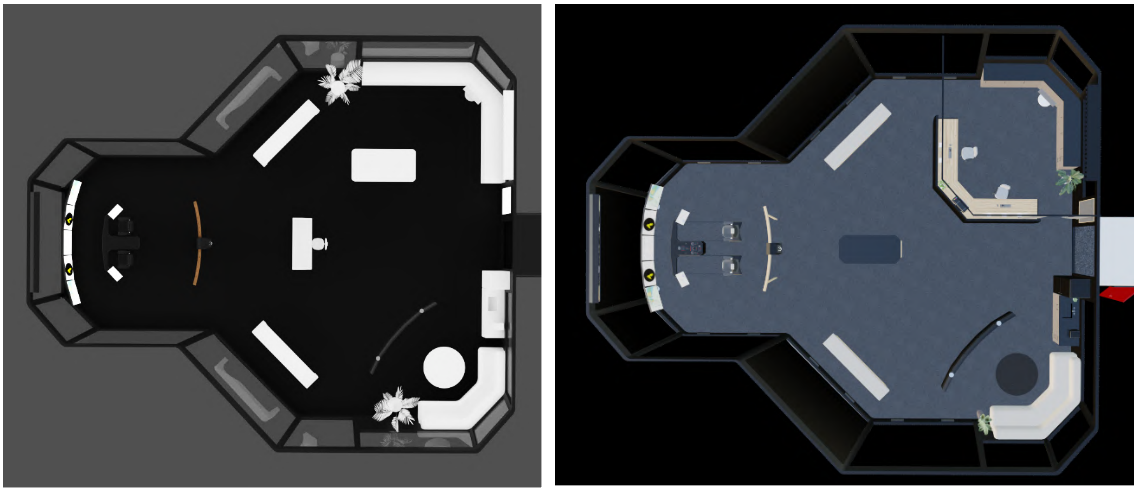


Figure 64: The layout before and after the changes to the third iteration.

Other parts of the bridge vision were mostly appreciated by the users during the evaluations and were kept as they were, including the seats, overhead display, central control table, break area, monitoring display, overall shape, and windows.

Aesthetics

The mood boards (see Appendix F) were also evaluated for the third iteration. The results were unfortunately too spread out to give a clear design direction, however, mood boards 2, 6, and 7 were deemed as the ones less suitable for a bridge environment. Instead, design directions from ABS (2018) in combination with discussions during the evaluation were taken into consideration when choosing the colors and materials for the third iteration.

F: Mood Boards

The seven different mood boards used during the concept evaluations are presented below. All images used in the mood boards were found on Unsplash (https://www.unsplash.com).

Mood Board 1:

Mood Board 2:

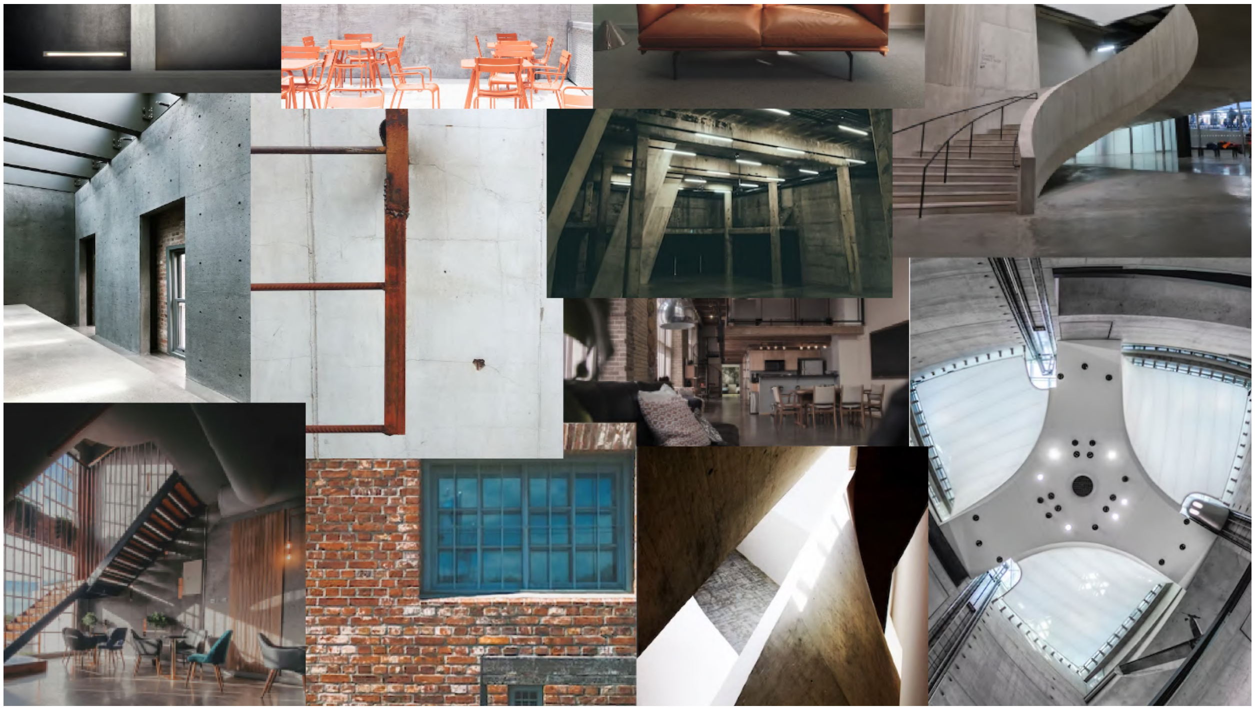
Mood Board 3:

Mood Board 4:

Mood Board 5:

Mood Board 6:

Mood Board 7:



G: KJ-Analysis

H: Interview Template

Below is the interview template used for interviews conducted during the field studies translated into English and divided up into different question areas.

Today's Bridge:
What's missing from today's command bridge?
Do you think the job on board contains too much sedentary or too much movement?
Is there anything on the bridge/in the context that you couldn't have done without?
What is the worst/biggest problem with today's bridge?
Is it easy/difficult to understand the size of the ship and what is around in, for example, narrow passages or ports?
Are there problems at night that are not in the daytime when it is light? On the contrary?
Layout:
Why is the shape of the command bridge the way it is today, do you think it is an optimal shape?
Would you prefer to have all instruments and buttons centered around a static working position or would you rather the bridge be more open and spread out?
If the work on the bridge had shifted to only observing the surroundings and systems to a greater degree, would there have been needs/wishes on the bridge as a workplace that may not exist today?
Automation:
Do you think automation on ships will increase? If so, how? Where is help/relief needed?
Will the work of the crew change? Is additional competence required?
If the ship had managed to drive itself to a higher degree than today, what response would you most have liked from the system to feel safe?
Communication:
How does communication with other vessels work? Is there anything that could work better?
How do you understand other ships' intentions/planned routes? Is it easy or difficult?
How does internal communication work? Are there times when internal communication on the bridge is lacking?
Future:
Screens and digital technology vs physical buttons/products?
Reality vs digital feedback?
Do you think that the wings with duplicates of the control systems will be necessary in the future, or would it have been possible to replace them with some other solution?
If all the windows were covered so that there was no visibility out, what tools would have been needed to still be able to drive the boat?
What do you think the bridge of the future will look like?
What kind of aids/technology would you have liked to be helpful?
What does your dream command bridge look like? Think freely, now, or far into the future.
Assuming that the ship could almost entirely run itself, what would you rather have spent the extra "free" time doing?
How do you view information projected onto windows? Can it be useful or is it unnecessary? Why?
How do you feel about wearing VR/AR glasses on the bridge to be able to see certain information? If so, what kind of information? Or would it have been unnecessary?
How do you look at a mobile controller that you can walk around with, think game controller.

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