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Period:	01.02.2013 - 22.5.2013
Group:	MA4-ID10
Supervisor:	Christian Tollestrup
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Appendix:	Digital
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ABSTRACT

Maritime transportation is the underlying force of today's global economy. It makes international trading possible, moves raw materials across the globe and does so in a way only shipping can – in extreme volumes and efficiency. But as the vessels are getting larger and the amount of cargo is growing, one could think that the crews also grow in size, but this is how ever not the case.
Skilled mariners are expensive and hard to come by, so automated systems are implemented to a great extent to take on duties that were unthinkable a decade ago. A high level of automation helps to cut cost and fuel consumption, but it is not without its challenges.
With a growing amount of electronics on board, the man-machine interaction is critical and most of the equipment on modern vessels is, to a large extent, designed for the machine rather than the human. This imposes a high risk of errors that can potentially lead to severe accidents and even disasters at sea.

The goal of this master thesis is to explore how to improve interaction between man and machine in critical manoeuvre situations at sea – a high-risk situation that is prone to mistakes if the interface is not designed with the user in mind.

The result of the project is a concept for a new control system that is to be located on both side of the ships control room (bridge). The system allows the user to intuitively do advanced manoeuvring, while having a high degree of attention to the overall state of the ship and outside surroundings.

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RENÉ WELLEJUS

SPECIAL THANKS TO...

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PREFACE

This report describes the process of a master project at Industrial Design at Aalborg University. The project is titled Motion Control System and documentation consists of a product report and a process report with corresponding digital appendix. References are stored on the USB-stick that accompanies the process report.

All sources are listed by the Harvard method.

READING GUIDE

Throughout this report the design team have focused a lot on how to communicate correctly to a first-time reader, which is why the report in divided into chapters that consist of several sections. Each chapter begins with an intro to tell the reader what to expect when reading. In each section an output box is made to highlight what decisions are made, or why the progress is moving in that given direction. Each chapter ends with a summary, which transforms all the section outputs into bullets. If the reader is in a hurry, the summary of each chapter should be the top priority – reading the summaries in one row will give the overall understanding of the project and the product development.

OVERALL SCOPE

The industry is new to the design team and because of that issue the project is full of challenges. The economical- and business parts are very diffuse and not at all accessible to gain information from any manufacturer because of the confidentiality. This means that throughout this project there will be a minimum of attention on the economical issues, such as implementation plans or straight business models.
But the most essential field in focus for this project, and what the design team focused on, was user-centred design. The opportunity to achieve more knowledge through a methodical approach when doing a research- and ideation phase, was something that attracted and affected the teams decision to choose this project as their master thesis.
The project objective is therefore to gain experience within a new industry, discover difficulties, frame the problem and then design a user-centred solution.

CHAPTER 1. INITIAL RESEARCH AND FRAMING

CHAPTER 2. USER NEEDS

CHAPTER 3. IDEATION

CHAPTER 4. CONCEPT REFINEMENT

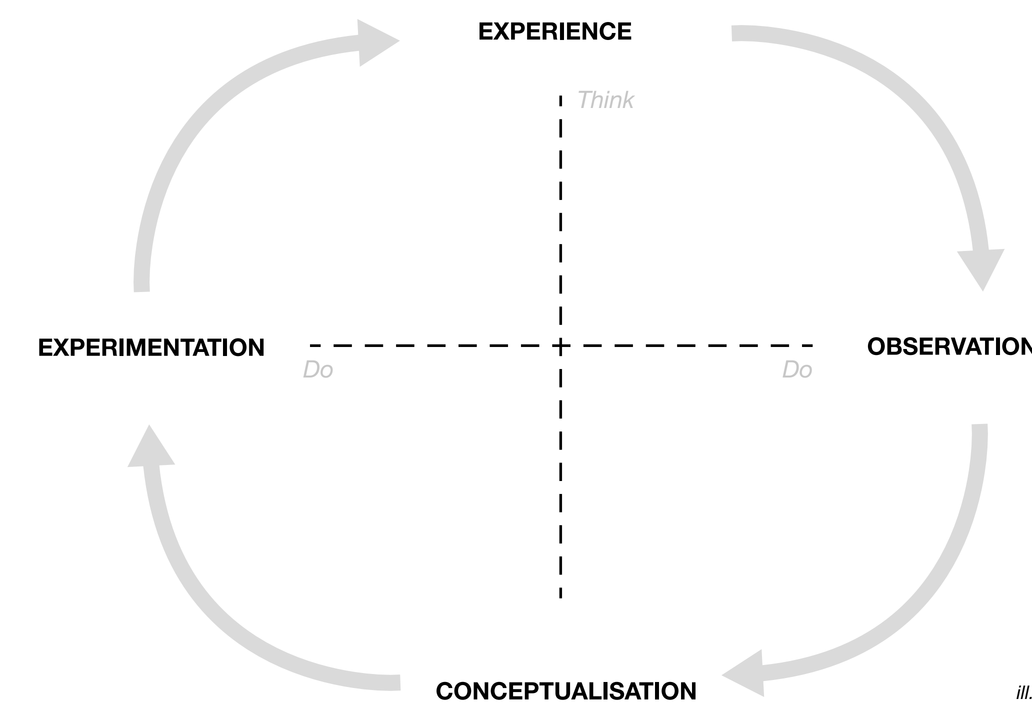
CHAPTER 5. DETAILING

CHAPTER 6. EVALUATION

CHAPTER 7. ILLUSTRATIONS AND REFERENCES

PROCESS STRUCTURE

The process has been dominated by a hands-on and experimental approach to both research and design phase. The most valuable knowledge and ideas was generated based on field research or by building models that allowed the team to act out situations on their own.



ill.1-5

CHAPTER 1.

INITIAL RESEARCH AND FRAMING

To get the project started, initial research was done to create a base for the further development of the future product. The topics covered in this chapter are mainly about the maritime industry and the context that the product should be designed to.

The maritime industry was quite unfamiliar to the design team, which was why many topics have been researched throughout the entire project period. In this chapter some topics will be described in form of a presentation of the context, product, stakeholders and of course the maritime industry in general. Lastly the output from these sections will be summed up in an initial framing, explaining the design team's initial approach to the project.

CONTEXT PRESENTATION

Every large vessel has a main control room called the bridge, which is where the Captain, Navigator or Officer controls and commands the vessel. Most bridges have a standard layout consisting of a center bridge, portside bridge wing and starboard bridge wing. Western shipyards have created a standard for the location and layout of instruments on the center bridge, but there are still great variations from one vessel to another.

The crew can control and manoeuvre the vessel from the center bridge or any of the two bridge wing panels, but they are typically used for specific scenarios. Harbour manoeuvring is mostly done at the wing panels where the view is better, but when cruising at the open sea, the center bridge offers greater comfort and higher level of instrumentation.
When the vessel is departing or arriving to a dock the Captain will manoeuvre the vessel from the bridge wing. When the ship has moved to open water he would then take control to the center bridge and then activate speed-pilot and other automations. The work-pressure and concentration level are therefore always higher in manoeuvring- and harbour situations rather than situations on open water. Automation is a big part of a modern bridge and many systems are in place to assist the crew, but due to the complexity and risk involved humans, is still very much a key actor in industry.

In shipping, time is money, and time plays a major part in the industry. If a vessel can travel faster to a given destination the more money is earned. Conflicting to this statement is the price on fuel and the vessel engine efficiency. Fuel has become very expensive, resulting in a reduced speed of many vessels compared to the time, where crude oil was not the primary concern. The captain must therefore balance between time and fuel consumption by traveling at the most efficient speed for as long as possible.

PROPULSION AND MANEOUVRE OF LARGE VESSELS

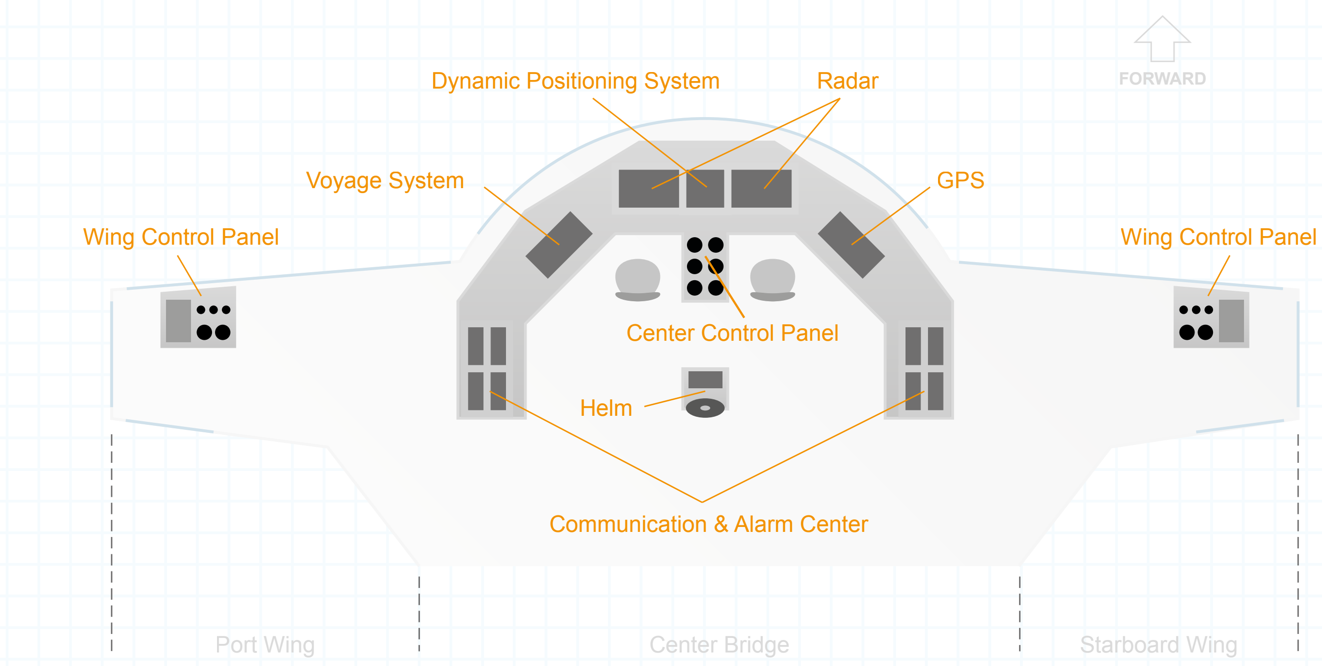
The following steering- and propulsion units are all controlled from the bridge and are what regulates movement of the ship.

Main Propeller: Can have fixed-pitch (FPP) or controllable-pitch (CPP) and is what drives the ship forward. Most large vessels have two propellers making it possible to use these to be used in both manoeuvre- and open sea situations.

Rudder: Is found on all large vessels with FPP and CPP propellers. Used for steering the direction of the ship. Every propeller is accompanied by a rudder.

Stern Thruster: Located on the back of the ship, these small propellers are used to push the stern to port- or starboard side. Stern thrusters are uncommon on medium to large vessels where two sets of main propellers and rudders enables the same manoeuvre capabilities.

Bow Thruster: Located on the front of the ship, these small propellers are used to push the bow to port- or starboard side. Two to three bow thrusters are normally used on large vessels.



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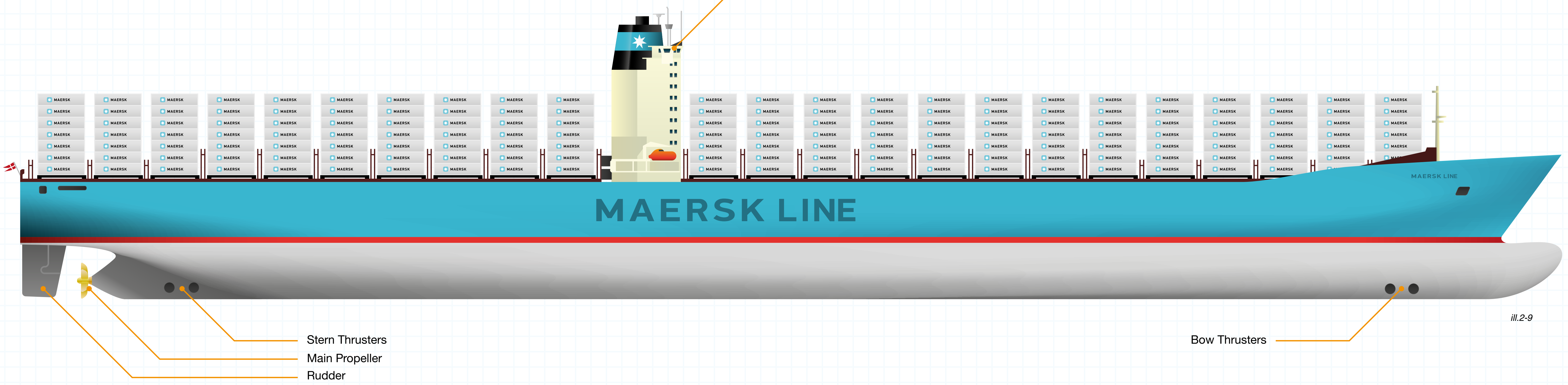


ill.2-9

img.1-10

img.2-10

img.3-10

img.4-10

STAKEHOLDER PRESENTATION

Designing a new product for the shipping industry will affect a range of stakeholders, which influences each other in one way or another. All the stakeholders have been mapped and can be seen on appendix A.

The primary stakeholders chosen for this project are listed below.

1. CREW ON THE BRIDGE

- Captain
- Master (Superintendent)
- Chief Officer
- Navigator

This group include the main users and a clear understanding of these is of high importance to the success of the design. Value provided to this group will reflect out to many other stakeholders. The primary focus for these stakeholders is estimated to be ease of use and reliability.

2. FIRST SHIP OWNER

This stakeholder will be the one paying for the product and also the one with the final say about what systems a new vessel should be build with. Primary focus for this stakeholder is estimated to be cost of operation and safety.

3. KNOWLEDGE INSTITUTIONS

- Danish Maritime schools
- MARTEC (Maritime Training & Education Center)

To ensure the success of the product, the team must understand how maritime schools educate in new systems. The potential challenges in educating for correct use must therefore be covered in the project. The primary focus for these stakeholders is estimated to be ease of use and future potential.

4. SHIPYARDS AND NAVAL ARCHITECTS

The product developed in this project will only be a small part of what can be described as the biggest products in the world, large maritime vessels. When designing and constructing these giants, a wide range of instruments and technical solutions have to be selected and installed. To be among the selected products, the design must take the selection process into account and understand what parameters are important for the initial build.
The primary focus for these stakeholders is estimated to be on a range of product features, freedom in location and visual appeal.

PRODUCT PRESENTATION

Every large vessel has a propulsion control system (PCS), which is the instrument that controls the forward and backward movement, by regulating the propellers pitch and engines rpm. The system is controlled from the bridge by a control unit panel (See img.5-12), which is found at four locations: the center bridge, one at each bridge wing and one in the engine room. The product is mainly designed for the center bridge and is primarily handled by the Captain or the Chief Officer/Navigator.

If any system failures or mistakes should happen the Captain can still control the ship by communicating with the Ship Engineer who then use the system in the engine room. This is done through a back-up system that surpasses the main electronic system called a machine-telegraph.

The PCS panel seen below, Alphatronic 3000, is manufactured by MAN Turbo & Diesel and is set to launch the market in fall of 2013.
The PCS enables the Captain to control the speed of the vessel by pulling the governor's lever at the center panel. Doing this tells the computer controller to regulate the pitch of the propellers and engine rpm to meet the Captains command in the most efficient way. Rudder and thrusters are also used for controlling the speed and direction of the ship, but they are not included in this interface.
The product of this project will be developed on the basis of MAN's PCS panel, and will aim to implement a thruster interface for added manoeuvre capabilities.

img.1-12

PRODUCT HISTORY

Here it can be seen how the interface design of the most recent MAN Diesel & Turbo PCS's have evolved over time. An overall analysis have been made to map out functionality and system architecture of the latest released product, the Alphatronic 2000.

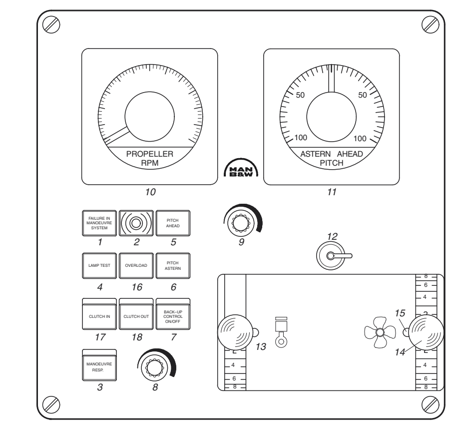
The Alphatronic 3000 is still in development and the design team have therefore not been able to go into details with the product.

ALPHATRONIC 2A

- Manoeuvre panel
- Control Unit
- Actuator for adjustment of engine speed governor
- Actuator for adjustment of propeller pitch

[MAN Diesel & Turbo, Alphatronic IIA, 2001]

1982



img.1-13

ALPHATRONIC 2000

- Quick system response and efficient propeller manoeuvrability
- Minimal service and maintenance requirements.
- User-friendly operator functions due to logic and ergonomic design of control panels.
- Redundant propulsion solutions using a combined shaft motor.
- Interface to dynamic positioning and joystick system.

[MAN Diesel & Turbo, Alphatronic 2000 PCS, 2000]

2000

img.2-13

ALPHATRONIC 3000

- Optimized thrust control and a speed pilot
- Efficient vessel manoeuvrability
- Three levels of propulsion control
- Panel design and functionality in form of modular concept to fit any ship's layouts.
- Configurable touch screen shows a wide range of functions.
- Can be installed with both engine types (two-or four-stroke).

[AMN Diesel & Turbo, Alphatronic 3000 PCS, 2012]

2013

img.3-13

COMPETING PRODUCTS

While researching for competing products for the Alphatronic 3000 it became evident that many products in this particular category are very similar. The styling and layout vary but the functionality is close to identical.
While researching for information about the products it was found that product B, C and D are all designed by the same Norwegian design agency called Hareide Design. This fact alone indicates that the industry is quite uniform and characterized by a “me-too” approach, making the rate of innovation slow.

Due to a high degree of confidentiality, it has not been possible to gain access to technical details, prices or other specifications about the competing products. The following list of features are therefore generated by analysing photos and reading sales texts from the manufacturers:

A. Wärtsilä Lipstronic 7000 CPP
[www.wartsila.com]
- Electric shaft system
- Remote start/stop of engines
- Speed pilot
- Build primarily for large vessels

B. Kongsberg KMMS AutoChief C20
[www.km.kongsberg.com]
- High-end and expensive solution
- Capable of controlling two- and four stroke engines
- Electric shaft system
- 2000-3000 units of the AutoChief series have been delivered

C. Rolls-Royce Helicon-X3
[www.rolls-royce.com]
- Dual system for redundancy build into the main lever
- Build for seated operation with accompanied screen
- Can interact seamlessly with dynamic positioning systems
- Push-buttons for all critical functions

D. Berg Propulsion BRC800
[www.bergpropulsion.com]
- All electronics are duplicated for maximum redundancy
- Daylight readable display
- Electric shaft system
- Settings and service data accessible directly on display
- Compatible with Berg Thruster controller (separate)

OUTPUT

- The design and functionality in this product type are very similar across competitors.
- All designs have a link to the traditional appearance of governor lever that regulates the speed of the vessel.
- Redundancy is mostly done by duplicating electronics, making the interface for normal and back-up mode the same.

B Kongsberg KMMS AutoChief C20

img.1-15


img.2-15

C Rolls-Royce Helicon-X3

img.1-14

A Wärtsilä Lipstronic 7000 CPP


img.3-15

D Berg Propulsion BRC800

MARITIME INDUSTRY

Travel, transportation and exploration by sea are an essential part of the history of civilisation. Scandinavians, Greeks, Chinese, Portuguese and many others were deeply dependent on the sea for trade, fishing and exploration of the world. Man's desire to explore and understand the world and, the knowledge to do so by sea have had a paramount effect on the progress and success of our species.

Today, shipping is something that many consumers take for granted, but it is nonetheless still a very important industry that interweaves markets and blurs boundaries like no other.
[IMO, 2012]

This section will give a brief look into the needs and future demands of shipping as an industry and business – later chapters will look into the specific user needs.

THE COMMERCIAL SHIPPING INDUSTRY

The shipping industry is vital for global trading and economy, accounting for approximately 90 per cent of all traded goods. Modern vessels carry a great variety of cargo ranging from raw materials like oil and gas to people, cars and food. In fact, the majority of products in the developed world have been at sea at some point of its lifetime – as a finished product or as raw materials waiting to be processed. The global fleet of merchant vessels, excluding passenger carriers and special-purpose vessels, is registered in over 150 countries and operates by more than one million crew-members of all nationalities.
[Deloitte, 2011]

Today international trade have made it almost impossible for any country to be self-sufficient. Every nation is dependent on each others export and import of what it produce, but also for what it lacks. The global economy has made it hard for a modern society to rely on domestic resources alone.
[p7, IMO, 2012]

Global economy and shipping are therefore highly interconnected and very dependent on each other, making shipping quite sensitive to a fall in global consumer demands. An example of this sensitivity was seen in the economic crisis of 2009 that lead to a drop in global shipping by almost 5 per cent. This does not sound as much at first, but since a large part of commercial shipping is covered by shipping of fundamental resources like coal and oil, one can only imagine how hard trade-vessels were hit.
The economy is on the other hand even more depended on shipping, and as the cost of fuel inclines, the cost of shipping does too. Increased costs results in constrains on global trading, therefore there has been a big demand to develop new technologies to solve the problem. These new technologies have pushed modern shipping into an era of merchant vessels that never before have been so immense, advanced and safe.
[p8, IMO, 2012]

But with increasing pressure to make new vessels bigger and more advanced, new problems arises. According to an in-depth report by Deloitte (the worlds second largest professional consulting firm), human resources are the new limitation on shipping and have been so since 2005. The 23 major international shipping companies, holding a total fleet of 1.125 vessels, were analysed and the lack of skilled crew were found to be the most dominant limitation for future growth in the industry.
Today officers make up for 35-40 per cent of the crew, indicating the high level of expertise needed to operate a modern vessel. The days where anybody could be taken on board a ship and learn the skills of a seafarer by a hands-on approach is more or less gone. A thorough education is needed for most jobs on board, making it difficult to man the growing number of highly advanced vessels leaving shipyards all over the world. The problem is especially profound in industries with a high demand for operation in complex situations and the raising payroll for the officers on these vessels also reflect just how valuable they are to the industry.
[p4, p10, Deloitte, 2011]

Another interesting perspective that can be drawn from the 2011 report is the fact that even though commercial vessels are growing in tonnage, the number of crew-members has been static or even declined in many cases. This is natural as more automation is introduced and good officers are harder to come by, but also represent a great weakness of modern shipping.
Even with simple automated tasks, crew-members will always be responsible for actions made and in emergency situations where automation fails or proves inadequate. The crew must be able to take command in a safe and controlled manner even in situations where only the most basic mechanical functions are functional. There is no doubt that automation have made travel by sea much safer, but with less people on board giant vessels, scaling emergency situations can also develop faster and with higher consequence than ever before. A further elaboration of this phenomenon will be presented later in this report.
[Lützhöft, 2002]

NAVY VESSELS

As learned during fieldtrip 2.0 (See p40) navy vessels are different from commercial vessels in many ways. Even though most features like propulsion control, engines, instruments etc. have great resemblance; the emerging problem of human resources is not present in a navy context.
On a navy vessel, crew are much more abundant than on commercial vessels. Because a navy vessel must be able to be fully manned for long periods of time with full battle-capability, a large crew is available at all times. These vessels are also designed and manned to take severe hits without loosing control and is therefore much less dependent on automation. As discovered on a later visit to Naval Base Frederikshavn the navy has a close to one-man-per-function approach that a commercial vessel could never afford.
The navy does in other words make up for less automation by having a much larger crew of competent mid-level crew that can assist officers. This is possible because economy is of an issue than it is in a commercial context.

The primary concern for this particular context is to do commands as fast and effective as possible and this must also be taken into account in a new product. The same is however also true for modern commercial vessels, and the design team have therefore chosen to focus on these as the primary context for the future product.

LIMITATIONS

As discovered during the initial research the shipping industry is quite difficult to work with in terms of access to information about instruments. A list of where these limitations occur and how they a4

img.1-16,17

ACCIDENTS AT SEA

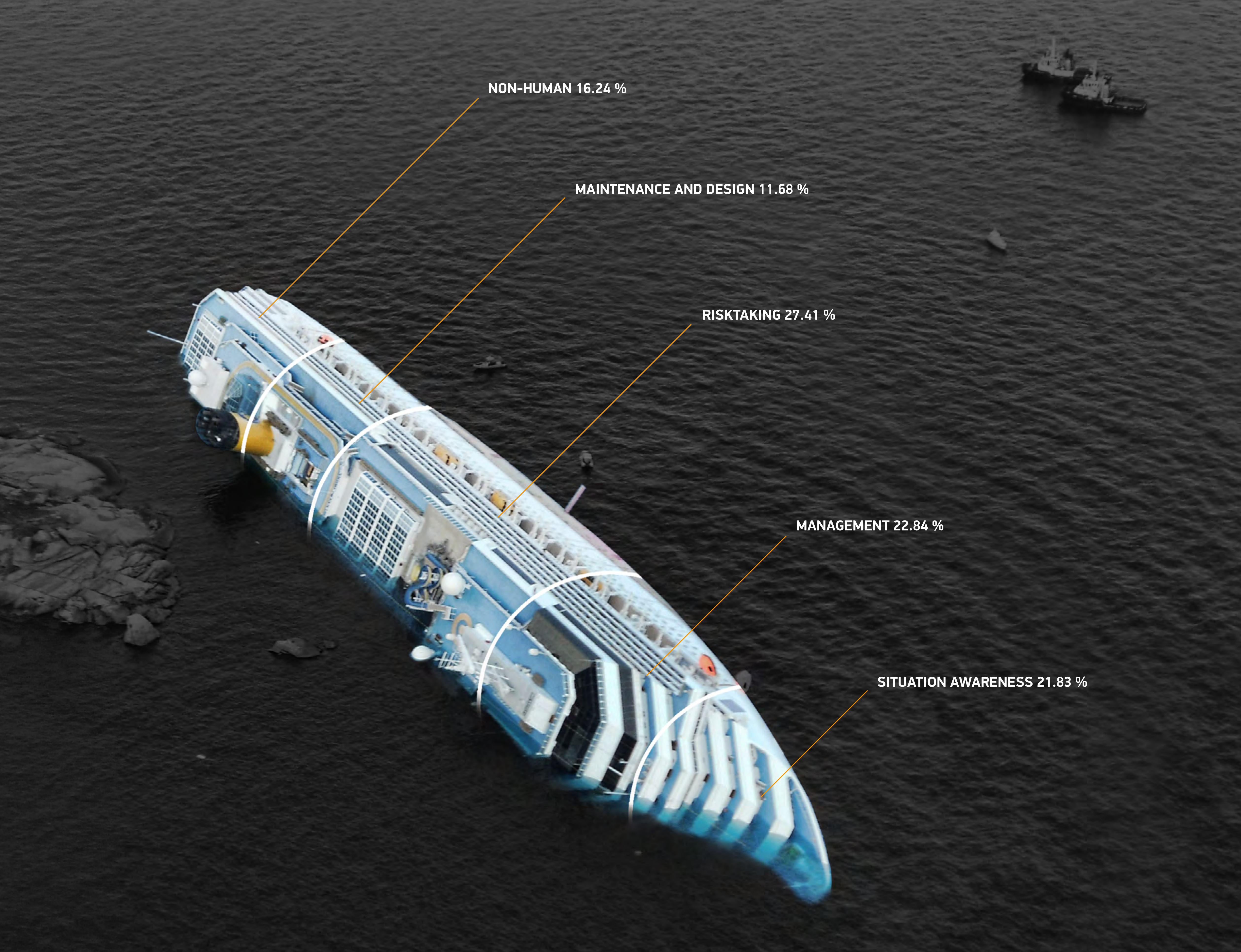
Due to the high value of the vessels, cargo and people on board, maritime accidents involving large vessels can have exceptionally high consequences. Even though modern vessels are designed to resist a certain amount of stress in emergency situations, nothing can protect it if the crew makes wrong decisions or reacts incorrectly according to procedure. This section will give a brief insight to the statistics of accident-generators in relation to accidents at sea.

Accidents caused on board big maritime vessels have been studied for several decades, but the American Bureau of Shipping made one of the more comprehensive and recent in 2004. Close to 200 accidents was analysed, resulting in five accident categories. As seen later on this page, human error is by far the most dominant factor causing almost 84 per cent of all accidents.
[p232, Baker & Seah, 2004]
The same analysis showed that of all near-root human induced errors 55 per cent were due to poor situation awareness and assessment, making it an overwhelmingly predominate factor in a majority of the recorded accidents.
[p238,Baker & Seah, 2004]

In 1990 a number of accidents were analysed specifically to figure out how human acts affect the risk of accidents at sea. It was found that most human errors are based upon missing information or wrong judgement hereof. The findings were as the following:

27% Had correct information but failed to see the problem.
21% Did not have information about the problem.
20% Failed to see the consequences of a choice.
16% Underestimated the negative fallouts of a choice.
15% Failed to see there were more than one choice of action.
1% Recognised the problem but made bad judgement.
[p279, Reason, 1990]

There are some natural deviations in these numbers, not only due to development in the industry over time, but also because of the lack of a standardised methods to define errors. It is however safe to say that human errors are of very high importance to safety at sea today and that a new product must assist the crew to attain better situation awareness and assessment.



img.1-18,19

INITIAL FRAMING

This section present the initial framing based on topics and problems discussed throughout this chapter. The framing will be updated multiple times as the project progresses and as the design team acquires new insights.

APPROACH TO DESIGN

The focus of the project is to explore and design a future interface design for the propulsion control system on large maritime vessels.

The design team see high potential in designing a highly user-centred product and believes that this approach can lead to a more integrated system that is more intuitive in use, thereby improving safety of operation.
Given that the user context and technology involved is unfamiliar to the design team, new learning possibilities will undoubtedly occur. The lack of experience in the specific context also forces the project into a highly method driven and user-orientated direction which is very much what the design team believes to be the core of their skill-set as industrial designers.

LIMITATIONS OF THE MARITIME INDUSTRY

- × Proving that a concept can be approved by legislation is difficult before it is in a state of fully functioning prototype and even then, the process is still very extensive and complex.
- × Sales price and production cost is fully disclosed by MAN and other manufacturers due to heavy competition and secrecy in the industry.
- × Since a PCS panel is mostly sold as a small part of a much bigger package, often together with large engines and propeller systems, the true cost of a PCS is illusive even to a potential buyer.
- × Because the vast majority of large vessels travel very long distances, observing users in real action, have to be limited to a local ferry. Other vessels and user-groups will be part of the research but it is problematic to observe them in real operations.
- × It is not possible to get a hold on competing products for comparison.
- × It was clear from the beginning that the limited knowledge of ship operation would require a certain amount of learning before real product development could begin. This was however not only a negative thing since it allowed for some untraditional thinking unbound by tradition and norms.

VISION

“Our vision is to reduce complexity and increase safety of propulsion control systems on board commercial and military vessels. We aim to design for the users on the bridge, not just the machine at the stern.”

MISSION

With a focus on the interface on the bridge, the design team will develop a propulsion control system that takes human factors into account while delivering added value for shipping companies and other stakeholders. The product will aim to make use of new technologies but only if it can be justified by the way it interacts with the user and if it correlate with the goal of adding safety of operation.

INITIAL DESIGN OBJECTIVES

- ✓ Create a new product on the basis of Alphatronic 3000
- ✓ Create a truly user-centred product.
- ✓ Reduce interface complexity for advanced propulsion control.
- ✓ Improve overall safety of operation.
- ✓ The design must take education and learning into account.
- ✓ Must feature a steep learning curve* making it fast to learn or adapt to.
- ✓ Focus on modern commercial vessels.
- ✓ Focus on large vessels where the most complex manoeuvre situation is in-harbour (not offshore supply vessels and work ships).

** Steep learning curve being a learning process where you gain proficiency over a short period of time and/or a limited number of trails.*

As expected early in the process, the list of design objectives was short and abstract.
To gain more knowledge, and add further design objectives and more tangible specifications, the team set out to observe and talk to not only manufacturers and users, but also experts in the field of human psychology, maritime accident investigation and maritime education. The next chapter will give an insight into the process and how it affected the direction of the project.

SUMMARY - INITIAL RESEARCH

- Crew-members, ship owners, knowledge institutions, ship builders and architects are all main stakeholders in this project and the team should take their needs into account when designing a new user-centred product. (p.11)
- The future product needs to integrate thruster control to become a more flexible and complete product so no confusions or errors will happen when operating. (p.12)
- Today’s design is too conservative and too cautious. A single design consultancy have designed three PCS styles for three different companies. New innovative user-centred solutions are required to raise competition and bring more awareness to the PCS design. (p.14)
- An extensive investigation have been made by the company Deloitte, that said automation becomes more and more integrated on today’s large vessels, which requires higher educated crew-members. This does not alone affect the number of crew-members on board the bridge, but also the number of educated captains is falling, while the number of uneducated are raising, which could lead to future accidents. (p.16)
- The most important for the future product is efficiency. Being able to do commands fast and effective while not loosing concentration, will properly result in fewer mistakes on board a vessel. (p.17)

CHAPTER 2.

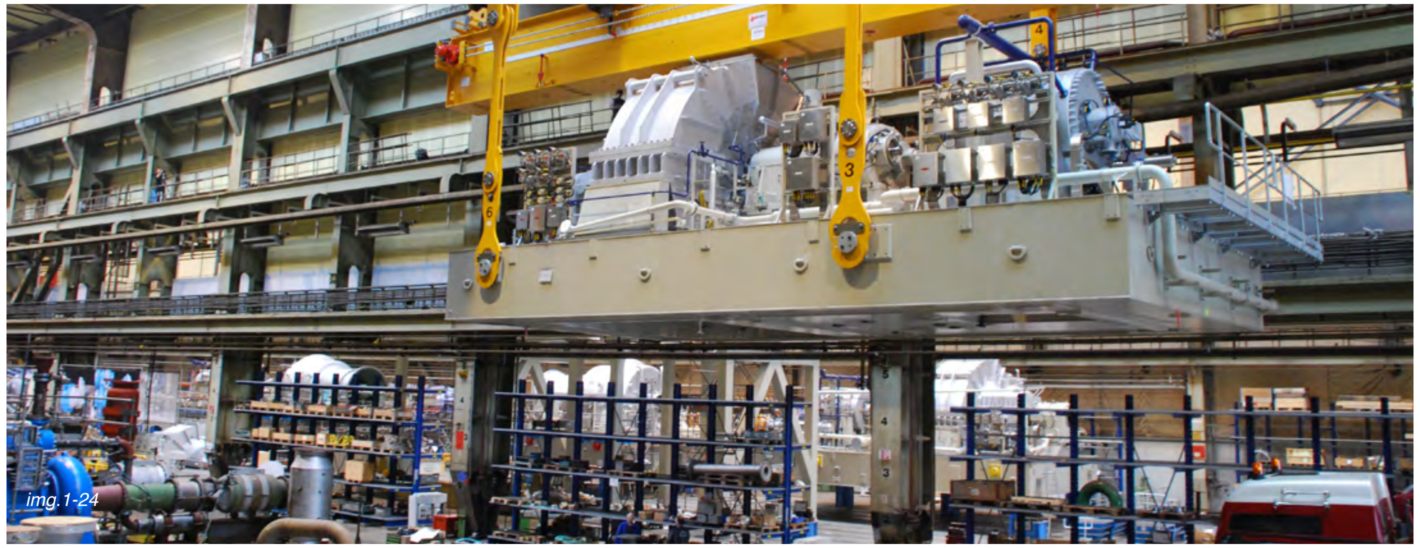
USER NEEDS

Achieving knowledge and even more being able to emphasize with the users is very important to continue the design process. This chapter elaborates the user needs through different methods such as fieldtrips visiting a manufacturer and specific users.

Interview with specialists within the Maritime Accident Investigation Board and behaviour psychology presents the opportunity to fully understand the general needs of a user in a maritime context.

This chapter will be the beginning of an understanding of the user and context that will ultimately lead up to knowledge about how to design for enhance usability and reduce risk of human errors.

FIELDTRIP 1 – MANUFACTURER



img.1-24

img.2-24

img.3-24

Attendees
Dennis Jensen - Master student, Aalborg University
René B. Wellejus - Master student, Aalborg University
Kurt Jensen - Manager, Head of Propulsion Control, MAN Diesel & Turbo

Location: MAN Diesel & Turbo, Frederikshavn - February 4th, 2013

Objective: Collect general knowledge within the shipping industry, mainly about the interface of the propulsion control system and to discover any needs observed by the manufacturer.

RESUME

It was decided to visit MAN Diesel & Turbo to get a better understanding of the current product and how the system works and also to gather as much material and data as possible to start the research phase. MAN Group have more than 250 years of experience in design for the maritime industry and the design team therefore found it natural to start the process by tapping into this knowledge.

When entering the building, the first thing that was handed out to the team, by the secretary at the information desk, was a small fire and safety brochure. This was the beginning of understanding just how focused a big cooperation like MAN strive to comply with all the safety regulations. All internal news displayed on a big screen hanging on the wall in the reception, showing everything from number of work related accidents to an informal meeting with Aalborg University students – management and precision was clearly the name of the game in this company.

After a moment of waiting in the reception area, a man introduced himself (Kurt Jensen) as Head of Propulsion Control in the department of Propeller & Aft-Ship. He welcomed and escorted the team to a big conference room were he had prepared a presentation about the company and the product they currently are working on. During the meeting questions was asked and answered from both sides of the table. The need to explore the future of PCS interfaces originally came to AAU from MAN, but it was clear that they were not aware of problems with the current product, which naturally made Kurt Jensen very curious about what the project was going to be about.

After, Kurt Jensen offered a guided tour of the company. The tour enabled the team to gain some real understanding of how engines, propellers and the propulsion control system on big vessels interact to produce a wanted outcome. A presentation of the test facilities where new interfaces are tried out also gave a much deeper understanding of the needed functionality and safety features in the product.
All this knowledge was very valuable for the team, but leaving without a concrete problem to work on also made it clear that much of the future work would have to be done in the field. MAN was clearly very focused on regulations and extremely skilled at solving technical problems, but the team had a notion that the interface of the system was designed mostly for the engine rather than the end-user. This impression was the spark of what would later turn into a highly user-oriented process.

OUTPUT

It was decided by the design team to focus on the user and their needs rather than the legislations surrounding a high-risk product like this. Legislations are essential for the maritime industry, but it was clear that the potential for innovation would be very limited if these were not put aside for this project.
MAN was not aware of any direct needs of improvements for the current design but had a strong wish to look into the future of propulsion control. This presented the team with the opportunity to design a solution from scratch with a highly user-oriented process.

The only thing mentioned from MAN, as a possible wish for a future product, was the ability to control thrusters, which today was handled with other interfaces today.

It was decided as quickly as possible to visit the users in a real context to understand their work habits and discover real user-needs. Meanwhile some research should be done to better understand the system behind the interface to gain knowledge on how it works and which features it carries.
It was decided to do further research about other industries to learn how they design for similar control situations and conditions, which could reveal design features that the new product could utilise.

OTHER INDUSTRIES

After visiting MAN Turbo & Diesel, experiencing how complex products can manoeuvre a big vessel, the design team decided to take a look at other industries to explore different approaches on similar challenges.

A wide range of products was analysed and the output is listed on these pages. Common to all the products that were of inspiration was, that they all were designed for advanced manoeuvre situations. The bullet points that accompany the images are features that the design team aim to implement in the future product development.

EXCAVATOR (CATERPILLAR 308E CR SB) >

- ✓ Handbrake must be pulled before the driver can physically leave the cockpit, thereby preventing accidents.
- ✓ Highly ergonomic interaction points by placing controls where the hands are most relaxed, which improves safe operations.

img.2-26

F1 STEERING WHEEL >

- ✓ Clear colour coding of functions creates hierarchy and relations.
- ✓ By having the display in wheel the most crucial information is closer to the eyes and easier to read fast.

img.1-26

< MOBILE CRANES CONTROLLERS

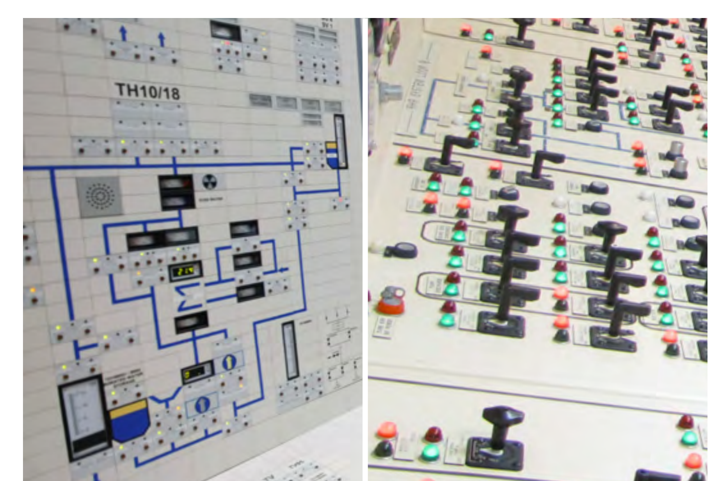
- ✓ Mobile solution makes it possible for the operator to move to the best view.
- ✓ Simplistic interface with only primary features.
- ✓ Durable construction creates trust and reliability but also hard use.

img.3-26

img.1-27

DJ MIXING TABLES >

- ✓ Soft touch buttons with light make operations easy in dark situations.
- ✓ Clear tactile feedback and surface difference between buttons, creates less demand for visual attention.
- ✓ Symmetry reduces complexity.



img.3-27

< FIGHTER JET COCKPIT (SAAB JAS 39 GRIPEN)

- ✓ Detailed information is located as high as possible for reduced eye movement and time consumption when looking away from the outside surroundings.
- ✓ Functions with a high degree of consequence are marked with danger-areas (yellow and black stripes).
- ✓ Touch display is accompanied by hard-buttons.

img.2-27

< NUCLEAR POWER PLANTS

- ✓ Lifelines indicate how functions affect each other.
- ✓ Big buttons indicate big decisions or consequences.

INTERVIEWS

As implied at Fieldtrip 1, safety is without a doubt the biggest concern when dealing with operation of large maritime vessels. The team therefore decided to contact two specialists within the field of accidents at sea, to gain knowledge about what threatens the safety of crew and vessel.


img.1-28

SVEND KARSTENSEN, INVESTIGATION MANAGER

Department of Maritime Accidents, DMA

To better understand what kind of mistakes and equipment failures that contributes to accidents at sea, the team contacted Svend Karstensen, from the Danish Maritime Authority (DMA). He is the Investigation Manager in the department for maritime accidents and is responsible for the investigation of all accidents in Danish waters. Finding the errors that lead to accidents is his primary function.

"WE DO NOT DIVIDE ACCIDENTS INTO MACHINE OR HUMAN ERRORS, BUT RATHER SEES MACHINE ERROR AS A SERIES OF HUMAN ERRORS MADE AT AN EARLIER STATE"

This way of thinking has been introduced the latest years because DMA have learned more about the true nature of accidents. Accidents cannot be described as a single error because a vessel is designed to cope with failure – accidents are therefore due to a series of events that turn simple errors, misunderstandings and wrong reactions into major accidents.
Svend did not have any concrete accidents involving a PCS and did not see the bridge instruments as a major contributor to accidents. Failure to maintain the vessel was, in his opinion, the major forerunner for accidents.
The team later discovered, that the accident in the port of Frederikshavn (See p.34), have not been investigated in-depth by DMA. The accident happened due to a human mistake followed by a failure to detect this mistake before the accidents happened. Therefore there was no direct failure of material or equipment and DMA did not see a need to investigate the case. This contradicts what design team were told by Svend Karstensen and made it clear that alternative specialists should be asked, to learn more about how human behaviour and interaction with instruments fail.
By talking to DMA, the design team learned that a Danish postdoc in behavioural psychology had been working with the subject of human errors in the maritime context for years. Her name is Inge Linda Wilms and she was the next person to contact.


img.1-29

INGE LINDA WILMS, POSTDOC

Department for psychology, University of Copenhagen

Inge Wilms is a postdoc in behavioural psychology and today she is doing research and teaches in the subjects of cognition, human-computer interaction and applied cognitive psychology including robotics, tools, traffic and tools. Inge showed up to be the right person to talk to in relation to understand user-behaviour in a maritime context.

Talking on the phone with her for almost one and a half hour, a lot of knowledge was gained including some highly valuable references for the further research. The most important learning points from talking to Inge was the following:

- Instruments should act as an extension to the limbs and senses of the user.
- Adding layers of information will make it easier to overlook the basics.
- Human error and machine error cannot be separated – they are highly interconnected.
- Added complexity and layers of information deteriorates decision-making based on logics and rationality.
- Touch screens are used in too great an extend in modern maritime instruments – they are not that appropriate for most operations because of the movement of the ship and the lack of feeling with what you are doing.
- Technology must be used because it creates a better solution, not because it is "smart" and new. Touch screens are a good example of a technology that is implemented in too many applications in maritime instruments – many of these would be much better of with regular hard-buttons.
- Analogue and graphical instruments are faster and much easier to understand by the user than numbers and digits (digital watch vs. analogue watch).
- Indication of minor errors is often understated, leading the user to fail to detect it.
- A complete failure protection is a utopia from the engineering world – things will fail and the smartest thing the design team can do is to design for handling errors not just try to prevent them.
- If something is automated it must be made clear to the user what the machine is doing.

"WE HUMANS CANNOT AVOID MAKING MISTAKES – ACTUALLY THAT'S HOW WE LEARN NEW THINGS AND THE WORLD WE BUILD AROUND OURSELVES MUST TAKE THAT INTO ACCOUNT"

After talking to Inge Wilms, it was clear that she had encountered many poorly designed and excessively sophisticated interfaces in her research of accidents involving maritime vessels. Use of technology is a big driver for the sale of new products and many designs do not take its origin in the end-user. She also pointed the design team in the direction of literature and case studies that could help avoiding some of the mistakes that are present in so many of todays design solutions.

COGNITIVE PSYCHOLOGY

Interaction design in a high-risk and complex situations, like manoeuvring large vessels, require a deep understanding of how feedback and actions are perceived by the user. To successfully design an advanced control system like this, the design team must therefore ensure that the user acquires, process and store information about his actions to control the ship in a way that correlates with what actually happening. By taking these mental processes into account, human errors and friction in the workflow can be reduced by making it easier for the user to make the right decisions.
Since cognitive psychology is an extremely broad field, it will not be handled in this section directly, but rather used as an evaluating tool later on in case studies, field research, concepts and more. Looking at statistics of maritime accidents, it also becomes clear that cognitive errors have a paramount influence on safety at sea. The effect is so profound that close to 84% of all accidents happens because of lacking action or wrong reaction by the humans. Only the remaining 16% are due to natural causes or material failure that could not be prevented by proper handling.
[p232, Baker & Seah, 2004]

To better understand what cognitive challenges the crew on the bridge face today, the next sections will elaborate what type of errors lead to accidents and how they relate to human cognition.

HUMAN ERROR

There are three types of human error that results in human failure: slips, lapses and mistakes. As mentioned earlier, human error has been shown to be the most frequent cause of accidents at sea, which is why maritime instruments have a number of accident prevention-features focusing on eliminating these.
[p.273, Reason, J. 1990]

Human error is a structured and cognitive failure, which in the end can cause accidents, as illustrated on illustration 1. To give a better understanding of what human errors are and how they occur, the following sections will describe some of the most general error-types.

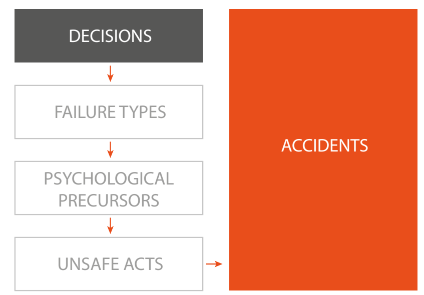
UNSAFE ACTS

Accidents are always caused by unsafe acts. This does however not mean that the users involved are aware of the pending dangers. In most cases the users does not or cannot know how their actions will contribute to an accident. To prevent any unsafe acts of happening, a defence-mechanism is often built-in into high-risk systems.

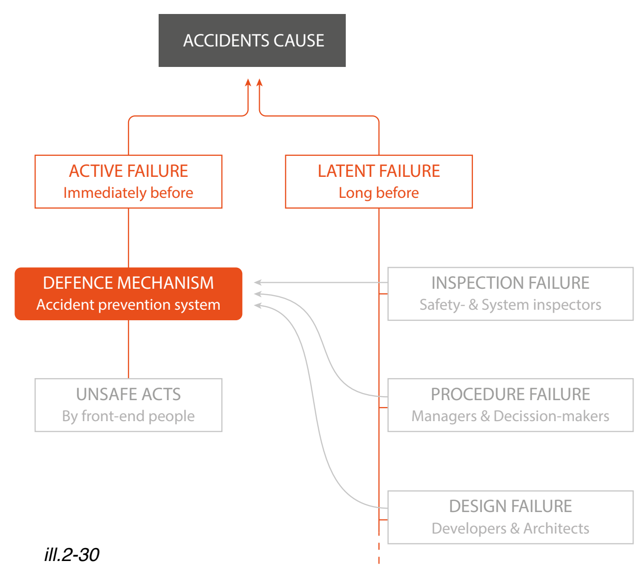
The underlying assumption appears to be that man will always make mistakes, and that a system should be designed to be as fool proof as possible. If a "fool proof" system were to be involved in an accident, it would therefore indicate that there was a hole in the defence mechanism. Accidents of such is often caused by general failures e.g. if a user is short on time and has to do a time consuming job, he will automatically think of a short cut to do his job quicker. These short cuts lead the user to do things that the engineers did not expect and defence-mechanisms will therefore be undermined. General failures can be divided into two failure types: active- and latent failures. As seen on illustration 2, active failures are based on the actions of the users or failure of defence mechanisms. Latent failures are a result of poor inspection, procedure or design of the system – a failing defence mechanism will therefore involve a latent failure in a majority of cases.
[p.275, Reason, 1990]

FAILURES

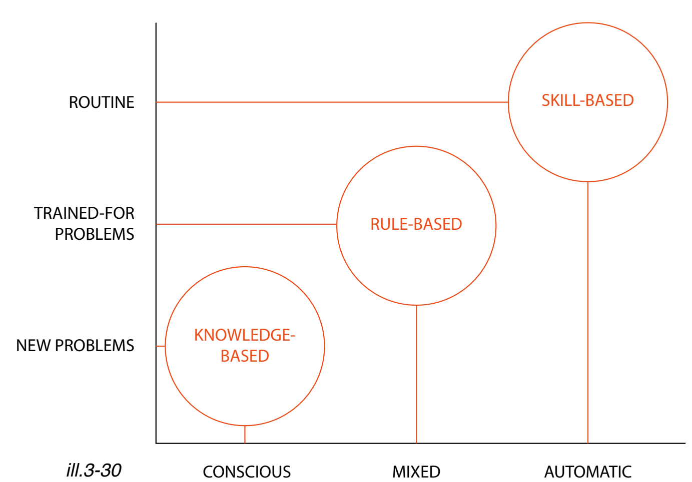
Active failures are unsafe acts that happen right before or during the accident. Usually users on the front line of the system like; control-room personnel, drivers, pilots, ship's crew etc. perform the active failures.
Latent failures are created a long time before the accident happens and are usually created by those on the upper-levels of the system such as decision-makers, designers, managers, inspectors etc.
The connection between active- and latent failures is the psychological precursors, which as mentioned earlier could be the decision to take a short cut to do a time consuming job faster.
[p275, Reason, 1990]]



ill.1-30



ill.2-30



ill.3-30

HUMAN BEHAVIOUR

Human behaviour can be divided into three levels of control as seen on illustration 3. At the skill-based level the behaviour is automatically controlled by stored patterns of preprogrammed instructions. If the outcome differs from the expected the control passes down to the rule-based level. Here problems are identified and if the problem is of a familiar pattern there is a stored solution rule in form of the "if-then" type – if this is the problem, then do that. This type of rule is applied without a full analysis or deep understanding of the problem. If a rule-based solution removes the problem, control is passed back up to the skill-based level. If it does not the control may be passed down to the knowledge-based level. Here solutions are generated on the basis of a full understanding of the factors that caused the problem. Knowledge about functions and relationships can be combined in new manners, so that original and creative solutions are found.
[p.282-283, Reason, 1990]

SLIPS, LAPSES AND MISTAKES

Slips and lapses are both part of the skill-based level and happen in very familiar situations without much conscious attention e.g. driving a car, which is a very familiar type of task but is very vulnerable to slips and lapses if attention is diverted even for a moment [p.277-278, Reason, 1990]]

Mistakes are decisions that are wrong but thought to be right. There are two main types of mistakes: rule-based mistake, which is when a user is confronted with an unplanned-for situation, but is likely to identify it with a familiar pattern. He is therefore likely to apply a rule-based problem solving. But the rule-applying processes can be in error e.g. misapplying a normally good rule by failing to spot the indications of difference in the situation. An example could be a doctor that fails to identify that a child with fever, in an on-going flu epidemic, actually has another more serious sicknesses involving the same symptoms.

The other type of mistake is knowledge-based mistake, which happens in total new situations and no pre-packaged problem-solving rules exist to solve the problem. The mistake therefore happens because of a simple lack of knowledge.
[p.45, Reason, 2008]

VIOLATIONS

Violations are intentional risk-taking and the user is in other words deliberately doing the wrong thing. The violation of health and safety rules or procedures is one of the biggest causes of accidents and injuries at work. [hse.gov.uk, 2013]. Violations happen in each of the three levels of control (See illustration 3 and 4).

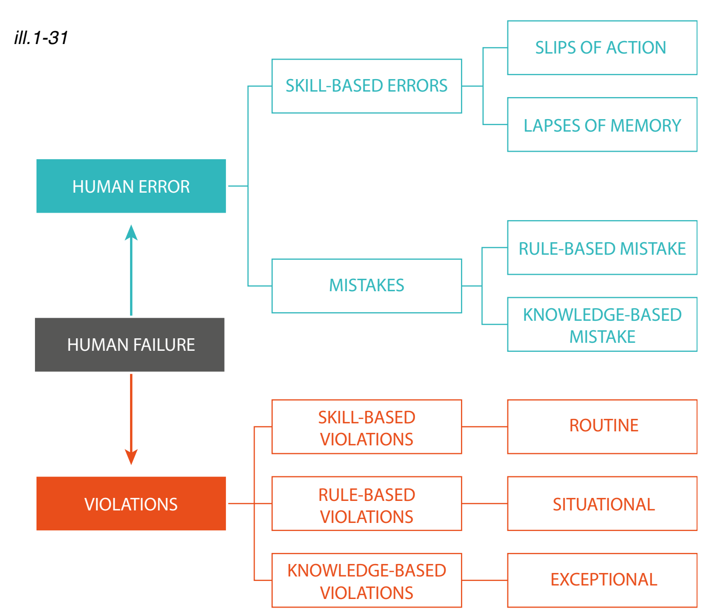
A **skill-based** violation is also called a routine violation because it is based on a user's own alternative to a safe action. An example could be walking in the park following a path and then to safe time cut a corner by walking on the grass making a new not-planned route. This form of violation is rarely punished but can form bad habits if applied in high-risk situations.

A **rule-based** violation is also called a situational violation and it is mostly safety violation of procedures, rules and regulations that are written down to control the user's behaviour in problematic or risky situations.
One example is an operator working at a train station attaching wagons to the train. Only when the wagons are stopped can the operator get down between them to make the necessary coupling. Sometimes the shackle is too short to connect the wagons if they are at their full extension, which means that the job can only be done when the wagons are momentarily compressed as the wagons first come into contact. Thus the only immediate way to join these wagons is by remaining between them during the connection. Many operators have died as the result of being trapped between the wagons even though safety regulations have been written to avoid this from happening. Rule-based violations are more deliberate than skill-based violations meaning that violations are done in the belief that they will not have negative consequences.

Knowledge-based violations are also called exceptional violations and happen mostly in new and atypical situations that the user is trained for but never have experienced before. The problems often involve a rare but trained-for situation or an unlikely combination of individually familiar incidents
[p.51-54, Reason, 2008]

An example could be a newly educated forest ranger that suddenly finds himself unexpectedly close to a dangerous animal (bear, wolf etc.). He is well trained for the situation and knows he should stay calm and back away slowly, but might end up violating that knowledge by running away in panic and thereby increasing the risk of an attack.

ill.1-31



MARITIME SPECIFIC ERRORS

While researching the subject of human errors some cases and theories were found to be quite specific and directly usable in the maritime industry.

AUTOMATION SURPRISE

It has been shown that operators will monitor less effectively when automation is installed, and even more so if the automation has been operating acceptably for a long period.
[p 775-779, Bainbridge, 1983]

In the case of an automation failure, a cognitively under loaded crew will increase the risk of accidents because they are not on alert and will be exposed to automation surprise, if the system do not inform them correctly
[p.1261, Grootjen, 2006]

Research shows that the factors, which strongly increase the potential for automation surprises are:

- Automated systems act on their own without immediately preceding directions from their human partner.
- If crew members do not know how their machine partners work in specific situations.
- Weak feedback about the activities and future behaviour relative to the state of the world.

Failure in terms of automation surprises is also highly reinforced by "non-events", being events that actually happen but is not indicated to the decision maker. [p7, Lützhöft, 2002]

"INCREASING AUTOMATION TO REDUCE THE INFLUENCE OF HUMAN WEAKNESSES DOES NOT WORK. AUTOMATION CREATES NEW HUMAN WEAKNESSES, AND IT AMPLIFIES EXISTING ONES. HUMAN ERROR DOES NOT VANISH; AUTOMATION CHANGES ITS NATURE. THE MORE AUTONOMOUS THE MACHINE, THE MORE THE CONSEQUENCES OF ERROR GET DISPLACED INTO THE FUTURE, FURTHER COMPROMISING OPPORTUNITIES TO RECOVER."

[p 12, Lützhöft, 2002]

Since automation is not going away anytime soon (rather the opposite), it is however important to know what defines a well-designed feedback system for automation. A 2002 article from Linköping Institute of Technology (Sweden), "On your watch: automation on the bridge" by M. H. Lützhöft and S.W.A. Dekker, three basic information layers must be included:

Event-based: representations need to highlight changes and events happening because of automation.

Future-oriented: in addition to historical information, human operators in dynamic systems need support for anticipating changes and knowing what to expect and where to look next.

Pattern-based: Operators must be able to quickly scan displays and pick up possible abnormalities without having to engage in difficult cognitive work. By relying on pattern- or form based representations, automation has an enormous potential to convert difficult mental tasks into straightforward perceptual ones.
In case of automation, these three information layers must be included in the future product.

COGNITIVE OVER AND UNDER LOAD

According to the 2006 article "Cognitive task load in a naval ship control centre: from identification to prediction" by M. Grootjen , M. A. Neerincx & J. A. Veltman, there are several important things to take into account in relation to cognitive task loads.

The writers of the article measures cognitive task loads, as what they call subjective mental effort. It is subjective because it is not scientifically measurable and has to be assessed by a number of decisions including a test-subjects own opinion. Even though this approach introduce a number of unknown variable, some clear results were found:

- The level of information processed has the greatest impact on the subjective mental effort.
- A substantial increase in subjective mental effort was also found in conditions with a high level of task-set switching.
- Reduced alertness is a well-known problem that appears when operators have to monitor tasks continuously or when boredom arises in highly repetitive tasks.
- Adaptive systems are recommended to ensure that the crew has things to do when automation is working and thereby reduce the risk of cognitive under load, resulting in an increase in alertness [p1262, Grootjen, 2006]. This could be in form of features that allow the crew to check the state of the ship or access other information that is not directly linked to the primary functions.

EXPECTANCY LEADING TO ERROR

Numerous case studies involving maritime accidents have shown signs that the expectancy of the crew can distort their view on the outside surroundings. For example, if the GPS map indicates that a buoy should be located in front of the vessel, the Captain will tend to see that buoy even if it might be something different [p10, Lützhöft, 2002].

"[HUMANS HAVE] THE REASONABLE EXPECTATION THAT THE RECURRENCES OF THE PAST PROVIDE A FAIR GUIDE TO THE LIKELIHOODS OF THE FUTURE."

[p. 8, Reason, 1988]

It is not uncommon for humans to misinterpret what we see, but it gets dangerous when a misinterpretation is combined with technical failures of radar or similar systems.

An example of just this type of accident is the grounding of the cruise liner, Royal Majesty, that happened in 1997 due to a mix of a GPS malfunction that had the autopilot sailing on the wrong course and a human misinterpretation of the ships location. None of her 1.000 passengers were injured but it did cost the owner no less than $7 million in repairs. [nautinst.org, 2013]

NEGLECTING EFFECT OF SUNLIGHT

As observed in later field studies, the manufacturers of many displays on the bridge have neglected the effect of sunlight. Direct sunlight will always occur on the bridge because of the vast amount of windows and reflections from the ocean.

The result is displays and indicators that can be difficult to read in direct sunlight leading risk of events not being noticed by the crew. An example of this will be described on the next pages.

FINDINGS

Besides the maritime specific findings, the output of this chapter was to achieve the correct terms and language for analysing cases and fieldwork in the future process. Also reading a range of literature within human error has given the design team insight to what errors to expect in certain situations relating to man-machine interfaces.

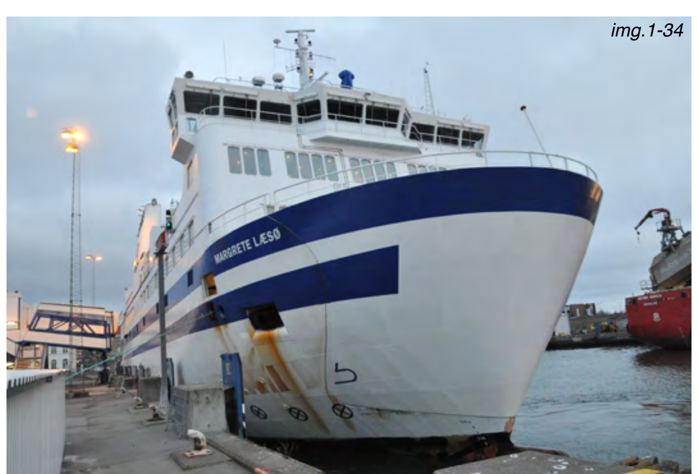
Specific design parameters will be listed in the summary of this chapter on page 56.

CASE: FREDERIKSHAVN 19/5/2012

In the afternoon around 20:00 (8pm) the Læsø ferry was ready to enter the port of Frederikshavn. The Captain had taken the command to the starboard wing panel, to ease the in-harbour manoeuvring and started to move the joystick, the same way he were used to. At first, the ship seemed to react as it should, but the speed did not decrease as fast as is should.
The Captain then realized that he had only control of one of the two main propellers and that the other was still commanded by the speed-pilot and was therefore trying to maintain cruise speed.
Due to the delay of motion with a relatively big vessel like the Læsø ferry, the Captain was entirely conscious about the fact that a collision was inevitable and that he therefore had to take precautionary measures.
The Captain decided to take act and managed to steer the ferry in direction of an empty dockside to avoid damaging other vessels or dock personnel. The ferry hit the dockside hard and 5 people were lightly wounded and one suffered severe injuries. The collision also crashed multiple cars on the deck of the ferry.

The reason behind this accident was poor communication and poor interaction between man and machine. The Captain thought he had taken the control out to the wing panel but, what he had not realized was that he had pushed the wrong button for one of the engines.
At that specific time, the sun was low over the horizon, which meant that the sun's reflections interfered with light-indicators on the instruments. This had the Captain confused to believe that he had pushed the correct buttons, when in reality, he only had taken control of one of the two propellers.
There is a build-in defence mechanism in the wing panel that does not allow operation without control of the propellers, but it was deactivated because one propeller was activated correctly.

After the collision the ferry company along with the Danish Maritime Authority located the error and blamed the Captain for the accident because he had pushed the wrong button on the center panel. To avoid any future accidents of this kind, experience reports from all crew members were made to ensure a synchronized and "fool-proof" routine.



img.1-34

DECODING THE ACCIDENT

1: Latent failure
The design of the interface is difficult to interpret and can easily be misjudged if exposed to sun light reflections. (See img.1, 35). Also too many colours and lacking hierarchy make it prone to mistakes.

2: Skill-based error
The captain does his routines before entering the harbour. He wants to disable the speed pilot on both engines and take control, by pushing two buttons on the center panel. One button is incorrect pushed but has not been noticed by the captain, which results in one engine still being in speed-pilot mode.

3: Latent failure
The system allows the captain to take control to the wing even though one of the main engines still is in speed-pilot mode. The speed-pilot is a late add-on product and is not incorporated properly into the main alarm system. The captain is therefore still not aware that one of his engines is out of his control.

4: Rule-based mistake
When the ferry is inside the harbour the captain notices some unexpected results when manoeuvring the ferry but fail to locate the error because he is able control the ship to some degree, it just do not react as strongly as he expected.
After realising that something is wrong he correctly starts to go through system regulations and safety procedures to locate the error, but at this point it is too late. The captain was unaware that he could have control on the wing without the command of both main propellers.

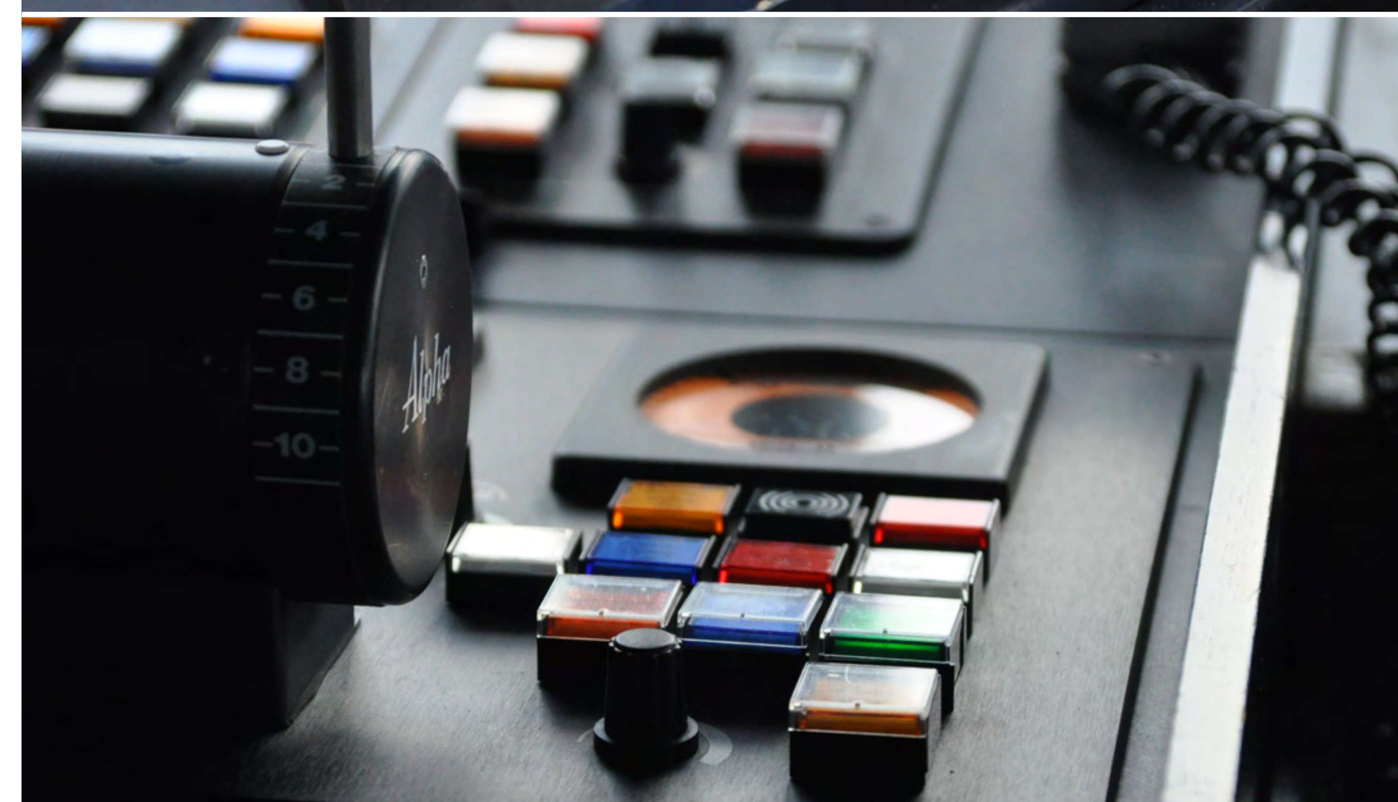
5: Knowledge-based violation
The pace of the ferry is too high and the captain is now at fully informed about the situation, but does not know how to solve the problem fast enough. The situation is new to him and his best option is to hit the dock away from other vessels, accepting the consequences of his decision.

KEY FINDINGS

The design of the interface panel is what started this accident and a poor alarm system is what allowed it to continue. The user did make mistakes, but these could easily have been prevented from scaling into a full-blown accident by better design and alarm systems. But instead of blaming the engineers behind the system, the captain was made responsible of the event and that is in design teams opinion a quite lacy to end an accidents investigation.

The outcome of this case study is that the future product must take the effect of the environment seriously and also ensure that logic are strong, thereby reducing the time to detect the human errors that cannot be prevented.

Heavy use of colour and a lack of hierarchy make the panel prone to mistakes.
img.1-35



Reflecting on instrument panels make buttons unreadable and the sun interfere with light in the buttons.
img.2-35

HUMAN SENSES

Based on initial field research (see p.25), it is clear that the crew on board today's vessels are highly reliant on the visual input from both instruments and the outside surroundings. When observing the Captain on duty one will immediately notice just how much his eyes are flicking from the instruments out on the sea and back again. No matter what the Captain is doing he will instinctively try to maintain a complete overview of the situation of the vessel, sea and other vessels and obstacles that might affect his decisions.

Humans are by nature extremely visually oriented. The vision is the sense that we use to create logic in the world around us and it enables us to make fast assessments of complex situations in a way that no other sense can. In fact 70 per cent of the neurones of the brain sub-serve the visual system in one way or another, making it the most powerful sense in the human body. [Discovery, 2010]

Vision is however not our only highly developed sense and because it is already coping with a great load of information, the design team decided to explore what other senses might be appropriate to use as an interaction form in this project.

MAPPING HUMAN SENSES

By mapping what other senses humans have it is clear that only a few of them are appropriate for this particular project. The following senses will be elaborated and the rest of them can be seen on Appendix B.

- The Auditory (Hearing)
- Tactility
- Proprioception (Limbs position)

Auditory (Hearing)
The auditory sense is the latest developed sense in the human body. Evolving from sea creatures that did not hear, but actually felt vibration and pressure changes in water instead, animals on land developed a new sense to allow them to hear sounds traveling through air. This new adaptation literally developed as an offshoot on the vestibular sense, which means balance and hearing is closely related for land going animals and humans.

Being able to detect sound is very important. Through sound humans can detect danger but it also allows us to communicate in complex languages. Sound also sets the scene for what we see and can affect the way we interpret the world. Imagine a video of a shark swimming elegantly in open water with a piece of classical music playing in the background – now replace that music with the soundtrack from Jaws, and the shark suddenly appear to be much more dangerous than before. This relation is of course also affected by the fact that we know what the music relates to, but it is very instinctive to use sound to determine the level of danger, excitement etc. from sound.
Some sounds even have a direct physical effect on our bodies, like the sound of nails on a blackboard or a fork scratching a dinner plate. Some reactions are learned others are hard-wired from birth.

Output: Audiotory (Hearing)
In relation to this project, one of the most powerful features of the auditory sense is the fact that it never sleeps. Our ears are constantly on the watch for danger and that is why certain subtle sounds can make us jump out of bed in panic and others hardly can wake us even if they are much louder. Using sound is therefore a powerful thing in complex situations where you want to make an indication of an error or an important event. But many other instruments and things on board vessel bridges make sounds and noises, so it must be done in a manner that do not overload the Captain and is clearly distinguished from other sounds.

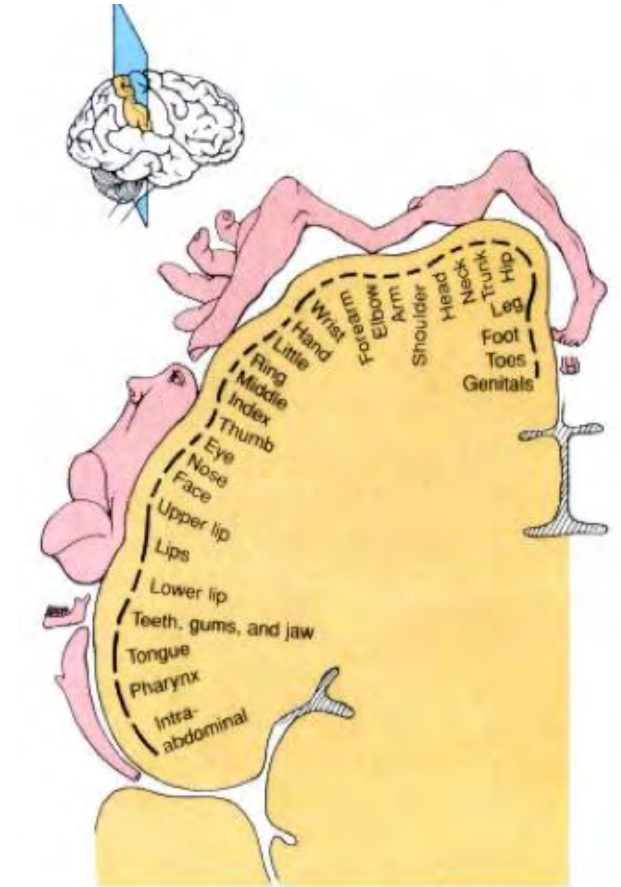
Tactility
Right after vision, the ability to sense tactility is the developed sense in humans.
Sensing touch allows manipulating objects, create things and understand the substance of our surroundings. Touch also creates bonds between humans and even more between humans and objects.
Much like vision, touch is empowered by the brain that translates signals into meaningful input. Our skin can essentially only sense three things: temperature, pressure and vibration. It is the brain that combines these variables with prior experiences to make up what we are actually touching.
The process happens so fast we never notice this, but it is very interesting because the brain's involvement makes it possible to prioritise tactile inputs. An example could be a wristwatch that one has been wearing for years – it feels completely different on the skin than first time it was tried on. This is not because the signals from the skin have changed; they are just ignored by the brain because they have become unimportant. It could be argued that the same thing could happen if a tactile feedback form is used in a constant form over longer periods of time.
In the context of shipping, vibrations are common and everything on the bridge can vibrate especially under heavy manoeuvring. Vibration would therefore be a bad way of interacting with the user in many cases. But because our tactile sense are so accurate, tactility can be utilised for many other purposes, like distinguishing areas of interaction, defining relation between buttons etc. Tactility could therefore potentially be used as a replacement or supporting feature that allow the user to rely less on visuals.

Output: Tactility
Humans are most sensitive in the areas that are used for interacting with the world and this is highly reflected when looking at the "wiring" of our brain. As seen on img.1-37 fine motor skills are present in areas with high sensitivity and this makes up for an interesting cocktail in relation to the design of man vs. machine interaction. By locating both in- and output in the same object a much richer interaction form could be established. With reference to the illustration it is obvious that the hands are a good choice for simultaneous input and output. It is however important to note that the reason why the sensory system is so strongly related in an area like this, very well might be because the brain needs some sort of feedback to control the motor functions accurately. It might therefore be appropriate to limit feedback if the hands are supposed to do precise movements with the same object.

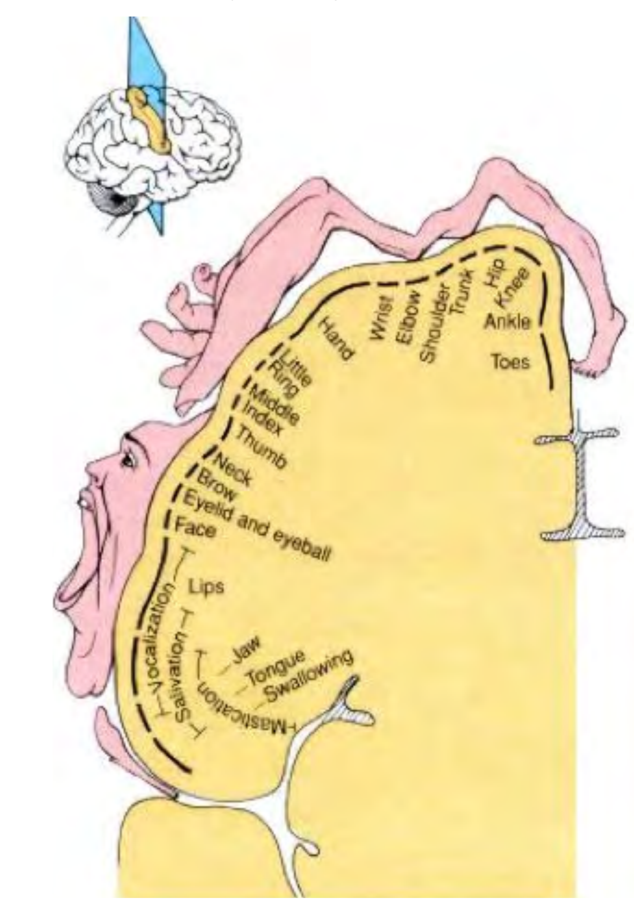
Proprioception (Limbs position)
Proprioception is human's ability to sense where our limbs are located in relation to each other. It is highly linked with our motor skills (ill. 1.37) and is used extensively when the body is in motion. It is the skill that allows us to move without falling, kick a football and swim or what ever we set our minds to.
The brain use prior experiences to calculate where the limbs should be in relation to each other to successfully execute a certain action. Arms, shoulders and torso have fine senses that, among other things, make us able to balance on two and even one leg. We can even balance with other objects, but to do so our brain makes complex calculations of just how the limbs should act to move an object of that weight and size while keeping a good balance.

Output: Proprioception (Limbs position)
Most people have tried to lift an empty milk-carton that were believed to contain milk – for a moment it feels like the carton defies gravity and is lifted with too much force because it is much lighter than expected. This expected resistance is important for interaction physically with objects, and tells us that physical resistance must be designed with great care in objects that must be manipulated accurately. It also tells us that poor design in systems with dynamic resistance could lead to too much force being used by the user, if the changes are not communicated correctly. On a vessel bridge during manoeuvring, this could result in a greater-than-expected manipulation of the controller and could lead to accidents and mistrust in the system. It is therefore of high importance that the force needed for accurate manipulation, easily can be understood by the user and dynamic resistance are used with great care.

The section Mapping Human Senses is based on the 2003 BBC series "Human Senses" and field-studies described later in this report. [BBC, 2013]



Somatosensory cortex in right cerebral hemisphere



Motor cortex in right hemisphere *img.1-37*

SUMMARY - USER NEEDS PART.1

- By doing a fieldtrip visiting MAN Dielsel & Turbo, it was discovered how large vessels are operated today and that MAN was not aware of any concrete problems with their current products. MAN does a hard work to obey rules and legislations throughout any design process, which in the design team's perspective, might hold back for new innovative designs. (p.25)

- Other industries were researched to gain knowledge on how alternative control panels looks like, and what features they carry. (p.26)

- Specialist within maritime accidents and human psychology were interviewed. It was found out that the majority of maritime accidents happen because of human errors. (p.28-29)

- Cognitive psychology turned out to be an important factor and should be used as a future tool to evaluate case studies, ideas and future concepts.

- Literature about human error has helped the design team to understand how and why decisions leads to accidents, and how to reduce them by focusing on human control orders: skill-based, rule-based and knowledge based. (p.30-31)

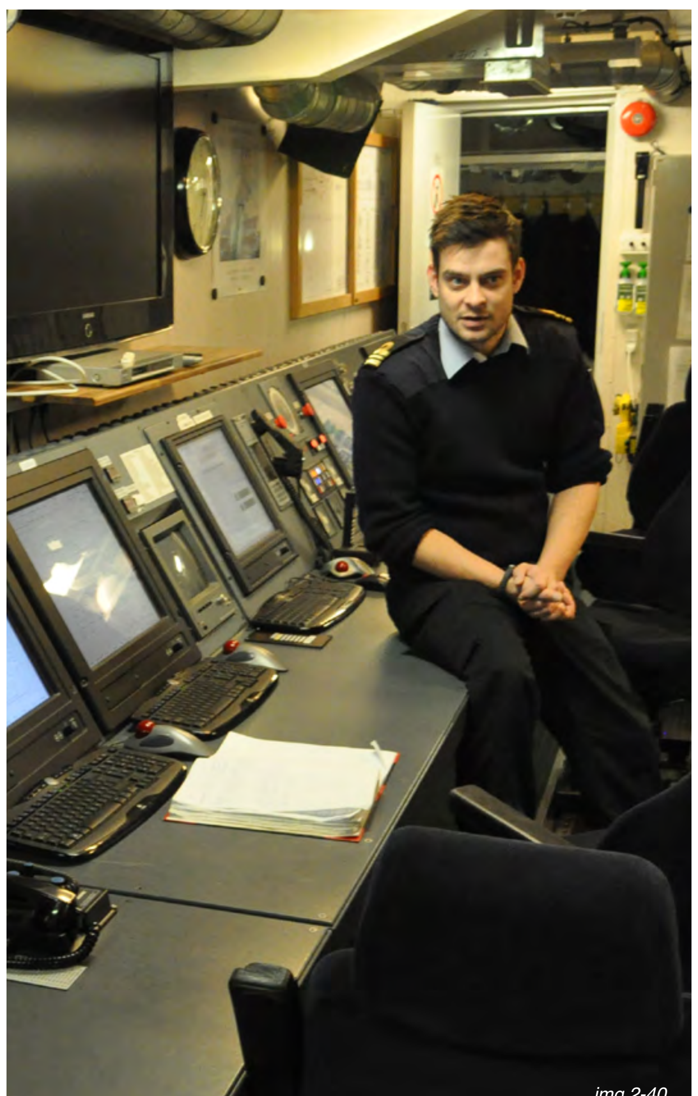
- Automation becomes more and more used on future vessels, but it does not necessarily mean that human weaknesses will be reduced. On the contrary, human errors become more evident as on board automation increase.

- By studying the case about the Læsø Ferry, the design team will focus on making the future product easy and intuitive in use. The user should not be confused or become in doubt when using a product with a high risk-factor. (p.34)

- The team has decided to implement technology that respects the human senses within vision, hearing, tactility and proprioception. Doing this should help reduce the load on the user's vision. (p.36-37)

FIELDTRIP 2 - REAL USERS

img.1-40



img.2-40

img.3-40

img.4-40

Primary attendees
Dennis Jensen - Master student, Aalborg University
René B. Wellejus - Master student, Aalborg University
Captain & Crew - Læsø Ferry
Crew - HDMS Absalon L16

Location:
Ferry: Margrethe Læsø, Frederikshavn/Læsø
20.2.2013 (morning)

Battleship: HDMS Absalon L16, Frederikshavn
20.2.2013 (afternoon)

Objective:
To see how the PCS are being used by a user in a real context on board a vessel and to gather information about work procedures and user habits when operating the vessel in different situations such as:
- Docking, arrival and departure
- During voyage
- Other manoeuvre situations

RESUME

Two meetings were arranged that day: one meeting with the Captain on the Læsø Ferry, and another with a Lieutenant on the navy vessel HDMS Absalon L16.

On board the Læsø Ferry's bridge a lot of new impressions were made and after the introduction to the Captain, observations and questions started to arise during the voyage, such as workflows and work procedures. Everything was noted in form of images and video clips. An interesting observation was the Captain's use of the PCS during the trip. It was very clear that the Captain used the PCS panel on the two wings more often than at the center. The PCS panel at the wings was only used to manoeuvre the vessel when docking, but it took up a lot of concentration from the Captain and some interesting new observations were made.

After the trip to Læsø and back again, it was time to go visit the navy vessel, HDMS Absalon L16. Getting on board the vessel took up some time because of the clearance and safety check. The impression of entering a secure navy vessel was very profound. Lieutenant Commander Christian made his greeting and started a tour on the vessel from the engine room to the bridge. Every time a room was entered, the team had to ask for approval to take photos because of the confidentiality of some equipment. The bridge on board Absalon L16 was very different in comparison to the Læsø Ferry's.
Lots of instruments and more panels existed on the bridge, and the team was told that several people operated the bridge when manoeuvring, limiting the need for automation. On the Læsø Ferry only the Captain was on the bridge during the voyage while having a co-pilot when manoeuvring.
A notable thing on Absalon L16 was all the redundancy systems, which on battleship are very important if the vessel is to survive an enemy attack.

OUTPUT

On the basis on the gathered information and material during the fieldtrip, it has been chosen to focus on the pcs-panels on the bridge wings instead of the panel on the center. The reason for this shift is that the level of interaction between man and machine at the wings are much higher than at the center, where most of its functionality are automated.
The load of tasks is also higher at the wings, which could lead to deeper explorations of automation but still with the user as a key actor in the overall system.
Furthermore it has been chosen that the product throughout this project should be designed for commercial vessels only. By talking to several navy crew members, it became clear that the heavy manning of navy vessels reduce the need for advanced systems to assist the captain. Meanwhile on a commercial vessel e.g. the Læsø Ferry the Captain performs the entire operation himself, which results in a heavy task load within a very short time frame. This selection does however not exclude the navy as a customer-base, but they are not the ones with the most urgent need for innovation.

IMPORTANT OBSERVATIONS

- Heavy task load when manoeuvring in harbour.
- Static wing panel with a forward orientation proves a problem for complex manoeuvres.
- Not having one had freed for support, reduces the balance of the captain when operating the wing panel.
- Sunlight reflections blur information on light-buttons and screens.
- It can be difficult to distinguish between an indicator light and a light-button.
- The captain takes his glasses on and off when ever he shifts view from the horizon to the instruments.
- Many buttons to press when taking command to the wing.
- Very poor hierarchy and use of colours in most instruments.
- Orientation on displays differs from each other. Some show the ships orientation in relation to the local orientation of the screen, while others show it in relation to the outside world (true motion display).
- A trackball is used instead of regular mouse for most computer screens.
- The instruments are a mix of new and old. Much of the modern functionality is added later.
- The crew did not trust equipment that had failed on them more than once.

- Lights have to be dim-able for night operation.
- The ferry enters the harbour with a relatively high speed because it optimizes overall fuel consumption to stay in cruise speed for as long as possible. The crew mentioned saving around 600.000dkk since this procedure was implemented. But the great delay from input to actual change in motion make it more hazardous because errors might be discovered too late – like in the case on p.34.
- Automation makes room for new routines and safety checks.

IMPORTANT QUOTES

While at sea with the Læsø Ferry, Captain Klavs Toxen Worm came with some quite insightful comments about his view on maritime instruments. With close to 50 years of experience at sea on a great range of vessels, his knowledge was of great value to the design team that, at this point, knew very little about this new context. Much of the things learned from Klavs can be implemented directly in the design of the future product, and his most important quotes are listed below.

“A device that enables a safer and more intuitive control of the ship could very well justify a retrofit. It would also be nice if it was more customized to our needs and weren’t just off-the-shelf components like today”

“The worst thing for an captain is to be annoyed with alarms that he is not supposed to act upon – engine temperature and so on is the responsibility of someone else and it can be really disturbing when doing difficult manoeuvres.”

“Alarms should not scream more that necessary – the bridge crew are supposed to act upon them but if they keep screaming it distract us more than anything. It’s like installing a fire alarm in the helmet of a fire fighter!”

“I like when I push a button and know, without a doubt, afterwards that it has been pushed. That seems basic but I encounter many buttons and touch displays that lack this feature”

“Analogue instruments are faster to read and can often give a better overview of the information (like a compass vs. digital course display), but most digital instruments are more precise and reliable. I trust all my digital instruments but not all the analogue ones because they have failed at some point in time.”


img.1-42


img.2-42


img.3-42

ADVANCED MANOEUVRING INTERFACES

In this section existing products that are able of doing complex manoeuvres from a bridge wing, will be analysed. As mentioned earlier in the Initial framing (see p.20), the possibility to acquire detailed information about the products from the manufacturers is difficult. The analysis will therefore take basis on sales materials, images and illustrations found on the Internet but also material gathered from fieldtrips.

RUDDER, THRUSTER AND GOVERNOR

The rudder enables the user to steer the vessel in a certain direction and is used often when manoeuvring. The governor instrument makes it possible for the user to adjust the forward or backward power level and the thruster instrument helps the vessel moving from side to side and is very efficient in manoeuvre situations if combined with a rudder. This is the system used on a vast majority of vessels.

RUDDER AND JOYSTICK

The rudder and joystick instruments enable the user to do two things; Ship course or rotation (rudder) and power-direction of the vessel (joystick). The ship course or rotation manipulates with the orientation of the vessel and the power-direction regulates in which way it should move. The joystick is especially interesting because it runs on a system that combines the main propellers and rudder, with the bow- and stern thrusters to create thrust in any direction. It is therefore easy for the captain to direct movement of the vessel while keeping his concentration on the outside surroundings.


img.1-43

img.2-43

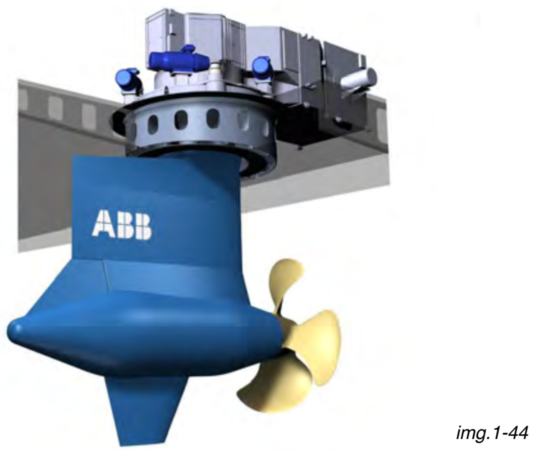
AZIPOD

The Azipod propellers enable the user to manoeuvre the vessel easier than manoeuvring with regular propellers. An Azipod is basically two or more main propellers mounted on a swivel that allow them to turn in any direction. The mount acts as a rudder so there are fewer variables for the captain to handle.
By having the ability to rotate the main propellers, it is possible for the user to direct a great amount of thrust exactly where it is needed. The Azipod instrument works somewhat like the joystick mentioned earlier. By rotating the joystick, it sets the direction the Azipod and by tilting the stick for- or backwards the power level and direction is set. See appendix C for more information on the Azipod system.

COMMAND CHAIR

The Rolls-Royce operation chair is designed for comfort and usability, ensuring a robust, flexible, modern and reliable operation environment [Rolls-Royce, 2011]. The chair has a wide product range including a joystick and a rudder. The difference from the two previous products is that all the instruments are integrated to the armrest on a chair, reducing body movement during manoeuvring. This type of product is often found in offshore vessels that have to manoeuvre for longer periods with high precision near oil rigs in very harsh conditions. In this context there's only one object (the oil rig) that the captain have to worry about, and the reduced body movement is therefore not an issue.


img.3-44



img.1-44


img.2-44

OUTPUT

The positive thing about the Azipod technology is the direct relation between instrument and the thrust output and the fact that the user has to think about fewer actions. It is quit intuitive in use and the user can easy manoeuvre the vessel while keeping his concentration on the outside. This approach could be interesting to move into the context of non-azipod vessels.

The positive thing about the rudder and joystick is that it combines the regular stern propellers with the bow- and stern thrusters, which means that the user can decide in which direction he wants the vessel to move without having to think about how the goal is reached. The goal-oriented way of steering is found to be a good way of combining automation efficiency with human intuition and judgement of a situation.

The commanding chair by Rolls Royce was found to be too specific for offshore special purpose vessels but there are some ideas that can be taken into the future products. One of these are the fact that the system is scraped from unnecessary features and indicators, another is that because it is all very well integrated, the instrumentation is packed into a more efficient workspace.


img.1-45

SHIP SIMULATOR TRIALS

As mentioned earlier, it was difficult to gather first-hand experiences from a diverse range of vessels. Most commercial vessels that leave Danish ports are at sea for weeks and when they finally dock again they are in different countries or even on different continents. Because of the time involved, that kind of field research was out of reach for the design team, but the need to understand the diversity and dynamics of different vessels, was still present.

As an alternative to get some indication on how different vessels manoeuvres, and to get a better understanding on their bridge layouts, a ship simulator was tested. The design team set out to explore handling, steering delay, bridge layouts, field of view and orientation of wing instruments.

The time with the simulator was spent trying different ship-types and sailing different missions like docking, harbour manoeuvring, rough sea sailing and much more. The list to the right describes the most profound findings from the ship simulator trials.
Simulator software: Ship Simulator Extremes by VSTEP, NL

KEY FINDING

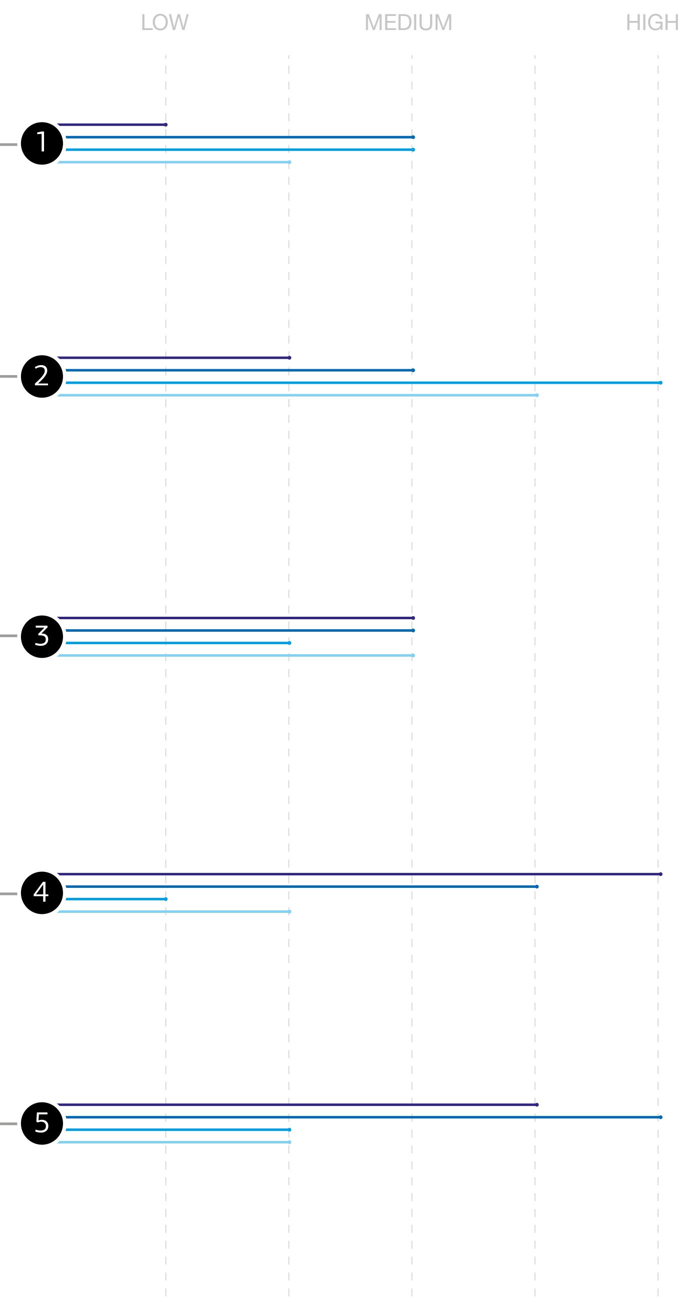
- The delay of input on the propulsion system is so great that you often rely completely on instruments.
- Larger vessels require captains to have higher skills at predicting manoeuvres into the future.
- Field of view is of very high priority on both center and wing positions.
- Captains have to move around a lot to gain the best view in unknown harbours.
- The design team experienced shifting to birds-eye-view in many situations because of the lack of feeling with the size of larger vessels. This is of cause not possible with real vessels, but it indicates just how difficult it is to judge the sheer size of most vessels.

MAPPING SCENARIOS

Based on the experience from the Læsø ferry (See page 41) a scenario map was created, to better understand the use of functions and to give the team tools for testing future ideas.
The most complex manoeuvre-situation was chosen to ensure that the challenges involving orientation and advanced functionality were covered. This situation takes place in the port of Frederikshavn when the ferry is returning from Læsø. To describe the actions being used, a five-step scenario overview and a load graph was created as seen on these pages.

SCENARIO LOAD-LEVELS

- Manoeuvre complexity
- Attention to surroundings
- Attention to instruments
- Functions in use



ill.1-46

STEP 1 - OPEN SEA (T: 0 MIN)

Location of captain: Center bridge
Location of co-navigator: Off bridge
Actions: Speed Pilot active. Command at the center panel. Cruise mode active
Primary view: Forward, Starboard, Port side

STEP 2 - WING TAKE-OVER (T: 1.40 MIN)

Location of captain: Center bridge > Bridge wing (Starboard)
Location of co-navigator: Center bridge
Actions: Speed Pilot deactivated from center. Thrusters activated from center > Adjusting power joystick forward on wing. Cruise mode activated from wing. Rudder manoeuvre.
Primary view: Forward

STEP 3 - TAKE MANUAL CONTROL (T: 5.40 MIN)

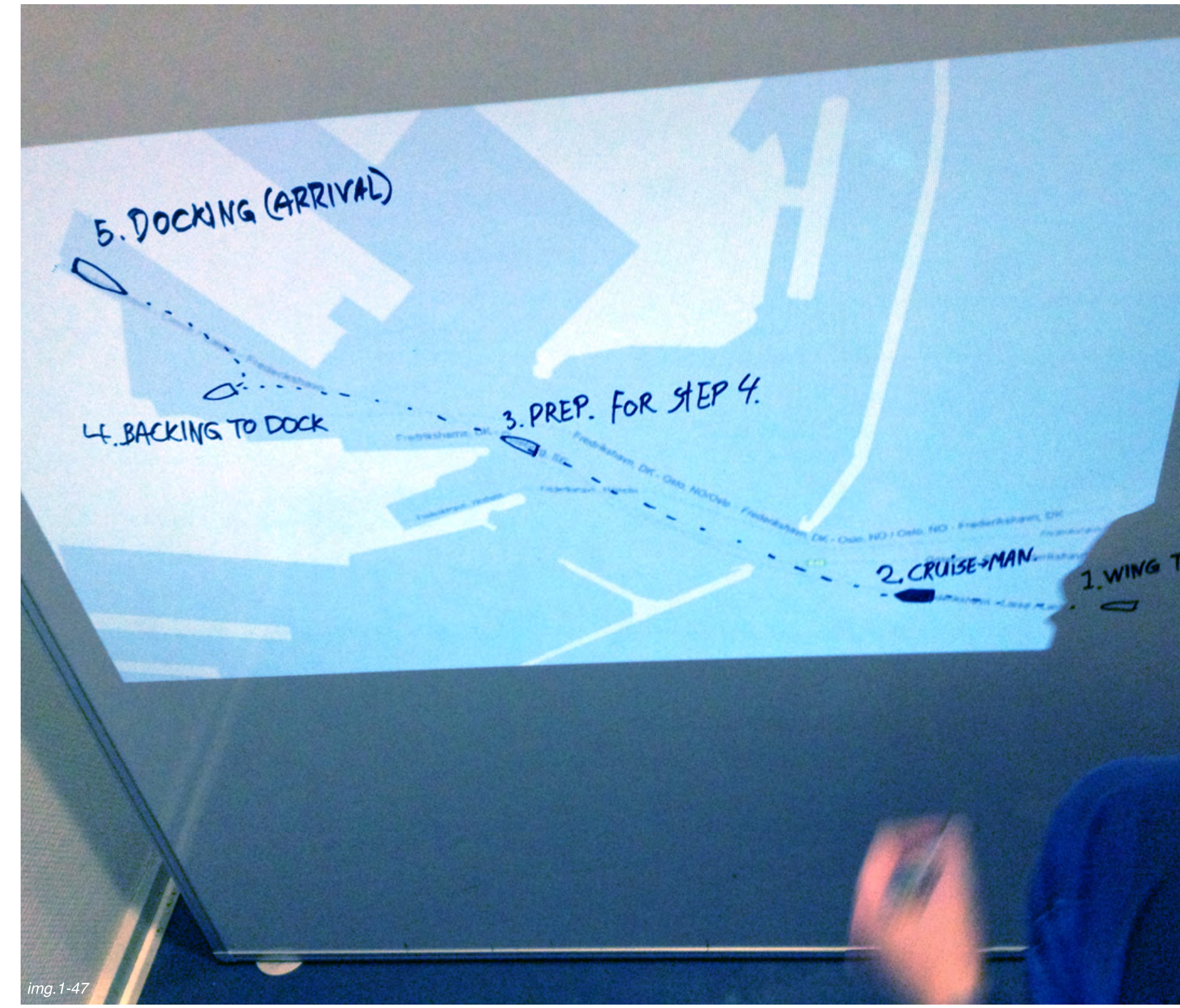
Location of captain: Bridge wing (Starboard)
Location of co-navigator: Center bridge
Actions: Adjusting gyro. Rudder manoeuvre. Cruise mode inactive > Manoeuvre mode activated. Rudder manoeuvre. Adjusting power joystick.
Primary view: Forward

STEP 4 - BACKING THE SHIP (T: 6.35 MIN)

Location of captain: Bridge wing (Starboard)
Location of co-navigator: Center bridge
Actions: Manoeuvre mode active. Rudder manoeuvre. Adjust power joystick.
Primary view: Forward, Starboard, Backwards

STEP 5 - DOCKING (T: 11.00 MIN)

Location of captain: Bridge wing (Starboard)
Location of co-navigator: Center bridge – opens carport
Actions: Manoeuvre mode active. Rudder manoeuvre. Adjust power joystick.
Primary view: Starboard, Backwards



img.1-47

Scenario mapping was done by mixing data from video and photo material with a map of port of Frederikshavn. By projecting the map on a whiteboard, the team were able to discuss the manoeuvres and fictive scenarios (emergencies, heavy weather, other vessels etc.) in rapid iterations.

A clear coherence between complex manoeuvres and less time and attention to instruments were found in all cases except for situations with very heavy snow and no visibility.
In all other cases, a rise in complexity will result in a reduced attention to instruments. It is therefore of high importance to design for fast readability and with clear hierarchy of information.

CREATING IDEATION TOOLS

After mapping the user scenario it became clear to the design team that it was necessary to build some tools for easier ideation and communication. The situation that the user is in when commanding the vessel from the wing is highly complex. There are many elements that one have to take into account when talking about this context and the team quickly found themselves in need of physical elements to demonstrate orientation problems, ergonomics and much more.

It was decided to create two sets of ideation tools based on findings from analysing existing wing bridges and important features on the wing panel.
These rough tools were mainly created to be used as a way to communicate more effectively within the group and to facilitate later ideation phases.

IDEATION TOOL 1: WING-BRIDGE

As seen on the images on page 49, there is a great range of different wing-bridge layouts and the sizes various from very small and narrow to big and wide. This let the team to work with the build of a 1:1 wing-bridge in a much flexibility manner (See img.5-49) and the result was a modular system that allowed for try-outs with different sizes of areas and also easier to move around.

IDEATION TOOL 2: ESSENTIAL CONTROL FEATURES

The important features during manoeuvring was noted during the fieldtrip on-board the Læsø ferry and Absalon L16. Each feature was made rapidly in models, as seen on the images (See img.1,2,3-48), enabling the team to use them while body-storming throughout the ideation (See p.50).

ill.1-48

img.1-48

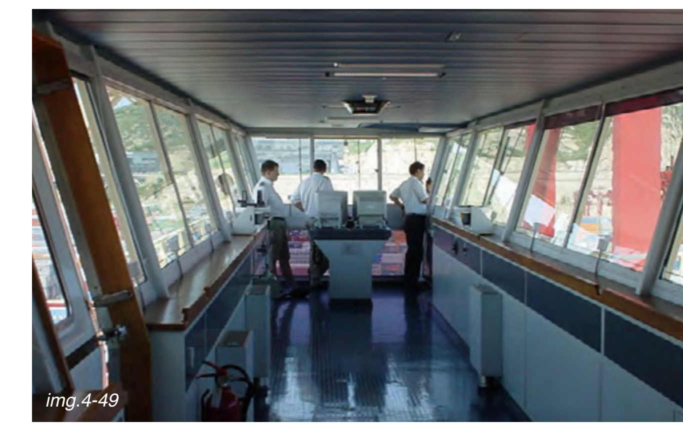
img.2-48

img.3-48

img.1-49

img.2-49

img.3-49



img.4-49

img.5-49

LAYOUT EXPLORATION

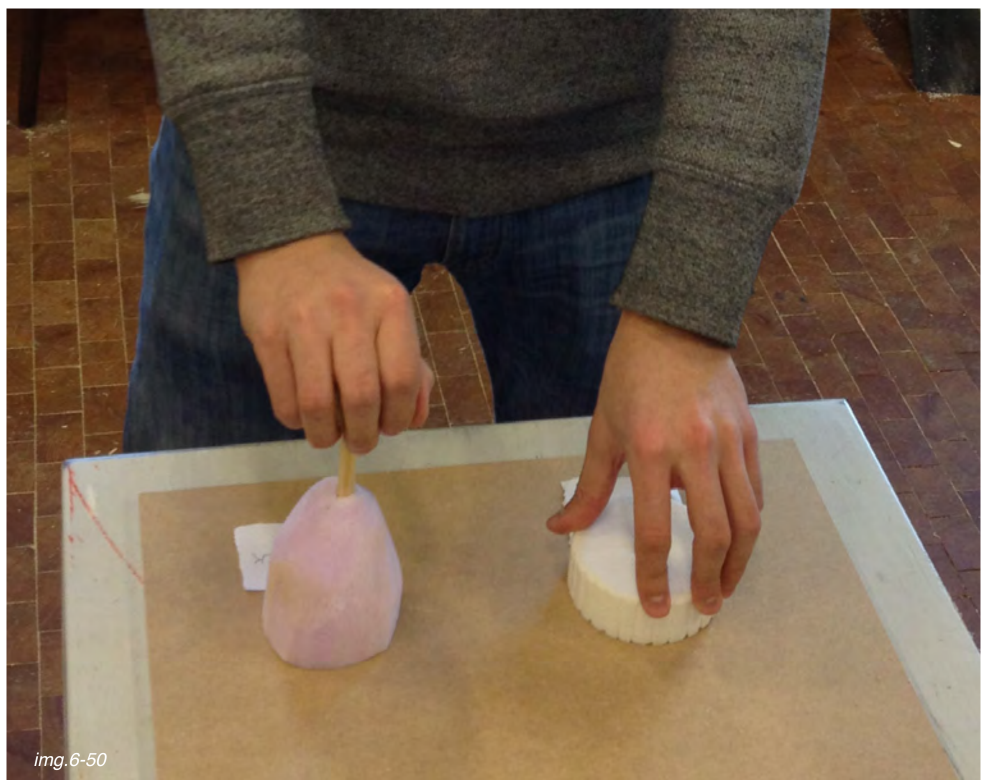
By use of the ideation tools described earlier, it was decided by the team to explore and determine a layout of the important and most used features on the panel. In this section the team have, through body-storming, developed a layout specification that takes basis on the user's perspective when operating a wing panel.
Shown below is a fraction of the many pictures that were taken while mapping how features should be located to optimise hierarchy and logic on the panel. The illustrations to the right shows the result from the session, which became the initial panel layout specification - aimed to be used later in the process when functions were to be located.

KEY FINDINGS

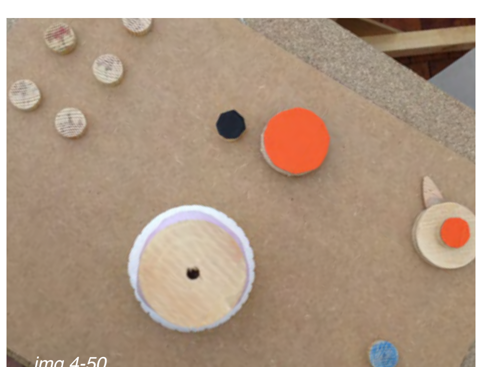
- The main problem with today's solutions is that they do not allow the user to control the two primary features simultaneously while having support for ballance.
- In real world use, the user always needs one hand free to hold on to a handrail but by handling two separate functions this is not possible. The user is also locked in an orientation that might not be optimal for a certain manoeuvre (See img.6-50). The project should focus on how to bring this functionality to the new product. Other features were set aside until a new concept could provide the user with an alternate input device to the rudder and joystick.

img1-50

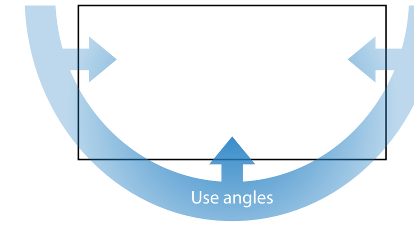

img.2-50


img.6-50

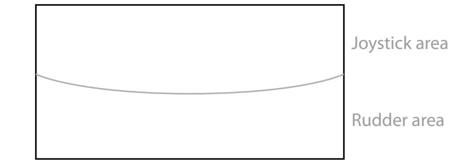

img.3-50


img.4-50

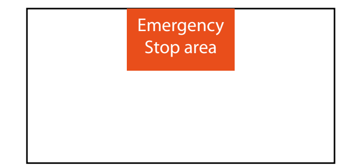

img.5-50

F1


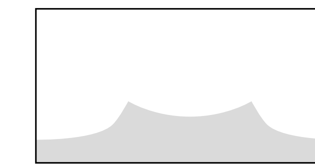
180 degree of operation is a direct user demand and increases the flexibility of the product while maneouvering.

F2


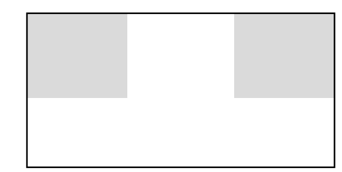
By placing the joystick in the area above the rudder or on top of the rudder, results in operations from all use-angles.

F3


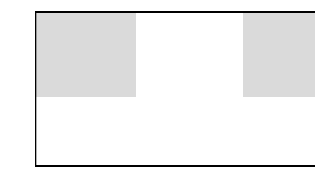
Emergency stop must be accessed from all use-angles but without risk of pressing by accident.

F4

Hand-rest area (keep surface clear)

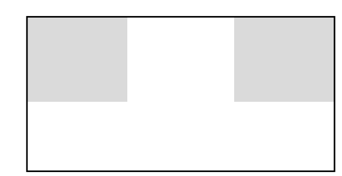
An area near the user must be held clear of pressure-sensitive functions and without objects that result in physical interference whith the user.

F5

Thruster start + Thruster power control

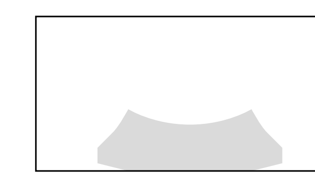
Thruster start and -power control can be located in one of the two areas, near display that give information about state of the thruster systems.

F6

Manoeuver Mode

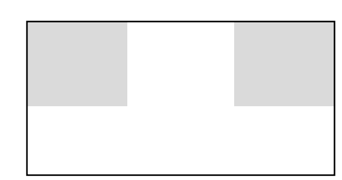
Manoeuvre mode can be located in one of the two areas together with F5

F7

Steering Mode

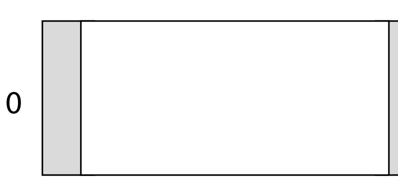
Steering mode can be located in one of the two areas close to joystick and rudder.

F8

Cake command

Take-command must be located and designed so it obstruct the use of joystick/rudder when command have not been activated at the wing panel.

F9

Light Intensity control

Light adjustment can be located in one of the two areas, but not together with elements from F5

F10

Extra features

Additional features such as wire phone, windscreen wipers, mouse track ball etc. should be located on both sides as an add-on to the main panel.

ill.1-51

VALUE MISSION

A value mission will help define the product by explaining how it can add value to the user. This specific value mission consists of several tags and should be seen as abstract guidelines for any future ideas and concepts.

INTUITIVE

The product should be easy to understand and to use. Within a short period of introduction, the user should be able to operate the product by him self. Important information must be quickly interpreted into action and in a way that assists the crew to make the right decisions in all situations.

SAFETY OF OPERATION

The designers must have a clear focus on safety of operation to reduce the risk of human error. As mentioned earlier, the majority of maritime accidents occur due to human errors and the product must therefore be designed specifically to the cognitive abilities of the crew. By simplifying the interface and information given, the load on the user is reduced, thereby freeing up time to focus on the surroundings and the overall state of the vessel.

TRUSTWORTHY

Any new concept must be able to meet the demands of a high-risk context. A failing wing control system can be dangerous if it happens while doing harbour manoeuvres where a switch to redundant systems might not happen in time. The design must therefore be able to control the ship in a reliable manner and be constructed with durability in mind.

PRIDE OF USE

The user should feel proud and important controlling a large vessel and the product should enhance that feeling by its appearance and function.

ENJOYABLE

By understanding tasks and interactions that motivates the crew, the product will keep, and maybe even amplify, the features that make the work as a Captain enjoyable. Also, uninteresting routine tasks that can be safely automated might become an integrated part of the system, thereby allowing the crew attends to more meaningful task.

img.1-52 Simple and intuitive design build for ease of user


img.2-52 Trust that a product will not fail you in critical situations

img.1-53 Nail gun with safety mechanism that do not allow nails to be fired if the gun is not pressed to a hard surface.


img.2-53 Pride in controlling advanced machinery


img.3-53 The joy of well designed interaction

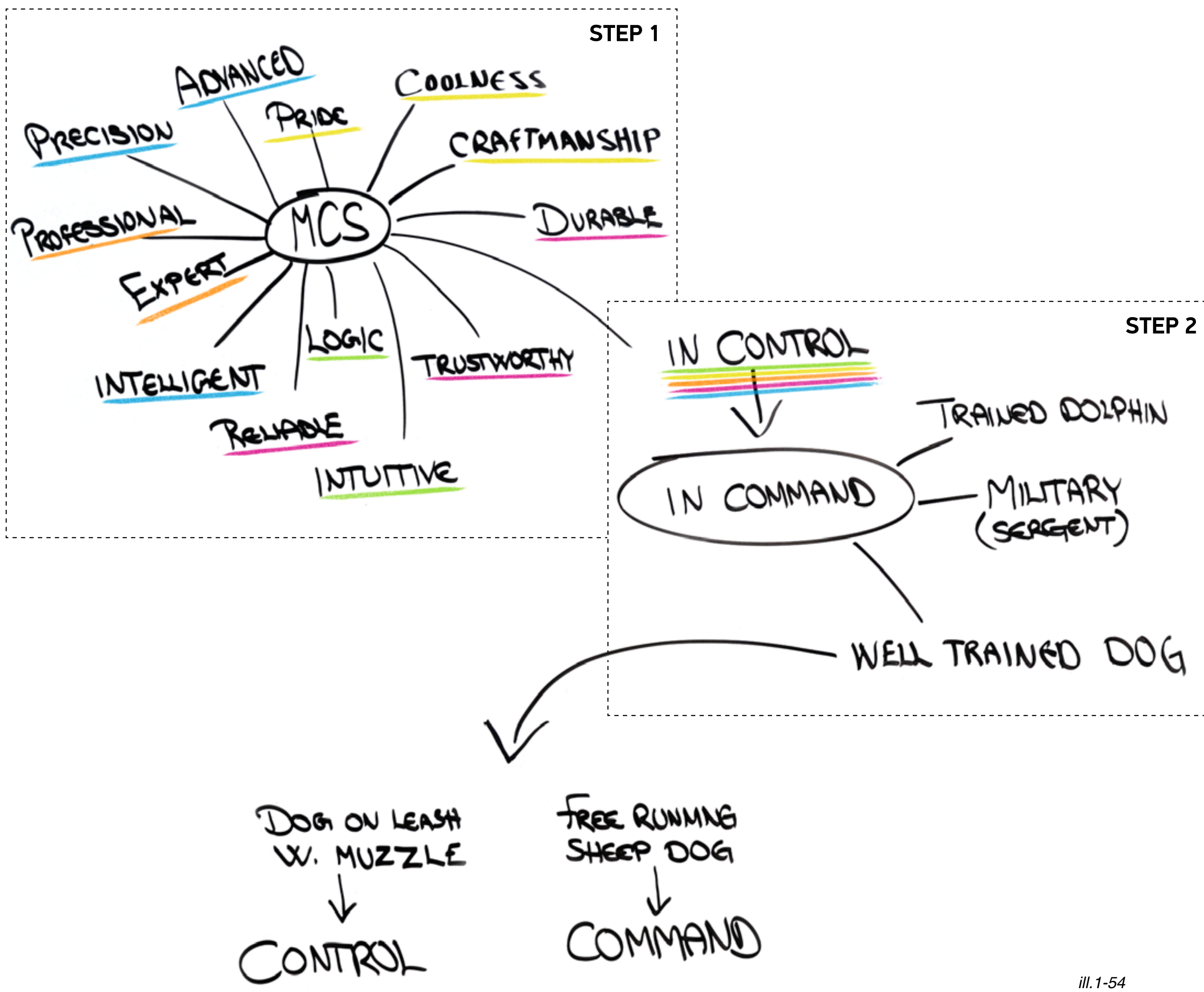
INTERACTION VISION: "THE SHEEP DOG"

The interaction vision was made for two reasons: to explore how different product characters could change the users perception of the product, and to be used as an active design parameter when creating and reviewing concepts.
In this section the interaction vision (See ill.1-54) will be explained and elaborated further to fully understand each choice made through each phase.

It must be noted that the interaction vision is a way to determine abstract and soft values for a product and they might therefore seem to be unrelated to the project at hand – but it is all an effort to map the wanted experience when using the new product.

NEW NAME

Up until this stage, the product name had remained "PCS" since the original goal was to design a new interface for the main propulsion control system. But during the design process, the project had changed focus out to the wing panel, which is handling much more than just main propulsion. Since the new product should enable full motion control of the vessel, including main propellers, engines, rudders and thrusters, a new name were required. The new working title was therefore changed into Motion Control System (MCS), to emphasize the enhanced capabilities of the product.



ill.1-54

img.2-55

IN CONTROL VS. IN COMMAND

In control = Dog on a leash with a muzzle
The owner feels in control of the dog because of the leash. He must tell the dog to walk or to stop walking by using the leash.

In command = Free running sheep dog
The owner commands the dog's movement on the field by only using shouts and different code whistles. In this situation the owner does not dictate how the dog should move, but only command in which direction he want the sheep to go, and the dog decide it's own movement to fulfil the owners commands.

STEP 1 – INTERACTION VALUE

At this step, the name of the product was centred within a circle, and related values such as professional, reliable, intuitive etc. was tagged to the product. When reaching a satisfied amount of values, each them were marked with a colour differentiating them into groups. Finally one value, "in control", was selected and passed on to step 2.
"In control" was chosen because it was perceived by the team to sum up the essence of being a Captain.

STEP 2 – PRODUCT CHARACTER

Next step were efforts to find values associating to "in control". This quickly led up to a discussion of the term control, and how it was a value that can be associated with both negative and positive use of power.
The term was therefore changed into "in command", because the team agreed that it is a way of control that relates to a more respectful relationship between the commander (captain) and the machine (vessel).

After reconfiguring the term, associations were drawn in an effort to generate a character for the product. Characters like military sergeant and trained dolphins were among the listed but one in particular were found to be well suited to the product – a well-trained sheepdog.

OUTPUT

As an output of the value and character development, the following abstract features were extracted:

- ✓ The user should not dictate every single movement of the ship, but rather focus on ordering the wanted output.
- ✓ It must not feel like the ship is forced to do actions, but rather that it fulfils commands out of respect to the user.
- ✓ The product should have a character that establishes a friendly but professional relationship.
- ✓ The product should aim to establish a character of an intelligent assistant rather than a dictated slave.
- ✓ The power relation between human and machine must be clear: the user must never feel like loosing control.

SUMMARY - USER NEEDS PART.2

- The design team chose to focus on the panel located at the wings instead of the center. This decision was because of the level of interaction between the user and the machine was much higher at the wing panels. Furthermore it has been chosen to leave aside navy vessels and focus only on commercial vessels because the user is much more loaded with tasks when operating alone than on board navy vessel where each feature has it's own crew-member. (p.41)
- In general, crew on board vessels tend to mistrust products if they fail multiple times when implemented. (p.41)
- The team needs to incorporate intuitive features in the future product such as in the azipod and joystick, making manoeuvring easier for the user in high-risk situations. (p.44)
- Only the primary features should be located on the future product resulting in the user wont loose his concentration on the outside surroundings while operating the vessel. (p.44)
- The team has mapped a specific scenario describing the most complex manoeuvring situation, and a clear change of load on the user happened. When preparing to take control at the wing panel, the load is high for the attention to the instruments and low for the attention for surroundings. When in manual control the load changes to the opposite, which means that the user operates the vessel without even paying attention to the instruments. (p.46)
- With the ideation tools an initial plan for the interaction layout was made. One of the important features that should be taken into consideration when designing the future product, is the awareness of only operating with one hand. (p.50)
- A value mission have been made to specify some values that can be used as guidelines when pitching and developing future concepts. (p.52)
- As a result of the interaction vision, it has been decided to transform being "in control" to being "in command". This should change the user's perception of the product and make the machine do routine work, while the user maintains his concentration on the outside surroundings. The most important thing is that the user never gets the feeling of loosing control of the machine. (p.55)
- The vision and mission (p.20) have, due to research and gained experience, been updated and the new editions can be seen on the adjacent page.

PREVIOUS VISION

~~"Our vision is to reduce complexity and increase safety of propulsion control systems on board commercial and military vessels. We aim to design for the users on the bridge, not just the machine at the stern."~~

VISION

"Our vision is to create a product that sets new standards for the way large vessels are controlled in complex manoeuvre situations".

MISSION

Design a human-centred bridge wing interface that allows the user to interact with the vessel in a more intuitive and safer manner.

CHAPTER 3.

IDEATION

Through this chapter it will be explained how various ideas can solve the user need described previously. Through a thorough research on different interaction technologies, sketching sessions, brain- and body storming, concepts was developed and assessed, by participating in pin-up presentations. A third fieldtrip was also conducted to confirm that the final concept was viable with real users in a maritime context.

PRESENTING USER NEEDS

Primary attendees
Dennis Jensen - Master student, Aalborg University
René B. Wellejus - Master student, Aalborg University
Kaare Eriksen - Associate professor, Aalborg University
Finn Schou - Teaching associate professor, Aalborg University
Marianne Stokholm – Professor, Aalborg University
MSc. 4 Industrial Design students – Aalborg University

Location:
Aalborg University, Aalborg
4.3.2013

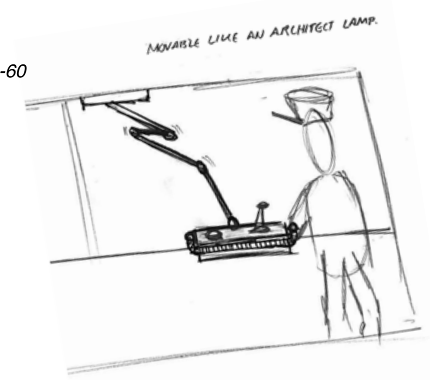
Objective:
To introduce the initial research material including the problem and today's current solution designed by MAN, while focusing on communicating effectively about the complex context. An additional objective was to get some feedback on the design teams approach to the project.

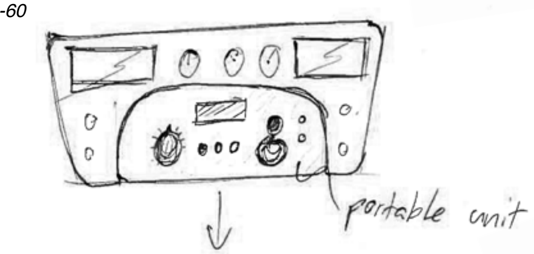
RESUME

The presentation consisted of a slide-show, which was on a very basic communication level so that anyone could understand the observed needs without having in-depth knowledge about maritime navigation.
After the presentation, it was clear to everyone attending what the project was about and the design team responded to any questions and comments that were raised by the attendees. One of the interesting comments was due to the fact that the design team had mentioned that the vision was to create a new market standard within the PCS industry. The attendees embraced this idea and the team was advised to de-prioritize the rules and legislations to avoid any constraints during the process. This would offer a higher level of innovation and help create an interesting product for an otherwise quite and conservative industry. Another comment was to keep the user-oriented focus and to figure out what added values the new product could offer the end-user.

OUTPUT

Many great comments were noted during the discussion, but much of the time was used to elaborate the context and use situation rather than gaining new inspiration to the project. The comments noted about the idea of designing a new standard for the market was however very interesting. It was therefore decided to have a more radical approach to the design, which meant that ideation and research about the future of interaction technologies had to done.

ill.1-60


ill.2-60


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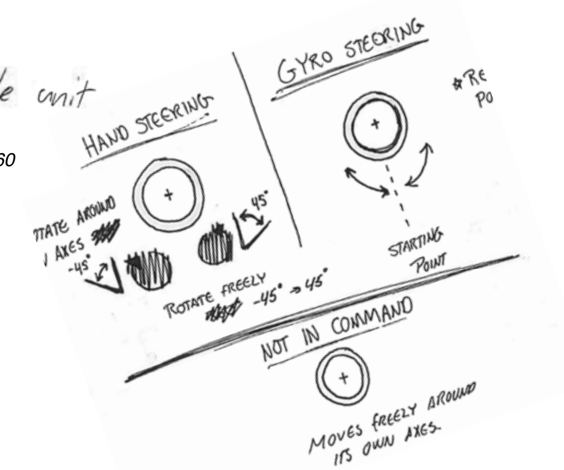
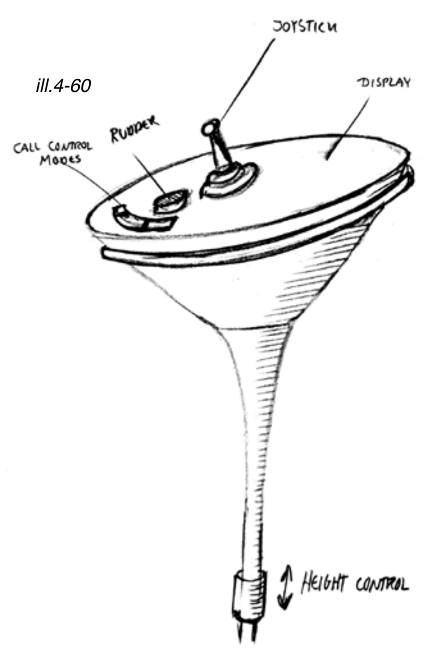
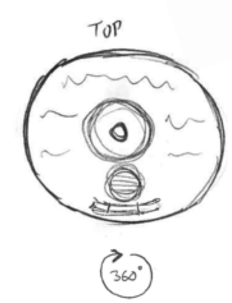
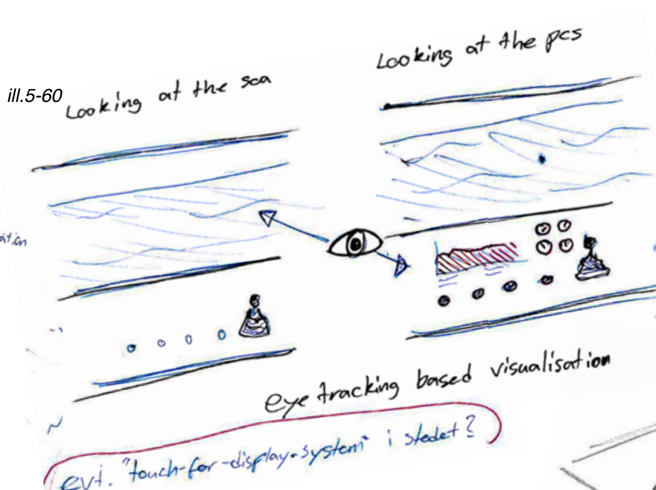
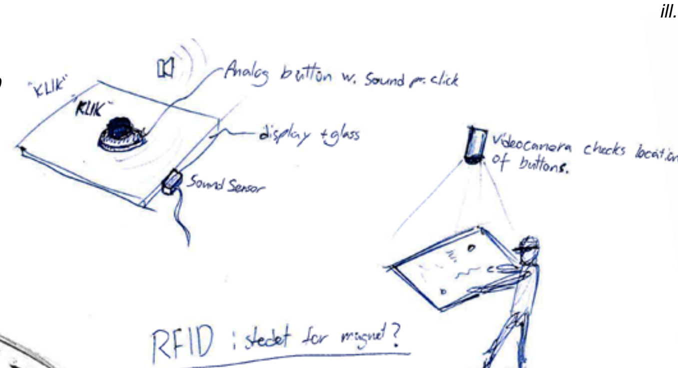


ill.4-60




ill.5-60


ill.6-60


ill.7-60

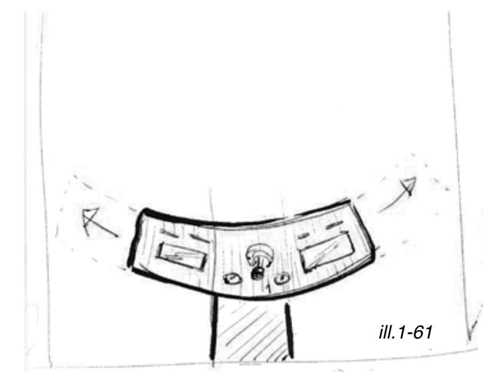

QUICK WING PANEL SKETCHING

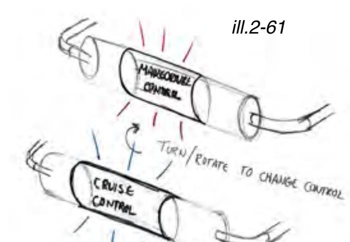
Before jumping into research about future interaction technologies, a short ideation on wing control panels were done to generate ideas before new knowledge might limit creativity.
The quick sketch session was concentrated on the bridge wing panel, because future research in interaction technology would cover more radical control methods.
The illustrations seen below are only a fraction of all the sketches made through the session. Many of the ideas were, at the beginning, concentrated on the existing panel, but some varied by introducing new ways of operating and many focused around the mobility of the user as seen on the illustrations.

Few of the ideas were chosen for further exploration, but the idea of operating a vessel with only one unit was found particularly interesting. It was therefore chosen to focus on how that idea could be transferred into a tangible concept.

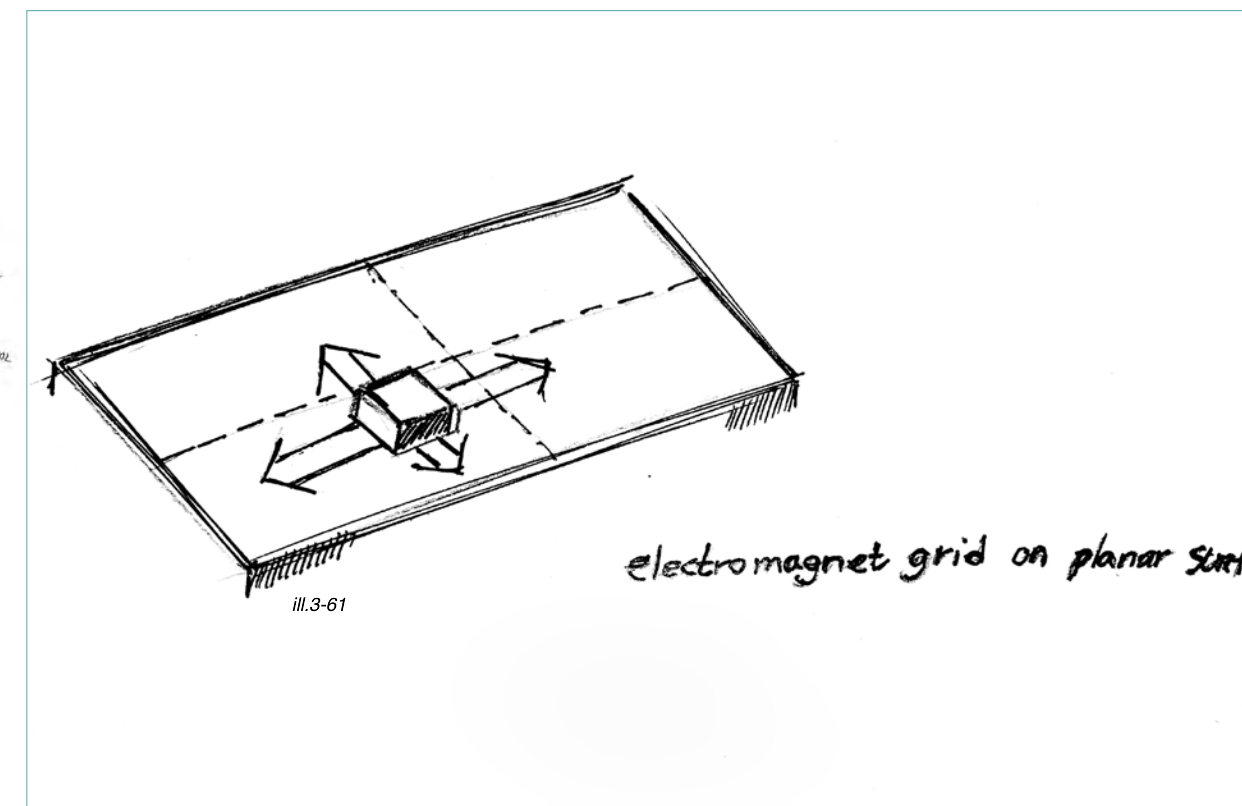
As seen on the rapid sketch in the box below, the idea consisted of a single unit that moves around on a surface. The X and Y movement of the unit was to imitate the vessel's movement and by rotating it, the user would control the rotation of the rudder. The idea was interesting because it allowed the user to operate with only one hand and from any angle – one of the biggest needs discovered in prior research.
The idea had potential to become something unique because of its new innovative operation of the vessel, which was why the design team later put a great deal of hours into the development of the functions, mechanics and interaction around the concept.

In the next section, the interaction technology will be explained in combination with the idea, which in the end lead to the first concept of the project (See p.63)


ill.1-61



ill.2-61



ill.3-61

ill.4-61

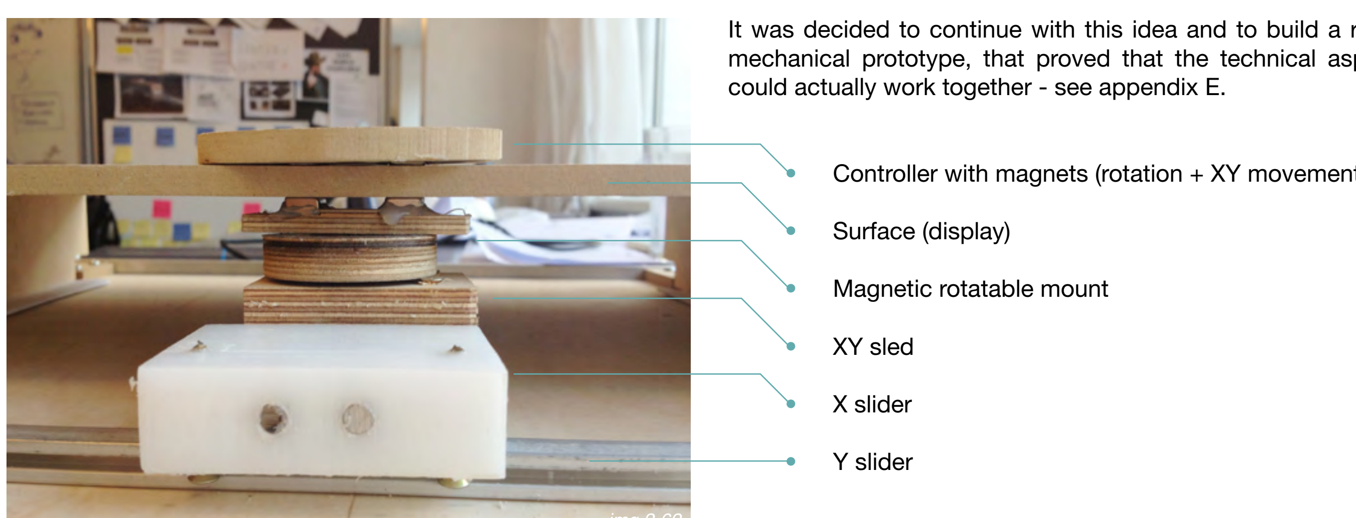

SELECTED INTERACTION TECH.

Today many forms of interaction technologies exist in various products and industries - see appendix D. As seen in the appendix, the design team explored a wide range of new and upcoming technologies and gained great inspiration in the idea of combining the features of some of these technologies.

With the described idea from the previous page in mind, it was clear that it was important for the user to feel tactile feedback when moving the controller on he platform. This prevents the user from breaking his concentration by looking away from the context in high-risk situations.
A solution with a physical object moving on a plane do however not provide the visual feedback that the user uses today to get the right orientation of the vessel.

These issues made the team focus on how the moving controller could move on a display to combine the best of both worlds. The idea sounded simple, but the challenge was the fact that the system should be able to be automated. By enabling the system to move the controller, it would be possible to create an "electric shaft" that synchronize all MCS' on the bridge, thereby reducing many unwanted steps in the operation procedure.

img.1-62



img.2-62

COMBINING TECHNOLOGIES

To make the wanted functionality possible, several technologies had to be combined to form the mechanical concept of the controller. It was decided to aim for a mix of the features found in the following technologies.

Digital display
Today it seems like every device have a screen or even a touch-enabled screen. Touch screens allow for an infinitely more flexible user interface (UI) than regular screens with hard buttons, because functionality is determined by software rather than hardware.
Touch screens are exceptionally good at many things, but in a context where the eyes of the crew should be focused on the horizon more than the instruments, there are strong limitations because of the lacking tactility. This technology must therefore be combined with other more physical controls. The touch capability could then be used for less important functions, that are not used to directly control the movement of the vessel and to display the status of the vessel.

Haptic control and feedback
The tactile and non-visual feedback that a regular joystick gives the user is well suited for the context and already in use in many modern systems. The haptic feedback allows the user to control the ship with great precision in a way that can be designed to fit the human physicality. A joystick is however not appropriate for rotation/rudder control and the physical controller must therefore integrate this function in an alternative way.

Automation
By learning from technologies known from CNC machines, the controller could synchronize across all MCS panels. Doing this, while having a display in between the automation system and the controller, is not without problems but as seen on the images (img.1-2,62) it was found possible by using strong magnets. These magnets were tested on real displays to ensure that they did not destroy or distort the pixels.

It was decided to continue with this idea and to build a rough mechanical prototype, that proved that the technical aspects could actually work together - see appendix E.

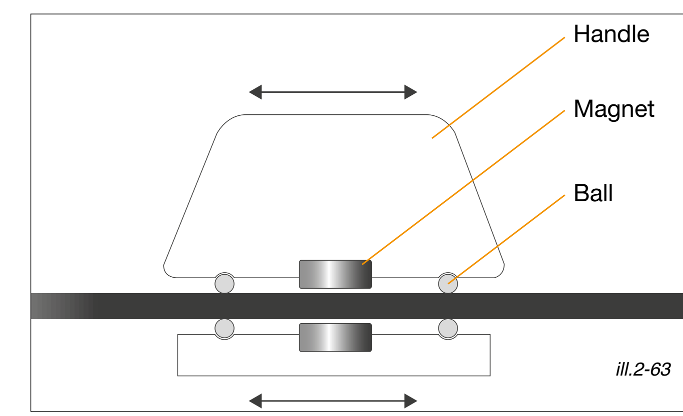
CONCEPT 1 - HAPTIC DISPLAY

ill.1-63

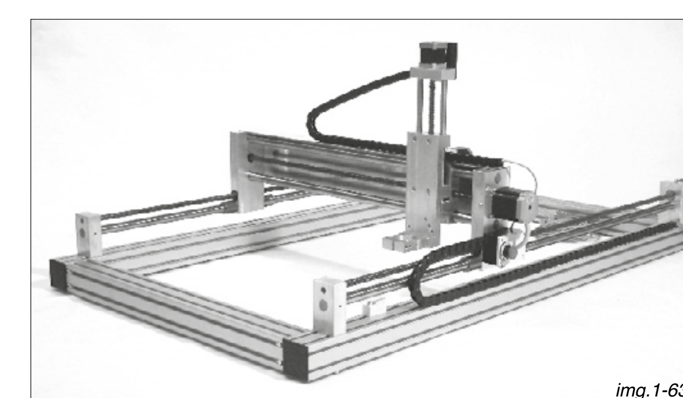
This concept makes it possible for the user to control the vessel with only one hand and thereby ensure that his other hand always has a firm grip on a handle to maintain his balance during voyage (See ill.1-63).
The idea is to add the current rudder with the joystick in a single unit and place that controller on a LED-screen located in a panel. The controller is attached with neodymium magnets as shown on the illustration (See ill.2-63), which now makes it possible for the controller to stick to the LED-screen and output a X Y coordinate.

Below the screen and panel a mechanical system (See img.1-63) is installed to follow the magnet moving on the topside, and it sends this output by sensors attached to a XY-table as known from CNC machinery. The output will be interpreted visually on the LED-screen, thereby showing the user how much power and in which direction the vessel is moving.

When command is not at the wing panel, the XY table moves the controller according to the commands from the active center panel, making it unnecessary to do any manual synchronization.



ill.2-63



img.1-63

PRESENTING THE CONCEPT

Primary attendees
Dennis Jensen - Master student, Aalborg University
René B. Wellejus - Master student, Aalborg University
Kaare Eriksen - Associate professor, Aalborg University
Finn Schou - Teaching associate professor, Aalborg University
Christian Tollestrup - Associate professor, Aalborg University
MSc. 4 Industrial Design students – Aalborg University

Location:
Aalborg University, Aalborg - 4.4.2013

Objective:
The primary objective was to present and get some feedback on concept 1. The secondary objective was to get comments about the process so far.

RESUME

The presentation consisted of a slide-show and a physical model describing how the mechanics of concept 1 could work. The whole presentation went well but the content was a bit misleading because of some missing research points, which was deliberately skipped to free time to explain and demonstrate the concept and get feedback on the idea. Instead the opposite happened and the comments and questions were mostly about why the team did not use technology like Google glasses and alike – all technologies that the team already had god reasons not to follow.

One of the comments was to take at step back in the design process and elaborate the design and look into the interaction again.

Another comment was to make the product as logic as possible in its way of use and furthermore let it be a visionary future product for the industry instead of a product that could be implemented as a panel in on a regular bridge today.

OUTPUT

After the presentation had ended it was decided by the team to take a step back in the process and start generating more concepts by exploring the researched interaction technologies one more time while thinking in a longer perspective. Also it was noted that the project had entered a stage where concrete feedback on concepts could only be gained from the team's supervisor or real users that have a more in-depth knowledge about the contexts than the audience at the midterm seminar. Explaining the complex context and product to people unfamiliar with the maritime context simply took up too much time of the pitch and left little room for useful feedback on ideas.
Discovering just how hard it was to explain the project showed the team that communication might be one of the big challenges of a project like this.

NEW CONCEPTS

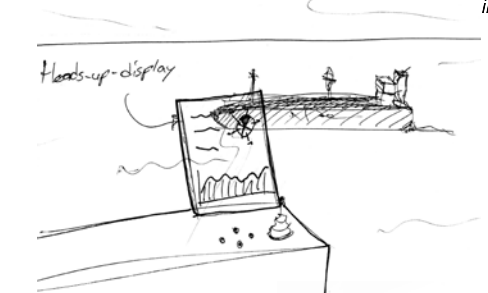
The researched interaction technologies (See appendix D) was explored and elaborated one more time. During this process, new approaches to the technologies were listed and these were later used as the base of a new sketching session. As seen on the illustrations below, new interaction technologies were thought into new more visionary ways to operate the vessel, such as head-up displays (HUD) and local drone-steering of the vessel.
The HUD is known from aviation and could open up new possibilities in the maritime industry. Now the user could look at a screen/window full of information while maintaining his concentration on the outside horizon. But HUD has a lot of disadvantages (see list below), which was why this idea was put aside.

- An area of the window will be dedicated to the HUD, making it as fixed as a regular display.
- HUD requires laser projection to cope with the light from the sun, but this type of projection have a limited colour range and level of detail, since everything must be drawn by a single laser beam. This would make some information, like maps unsuited for display on the windows.
- Reflections from light and daylight can overpower even the light of a powerful laser projector
- Works primarily on matte or tinted glass, which is not optimal for use in night operations where the crew is on the lookout for objects in low light conditions.

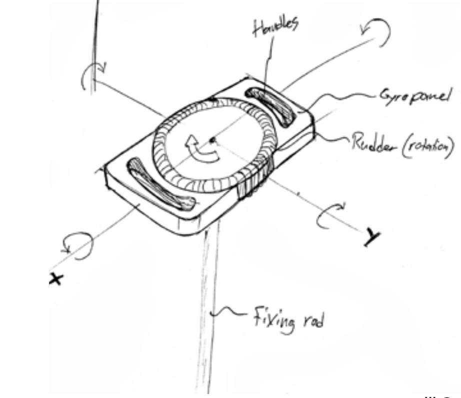
The idea of controlling the vessel with what the team has named "local-drone-steering", came from looking at the many new possibilities that drone technology have created and then give these abilities to the crew on board the vessel. These features could include a 360-camera view of the ship, night vision, infrared vision and much more. All these new signals would not be sent to a remote controller like the drones we know today, but directly to the bridge crew (See ill.4-65). The captain would not manoeuvre the vessel by looking out of the window, but by accessing the many camera views. This could empower the crew and let them take use of many new technologies available. This idea would turn out to be the second concept of the project.

A third idea was to control the vessel by tilting a controller (See ill.2-65). If the user wanted the vessel to go in any specific direction, tilting the controller in that direction would do it, and by rotating it the rudder would turn as well. This idea would turn out to be the third concept of the project.

Other ideas that did not make it to be concepts themselves were focused on a flexible use that let the user stand in any location and still have a ergonomically good position to the controller. This feature was to be implemented on both new concepts.

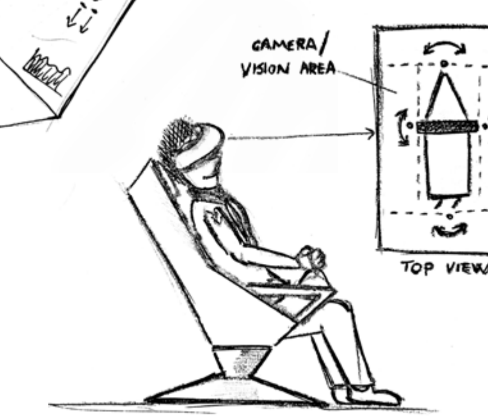


ill.1-65

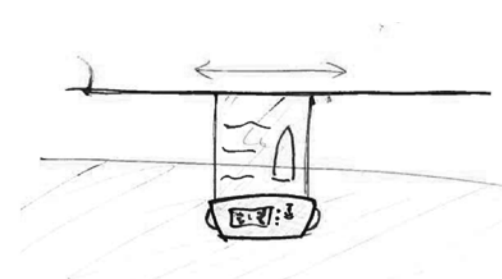


ill.2-65

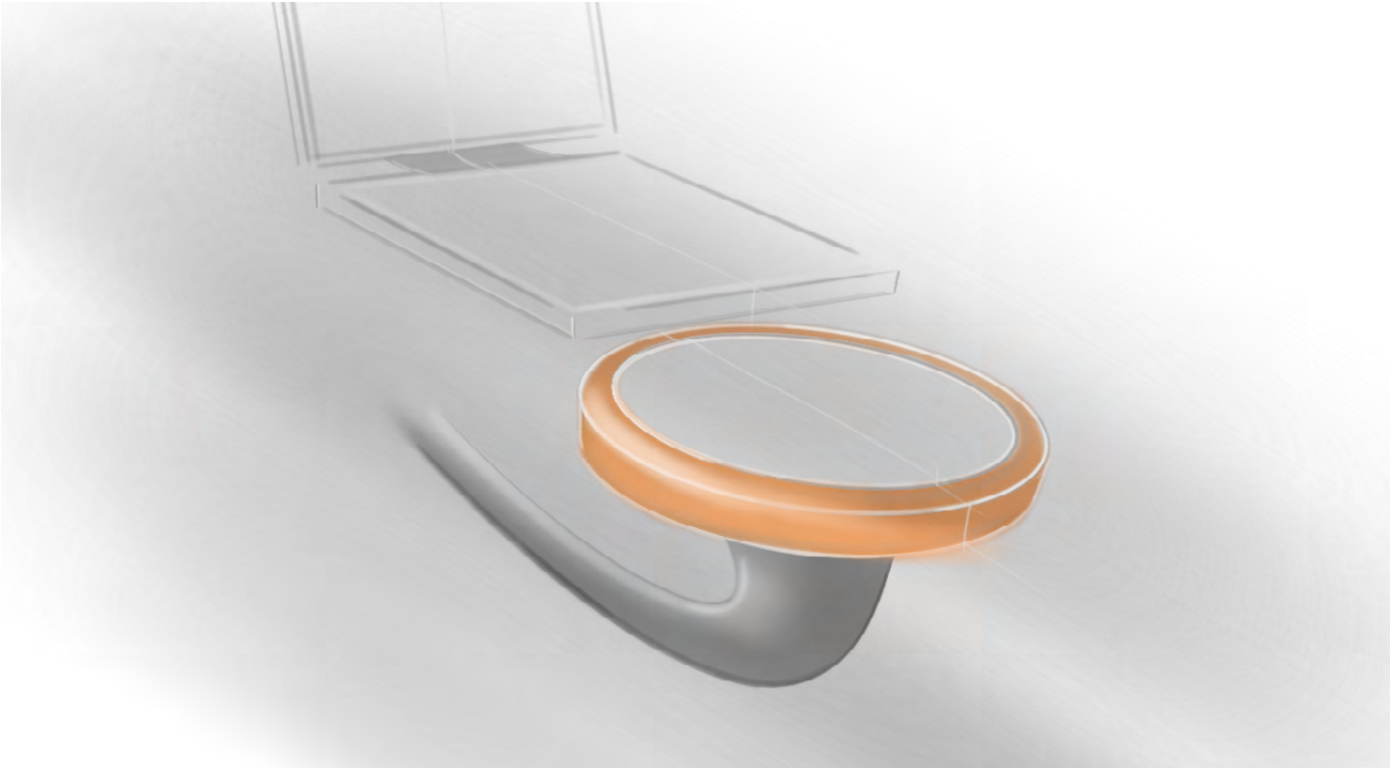
ill.3-65



ill.4-65


ill.5-65

CONCEPT 2 - TILT MOTION CONTROL



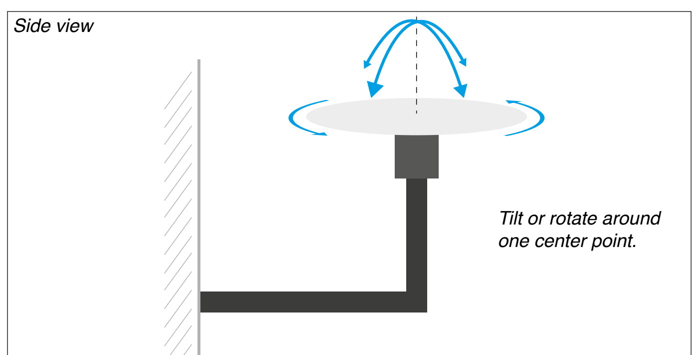
ill.1-66

This concept makes it possible for the user to maintain his vision and concentration on the horizon (See ill.1-66). The concept allows for both power and rotation control from all directions. The user steers the vessel with a circular motion controller, that is fixed in its center that allows it to tilt in all axes. The direction of the tilt determines what direction the ship moves by automatically combining main propellers, rudders and thrusters in an effective manner. The angle of the tilt regulates how much power the ship should use to go in the direction (See ill.2-66).

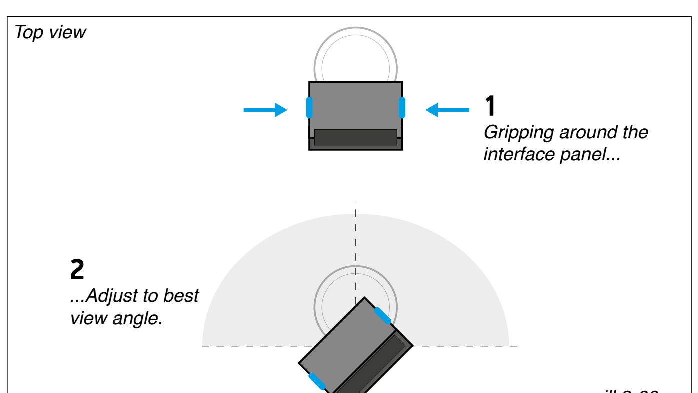
Beside the tilting function it is also capable of rotating, thereby controlling the rudder of the ship. To avoid rotation while tilting or the opposite, a safety function have been integrated in the controller allowing only one function at a time being active.

Above the motion controller a separate panel is located showing the interface, which consist of buttons to switch mode, a display showing engine and propeller outputs and a touch screen showing a radar- and GPS map.

By griping around the interface panel it loosens it's position (See ill.3-66) and is now able to rotate 180 degrees, enabling the user to have the screen positioned in the angle best suited for a particular situation. By dividing the interface panel from the motion controller, the total footprint of the wing "panel" have been reduced, making it possible to be located further out on the wing where the viewing angles are optimal for the captain.



ill.2-66



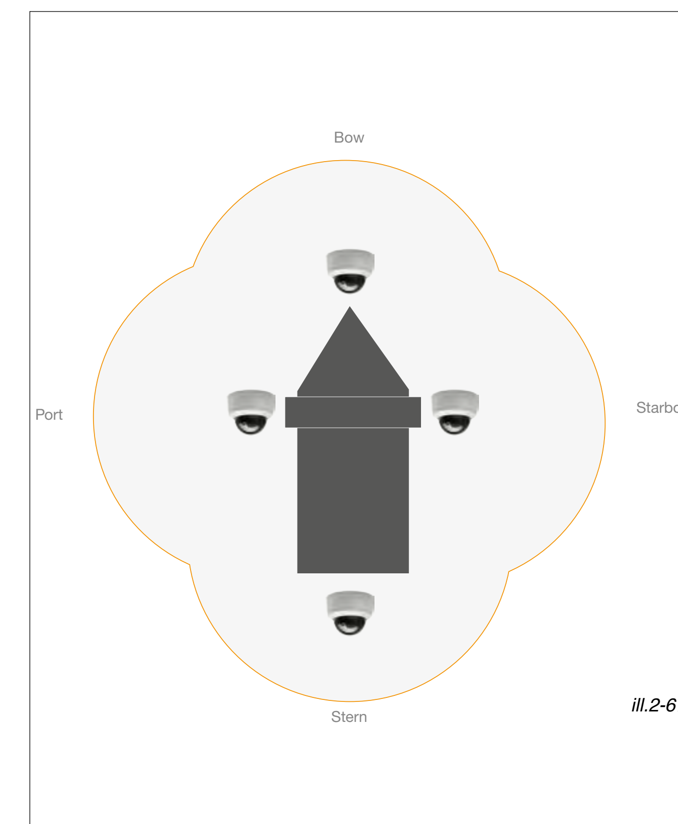
ill.3-66

CONCEPT 3 - DIGITAL SENSES

ill.1-67

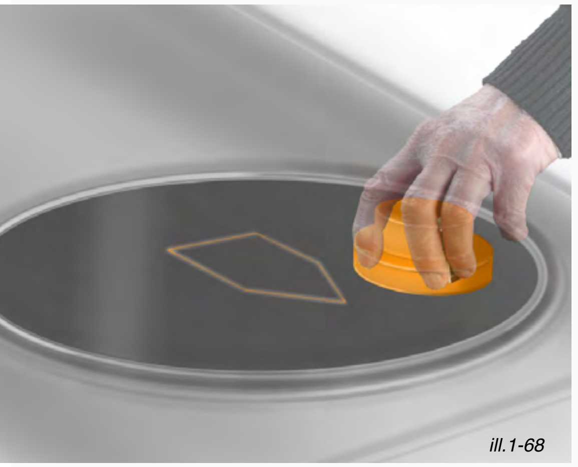
This concept differentiates itself by implementing a series of new technologies to steer and monitor a vessel. By wearing glasses similar to virtual reality glasses (See ill.1-67), the user's vision changes from his own, out to different camera views placed in multiple positions on the vessel (See ill.2-67). By using this concept the user can change in between the different camera views to manoeuvre and always make sure that the vessel is moving in the right direction without crashing anything. He will in other words never have a blind spot, and advanced camera technology could assist further in low-light conditions and alike.

The concept would include a command chair that would give the user access to all required controls, but all of these must be completely independent of visuals, since the eyes of the user are occupied by the glasses.
The interface in form of controlling units such as rudder, joystick etc. are located on the armrests, which makes it possible for the user to sit down and relax while steering the vessel. With this concept, a one-hand steering mechanism is not necessary since the captain is placed in a seat and therefore do not have to worry about his balance.



ill.2-67

KILLING SECTION



ill.1-68

This concept has a lot of unsolved questions. Just the fact that the user now should steer the vessel with only one hand by moving a single object is something that needs to be tested in a real context and presented and discussed with the users. Also the fact that the top part is connected with magnets might results in dangerous situations if the controller can be misplaced or taken of all together. The magnet adds another problem - friction, which makes it harder for the user to move the part around and might result in more wear on the display.
By doing another iteration to fix the magnet- and misplacement problems, the concept developed into a controller fixed to the screen surface, which then could move underneath the main panel. This corrected the main problems but it created new challenges that worked against the original goal of the concept.
The general idea for this concept is very interesting, but due to the high risk-context and a long list of unsolved mechanical problems, the concept was put on hold.

- ✓ One hand steering.
- ✓ Simple user interface (Top view).
- ✓ Clear visual feedback on LED-screen.
- ✓ Easy to customize via software rather than hardware.
- × The controller can be tarred of and misplaced.
- × Advanced mechanics below the LED-screen.
- × Mechanical locks occur in the XY table for some movements (See appendix E)

ill.2-68

This concept needs to be tested in a real context so any inconveniences can be discovered and then solved through another iteration. By making the controller uniform in its form it has no orientation, which is very desirable, but there might be problems with the rotation of the display when steering from multiple positions. The concept still has some challenges regarding the safety locks and how the mechanics should work when all functions are put into a single product. That is why the concept went through another iteration and thereby clarified, that all functions could be accommodated in the relatively small controller. It was decided that the controller should only be able to tilt if a safety mechanism is pressed. The same safety should lock for the rotation while using the tilt function. High potential was seen in this concept and even though it contains advanced mechanics, the major challenges seemed solvable within the time frame of the project.

- ✓ Keep vision and concentration on the horizon.
- ✓ Highly flexible orientation.
- ✓ Can be made to be durable and reliable.
- ✓ Potential to create an ergonomically good working position.
- × Highly advanced mechanics.
- × Balance might be a problem - must be tested.
- × Tilt-control might not be optimal for use on a moving vessels

ill.3-68

This concept is highly dependent on new technology to steer the vessel in a very different way than today. As discussed in the team, future vessels will be more and more automated, and before we know it, drone ferries and cargo ships will sail the oceans. This concept could be a step in that direction, but it intrudes a whole series of challenges that requires a vast amount of time, expertise and resources that the team did not have at this late stage of the project.

Beside these factors, the idea is very interesting. If a vessel can be controlled virtually by a person on board, it can also be controlled remotely. With a pair of glasses and a command chair the ship could be controlled from mainland and the shipping company could have a relatively small crew for a large fleet of modern vessels. This could revolutionize the whole industry and potentially also turn the work of a captain into a nine to five job, where the crew could go home to their families every day. Changing maritime jobs like this could solve the growing problems of getting qualified crew members as mentioned on page 16.

- ✓ Technology that empowers the user.
- ✓ Enables new types of ship design.
- ✓ Might be a step in the direction of solving manning future problems.
- × High risk of seasickness in views where the motion of the ship does not fit with what the user sees on in the glasses.
- × Difficult to test and create prototypes of the concept.
- × High cost of the system and high reliability on electronics.
- × A traditional bridge is still needed for redundancy.

OUTPUT

The three concepts all have a potential of becoming the next control unit for the maritime industry. Concept 1 has an advantage because it only requires one hand to steer the vessel, but it's mechanical challenges and safety issues caused it to be put on hold. Concept 3 is a completely different concept containing a new approach to technology and a new way of orientation for the user. The idea was quite interesting but because of the many uncertainties surrounding the concept and the limitations for prototyping and testing, this concept was put aside.
Concept 2 has very high potential because of the interaction between the user and machine. It is a new way to steer a vessel, but it does not alienate itself from the user, because of its easy perception and high level of usability. This concept were chosen to be validated in a real context and presented to real users, thereby proving that the concept could work while getting valuable feedback and pass it on into the concept refinement.

FIELDTRIP 3.0


img.1-70


img.2-70


img.3-70


img.4-70

Primary attendees
Dennis Jensen - Master student, Aalborg University
René B. Wellejus - Master student, Aalborg University
Anders Andersen – Principal, Skagen shipping academy
Teaching staff – Skagen shipping academy
Last semester students – Skagen shipping academy
Klavs Toxen Worm - Captain, Læsø Ferry

Location:
Skagen shipping academy, Skagen
17.4.2013 (morning)

Margrethe Læsø Ferry, Frederikshavn / Læsø
17.4.2013 (afternoon)

Objective:
The objective was to present and test the chosen concept to both highly experienced and less experienced users, by showing them a rapid prototype model of the concept. This was a critical step in the process and many unanswered questions about the functionality were to be answered. This was also a field trip that would show if the team had gone in the right direction or if a backtracking in the process was needed.

RESUME

To get a new and different perspective on the project and the chosen concept, Skagen shipping academy were visited. This is where future navigators get their education and license to operate a ship. The team wanted to utilize the fact that non of the students had extensive experience at sea and therefore were very open minded towards new ways of doing things. The teaching staff were all very experienced mariners and they were able to reflect the concept on to real use cases which were highly valued.

After entering the building, the principal Anders Andersen, presented one of the schools new bridge simulator that the students use to train for operation of a wide range of vessels and scenarios. The simulator was demonstrated and it was noted that the layout of the center bridge followed a standard that many new vessels apparently will use in their design. As with all other simulators, there were no wing panels and when the students wanted to go to the wing for a better view, it was simply a matter of changing the graphics on the displays. No physical movement was required and all instruments were still available, unlike on real ships where a much more limited wing-panel must be used. According to Anders Andersen, it would not be hard for a school to teach the use of a new wing-panel. Because there is no wing panels build directly in to the simulator, changing the system would be done simply by plugging it in as an add-on. This is already done today for Azipod systems.

After the demonstration of the simulator, Anders Andersen invited his graduate class to view the concept presentation and to come with their feedback and ideas in relation to the project. After a brief presentation of the basic idea and the rough prototype, a lot of positive feedback was given and many of the worries that the team had were resolved. The attendees were positive about the interaction form and balance were not seen as an issue, because the effects of the sea is much more subtle when a ship is near land. If the product were to be used on open sea, a small seat or stool could however be necessary for operation over long periods of time. This could be an add-on for vessels that manoeuvre near offshore windmills, oil-rigs or alike.
The overall response to the concept was very positive and the team were surprised to see how quickly the students and teachers understood the idea.

Leaving the shipping academy in Skagen with a positive gut feeling and pages of feedback on the concept, the team now went to present the idea to the crew of the Læsø ferry.
When on-board the Læsø Ferry's bridge the prototype was presented and explained while it being placed in the correct location on the wing. The Captain easily understood the purpose of the controller and was in general very positive to the idea and the product. The Captain helped improving the concept by telling which important functions he needed near each other. One of his concerns about the concept was the "take-command" feature and how that would work when the user leaves the wing and takes command on another panel. As noted, the ship cannot be "out of command" at any time and the new interface must therefore deactivate automatically when command is taken on other panels.
He also explained the work procedure one more time on a detail level, ensuring that everything about manoeuvring the vessel was understood correctly.

OUTPUT

Bringing only one concept was a bit of a gamble since a negative reception could have led to severe step backs for the project. But by going with the idea that the team had most belief in ended up freeing time to go in depth with details together with the users – gaining valuable feedback that was very much needed for the further refinement.
The concept and prototype was not as alien to the users as expected and the interest for the project was high because the participants could easily recognise the problems the team tried to solve. A lot of input and feedback was gained from the fieldtrip, and to get a clear overview it was decided to generate a list of needed improvements for the concept.
Due to the short amount of time remaining in the project at this stage, it was decided only to go in to details with the motion controller and to keep the rest of the product on a conceptual level.
An important insight noted while talking to Anders Andersen, was that it is not common to replace control instruments on an existing vessel and that it would be an idea to focus only on new-builds. According to the principal a vast majority of the vessels that will leave ship yards in a near future will have a clear need to do advanced manoeuvring. He therefore found the project to be highly relevant to the industry and was glad to see that someone was working with new alternatives to the conservative products that are used today.

SUMMARY IDEATION

- The design team decided to take a more radical approach when designing the product. This was done to make sure that the product would differentiate itself from the competitors. (p.60)
- The team experienced a big challenge in explaining the project to an audience with no knowledge or experience within the maritime industry. Communication was however very succesfull with audience familiar with the context. (p.64)
- After presenting the concept in front of an audience, the process took a step back to iterate new concept by examine the interaction technologies once more. This lead to two more concepts. (p.65)
- By researching future interaction technologies the team decided to combine several features to obtain a more innovative concept. This resulted in a concept, which could be operated with only one hand. (p.63)
- The three concepts was compared to each other and by listing pros and cons the choice landed on concept 2. The concept had a high usability and were easy to understand.
- Concept 2 was decided to test in a real user context so the team could get some feedback, from experienced users, to pass on to the concept refinement chapter. (p.69)
- A great amount of feedback was acquired and transferred into a "list of improvements", which can be seen to the right.

LIST OF IMPROVEMENTS:

The top screen should be around 15 inches big.

All functions that relate to the control of motion should be on the motion controller – functions the change settings for the controller should be on the control panel.

The motion controller must have a static plane that can act as a reference and show how the controller is tilted.

There must be safety features to ensure that the rudder can be adjusted without risk of tilting the controller by accident.

Detailed mechanics.

Safety and feedback in form of sound to support the physical adjustments in a non-visual way.

The display could have a "guide-mode" that show a detailed view of how the controller is affected. This could decrease the time needed for a student to become sufficiently experienced to do advanced manoeuvres.

Combining the concept with dynamic positioning technology could make it easier to do manoeuvres. This way rotation of the controller would simply decide the rotation of the ship; thereby remove the need to control the rudder directly.

Micro-adjustment of power and rotation is only needed in the stages before in-harbour manoeuvres.

The controller should be smaller than the one represented in the model (less than Ø40cm)

CHAPTER 4.

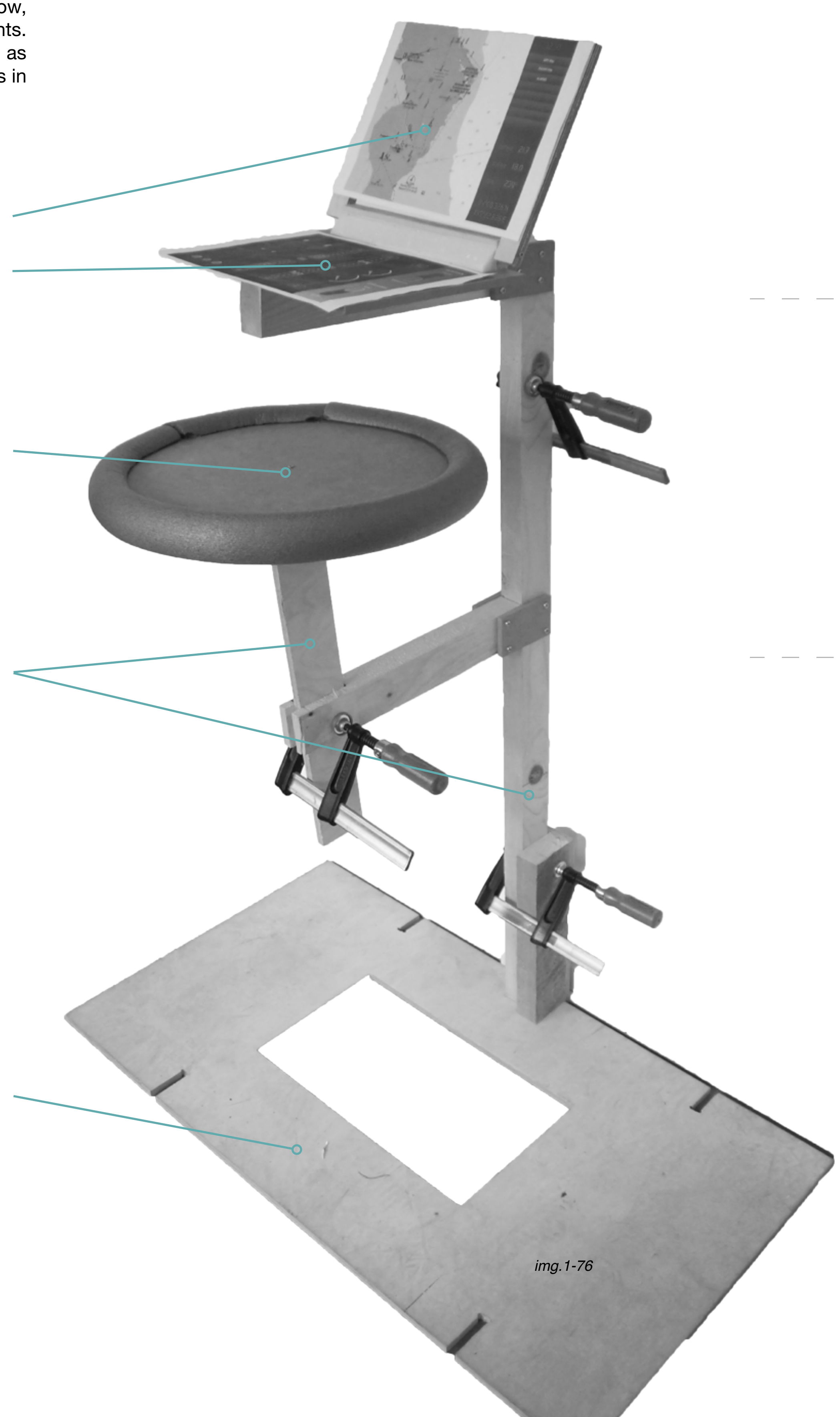
CONCEPT REFINEMENT

This chapter develops and refines the idea into a more realistic concept by developing the mechanics, interface, feedback etc. The refinement also exposes challenges that will have to be further detailed before the concept can be argued to be viable.

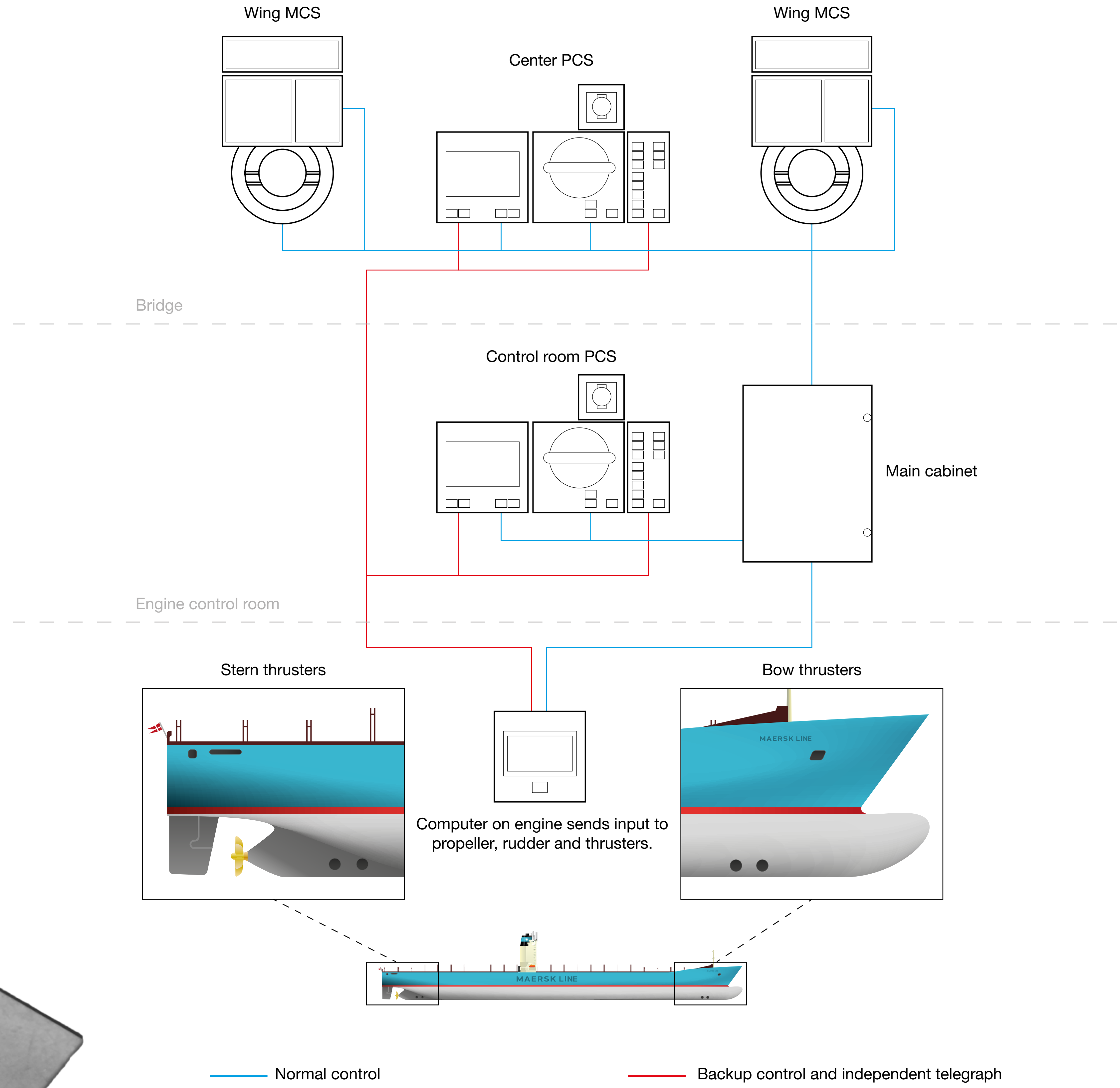
Additionally, this chapter will give the reader an understanding of how the product's composition and aesthetics will be appealing to the user and the context that it will be placed in.

CONCEPT OVERVIEW

To avoid any confusion when reading this chapter, an overview of the product elements have been made. This chapter will describe one product element at a time as seen on the image below, together with details that relates to the design of these elements. Also the product has been put into a system architecture, as seen on the adjacent page, showing how the controller works in relation to the propulsion systems on board.



img.1-76

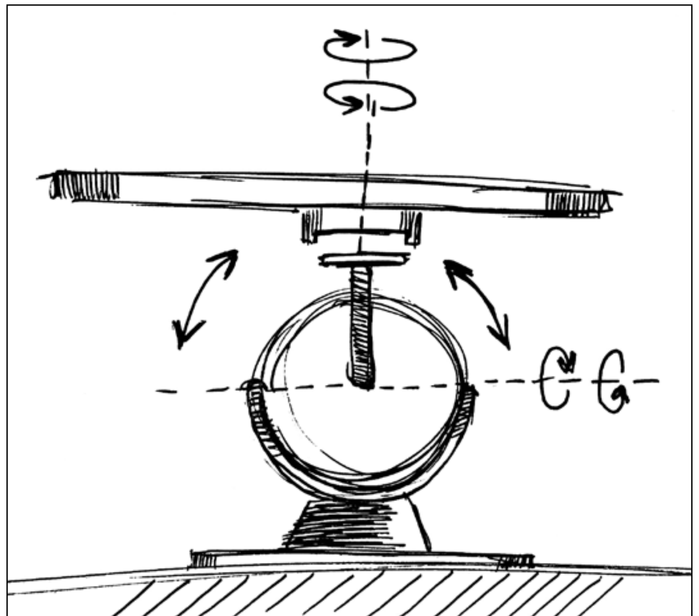


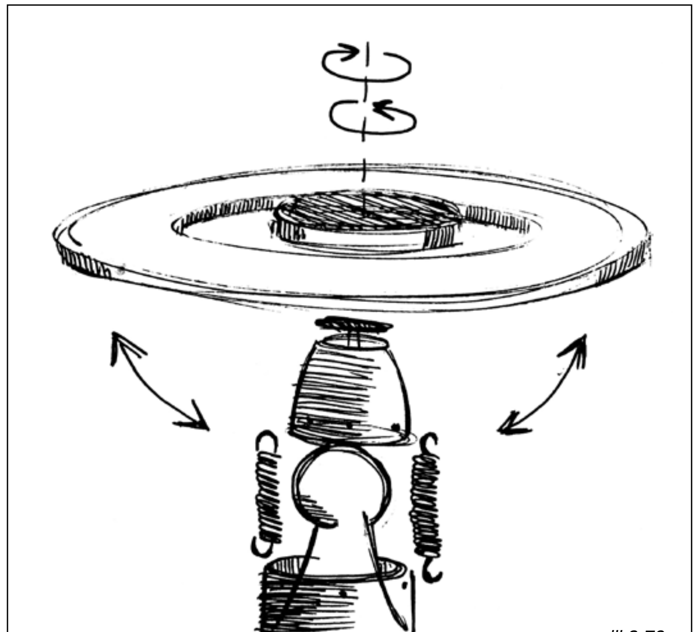
ill.1-77

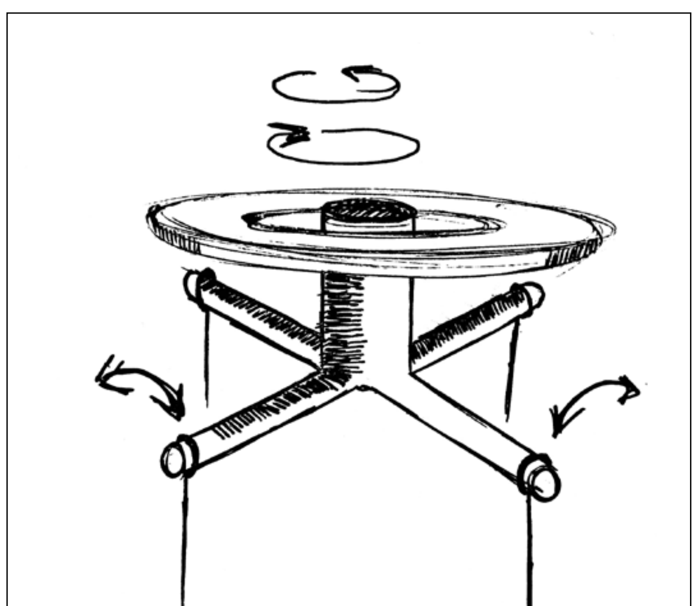
MECHANICAL PRINCIPLE

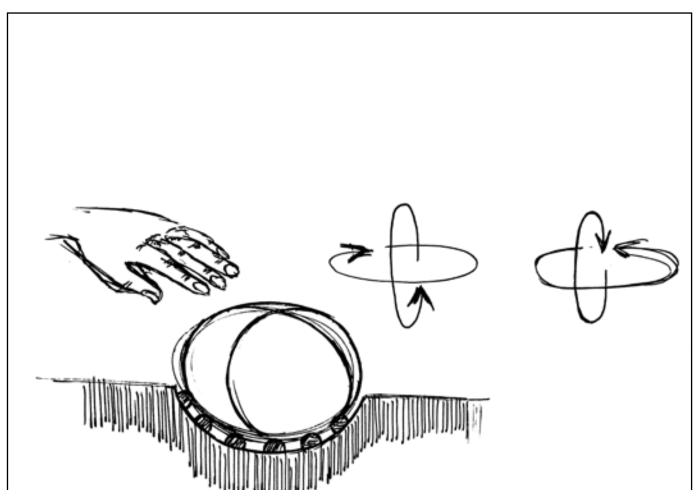
With only one concept in mind it was decided to focus on how the mechanics could be solved. Many suggestions were made, but only few could facilitate both user input and the system automation that is critical for the enablement of an electrical-shaft system as described earlier.

To do so, stepping motors had to be incorporated into the mechanics, and doing so narrowed the mechanical concept down to one interesting idea, as seen on the adjacent page.


ill.1-78


ill.2-78

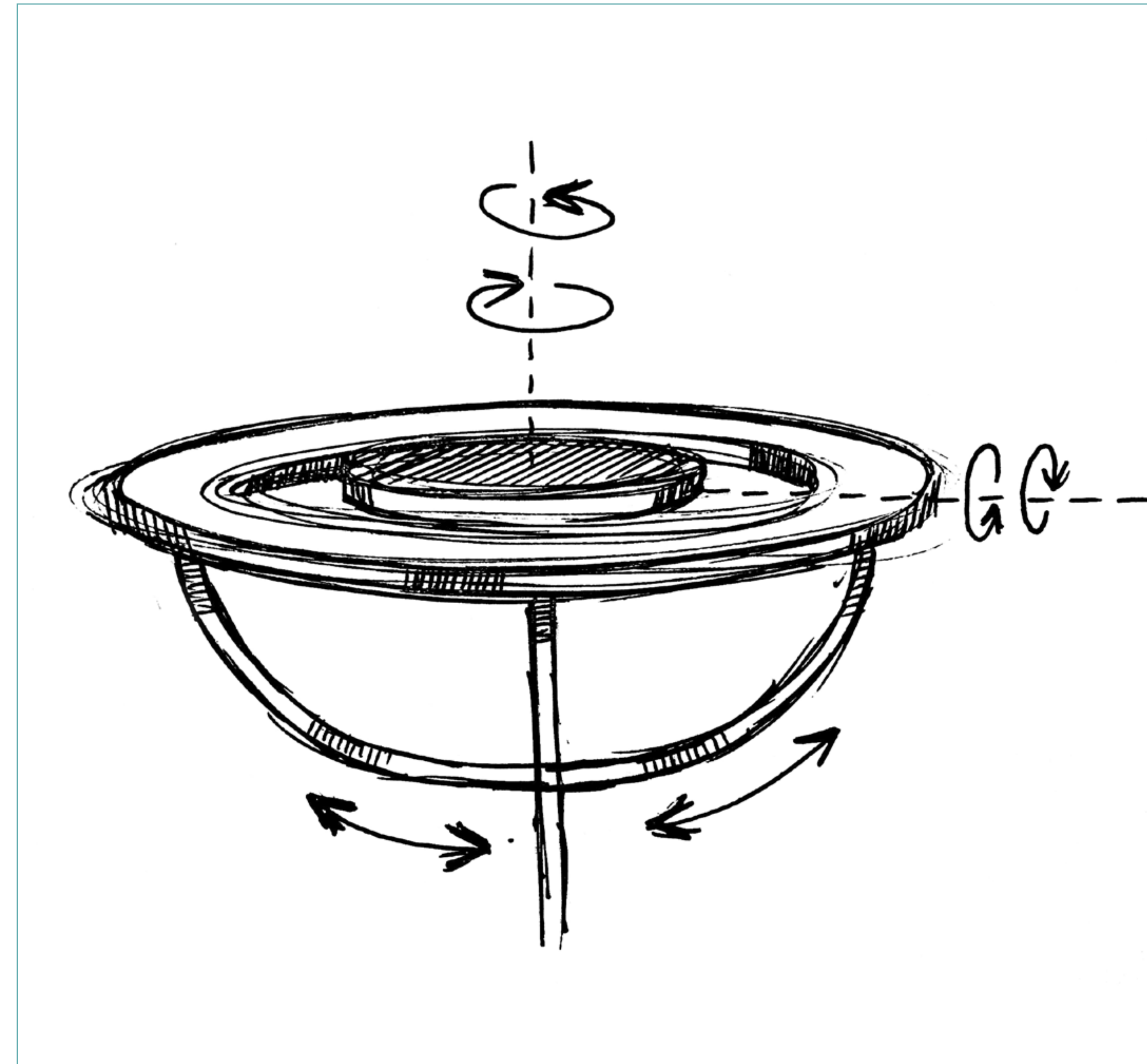

ill.3-78


ill.4-78

As seen on the illustration below, the mechanical concept consists of a fixed center plate with an outer ring, which can be rotated around the center's vertical axis and tilted. By attaching the outer ring to a circular pipe, the tilting motion on the first axis is translated down and away from the static center plate. The tilt motion of the other axis is enabled due to rotation in the brackets that attach the circular pipe to the outer ring.

By having two stepper motors driving each tilt axis movement of the controller can be made by the system. Movement made by the user can only happen when the motors are turned off and they could act as sensors in this stage. Additional sensors should be mounted for redundancy and additional measurements. Rotation of the outer ring would give an input for the system, but it would not have to be automated because its state is not indicated physically, but via LED's build into the ring.

This mechanical concept will be further developed throughout the process and finally described in the detailing chapter.


ill.1-79

ERGONOMICS

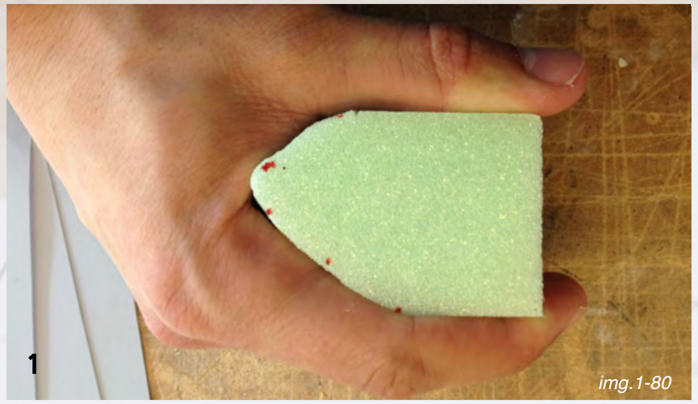
To ensure a firm grip while maintaining a high level of precision in the motion controller, ergonomic studies were done to pursue the optimal profile for the outer ring of the controller. This was of cause a highly subjective study that might be adjusted in the final product, if the user group finds other designs better suited.

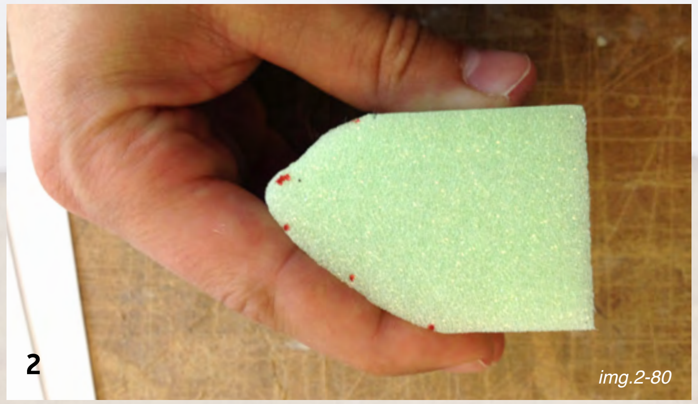
The ergonomic design takes root in observations from field trip 2 and 3, where users handled instruments in a very controlled and precise manner. Even big instruments with big grips, which could be used with more force, were handled with great care in most situations. This was a clear indication to include a mix of big and small ways of gripping the profile of the controller.
As seen on image 1, 2 and 3 a profile that allowed for diverse use was found by taking inspiration in the physical configuration of the human hand. Another way to do this is seen on picture 4 and 5 that demonstrates a design that are made specifically to allow both hand and finger gripping. Hand-grip would afford a larger and quicker movement of the controller, while the finger-grip allows for more precise movement, especially appropriate for minor adjustments in rotation.

A variation of the profile shown on picture 4 and 5 were chosen for the concept because it allowed the best level of control of all the designs tested. A combination of soft and sharp edges was implemented to give a reference contour for the fingers.

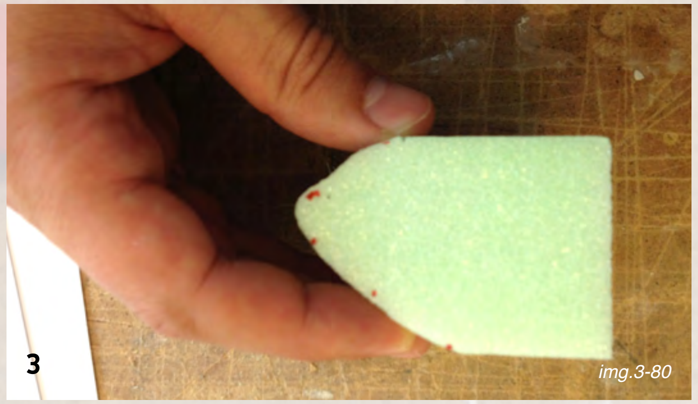
Based on other ergonomic tests with tall men (193 cm) and short women (155 cm), it was found that:

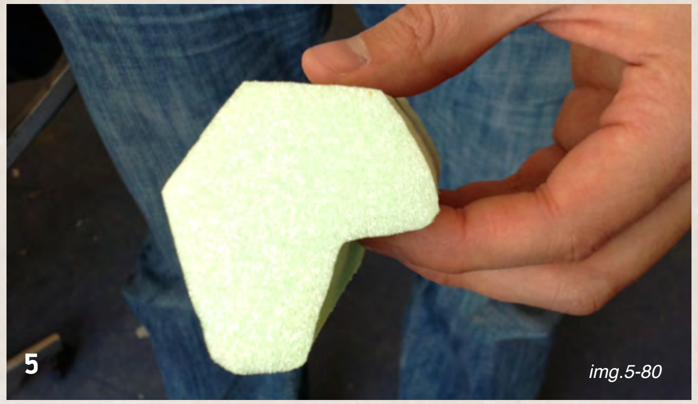
- ✓ The controller should be located in a height equal to the minimum comfortable working height of the 99 percentile man (1920 mm), which was found to be around 920 mm.
- ✓ Minimum outer diameter of the controller = 200 mm.
- ✓ Maximum outer diameter of the controller = 300 mm.
- ✓ Maximum tilt angle was assessed to be optimal between 17 and 20 degrees in all directions.

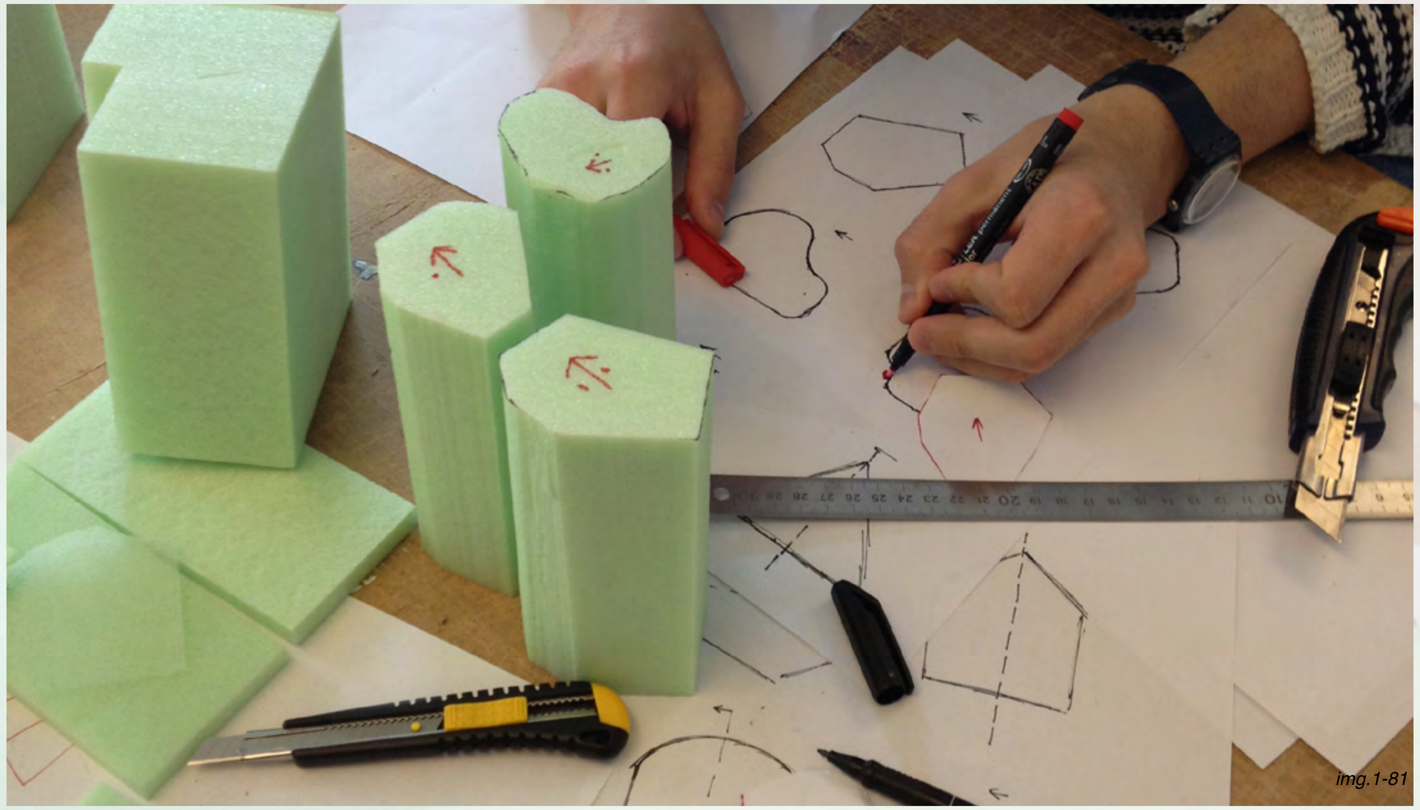

1 img.1-80


2 img.2-80


4 img.4-80


3 img.3-80


5 img.5-80


img.1-81


ill.1-81
193 cm (99 percentile man = 192 cm)


ill.1-81
173 cm (50 percentile man = 175 cm)


ill.1-81
155 cm (1 percentile man = 159 cm)

OPERATION PANEL

The operation panel consists of two units: a top unit of a LED touch-screen monitor named “Information display” and a bottom unit named “Motion-setting panel” with a physical buttons and an smaller LED monitor.
In this section it will be explained how and where the interface design can become more user friendly. First of all, the operation panel split in two to move it away from looking like a laptop computer, because the interaction expectations would be misguiding.
As seen on the illustrations below, the familiarity of a laptop was quit clear because of the size of the panels and the angles they are placed at.

ill.1-82

Ill. 1 Both units are connected to a circular rotation hinge, which add the feature to adjust the angle for the user’s perspective. The con of this form is the relation to a regular laptop is more or less unavoidable.

Ill. 2 Both units are integrated within one piece represented as a cut-out solid or a surface. This has an interesting effect because of the effect of having only one unit rather that two. The form carries a heavy weight expression, which could be too dominant in the overall expression combined with the motion controller.

Ill. 3 Both units are separate from each other and should be mounted separately with space in between them. The possibility for easy maintenance and repairs is a major advantage and custom solutions would also be simpler to do. A custom solution could e.g. be if the use of a specific vessel requires big separate screens for map or radar views or if heads up display technology were to replace the information display in the future

THE INTERFACE

The interface is a very important part of the complete user experience. Ass seen in appendix F, multiple suggestions were created and tested while conducting Fieldtrip 3. This section will explain how the chosen interface and its features works together with the user – see ill.1-83.
The layout of the “information monitor” is simple and strives to be operated as familiar as possible. It is designed to be customized, but would have default functions like alarm overview, GPS- and radar-maps. Functions like map interactivity e.g. pan and zoom would be done by finger gestures as known from smartphones and tablets. The sidebar contains a menu where the user can change the content displayed together with basic information from the ships GPS.
The layout of the “motion setting panel” is divided into two areas: one square area for display, and to the side of it, an area with physical buttons that operate the setting of the controller.

FEATURES OF THE MOTION-SETTINGS PANEL

- **Take command (Cruise or Manoeuvre):** When preparing for docking the user takes command by moving the physical slider button to the wanted control-mode and then rotate the knob 90 degrees. When another mode is more appropriate, the slider is simple shifted. When command is taken on another panel, the knob will rotate back to its origin. The slider will remain in the position that was last used.

- **Thruster start:** There are three physical buttons located on the display of the motion-setting panel, each controlling one thruster. The numbers varies depending on the vessel’s size and number of thrusters. These buttons allows the user to adjust the amount of power available to the sideways movement of the ship, by turning thrusters on or off.

- **Turning radius:** This feature is a wheel rotating around a horizontal axis that regulates the turning radius of the vessel. By having this feature, it is possible to adjust how quickly the system should react on adjustments made to its rotation. The function reacts only when in cruise mode – in manoeuvre mode actions are executed with no delay or power reduction.

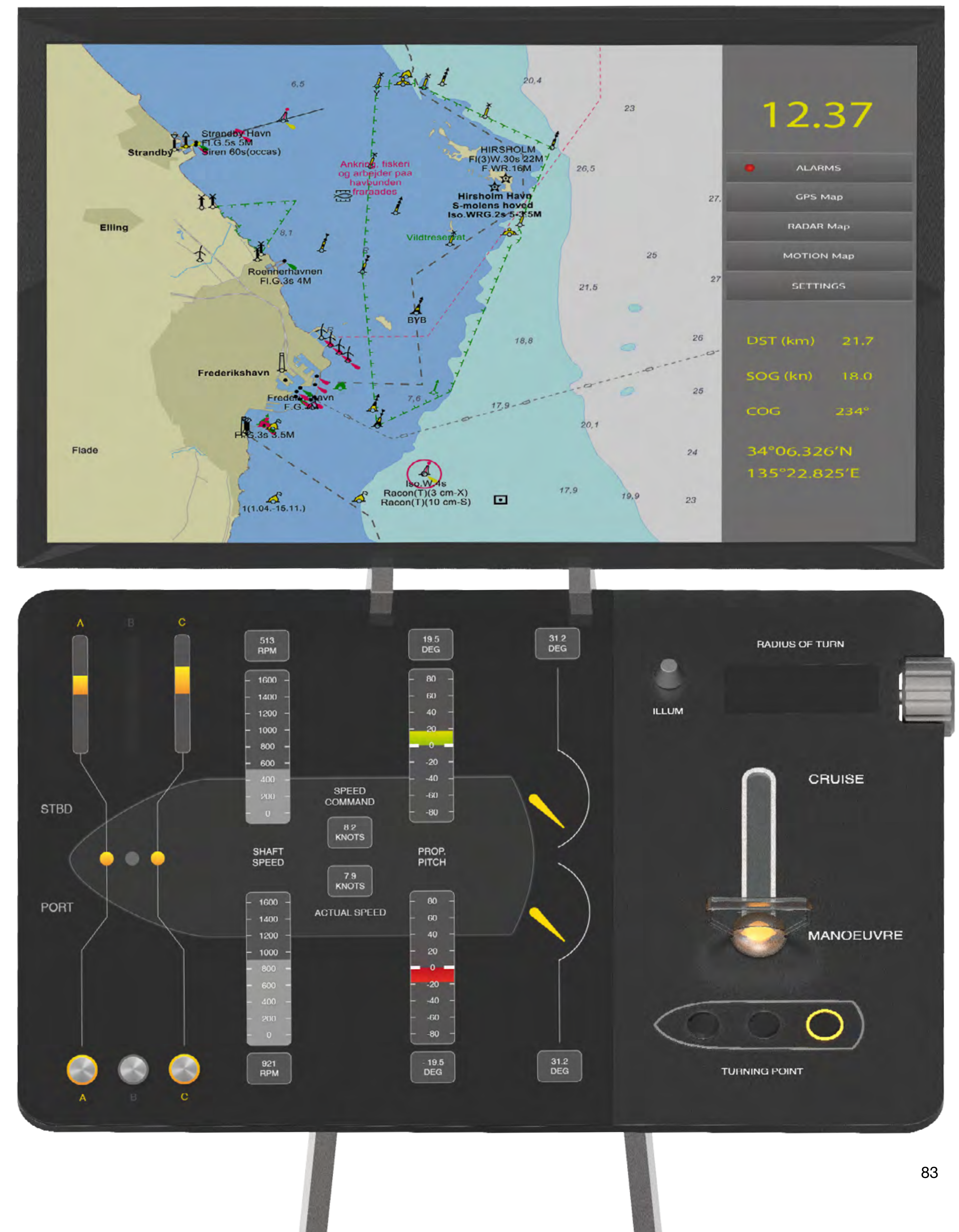
- **Turning points:** There are three buttons located on the motion-setting panel controlling the point of rotation of the vessel. This is mainly used in manoeuvre situations when in harbour and enables the Captain to do more advanced manoeuvres.

- **Light adjustment:** The light adjustment is a traditional feature found in all maritime navigation equipment. This used when sailing at night where bright displays would make the crew blind to details in the outside surroundings.

OUTPUT

The operation panel consists of two units, and they have to be separate when mounting them to the rest of the product. This adds flexibility in form of custom solutions for a specific user, maintenance, repairs or change of equipment during the products long life.
The interface’s graphic and physical buttons can be seen on the illustrations on the adjacent page and a storyboard explaining the use of it, can be seen in the product report. The operation panel will be kept on a conceptual level and will not be detailed further in this report.

ill.1-83

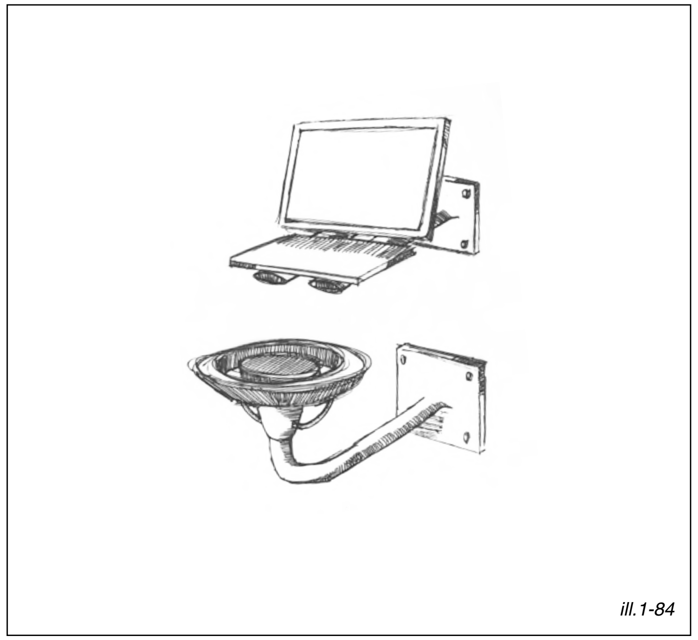


BASE STRUCTURE

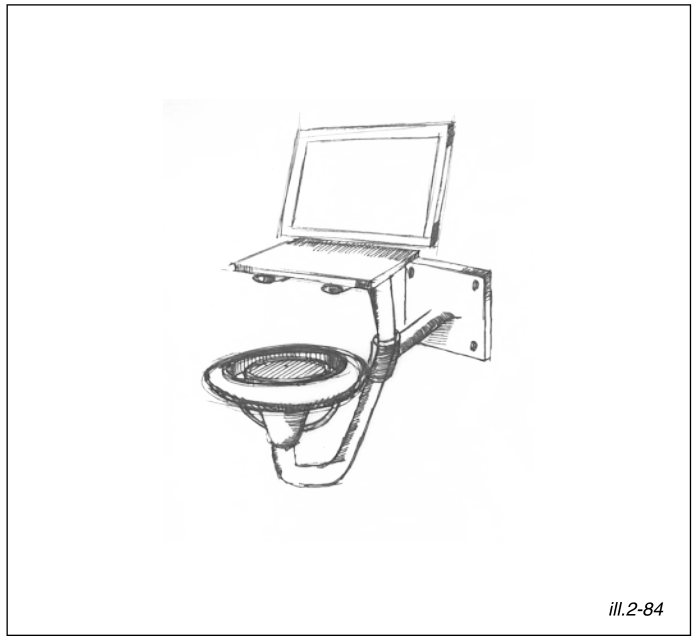
With the decided mechanical- and interface concept, a base structure was needed to bind the elements together into a single product. As seen on the illustrations below four basic ways of connecting and mounting the operation panel and the motion controller was made.

Ill.1-84 shows the operation panel and the motion controller mounted on the window frame leaving free space below.
Ill.2-84 shows the operation panel connected to the motion controller, and both of them are mounted on the window frame.
Ill.3-84 shows the operation panel mounted on the frame, while the motion controller now has a leg and is mounted to the floor.
Ill.4-84 shows the operation panel connected to the motion controller's leg, mounting the whole system to the floor.

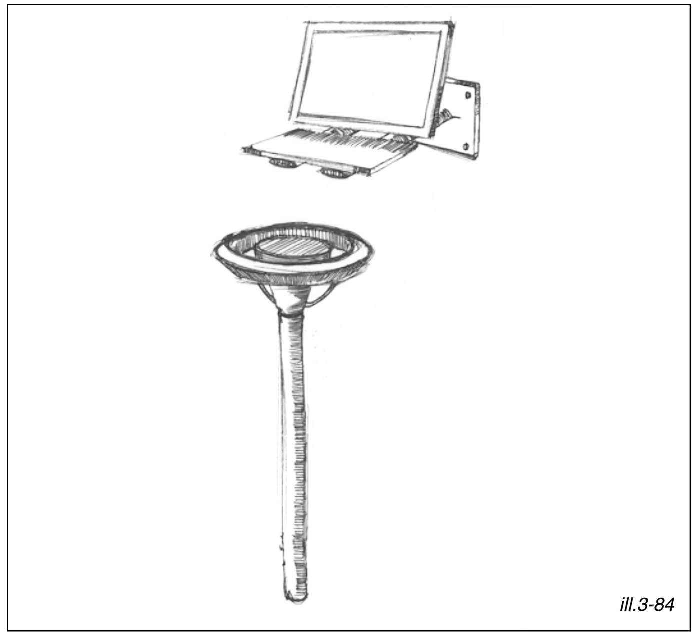
After setting up these four basic templates, the design team began developing various suggestions on how the right expression should be like.
It was decided to go with a floor-mounted structure as shown in ill. 4. By going in this direction, the system can be placed on any bridge in any location, in contrast to the other mounts that are dependent on having a rigid frame nearby. The visual language of a floor-mounted system was also found more appealing because it makes the product seem more integrated with the vessel.



ill.1-84



ill.2-84

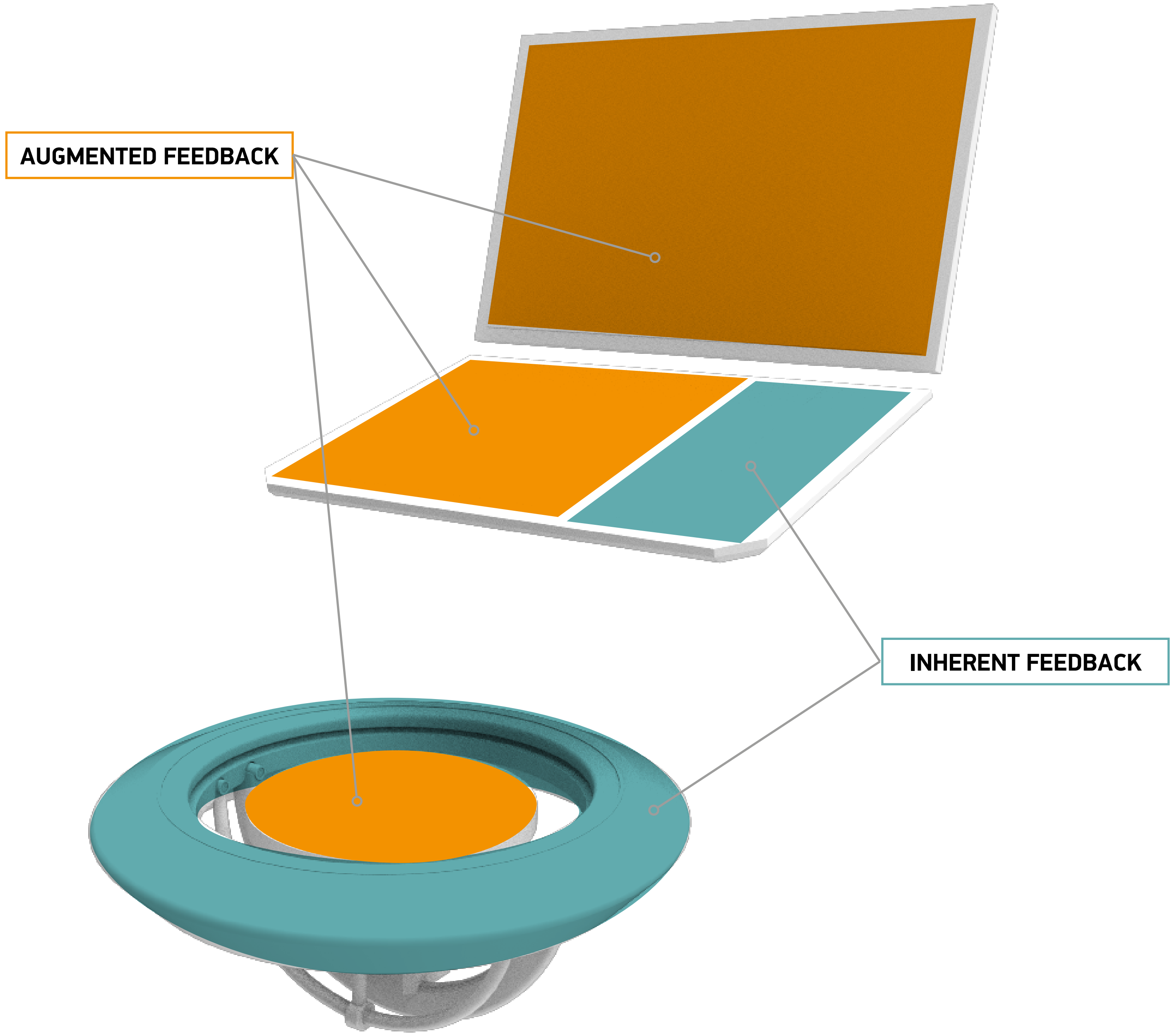


ill.3-84

ill.4-84

INTERACTION FEEDBACK

When using the product in any situation, feedback in form of sound, light or haptics are very important to design for the specific use of operations. The user should receive feedback in form of light and sound if any alarms should occur, but also receive feedback while operating the motion controller. There are two forms of feedback, which the design team will use to describe the interaction: inherent- and augmented feedback.
The illustration below shows where these feedbacks will occur and a more detailed feedback list of the motion controller can be seen on appendix G.



ill.1-85

AESTHETIC FUNCTIONS

In this section the aesthetics will be presented and explained how and why the product might appeal to the user. The design team is conscious about the subjectivity issue when describing aesthetics, which is why reference images is shown to back up the statements throughout the section.
Many factors contribute to the user's overall perception of the product e.g. visuals, sound, smell, taste and touch. In this case the design team has focused lot on how to make the overall composition of the product appealing to the user by ensuring that it will fit into the context of a vessel bridge.

Studying images of modern bridge designs, like the ones shown on the adjacent page (See img.1,2-87), revealed that the overall aesthetics of the bridge is very dependent on the production methods and materials of the vessel. Big glass areas and the fact that a vessel is build from large steel plates, generates a form that is quite industrial. The hull's speciality form is hydrodynamic, but this process is not used on the upper part of a ship – thereby the bridge maintains a very edgy look.
This study showed that the product should be more industrial than organic in its visuals - see img.1-86 and 2-86.

THE ICON ON THE BRIDGE

The motion controller is attached from underneath to the base structure, and leans toward the user. This was done to indicate openness and friendliness, which is important when trying to prevent the user in feeling like the product is overpowerering him.

The overall shape of the motion controller is circular with rounded edges, soft materials, ergonomic grip and a leather-like surface structure. This expression and style will welcome and tell the user that it is made to be touched, and the circular form indicates the ability to rotate.
The operation panel and base structure use the same expression and style, which is plain industrial in form of straight lines, sharp edges, cold technical materials and a rigid look. This style will tell the user that these components are not designed for interaction like the motion controller, and also implies a certain strength to the structure. On a more abstract level the soft and curved elements imitates the human interacting with the straight and hard being the machine.

The motion controller should be the icon for the product, which can only be done by designing the operation panel and base structure in a strong contrast to the circular controller. The base structure will become the structural part carrying the whole product, while the operation panel will be attached on top of it. They both have a style that refers to the structure of the vessel with simple surfaces and straight lines. Also a base mount is integrated to give the overall composition a more heavy and solid expression at the bottom, leading the user to view the structure as heavy and rigid - see img.2-86


img.1-86

img.2-86

img.1-87

img.2-87


img.3-87


ill.3-87

SUMMARY - CONCEPT REFINEMENT

- Ergonomic studies have been done to investigate which grip that is best suited for both tilt and rotation. Through research, the team has discovered that all equipment on board a bridge are being treated with soft and fine movements. (p.80)

- The operation panel's interface have to be as simple as possible so that the user wont be too overloaded with informations during manoeuvring. Familiar gestures should be implemented when designing the touch screen features. (p.82)

- The operation panel is divided in two panels, which adds flexibility and customisation. Also if the ship-owner wishes to change the touch-screen, it can be done without disassembling the whole product. (p.82)

- The base structure was mounted to the floor, which added visual weight to the product, while also creating a base for it to stand on. Besides a strong and rigid perception, the structure made the product visual appealing in the maritime context. (p.84)

- Designing a new interaction product requires clear feedback to the user. That is why augmented and inherent feedback have been visualized, and a thorough list can be seen on appendix G. describing all the of the products feedback features (p.85)

- The motion controller should stand as a clear contrast to the rest of the product, which was why curved lines and soft edges was investigated. On a more abstract level the soft and curved part imitated the human interacting with the straight and hard lines, representing the machine. (p.86)

- The operation panel and base structure should strive to attain an industrial look so that it would appeal to a user in a maritime context. This resulted in straight lines and chamfered edges, which can be seen on last page.

CHAPTER 5.

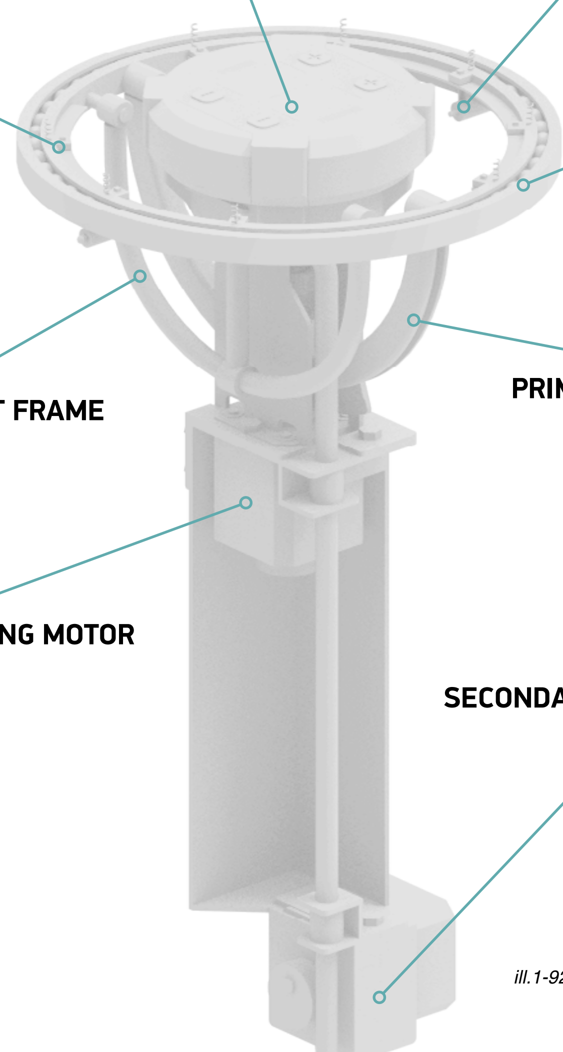
DETAILING

Throughout this chapter the product's feature will be presented and explained with illustrations of how the mechanical parts interacting with each other. It is important to note that the product have only entered its very early concept phase and the detailing will therefore be more concerned with the overall construction and technical plausibility, than actual dimensioning of sub-parts

Materials and surfaces will be explored and decided, while also describing general manufacturing methods. An economical section will describe the value created from the view of the primary stakeholders.

DETAIL OVERVIEW

The illustration below show which parts and components that are being described throughout this chapter. On the adjacent page the illustrations shows that the handle and ring-button will be detailed on a higher level than the rest of the mechanics, which will be on a constructional and plausible level.



ill.1-92

ill.1-93

MECHANICAL FEATURES

In this section, the mechanics within the motion controller will be explained and their contribution to the overall function of the product will be illustrated. To establish a clear overview, each mechanic feature have been singled out and explained in its own section.

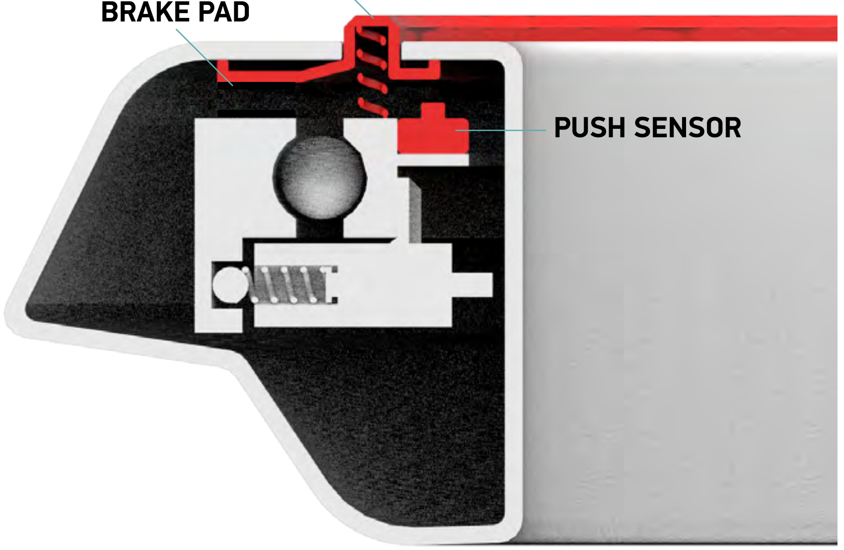
SAFETY TRIGGER

To avoid any mistakes to happen during operation of the motion controller, the team decided to integrate a safety trigger. The purpose of the trigger is to make the user feel in command when operating the vessel by not having too many operations going a one time. The trigger is therefore designed to switch the control mode between two options; tilting and rotation.
As a default the controller is always free to rotate, but if the user wish to tilt to adjust the power, the safety trigger has to be pushed down. This feature is well known in many other industries such as in craftsmen tools or in other high-risk tools.

The mechanical feature consists of several parts: a button-ring, a spring-mechanism, a brake pad and a sensor – see ill.1-93. The button is a thin circular button-ring that is located on the top of the controller handle, between the inner and outer shell.

The ring has to be pressed and kept down to activate the tilting movement. When the ring is pressed down, a sensor is pressed, deactivating a mechanical lock that is induced by stepper motors described later in this chapter.
The sensor is mounted on an inner track of a large ball bearing that allows the outer shell to rotate. When the button is pressed, a brake pad blocks the outer ring of the ball bearing, locking unable to rotate.

Multiple sensors are placed around the safety trigger, ensuring that is can be activated from all angles. When the user is done tilting the controller he release the button, and the system will lock the tilt in the given position and go back to a rotation-only state.



ill.1-94

TILTING

The new and innovative feature about the product is the multi-axial tilt operation. Gripping the handle, while pushing the safety trigger down, and then tilt the controller makes the vessel move.

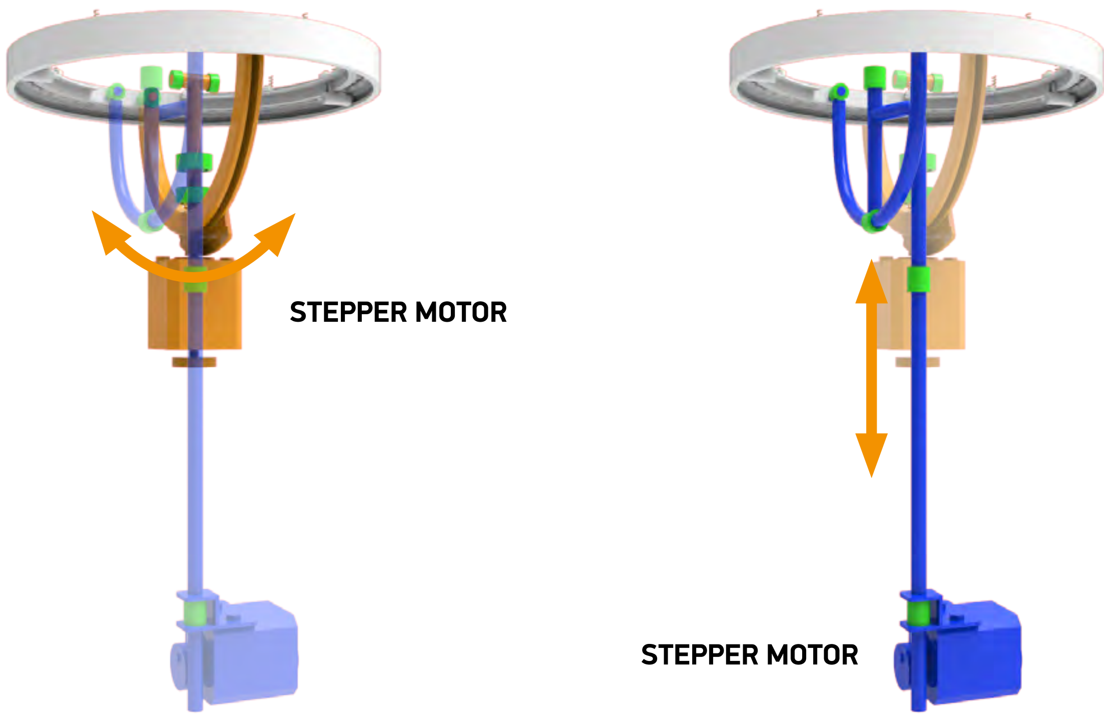
This movement is based on two mechanical systems that are both mounted to the inner ring of the ball bearing. The two are named primary- and a secondary tilt system - see ill.1-94.

The primary tilt system is responsible of tilt around the X-axis and is mounted on a hinge at the centreline of the motion controller. It translates the tilt into a rotation that is measured and actuated by a rotation sensor and a stepper motor.

The secondary tilt system is mounted in an offset location in relation to the primary tilt frame. When controller is tilted in around the Y-axis, the secondary frame is lifted or lowered. This movement is translated via a shaft down to a gear, which translates it to rotation of in a stepper motor and sensor.

To enable an electric shaft system, stepper motors have been attached to each tilt system. The stepper motors are connected to their systems by a gearing and would give the system a resistance that can be utilised for a quality feel of the controller.

By turning on the magnets in the stepper motors the tilt is locked. This feature is used to deactivate tilt in the Y-axis when in cruise mode, since this axis is in control of the thrusters and these are not active in cruise mode.

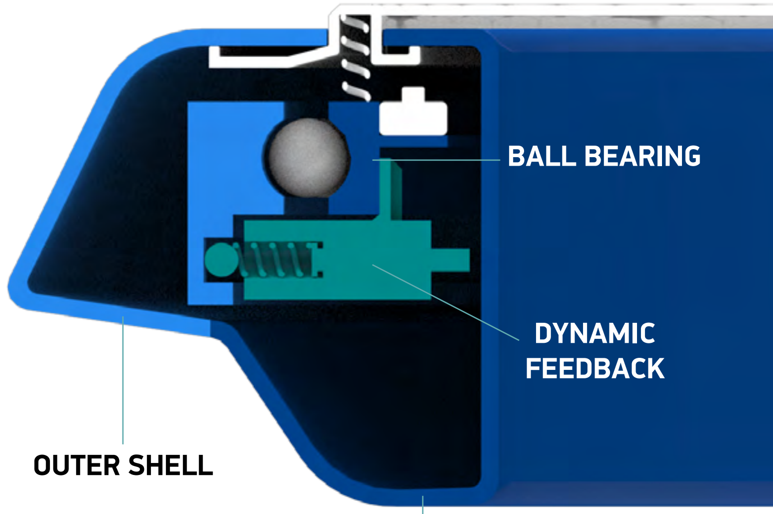


ill.1-95

ROTATION

Today the captain rotates a separate unit to change the heading or rotate the rudders of the vessel. In the new product, an integrated rotation controller build into the handle of the controller has replaced this rudder.
Rotating the outer shell of the controller, without pushing the safety trigger, will make adjustment to the heading of the vessel. This mechanical movement is based on several parts: the outer shell, inner shell, a ball bearing and a dynamic feedback unit – see ill.2-94.
Starting from the inside, the ball bearing makes the controller rotate. The inner shell is fixed to the inner track of the ball bearing and cannot rotate. The outer shell is fixed to the ball bearing's outer track, which enables rotation.

To get feedback when rotating, a dynamic feedback unit is mounted on the inner track while pressing a metal ball on to a grooved track on the rotating parts – see ill.3-94. Included in this function, is a solenoid that enables the system to increase the feedback, when rotation is at zero. The function is dynamic to allow the rotation to be included in the electric shaft system without having to rotate the outer shell mechanically.



ill.2-95

MATERIAL, SURFACE AND PRODUCTION

This section is made give a brief understanding of the general thoughts on materials, surfaces and production methods.
Due to the many unknown expected production volumes, many different production methods could be in play for this product. Throughout this section, the design team describes how some of the more critical element could be manufactured in a low-volume scenario.

MOTION CONTROLLER - HANDLE

The handle is divided into two separate parts. The first part is attached to the primary tilting frame of the motion controller and the second part is attached to the ball bearing's outer track. The use of the two are different because rotation often are small adjustments, where tilting is done with bigger movements – the surfaces are therefore made with the same pattern but in different scales as seen on ill.1-96.

Surfaces: First part Mold-Tech MT 9081, second part Mold-Tech MT 9080

Materials: For these parts, a combination of materials has been chosen. To make the structure rigid with a subtle soft touch, an inner ABS shell is combined with an outer layer of Tekbond® from Teknor Apex. This combination of materials has been used for hand tools, grips, sports equipment and alike for decades and have proven great performance in terms of wear and longevity [Teknorapex.com]. The hardness of the material should be around Shore A 80 for a medium hardness with a feel slightly harder than the feel of a tire thread - see ill.1-97.

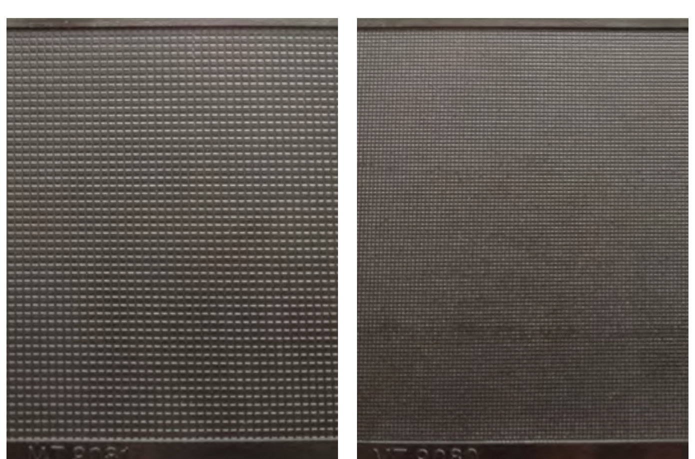
Production: The shape of the handle is a challenge for the manufacturing process, and to be able to proportion it, specialist would bee needed for advice. The design team do however have the following proposal:

- A mould created is created with electrical discharge machining (EDM), thereby allowing for the selected surface textures to be created. The mould could have core retraction for the inner cavities but a slight change in the design could allow for a simple mould design.
- Soft Tekbond® material is poured in via a material-inlet in the mould.
- The mould is heated and rotated to get an even layer.
- The material inlet is used again to pour in the ABS material.
- The mould is heated up and rotated again to distribute the new material and bond it to the first layer.
- After moulding, the outer handle is cut out to several sub-parts to allow it to be mounted on the dynamic outer track.

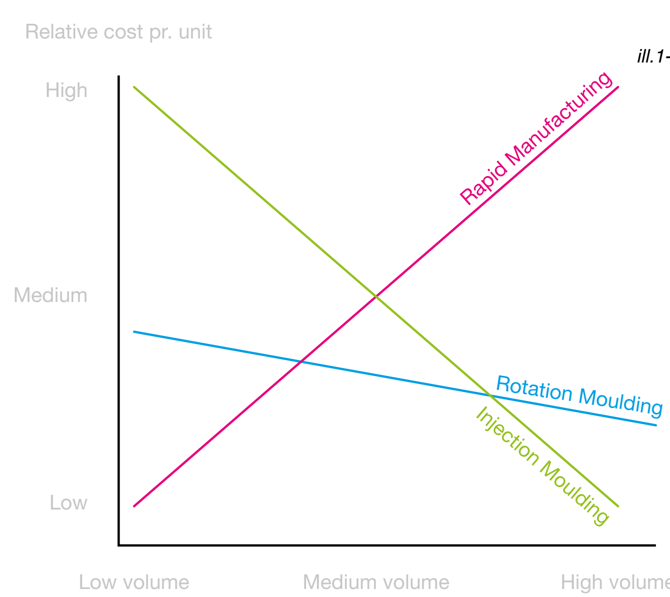
This production method have been observed at Dan Hill Plast A/S and due to the low number of units this relatively comprehensive process would be cheaper than injection moulding of the individual parts. A drawback of rotation moulding is the fact that the layer thickness cannot be controlled as precisely as with injection moulded parts, but this is not seen as a major problem for these particular parts.

The selected production method is heavily affected by the volume of production and what process to choose cannot be defined at this moment. As shown on the rather abstract illustration below (ill.1-96), the higher the volume, the cheaper injection and rotation mould gets. Rapid manufacturing, like 3D printing, do not have any real benefit of scale but is cheaper at low volumes because there is no need for expensive tooling.

img.1-96



ill.1-96



ill.1-97

RING-BUTTON

Surfaces: Brushed.
Materials: Cast Aluminium.
Production: The part is manufactured by permanent mould casting. A two-piece cast iron mould is put together to enclose the form; the melted aluminium is then poured in by gravity and set to harden. Afterwards any excess materials are removed and a finishing process creates the wanted surface quality. This part would be anodized to create a surface that is less affected by chemicals and wear.

STATIC CENTER

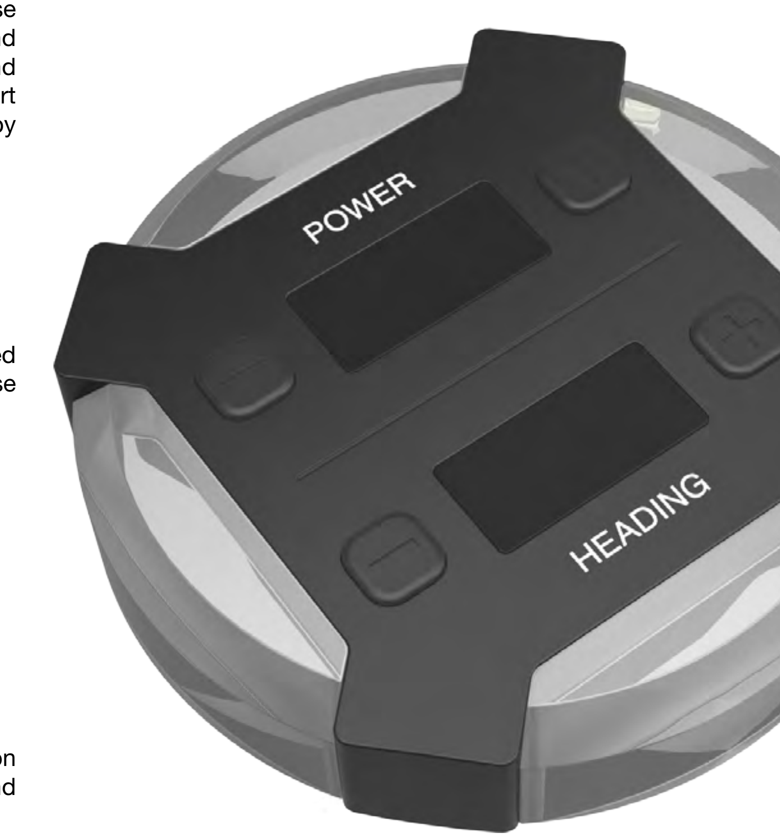
Surfaces: Similar to Mold-Tech MT 1055-2.
Materials: Polyurethane
Production: This unit could be produced as an injection moulded part, but for low quantity it would probably be cheaper to use vacuum-casting process.

STATIC CENTER TRANSPARENT INDICATORS

Surfaces: High gloss
Materials: Transparent Poly methyl methacrylate / Acrylic
Production: Manufactured by vacuum-forming or -casting.

STATIC CENTER BUTTONS

Surfaces: Soft touch similar to Mold-Tech MT-1 11040
Materials: Poly methyl methacrylate (PMMA) / Acrylic
Production: Buttons are manufactured by compression moulding to give a solid feel as known from remote controls and other consumer electronics.



ill.2-97

THE PRODUCT AS A WHOLE

This is a simple overview of the remaining product elements and their materials and production methods.

Base Structure: Brushed aluminium, cut with a water-jet and welded together.

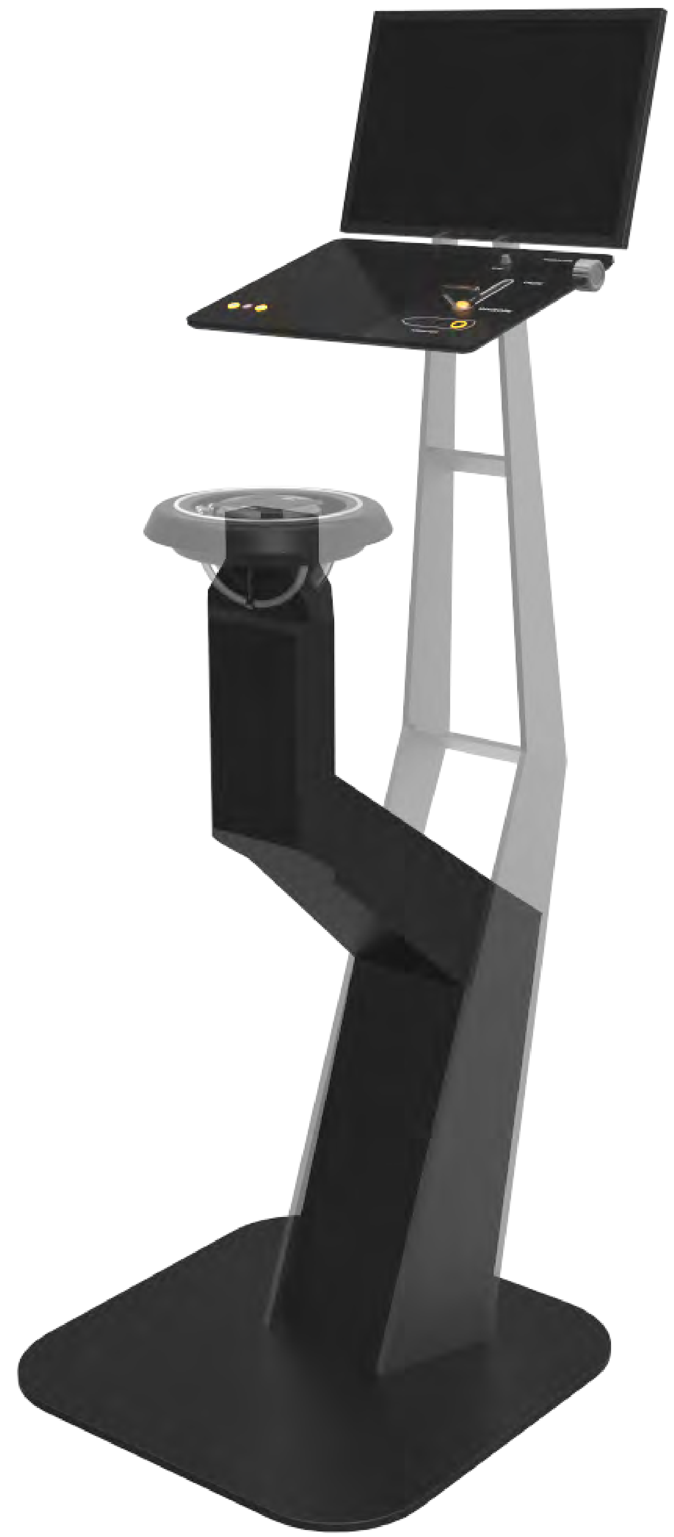
Base Mount: Rotation moulded black ABS

Brackets: 2mm steel sheets cut with water-jet and bend to house the mechanics. Bolted together with other parts.

Information monitor: Stock LED monitor with reinforced back-side made in cut steel plate.

Motion setting panel: Vacuum formed polyurethane with a brushed finish

Motion setting display: Stock LED-screen with a clear glass cover



ill.1-98

ECONOMICAL ASPECTS

Because of the limitations of the industry (See p.20) it is difficult, if not impossible, for a project like this to include concrete numbers and information for the business side of a new product. An example has therefore been made to demonstrate how the product can create value for the primary stakeholders.
The values have been divided into categories of pain and gain for the individual stakeholders, to illustrate how a sales department might pitch the product.

FIRST SHIP OWNER (EX. MAERSK LINE)

Pain

- Would like effective open water sailing but without loosing the ability to do advanced manoeuvres in busy and shallow ports.

- Modern high-manoeuvre technology like Azipod and Voith Schneider propellers have a very high initial cost and are mounted underneath the ship, thereby increasing the overall draft. To enable big vessels to enter ports with these propeller types, the hull must decrease and therefore the load capability is reduced. This need means that merchant vessels are “stuck” with more traditional propulsion technologies that are not as easy to manoeuvre.

Gain

- Keeps the existing propulsion technology on today’s vessels but improves the operation of manoeuvring. Making it possible to have a lower initial cost and good fuel efficiency, while still having advanced manoeuvre capabilities.

- The product is flexible regarding customisation and can be fitted to the exact needs of the shipping company and its vessels.

- A product that is designed not only to the ergonomics of the user, but also for a better cognitive use, will ultimately lead to fewer accidents and spare the company from both expense and bad press.

CREW ON BRIDGE (EX. CREW OF THE NEW SHIP)

Pain

- Advanced manoeuvring can be done manually by controlling propellers, rudders and thrusters individually, but this requires a series of routines based on many years of experience with the same vessel and the same harbours.

- There are instruments on the market today that allow the crew to do advanced manoeuvres without the need for new propulsion technology, but a third party and not the manufacturers of the propulsion systems, typically build these. As indicated by users on Fieldtrip 2 and 3, there are also many examples where these systems never gain trust among the crew because they are not intuitive enough and therefore end up not being used.

- If instruments are not designed to encounter human errors, the crew, and not the engineers, tend to be blamed for any accidents.

Gain

- The crew will get a product that is highly reliable and capable. The level of information has been narrowed down to the essentials, thereby enabling the user to maintain his concentration on the outside horizon. Interacting happens on the terms of the user, making him feel in control and confident in any situation.

KNOWLEDGE INSTITUTION (EX. SKAGEN SHIPPING ACADEMY)

Pain

- Must teach the future officers in both old and new instrumentation and must therefore be able to see a future perspective for a new product before it is taken in.

- New graduates coming from the academy must be able to get jobs, and the expanding markets with high demand for manoeuvring are therefore of great interest.

Gain

- If a big and well know company like MAN Diesel & Turbo assist the academy in education in the future of propulsion control, the new generations of officers would have a higher likelihood of getting jobs on board vessels with the new interface.

- By teaching in new systems that might create future standards in propulsion control, the academy could attract more students.

- The product could easily be made as an add-on to existing simulators, thereby greatly lowering the cost of implementation in the education.

NAVAL ARCHITECT & SHIPYARD (EX. ORSKOV YARD)

Pain

- Installing a mix of different systems ass done on many of today's vessels requires a great deal of custom technical solutions.
- A customer will always have unique requirements and no true standard exist for laying out instruments on the bridge panels and wing. Naval architects are not educated in user-experience and may not have in-depth knowledge about how to facilitate safe, ergonomic and easy use of primary instruments.

Gain

- One complete solution that is well integrated in the engine- and propeller-systems, while offering a customisation via touch displays.
- The product enables a complete freedom of location regardless of the overall layout of the bridge wing. The product can be mounted in 90-degree intervals to offer optimal viewing angles for the specific vessel.

MANUFACTURER (EX. MAN DIESEL AND TURBO)

Besides creating value for the important stakeholders, selling the products must naturally also create value for the manufacturer. This is also described as a pain and gain, but additionally holds a profit and risk category to illustrate potential risks of developing and selling the product.

Pain

- MAN Diesel & Turbo has a remarkably well-established brand in the maritime industry, but is not present outside power and propulsion products.
- They have no products for high manoeuvre vessels, which is a vastly growing market as findings of Fieldtrip 3 pointed out. MAN's products are primarily focused around common propulsion setups that is highly effective on open sea, but cannot compete with the Azipod and other modern systems in advanced manoeuvre situations.
- MAN's currently mentality about design solutions is very conservative and bound to traditions, especially in regards to user-centred design. On that part their competitors is several steps ahead, but the market is still moving quite slow.

Gain

- By creating an interface product that empowers a common propulsion setup when doing advanced manoeuvring, MAN can engage new customers that would not consider this setup earlier.
- By launching an interface that is more than just an instrument for the main engines and propellers, the company will gain access to new markets in an industry where MAN Diesel & Turbo is all ready a highly established brand.
- As learned on Fieldtrip 1, the maritime industry is always about ten years behind the automotive industry in terms of technology. But since VW owns about 75% of MAN SE [bloomberg.com, 2013], expertise within the entire enterprise could be utilised to push the new product ahead of the competitors.

Risk

- Developing a completely new product will always have a certain economical risk and an advanced high-risk product like this would have a very high development cost.
- Due to the high level of trust in the brand, the consequence of putting a faulty product on the market would be very high. Clients expect the highest quality and if one product does not meet this standard, it may have negative effect on sales of others like, engines and propellers.
- The new product may have a hard time getting approved by legislation because it is very different from products on the market today – this may cause a delay in production and increasing the total resources spent before first sale.

Profit

- Economical profits will differ heavily due to the dynamic pricing mechanisms that the product is affected by. These profits are therefore very dependent on market conditions, volume of sale, bundle deals and negotiation power of client and manufacturer. [p33, Osterwalder, 2010]
- By bundling their highly effective engines and propellers with new interface products that expand manoeuvre capabilities, MAN could expand its customer segment and create long-term economical growth.

FURTHER DEVELOPMENT

Because of the limited time for this project, the product has only reached an overall concept level and some features are not developed and described in the report.
Below are two lists made to show primary and secondary challenges with the product, as it is on the time of hand-in.

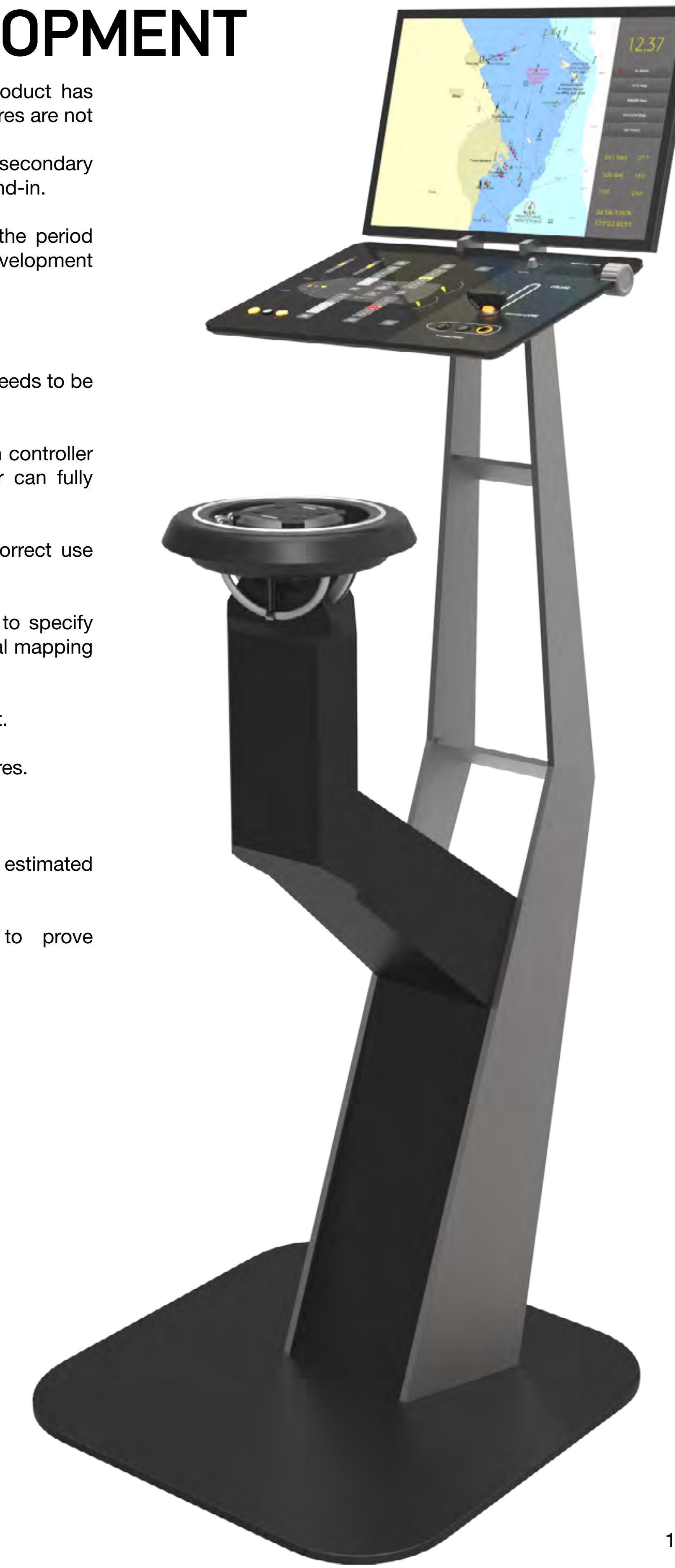
Some of the listed areas may therefore change in the period between hand-in and the exam-presentation, as the development continues.

PRIMARY CHALLENGES

- Mechanic prototyping - will be challenging, but needs to be done to prove the concepts movements.
- Physical feedback when adjusting on the motion controller needs to be designed, to ensure that the user can fully understand the interaction with the product.
- Context scene to place the model in, so the correct use scenario can be acted out and tested.
- Mapping detailed system interaction patterns - to specify mechanical and electronic requirements. An initial mapping can be found in appendix H.
- User testing and validation of the refined concept.
- 1:1 model, to test ergonomic and aesthetic features.

SECONDARY CHALLENGES

- Manufacturing and price calculations needs to be estimated to get a concrete overview of the cost.
- Material testing including a FEM-analysis to prove mechanical and material strength.
- Life cycle analyses.



CHAPTER 6.

EVALUATION

CONCLUSION

The product developed throughout this project has just barely entered its concept-stage. A vast amount of tests, prototypes and refinements is highly needed, before it can even be considered to be plausible and even more so to be considered feasible. The product is dependent on a range of high-tech electronics and mechanical features to operate and if these turn out to make the product too expensive, it may outweigh the user-benefits in terms of market value.
All these considerations and tasks will without a doubt change the design later on in the process, but the design team do have a strong believe that the general concept have the potential to go all the way into production.

The result of working alongside a vast amount of unknown variables has led to a highly dynamic process, but most of the important needs were defined relatively early on. The knowledge to react and design for these needs could however, not be done before a vast amount of knowledge was gathered.
A user-oriented approach has led to a product that is radically different from existing products, without alienating the users or the context. As proved on fieldtrip 3, the users were very positive to this change in the propulsion control interface and the general idea behind the product has been well received by these stakeholders.

This section will aim to evaluate the result of the project by weighing it against the goals set in the latest vision, mission.

“TO CREATE A PRODUCT THAT SETS NEW STANDARDS FOR THE WAY LARGE VESSELS ARE CONTROLLED IN COMPLEX MANOEUVRE SITUATIONS”.

Vision, p.57

To set a new standard requires a thorough analysis on the current market and the products that exists in it. Research about product-competitors was made by field studies and a simple search on the Internet, which resulted in many different and old products from several maritime companies. Throughout the analysis the team discovered that one single agency had designed multiple products to a range of the biggest companies. This came as a chock to the team, and right then, the ambition and determination to design something new and innovative for this conservative industry rose even more.

The designed product needs to be fully tested and validated by a variety of real users, but legislation stakeholders will also have a say about what products can enter the market. The many new features and solutions that are presented in the product might make the process of approval from legislation organisation a long and hard battle.
Even though there are many unknowns to the concept, it does point in the direction of a new and highly needed approach to design in the maritime industry. Advanced and optimised technology is no longer enough and he highly automated systems have been proven to generate new challenges, that affects the safety to a great extent.
Human-cantered design is not seen in many bridge instruments today, but the new and advanced systems might very well be forced to take these aspects into account to reduce accidents.

The concept presented in this project is an example of this merger of human oriented, yet highly automated interface design. The way the vessel is operated has been completely re-designed, but it have been with a high attention to the users routines and expectations, making it seem familiar even though it is quite different.
If the product were realised, these features will hopefully reduce the risk of human mistakes appearing during complex manoeuvres in high-risk situations.

Like most of today’s solutions, this wing-control product does not have any redundant systems and rely on the center bridge as a backup. The simplicity and layout of the interface help reduce errors by humans, but it is not immune from technical failure. It would therefore be smart to implement redundancy in the primary functions of the motion controller.

DESIGN A HUMAN-CENTRED BRIDGE WING INTERFACE THAT ALLOWS THE USER TO INTERACT WITH THE VESSEL IN A MORE INTUITIVE AND SAFER MANNER.

Mission, p.57

Designing an intuitive product was a great challenge and a range of body storming sessions was held to gain some sort of knowledge on what intuitive means in a context like the maritime industry.
As it turned out, the users do not necessarily see intuitive design as something that you could walk up to and use right away. If this were the case, it would probably not have the functionality required and capability would decrease to facilitate simplicity.
In contrast *intuitive* are more a question of transparency and relation to other instruments. Some training is necessary for most professional tools, but if the user cannot understand how their input is turned into actions, trust will hardly fast.
As field research taught the team, many modern, highly capable and expensive systems are not used because of a lack of transparency even though they might very well be easier to use than older products.

The product of this report tries to deal with this challenge by having several features that lets the user see how the mechanics that he knows is affected by the new system that he is yet to get used to.

Getting users to actually use new and user friendly control systems is therefore also one of the big challenges for safety in relation to human error - the number one generator for accidents at sea.

REFLECTION

At the very beginning of this project, the team had clear expectations that it would involve a high degree of technical detailing, future technologies and in general lead in a quite technical direction. The cooperation with a company that were willing to assist in a technical development also pointed the team to believe that this was the way to go. These initial thoughts have however changed quite a bit throughout the project.

Because the point of origin were driven by a vision to look 10-15 years into the future of an advanced interface product, the team had fallen into what could be called a technology-trap. The long perspective and a high-tech and expensive product got the team of on a wrong foot, looking for new technologies to introduce new possibilities in the maritime context. Many hours were spent, researching the latest interaction technologies and trying to predict what stage they would be in 10 years – and no real output was generated. It later became clear that this approach probably is identical to the one that have created the majority of the bad user experiences on board maritime vessels. As it was learned later on, this urge to use new technology, just because it is new, is probably one of the biggest pitfalls when designing high-tech products.

What ended up creating real value for the team was to go the opposite way around and observe the end-users, and thereby discover their true needs. Then it is appropriate to start designing and finding technology that could be brought into play.

Luckily, this realisation came relatively early on. By swapping technology research and technical development for a very hands-on approach with trashy prototypes and fieldtrips, the team ended up moving much faster in the direction of a useful concept.

A CHANGE IN MIND-SET

One of the things that annoyed the team through most of the project was the ever-present question about legislations and conservatism in the industry. At times it felt like these rules had paralyzed a whole industry in terms of will to innovate, but nearing the end of the project period some of this criticism have been turned. As designers we are raised to break rules and challenge the conventional – a sure fire way to create interesting ideas, but it have its limitations in a context like this one. When creating new ideas, it is easy to forget that conservative legislation is not created to kill innovation, but rather to allow only the right products into the market. It is about creating a safety net around a high-risk situation where design and engineering flaws can cause everything from a late arrival of a ferry to a full size catastrophe.

CLEAN-SLATE

One of the most daunting things about taking on a project like this was the fact that none of the team members knew anything about the context - let alone the product. But this was also the motivation, because it presented the chance to prove that we could work in a method-driven manner with complex, yet poorly defined needs. We knew it would be a major challenge, but that was the whole point of doing it – to push boundaries for our own design-capabilities.

CHAPTER 7.

ILLUSTRATIONS AND REFERENCES

ILLUSTRATIONS

Ill.1-5
Own illustration

Ill.1-9
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Ill. 2-9
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Img.1-10
http://www.nettavisen.no/innenriks/politikk/article2599137.ece
Img.2-10
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Img.1-12
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Img.1-13
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Img.2-13
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Img.3-13
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Img.1-18
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Img.2-44
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Img.1-45
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Img.2-86

Img.1-87
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Ill.1-98
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