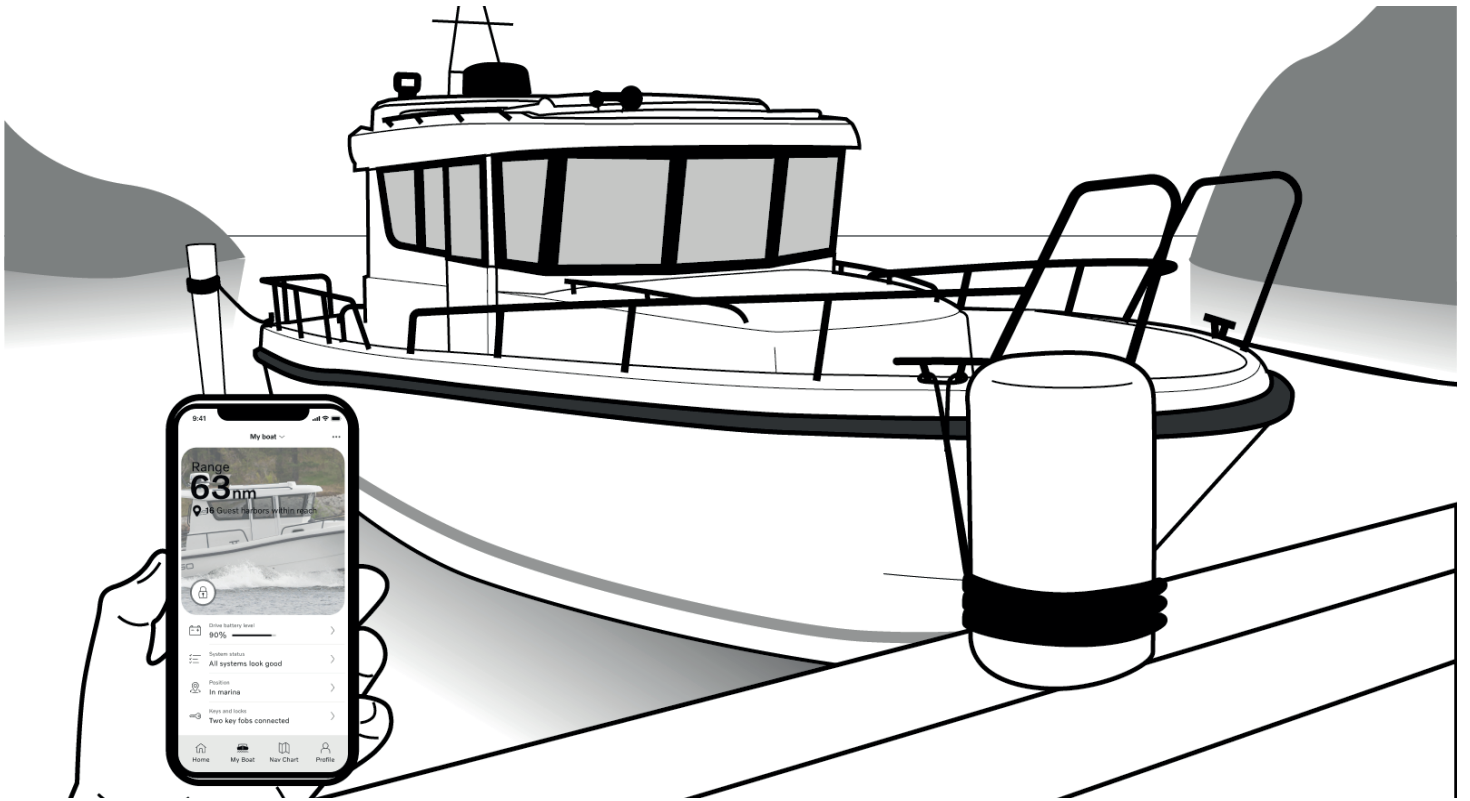




**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



# The Key to Boating for Everyone

Designing New Means of Accessing Marine Vessels

Master's thesis in Industrial Design Engineering

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Master of Science Thesis (IMSX30)

The Key to Boating for Everyone

Designing New Means of Accessing Marine Vessels

In collaboration with Volvo Penta

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Cover: A smartphone used to access a marine vessel.

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# **The Key to Boating For Everyone**

**Designing New Means Of Accessing Marine Vessels**

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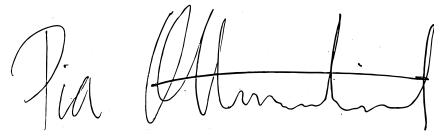
We are grateful to have been welcomed to the Vehicle Controls group at Volvo Penta and the people at Volvo Group Design. They have all been great sources of information and we have always felt that we were encouraged to ask questions and learn from their expertise. They also have very good fika (coffee & cakes) which we have made sure to take advantage of.

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Johan Eriksson



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Pia Otterlind

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## Abstract

The point of interest of this project was to develop a new means of onboarding marine vessels. The thesis has been done in collaboration with Volvo Penta. The aim has been to evaluate how a vessel equipped with their propulsion and electronic vessel control system's method of unlocking can be developed for the next generation of boating. Upon examining the marine market as well as neighboring markets it was discovered that connectivity and Internet of Things are fields which can elevate the experience of onboarding, therefore, the thesis sought to develop a new unlocking system that gave users an expanded access to their marine vessel. The design process of the project has been done by gathering insight from different stakeholders and potential users. After the user research was compiled, it was applied in a design process where concepts for a new system were ideated. The process resulted in a new proposed system for unlocking marine vessels. The new system includes both a digital interface and a new physical key fob. The two represented artefacts for front-end interaction in the system and were designed based on usability theory. Further, they were developed in an iterative, human-based design process, where continuous evaluations with potential users were a key deciding factor.

**Keywords:** Usability, User Experience, Marine Vessels, Unlocking

# Words and Terminology

EVC - Electronic Vessel Control

Key fob – An artifact that is used to unlock a vessel

Helm - An operating station for controlling the vessel

UX – User Experience

UI – User Interface

OEM - Original Equipment Manufacturer

MOB – Man Overboard

RKES – Remote Keyless Entry and Start

PKES – Passive Keyless Entry and Start

SAR – Search and Rescue

IoT – Internet of things

RFID - Radio Frequency Identification

HTA - Hierarchical Task Analysis

ECW - Enhanced Cognitive Walkthrough

PUEA - Predictive Error User Analysis

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# 1. Introduction

Volvo Penta (2023) has released a vision for their future, based on the notion of Boating for Everyone. The vision includes many improvements to the sustainability of boating, one of them being boating as a service, which both increases the utilization rate of individual marine vessels and would allow more people to enjoy the sea. To meet the vision of boating for everyone, such a service would have to be accessible to many. Currently, every boat has a unique installation, rendering the onboarding process of each boat different.

Volvo Penta manufactures marine diesel and gasoline engines for boats. The diesel engines sold by Volvo Penta are used in larger boats equipped with a cabin or other internal compartments. The gasoline segment is used in smaller powerboats or day cruisers. Along with their engines, Volvo Penta provides their Electronic Vessel Control (EVC) system which is a digital interface used for controlling the engines. The EVC system also includes human-machine interfaces (HMIs) such as engine control levers, steering wheels, joysticks, information displays, and multifunctional displays. These human-machine interfaces are all placed in the helm, the driving environment of a boat.

The rest of a boat is delivered by other actors: Boatbuilders, who build the hull and internal compartments, and Original Equipment Manufacturers (OEM) who supply systems which complement the EVC system, such as bow and stern thrusters, switchboards, marine radio equipment. In this system of marine vessel construction, Volvo Penta has a low interaction with the end user, and the shipyard supplying the boat to its end customers is the responsible actor in end customer interaction. Also, Volvo Penta loses control of how their HMIs are installed in a boat, since the boatbuilder is responsible for delivering the full vessel, thus making their own decisions. In cases where Volvo Penta does not deliver a desired function, they are delivered by another OEM, and their HMIs will be installed in the helm environment as well. This hampers the desire to create a uniform helm environment and reduces the control Volvo Penta has of the experience of driving the boat. While the helm is relevant when driving a boat, it is only part of the boating experience. All other areas of a boat will be delivered by another OEM.



*Figure 1: A cluttered helm station featuring a wide range of different components from different manufacturers.*

## 1.1 Background

This thesis work is the second in a series, studying the evolution of the future boating experience. The previous work by Thyni (2022) explores how marine vessel maneuvering changes as marine propulsion shifts from combustion engines to electric motors. One of his findings was that the start-up sequence of boats was difficult to understand for new boaters. Since his focus was to design a holistic concept for the entire helm, this was a sidetrack of his result. He also discussed the future of boating with implications such as boat sharing and servitization, and how to accommodate different users using the same boat. These results were concepts of how the startup procedure of boats could be simplified within the helm. However, there are many actions which a user must complete before starting the engines. The onboarding process of marine vessels is unexplored.

### 1.1.1 Electrification of Marine Propulsion

Volvo Pentas' vision is to become a world leader in sustainable power solutions (Volvo Penta, n.d.-e). As this endeavor evolves, there will be a transition from combustion-powered systems to electromobility. Electromobility incorporates using an electric power train to power vessels and is one way the transporting sector is targeting to meet the future sustainability goals (Arora, 2021). Electric propulsion reduces the need for fossil fuels which is a contributing factor to greenhouse gas emissions and polluted air. The switch to fully electric power sources will mean both challenges and opportunities for actors within the field and there are many details to work on before Volvo Penta can operate as a supplier of electric powertrains (Volvo Penta, 2022).

A combustion engine is required to keep an idle speed to stay active (Taylor, 1996). This means a combustion engine must be started before driving can commence. The standard method to start combustion engines is with an electric starter motor. The motor is powered by a starter battery which in its turn is charged by an alternator, powered by the engine while running. Beyond the sustainability impact of electric propulsion, Porru et al. (2020) discussed some benefits of using electric motors instead of traditional combustion engines. Electric propulsion is silent - increasing comfort on board, batteries are rechargeable while at sea through renewable means, and operating and maintaining electric motors is cheaper as compared to combustion engines. Another benefit of electric drive over conventional combustion engines is that with no required idle speed, the electric motor does not require additional actions to be initiated before driving can commence. Since an electric motor is active as soon as the motor is subjected to a voltage, electrification affects the start-up process of marine vessels, and could change it in some ways. One such change is that the need for igniting an engine is not needed. This will change the current start up procedure slightly since the initial user action is to enable ignition on. Currently, the state of engaged ignition is required to read engine data. Moving towards electric power opens for the possibility of accessing vessel data more fluidly. An electric boat will require constant power to remain operational. This will enable the possibility to have constant live data from the vessel if desired, like the properties that smart-cars and smart-homes have today.

### 1.1.2 Customer segments

Volvo Penta marine has two major customer segments they cater to: Leisure Boating and Marine Commercial. Within the leisure segment, there are four sub-segments: Superyacht, yacht, powerboat, and sailboat (Volvo Penta, n.d.-c). Whereas in the commercial segment the applications vary, thus Penta delivers propulsion packages, or generator sets (Gensets), or auxiliary engines (Volvo Penta, n.d.-d). However, the same products are delivered to both segments. Therefore, they are not defined by the products which they buy but how they are used and by whom. As the name suggests, a leisure craft is used for recreational purposes whereas a commercial craft is a working vessel. In some cases, a vessel can be commercially

used for pleasure, such as a superyacht which because of its size requires a professional crew to operate it and passengers are paying for their time onboard, it is then perceived as a commercial craft (Lag om ändring i lagen (1994:1776) om skatt på energi, 2015; Transport Canada, 2018). Another factor which separates the segments is classification. Most working boats require classification standards to be operated. The standards regard marine safety and emissions and differ based on the country which the vessel operates under and in some cases the geographical area in which the boat operates. To ease the process of certifying marine vessels for boat builders, an OEM can type-approve their components to fit the classification requirements of the market it will operate in (Transportstyrelsen, 2022). A type-approved component is accepted in both commercial and leisure applications but only required in commercial installations.

### **1.1.2.1 Leisure Boating**

As mentioned, the leisure segment is limited to pleasure craft. They range from sail boats to motorboats between 20 and 80 feet in length. Boats are expensive products, and the price is rising faster than inflation rates (Linchpin SEO, 2023). The high price tag is reflected in the customer demand for boats, and they desire high-end products with the latest technology and comfort. Compared to a commercial craft, a pleasure craft is built for more than driving meaning the living areas and functions of the boat are emphasized. Leading the helm station to be of lower priority. Still, the boat builder wants to incorporate all the functions the customers' demand. Since some functionality is unavailable from the manufacturer of the boat's main engines, the boat builders must incorporate HMIs from different manufacturers into the helm. This clutters the helm station and impacts the driving experience negatively. Therefore, boat builders who construct leisure boats opt to use as many HMIs as possible from the same manufacturer as the engines the boat is equipped with. This problem is even more prominent in older boats in which owners tend to upgrade each subsystem independently.

### **1.1.2.2 Marine Commercial**

Working vessels are optimized to be used in their specific tasks. In contrast to pleasure crafts, end users are included in the boat's manufacturing. Since it is a workspace, it is customized to fit the user needs, and ergonomics, both physical and cognitive, for the driver is deemed more important than in a leisure boat. Therefore, the helm station is built around the driver and their needs. In these boats, the systems best suited for the task at hand are used. Since the driver of the boat will use the boat in their daily work, a cluttered helm is less of a problem, since they will learn the different interaction patterns with the different HMIs. While it is beneficial for a commercial vessel to use HMIs specifically designed for the engines they are equipped with, these boats more often use HMIs from other OEMs (Original Equipment Manufacturers). This may be because they use drives which are not delivered by the engine manufacturer or because they find other solutions more fitting, or more comfortable. The two segments differ widely in both use and culture. Leisure customers desire comfort and luxury while commercial customers want reliability and ergonomics. The variation makes it difficult to provide a product which accommodates both segments' demands.

### **1.1.3 Servitization in the Marine Market**

Because of the high cost of purchasing and maintaining a boat, many boat purchases are of second-hand vessels. This is not set to change with the current evolution of price. However, there are actors who target those incapable or unwanting to own a boat, with boating as a service. Most of them are structured as boat clubs, where a person can join for an annual fee and then rent boats on-demand. This model has more benefits than a lower price. It eliminates the work which it is to own products such as maintenance. Further, it lays the ground for closer customer relations and deeper customer insights than the interaction of a one-time sale. Provided that fewer products must be constructed; it also reduces the producer's carbon footprint. However, there are challenges with such models. Customers believe that personal ownership is more convenient, which brings a need to educate customers on the accessibility

of the service provided. As a business model, it also works best for products with a long lifespan (Orasmaa et al., 2020).

### 1.1.4 Locking and Unlocking Boats

Unlike cars, in most boats, unlocking doors and an ignition lock all with the same key is not the only step the user needs to take before they can venture off on their vessel. Most boats are equipped with locks that serve to limit access for unauthorized people to get into a boat's indoor areas such as the helm or the cabin through standard doors with normal locks or padlocks. Additionally, each engine will be equipped with its individual starter battery which requires a physical switch to engage, and the boat will also house a battery for domestic power with its own switch. These additional steps for a user to go through could be considered a nuisance.

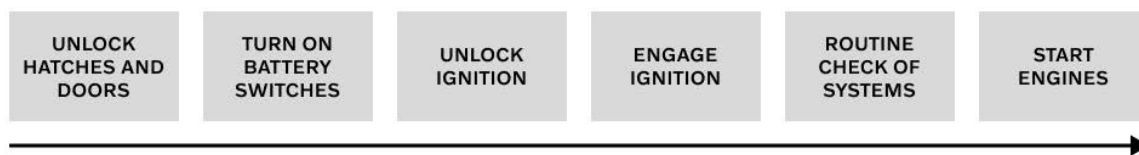


Figure 2: Flowchart showing the required steps to onboard a Volvo Penta equipped marine vessel

Changes will happen to Volvo Penta's unlocking system due to bigger changes related to the future with electric propulsion. Therefore, this is an excellent time to upgrade the unlocking system and its user experience. An elevated user experience of unlocking an electric boat compared to a combustion engine propelled boat contributes to the appeal of using a more sustainable system.

## 1.2 Aim and Purpose

The aim of this project was to develop new means of onboarding marine vessels which ties into the Boating for Everyone vision. The focus was to create a future concept for how the way of unlocking a marine vessel can look like within the period of ten years. The solution should compete with current rival solutions and enable a flexible key system to suit both of Volvo Penta's customer segments.

## 1.3 Objectives

- Define the current issues of boat access and unlocking and explore current solutions seeking to mitigate these issues.
- Find user needs and wishes for the future of boat unlocking.
- Design a solution to improve the user experience of unlocking and onboarding boats.

## 1.4 Delimitations

Since Volvo Penta has limited ownership over the driver environment due to being a parts manufacturer it is difficult to have complete control of the final customer experience. This means that within the chosen scope of the onboarding experience Volvo has limited control over how onboarding will look like regarding how the driver environment will open and in what sequence things will happen when a boat leaves the harbor. Therefore, some aspects of onboarding will not be addressed as they cannot be part of the company's product range soon.

## 1.5 Methodological Overview

This project's goal was to design a concept for a new means of unlocking marine vessels. Throughout, a user centered design approach has been used. A user centered design project is an iterative process. Bligård (2015) explains this process from a human-machine interaction perspective. The framework constructed by Bligård aims to combine sequential project planning models with iterative processes to bring out the benefits of both. While this project has not fully followed the process proposed by Bligård, his model serves as an adequate explanation of the activities conducted throughout. He describes distinct levels of design; performance, use, architecture, interaction, and elements. Each level includes a problem, structure, function, activity, and realization.

In the model, the result of each level serves as a basis for the next level. Noticeably, the level of detail increases which each column. This project started with defining the main problem and aimed to realize the shape and user interface on a conceptual level in an iterative nature. Evaluating the current state of solutions has provided new question statements which have started a new iteration in which each requires additional information to be gathered.

To concretize some stages of the project, it was split into three major phases: discovery, system design, and front-end design. Discovery refers to the investigatory part of the project, where user needs were found. The outcome of the discovery phase was a specification of user needs through specific use cases. The information gathered through the discovery phase was then implemented into a conceptual system design. The process included specifying requirements on a functional level and designing a system which could support said functionality. The system could then lay the ground for designing the front-end interaction between human and machine. This phase is labeled front-end design. However, as Figure 1 suggests, the phases all interact with one another. Even though there are prerequisites before each phase can start, some user needs are required before starting the system design, and there must be a system supporting the front end. However, the gates between the phases have remained open. Since a finding when evaluating the front-end interface might contradict earlier findings, or add more information, the requirements of the system, and interaction changes.

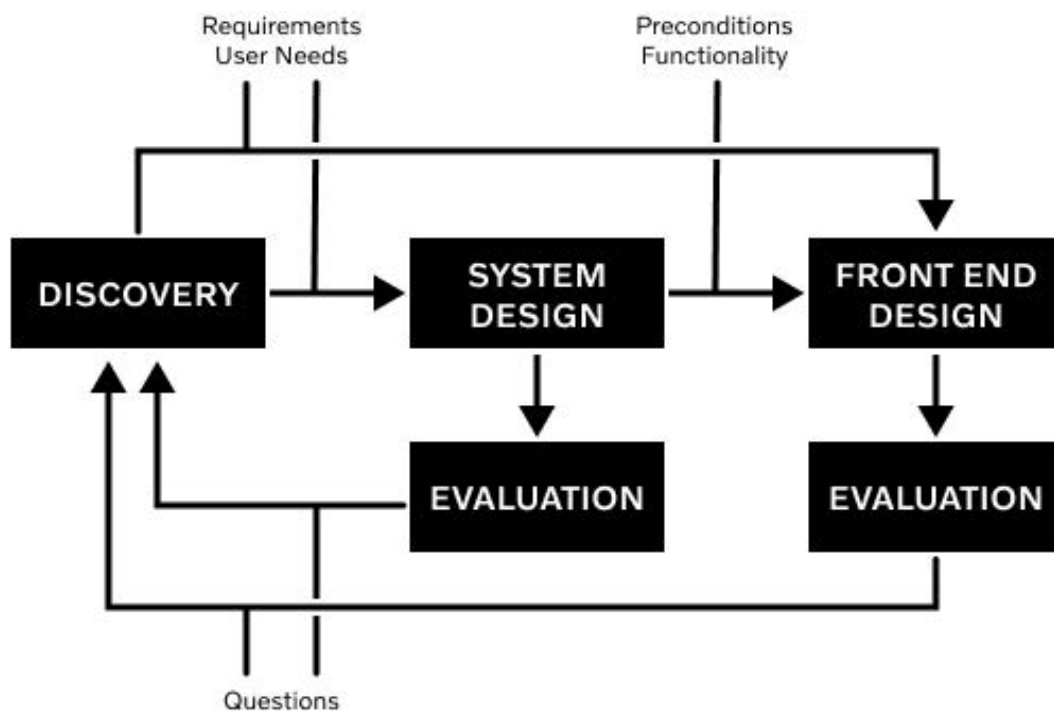


Figure 3: The iterative process applied in the project. Authors' own image.

## 1.6 Thesis Outline

The structure of this report follows the methodological approach used throughout the thesis project. It follows the design process conducted and includes the three phases of the project. Below, the chapters of the report are listed and explained to provide a guide of how to navigate and read the report.

1. Introduction  
The introduction provides a background to the project by explaining the basic context in which the project was conducted. Bringing up current issues regarding boat unlocking. The chapter also includes the project's aim and objectives and an overview of the design methodology used.
2. Phase 1 – Discovery  
The discovery phase presents the identification of needs in the project. Analyzing different unlocking methods for boats, boat monitoring systems, and user desires, the chapter explains both methods used and their outcome. The result is presented as a collection of use cases and their corresponding needs.
3. Phase 2 – System Design  
The system design chapter shows how needs are implemented as requirements and functions, and a system for boat unlocking is constructed. The chapter includes relevant theory regarding technology needed for the system. Also, methods for ideation and design of the system are presented.
4. Phase 3 – Designing the Front-End  
The front-end design chapter includes the process of designing user interfaces used to interact with the system. It includes usability, and design theory to explain how the design came to be. Further, the evaluation of the interfaces is presented along with the final design.
5. Result  
Each phase chapter presents the process and results of its own sub-goal. The result chapter gathers all the results to show a holistic view of the functionality developed throughout the project.
6. Discussion  
The discussion examines and concludes the project, tying up loose ends. It also presents the future areas of investigation if this project is to be continued.

## 2. Phase 1 - Discovery

This chapter aims to explain findings from the information gathering part of this project. It explains the methods used and what was learned from them. The result of the discovery phase was a map of different users. From the map, four extremes were compiled into use cases with their respective user needs.

### 2.1 Benchmarking

Benchmarking is a term that describes a comparative evaluation where one can look at what makes competitors successful in each context to understand if one can learn from their approach. Moran (2020) summarizes the method as “UX benchmarking refers to evaluating a product or service’s user experience by using metrics to gauge its relative performance against a meaningful standard.” (Moran, 2020).

The benchmarking study for this project was performed to gain insight into competitor strategies and features that could be beneficial for future development. It looked at key and sharing service solutions on both the marine and automotive markets to widen the scope of possibility, as well as safety lanyard and connectivity features. The distinctive features were compared to find qualities which could provide value to a future solution. This provided a basic understanding of some of both direct and indirect competitors for Volvo Penta.

The benchmark completely disregarded competitors who utilize a turnkey as their method of unlocking. While turnkeys remain the standard unlocking solution which most marine engine manufacturers deliver, all turnkeys possess the same functionality. Further, turnkeys do not solve any of the issues this project aimed to solve. Therefore, they were regarded as not modern enough to be a suitable solution on the marine market today.

#### 2.1.1 Volvo Penta e-Key and e-Key Remote

Volvo Penta delivers two electric locking mechanisms for the EVC system. E-Key, which is a RFID tag the user swipes at the EKS panel to unlock the ignition, and e-Key remote, which is bundled with a battery management system and allows for unlocking of the ignition from up to 100 meters away (Volvo Penta, 2016). The e-key tag is limited to locking and unlocking the ignition in interaction with the EKS panel. After authentication, the user should engage the ignition button (or buttons if there are multiple engines) and then they can start by pressing the start/stop button on the EKS panel. The e-Key remote is sold as a part of the Battery Management System that Volvo Penta offers their customers (Volvo Penta, n.d.-a). The remote key has its own on and off button to unlock and activate the ignition as well as disabling it. It is also equipped with two auxiliary buttons, marked as 1 and 2, which can be connected to several distinct functions, such as controlling anchors or lights. These buttons can be connected to functionalities via the Battery Management System.

The e-Key tag was found to be a utilitarian product. It is simple with a simple product task. Things that were remarked on during the benchmarking about the product were that it had a poor identity and that it did not convey the intended use of the product clearly. It was also noted that the product did not give a premium feel. The small size and low weight of the e-Key made it feel easy to lose, especially in its use context where the product is swiped on the EKS panel and then stored somewhere in the helm given that the product has no purpose while the engine is running. From conversations with Volvo Penta employees, it was said that it was common to see the e-Key tag hung in the helm in a Ziplock bag.

The e-Key remote is in many ways a top-of-the-line product compared to competitor solutions. Starting the system from a range from up to 100m was unique among the marine products and is more like how a modern car key operates. This functionality was liked among

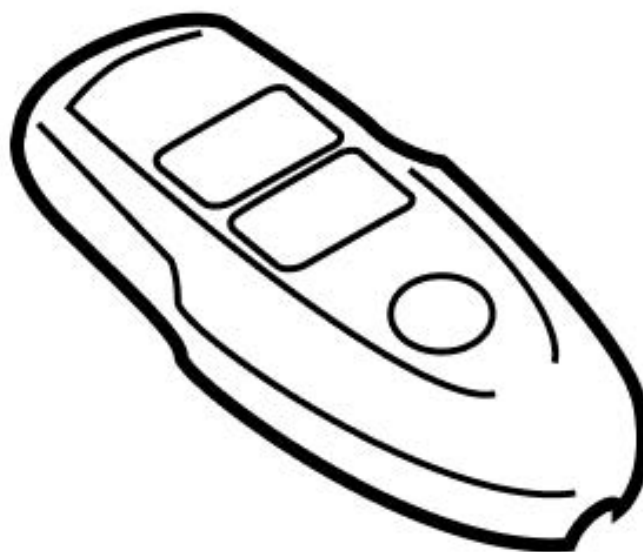
the users interviewed that used the remote key and one input was that some liked that they could see the system light up from afar with the Volvo Penta logo. The option to use auxiliary buttons was however met with less enthusiasm. The icons on the buttons do not convey their use, and they were not utilized for anything by the companies own test boats. The semantics of the product were found to be simple and manufactured and it did not convey much Volvo Penta identity.



*Figure 4: Volvo Penta eKey remote*

### **2.1.2 Yamaha Electric Key Switch**

This key works in a comparable way to Penta's remote key. Used to unlock the ignition from a far or as keyless start when on board the boat. Yamaha marine mostly produces outboard motors for smaller craft than Penta delivers to, which makes the keyless start more useful, since there is no cabin to unlock before arriving at the helm (Yamaha Motor Company, n.d.).



*Figure 5: Yamaha Electric Key Switch.*

### 2.1.3 Suzuki Marine Keyless Start System

Like Yamaha's key, Suzuki's enables keyless start. However, the key fob is only equipped with a lock button, therefore the user must board the boat to engage the engines (Suzuki Marine Europe, 2014). Suzuki's system does not include an ignition lock. Thus, a physical main switch for the electricity on board must be activated before the key finds any use. Adding to this, Suzuki has also opted for a physical safety lanyard which must be fastened before the start switch is operable.



Figure 6: Suzuki Marine Keyless Start System key fob.

### 2.1.4 Coastkey

Coastkey is an aftermarket solution for remote start. It includes both start fobs and MOB fobs. The ignition can be unlocked either through a code panel or a key fob (CoastKey, n.d.). A smart function of the Coastkey system is that it can start up to four drivelines from a single button push. It will then start the engines in sequence. This operation can be remotely controlled with the key fob. Since the Coastkey is a third-party solution, it is not connected to a battery management system, thus the user will have to engage electrical switches before its functionality can be used.



Figure 7: Coastkey fob.

### 2.1.5 1st Mate

1st Mate is primarily a MOB (Man Overboard) system, a kill switch which disables a boat's engines (1st Mate, 2020). It operates wirelessly and disables the engines when a fob leaves the range of a wireless transceiver. It can connect to the boat's navigation equipment to show where the fob was disconnected and connects to a mobile application where you can modify settings in the system. The secondhand functionality is an immobilizer. By activating the immobilizer function, the engines are locked until the immobilizer is deactivated. An important note to the 1st Mate is that it is not a standalone unlocking product, the boat still requires keys for its motors.

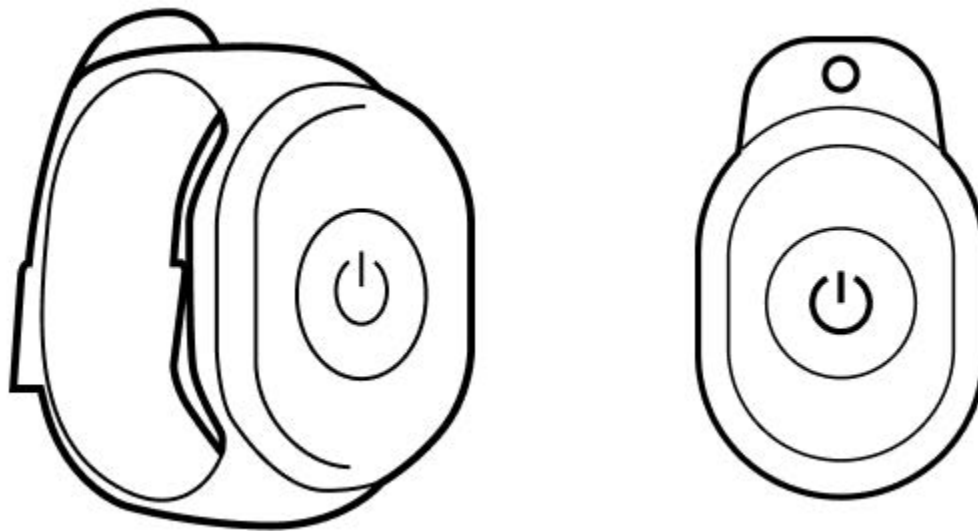


Figure 8: 1st Mate MOB fob.

### 2.1.6 Fell Marine MOB+

The MOB+ is purely a remote kill switch. Like 1st Mate, it switches off engines when it has been disconnected from a wireless transceiver. It also has a hardware emergency stop button and a small LED (Light Emitting Diode) interface to show how many MOB fobs are connected (Fell Marine, 2021).

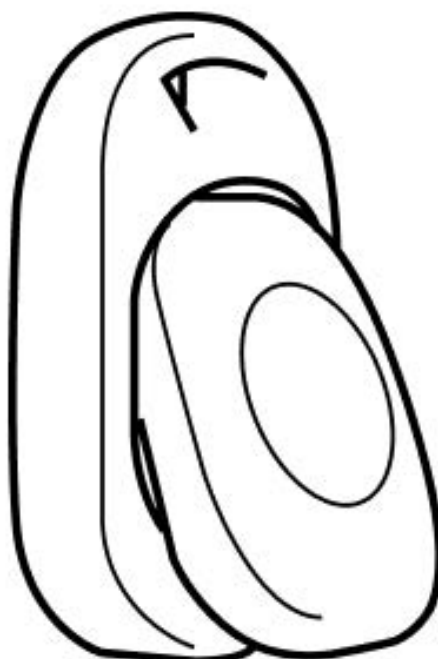


Figure 9: Fell Marine MOB+ fob.

## 2.1.7 Volvo Cars

Volvo Cars' keys are both RKES (Remote Keyless Entry and Start) and PKES (Passive Keyless Entry and Start). Users are provided with buttons on the fob but pulling a door handle when a key is close to the car will also unlock it. When the car is unlocked, the ignition is also automatically engaged. With a passive start system, a user needs only to turn a knob to get the engine started, or in electric cars, press the brake pedal (Volvo Cars, 2023). Adding to this, newer cars from Volvo Cars allow locking and unlocking the car from a digital key in a smartphone application. In the application, it is also possible to see if any car windows are down and where the car is parked. Further, a user can send their desired destination to the car through their phone to have navigation ready, as well as pre-heating the engine or engaging the air conditioner (Volvo Cars, 2016).

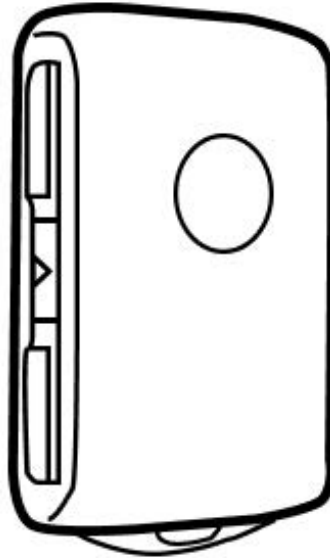


Figure 10: Volvo Cars key fob.

## 2.1.8 Torqeedo

Torqeedo produces electric motors for smaller boats. They have a modular approach to their products with a simple and friendly design. Their key solution is a tag that is placed on a designated slot on the control surface, and it attaches magnetically. The tag is fastened to a string which is supposed to be attached to the driver to act as a kill switch if the driver falls overboard. Torqeedo's strength lies in their straightforward design which makes the unlocking process intuitive and easy for the user (Torqeedo, 2023).

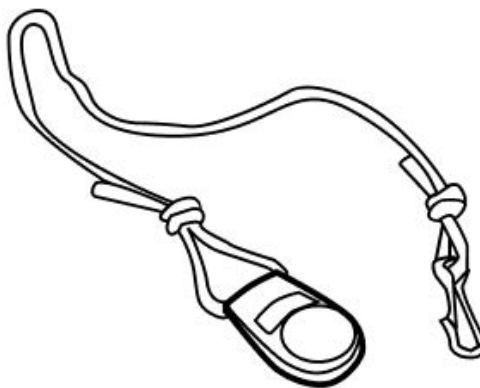


Figure 11: Volvo Cars key fob.

## 2.1.9 Strana

Strana boats is a new boat builder which constructs fully electric boats with built-in sharing capabilities. Strana users utilize the Strana app to both boat sharing and unlocking. Via the app users can list their own boat for sharing with other Strana users and it is possible to both share the boat for shorter listings and for long time co-usage . (Strana Boats, n.d.)

This product has an interesting way of looking at boat ownership and it feels modern. Co-usage and rental business models can be an efficient way for vessels such as boats and cars to maximize their usage as discussed in section 1.1.3 Servitization in the Marine Market.

## 2.1.10 Siren Marine

Siren Marine is a remote boat monitoring system that connects to a user's smartphone. The system has many features and benefits for a boat. There are many different monitoring devices that can connect to a Siren Marine system to monitor things such as bilge water, batteries, or utilities such as a refrigerator. Their GPS (Global Positioning System) tracking enables features such as geofencing that enables the user to track their vessel and see get notifications if it would be stolen or operated in an unauthorized area. Their application can receive alerts and operate as a user interface where they can control connected systems via digital switches. This type of product has a lot to offer in the marine market. Connectivity is a sought-after quality in more areas since it offers users both control and comfort that their vessel is OK when they are away.

## 2.1.11 Easy Connect

Easy Connect is Volvo Pentas app which currently serves the function of checking engine status and journey planning. The system uses a device that reads engine and driveline diagnostic data which the user can access via their smartphone or tablet (Volvo Penta, n.d.-b). To access these features the user buys an interface kit that connects to the EVC system, they can then connect their smart device to this interface kit via Bluetooth. The system is not connected when the EVC system is turned off, meaning it cannot show current data, only the status of the vessel from when it was last active. Easy Connect was deemed important to include in the benchmarking because it is the current application solution that Volvo Penta provides their users. Even though the scenario for using the app is different to what this project focuses on it was useful to establish a baseline for what Volvo Penta finds important to include in their application.

Easy Connect has some features that can elevate the boating experience for a user, and it can have good qualities to help the user keep track of service intervals and other engine-related information (Volvo Penta, n.d.-b). The journey planner is a good feature that adds more value to the application. What the application lacks is true connectivity. The competitor Siren Marine can read and send status updates, which is particularly useful since it can communicate live positioning data and battery status updates. A non-connected system will always lack true comfort and control over a vessel since it does not offer the user the same level of preparedness before arriving at the docks.

## 2.2 Interviews

Seven interviews were conducted to gather qualitative data relating to various parts of the project. The interviews were semi-structured with some prepared questions which can be found in Appendix A, with additional probing questions. Interviewees were instructed to speak their mind and speak openly about their opinions and insights from their area of expertise. Interviews were primarily conducted with employees of Volvo Penta and were centered around their expertise in their professional role, but since many of Penta's employees are boating enthusiasts outside of working hours, they could also provide their input from a user perspective.

It was noted during the interviews that there were conflicting desires for a new unlocking

system, primarily from a user perspective of the leisure variety. During further examination of the interviews, it was determined that there are primarily two distinct types of leisure personas: The planner and the spontaneous cruiser.

The planner uses their boat in a very intentional way. They are meticulous and service their boat before an excursion, they visit their boat to check statuses to make sure that their vessel is ready for an outing. They saw little need to make unlocking less complicated as they always kept track of their keys and did not see themselves likely to be near their boat without having all their boat keys with them. Although some noted that it was an inconvenience to carry multiple keys. They were however intrigued by more connectivity in boats to monitor stats and positioning. “There is nothing spontaneous about boating.”

The spontaneous cruiser is more likely to want to use their boat more casually than the planner. They listed nice weather as a reason that one might want to go on a spontaneous outing. They also mentioned the desire to be able to drop by their boat by the docks on a whim. Today that could be an issue since they do not usually carry their boat keys with them. They also expressed that not knowing if the boat is ready for usage is a pain point as the uncertainty can be a reason to not go on a spontaneous outing.

One interview was conducted with an employe from the North American part of Volvo Penta to gain insight into the North American market. They highlighted convenience and budget as a major factor to cater to. They noted that leisure usage differed from the European market and that day trips or fishing were the most usual types of activity and that overnight stays on your boat were less common. The interviewee also mentioned connectivity as something that people want and that many users currently find creative after-market solutions to fulfill their needs such as using a connected security camera to surveillance their boat.

Some of the interviews were conducted with personnel who have insight into how Volvo Penta’s commercial segment operates and what their needs and desires are. Factors to consider from the commercial segment are:

- Does the vessel have a set schedule and is operating on a regular basis or is it used at random ventures where the vessel needs to be accessible at any moment?
- Different people will require access to the vessel due to factors that include people working in shifts and maintenance personnel accessing the boat for service.
- Certain sectors have increased security demands which need to be accounted for to ensure a secure vessel that is difficult to compromise without authentication.
- Connected systems are desired for fleet management purposes and to enable access to onboard data from afar.

Different commercial uses that are important to keep in mind to emphasize the range of utility that a commercial vessel can have can be emergency response, ferry service and military use. Emergency response at sea in Sweden is typically done by Sjöräddningsällskapet (Swedish Marine Rescue Society) in coordination with the authorities (Sjöräddningssällskapet, 2022). It is important that emergency operations such as Search and Rescue (SAR) can set off from the marina as soon as possible after getting an emergency call due to the possibility of lives being at risk if a boat is in distress. For this project it is important to keep this situation in mind as it is vital to make sure that a new method of unlocking does not make the user journey from emergency call to setting off more complicated. Ideally, it should make it more streamlined and easier to set off.

Ferry services typically operate regularly with set times for departures and arrivals. They are in use for long intervals and there might be different crew starting the opening shift than the one closing. That means that this project should keep in mind to accommodate multiple

different users within a user journey as it could be different people who lock and unlock a vessel. Therefore, a key should be sharable in some way.

In cases where vessel data can be considered sensitive information, such as military and police boats. Demands are set on the project, primarily from security aspects. The integrity of the system must be resilient in protecting the data from unauthorized use. An aspect which is important to consider for a connected solution. One solution could be the choice to opt out of a connected solution for sensitive applications. Another is to create a solution which matches the security requirements which require high integrity.

## 2.3 Mapping use cases

To get an overview of the different use cases that have been discussed they were put into a perceptual map. A perceptual map is primarily used to understand customer perception of a product by analyzing where on a graph with two axes and where both the vertical and horizontal axis are labeled as two different words, which are considered as important criteria, the customer thinks that a certain product is (Mindtools, n.d.). The positioning on the map can help to get a visual understanding of where products are positioned. This project, however, applied the perceptual map in an unconventional way. It was used to map out many of the intended use cases of a boat. The criteria that were found to be most representative of the differences in the marine market were determined to be: Leisure- Commercial and Spontaneous- Planned. The leisure- commercial scale ranges from pure joyrides in your boat to businesses such as ferry services or fishing, where the middle of the scale can involve important tasks, such as servicing your vessel or checking utilities. The spontaneous- planned scale ranges from trips with a boat that can happen at a moment's notice, such as emergency response or a casual stop at the marina to highly planned activities such as a scheduled ferry service or a planned vacation. The map helps differentiate what are noticeable criteria for each different use case and can help visualize the level of preparedness that the user needs for each use case to be able to happen. The level of preparedness is important to consider when examining the startup procedure of a boat. How much the user needs to prepare before setting off is related to how easy it will be to get out on the water from the moment that the urge to go boating occurs.

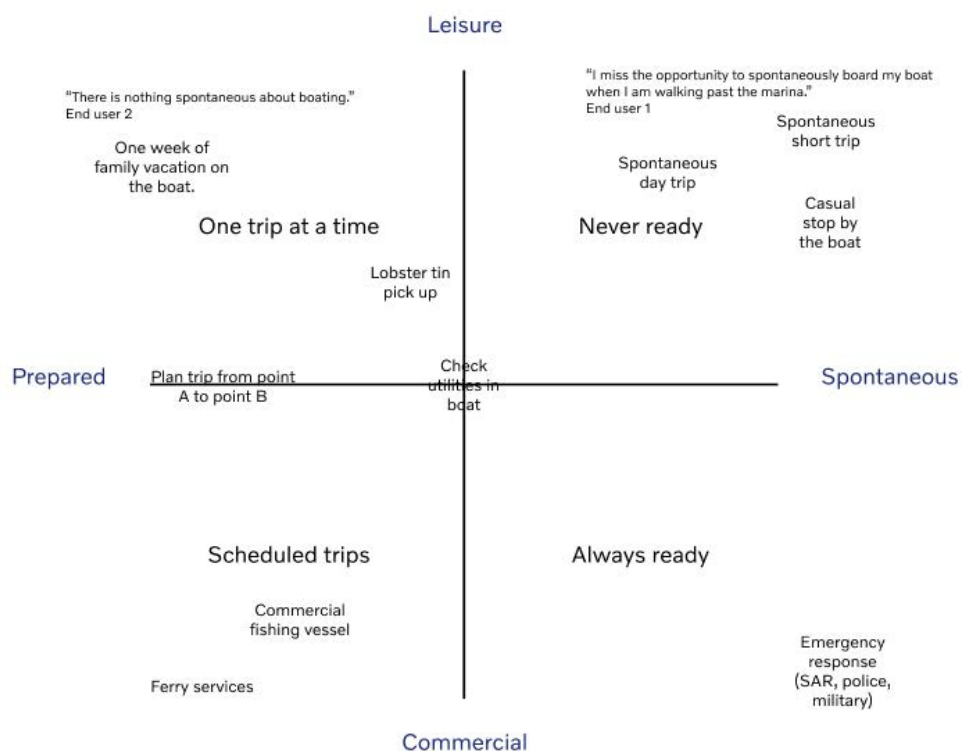


Figure 12: Perceptual map of user groups.

## 2.4 Field Studies

Several observational studies were conducted as a part of the project. One of which was visiting the Gothenburg boat fair. This consisted of visiting different boats that were from different shipyards and investigating both how Volvo Pentas current solutions are installed in boats today as well as seeing what current practices for competitor's solutions are. Many diverse types of both leisure and commercial vessels were entered. The most common choice of unlocking method was a turnkey with an accompanying number of start/stop buttons corresponding to the number of drivetrains on the vessel. On vessels with more than one driveline there was a key for each.

An interesting finding concerning MOB (Man Overboard) functionalities was that many boats featured physical safety lanyards that were connected closely to the steering position. This was not found as odd in cases where the helm of the boat was open where there is a risk that the driver can be thrown off the boat but in cases where the safety lanyard was inside a closed helm of the boat one needs to question the addition of the feature. It is within reason to say that a physical safety lanyard that is inside a closed helm is strange since the driver will not be at much risk of falling overboard. If the driver needed to step out of the driver's environment it is likely that they would disconnect their attachment to the safety lanyard instead of disconnecting the safety lanyard itself. This means that if they fall off when they are outside the helm the MOB functionality will not trigger.

Another interesting find was a note placed on the cabin door of a new premium boat. The note read "Warning! Different key/lock numbers for side and rear door. Please use dedicated keys.". The note was most likely there as a reminder for the user to keep their keys organized and highlighted the issue of there often being many different keys to keep track of for outings with a boat.



Figure 13: Note on boat cabin door reminding user to keep track of keys.

Another study was to attend a test run of one of the working boats that are used to test the company's engines. The purpose of this was to observe how a commercial usage situation of a boat could be and see how the drivers' routines looked like, as well as ask questions related to unlocking and onboarding. It also served as a demonstration of how the e-key remote works in a real-world setting. The driver of the boat noted that he liked the functionality of the e-key remote with its ability to start the system from afar. They liked the feedback of the screens lighting up when they approached the boat.

## 2.5 Use Cases

The result of the discovery phase of this project was a perceptual map of different use cases. The map consisted of two dimensions, commercial to leisure, and spontaneous to planned. This was made to provide a concise list of many different use cases. Lastly, the four most descriptive use cases were elaborated via scenarios to give a more detailed view of the user insights found and the requirements for each use case put on the solutions in the project. The use cases are presented to give insight into the broad scope of uses for a boat with a Volvo Penta system. The use cases were part of a co-creation workshop conducted with several Volvo Penta employees. As a part of the workshop user needs for the use cases were put together.

### 2.5.1 Planned Leisure

This use case is based on the findings from the interviews where the planning personality was found to be common. The planned leisure use case relates to boating trips which are planned more than a day in advance. Given the time to plan, a user will already have goals for their trip. This type of user is likely to prepare their boat for a trip some days ahead of their trip by checking that systems and utilities are working as they should. Pain points for the planner might be if they are able to remember all the information, they need to be sure that their plan runs smoothly. Minimizing things to keep track of could also be a desired functionality for them. The typical scenario for this type of use case is the Vacationer. Presented below is a written scenario based on their intended behavior.

Tomorrow it is time to go on the annual big boating vacation. You are excited and have planned a route with interesting spots to visit with your guests. You were down in the marina yesterday and had a look so that everything would be smooth during takeoff but now that you think of it you cannot remember if you filled the freshwater tank. You also put some beverages in the fridge, but was it turned on? You really want to impress your guests with a cool beverage to welcome them aboard. It is looking to be a really hot summer day tomorrow so maybe you should go to the boat early before the guests arrive to start up the A/C unit, so they do not have to put away their stuff in a cabin that is closer to a sauna. You could go to the marina earlier tomorrow, but it would also be nice to sleep in a bit.

The scenario highlights a need to make sure that their vessel is in good condition for an outing and their desire to know that systems will be running smoothly for when they are set to take off.



Figure 14: Example of a typical vessel for the Planned Leisure use case. Image reproduced with permission CC BY 2.0 from Nyman (2013).

## 2.5.2 Planned Commercial

The planned commercial use case relates to scheduled trips for work boats where the captain will often know what to expect from the trip and the boats are regularly maintained and refueled. This type includes ferry services and commercial fishing vessels. Things to consider for this use case include how shifts for crew affect the operation of the vessel, this includes both how they keep track of systems and utility information as well as how they share keys between themselves. The scenario written below aims to show how this might play out in practice for a Ferry Service in the archipelago.

It is early morning and time for another shift driving a ferry in the archipelago. Routes and departure times are well known to you. Since your last shift, two other captains have driven the ship. While all captains follow the same start-up and handover routines, the vessel's status is unknown to you before your arrival at the dock. Since passengers are waiting to get to and from the archipelago, timekeeping is important. Therefore, you wish all checklists are as quick and easy to complete as possible.

The scenario highlights that it is reasonable that it can be hard to keep track of certain things in-between shifts and that there is room for solutions to alleviate this for people. Since time is often a key factor for the crew to keep track of things that can help make routines go quicker is surely an asset.



*Figure 15: Example of a typical vessel for the Planned Commercial use case. Image reproduced with permission CC BY 2.0 from Nyman (2020d).*

### 2.5.3 Spontaneous Leisure

This type of user is based on the findings from the interviews where some expressed their desire to access their boat more spontaneously than they currently can. Spontaneous Leisure trips are unplanned recreational outings. Pain points for the user in this scenario is to have certain things planned to go out on an outing. This could include things such as fuel or having the key in their possession. A casual boat user might not remember how much fuel was left in the boat from the last outing and they might not carry the keys to the boat everywhere they go. These factors can be viewed as obstacles that can hinder a user from utilizing their boat. The solution should try to amend these things in mind to increase boat usage. The scenario for this use case is the Spontaneous Evening Cruise which is presented below.

There is no initial plan for an outing at sea. The weather prognosis was not looking too good for this day, but it might be clearing up. You were supposed to meet a friend after work and go to a bar. This friend has been asking for some time to go out on a trip on your boat and you think that today might be a good occasion now that the weather might be clearing up. You are at work and cannot prepare for this outing like you are used to. The last person that used the boat was the person that you co-own the boat with, and you are not sure how they left the boat. You cannot get a hold of them to ask.

This scenario highlights the users' lack of information which can make it more difficult to go boating. Having access to information about a boat's status for fuel, systems and utilities could make it more likely that they can trust that the boat is ready for use. It also shines a light on how getting access to a boat might be difficult in some cases since there can be difficulty in getting ahold of your keys.



*Figure 16: Example of a typical vessel for the Spontaneous Leisure use case. Image reproduced with permission CC BY 2.0 from Nyman (2020a).*

## 2.5.4 Spontaneous Commercial

Spontaneous commercial trips are outings such as emergency response. Based on the interviews conducted, it is common for the boat on this type of outing to be prepared for the next take off after they have reached the harbor from the outing before. What makes this type of outing labeled as spontaneous commercial is that although the driver is on call, they can never know when they must go out for an emergency. The driver assigned to the emergency is likely to not have been the one driving the boat on the previous occasion and must make sure that the vessel is fit for the next mission. A typical spontaneous commercial scenario is Search and Rescue (SAR) operation which is elaborated on below.

An early morning in the autumn, the alarm goes off. A boat has been shipwrecked and its crew have all fallen overboard. You know you and other emergency responders are short of time and want to depart as fast as possible. At the station, your boat is always refueled/recharged upon return from a call. There should also be a status check of all drivelines and systems regularly, but it is sometimes overlooked in favor of efficient take-offs. Similarly, the ship journal usually misses a few entries when the boat has been left in a hurry.

The scenario highlights that time is a crucial factor in a SAR situation, and if it is possible to make any step more efficient, it will be an asset in an emergency response. Acquiring status information and getting access to the correct boat for the mission as soon as possible are important steps before heading off and if it is possible to make that process smoother it will be a benefit. This type of operation also needs vessel sharing among different drivers, which is important to consider.



Figure 17: Example of a typical vessel for the Spontaneous Commercial use case. Image reproduced with permission CC BY 2.0 from Nyman (2020c).



# 3. Phase 2 - System Design

This chapter explains how the new unlocking system is set to operate and how the ideation process to produce this system looked like. It goes in depth on how some intended features work, the theory behind them, and ideation and evaluation methods. Some features explored will not be explicitly implemented in the new system design as that would be too large of a project to evaluate the full scope of. As these features have all been part of this project's ideation, it is important to understand how they could be implemented in the system and were dealt with during the ideation process. The idea of the new system was to offer a platform for these features to be implemented, therefore it is valid to explain how they work to clarify that a system like the one explored in this project has a lot to offer a user.

## 3.1 Human-Machine Systems

Bligård (2015) explains human-machine systems as a system in which humans and machines are their own subsystems which form a system capable of more than each subsystem is individually. Each human-machine system operates in a context to fulfill a goal, to transmit information, energy, or matter from human to machine or vice versa. The context which a system is active in affects it directly and is thus important to consider. Humans, machines, and contexts can vary while the system goal remains the same. The main channel for communication, or information transmitting between human, and machine is an HMI, where the machine can present information and the human can control the machine.

## 3.2 Technical Context

To provide usability, appropriate use of technology is important, and in compatibility cases it can be vital. In parallel to ideation when designing the system, technology suited for the task was researched. Current technology placed in boats, which the system designed would need to be compatible with, and technology from other contexts which could be implemented to enhance the system's functionality.

### 3.2.1 Communication in Marine Electronics

Marine onboard electronic devices use Controller Area Network (CAN) buses using the NMEA 2000 protocol. As Cassidy (1999), chairman of the National Marine Electronics Association explains, an NMEA 2000 network consists of several interconnected devices, such as GPS receivers, chart plotters, radars, sonars, and fuel level sensors. The devices are all connected to the NMEA 2000 backbone, providing power, and allowing data transfer. By using CAN buses, the network allows for all devices in the network to communicate simultaneously, and the protocol provides ways for the network to categorize the data. Since many marine electronic devices are built to communicate through the NMEA 2000 protocol, it admits scalability and modularity to onboard systems. The only limitations being a maximum total cable length of 200 meters and a maximum of 50 devices in total, to ensure an information transferal rate of 250 Kbit/s. Overall, the NMEA protocol is a prerequisite for an integrated marine electronic system.

The Volvo Penta EVC system uses its own CAN protocol which can communicate with an NMEA 2000 network through a gateway. One such gateway is the Easy Connect interface, a component which allows users to read system data in their smartphone or tablet. The Easy Connect interface is equipped with both EVC and NMEA 2000 connections and can serve as a gateway between them, beyond its main functionality. Another way to integrate an EVC installation to a NMEA 2000 network is the Information Gateway (IGW), which allows the EVC system to communicate with more onboard systems (Volvo Penta, 2015).

### **3.2.2 Battery Management and Digital Switches**

All onboard electronics require power. In marine vessels, batteries are the main power supply. The batteries are supplied with charge either by an alternator which gets its power from the engine, renewable power sources (e.g., wind or solar power), or shore power (a cable connecting the boat to a land-based power grid). Since electricity is required for onboard systems to function, from powering a refrigerator to starting engines, maintaining battery power is important. The traditional way to monitor battery status onboard is through a voltmeter and interpret the readings. Further, the conventional way to switch power on or off is with a physical switch which closes or opens the circuit which the battery supplies voltage to. Moreover, the common practice is to supply one battery per engine and at least one for domestic functions. Each battery has its own closed circuit and is charged independently.

To simplify battery management, there are systems which aid in the endeavor by automating retrieval of battery status and consumption, as well as enabling simpler switching. To expand the usefulness of a battery management system, it can be equipped with or combined with digital switches.

### **3.2.3 Keyless Entry and Start**

Remote Keyless Entry and Start (RKES) and Passive Keyless Entry and Start (PKES) are methods of unlocking and starting vehicles without the need of a turnkey in a physical lock. Both methods emerged in the 1990s and have found themselves to be the definition of a modern car key fob. RKES refers to classic remote key fobs, with an electric actuator which sends a radio signal toward a receiver which interprets the signal and unlocks. PKES is the modern approach in which the key fob itself is passive and the receiving end, the lock, actively sends a signal to the key fob, which responds (Alrabady and Mahmud, 2005). Usually initiated by an action such as pulling a door handle. For both RKES and PKES, communication between key fob and receiver is facilitated by either Radio Frequency Identification (RFID), Bluetooth, Near Field Communication (NFC), or Wi-Fi (Areed, 2019). PKES is a quality-of-life upgrade since it reduces the user's need to physically interact with a key. However, there are safety concerns with using PKES. While most PKES systems use some sort of encryption in their communication between key fob and receiver, listening in on both signals is usually enough to find the encryption key, and copy the key fob's signal (Oguma et al., 2011; Wouters et al., 2019).

Smart locks, meaning locks that are connected to the internet and can be unlocked by any authorized device or interface, such as a smartphone or smart key, offer higher security. One factor being connectivity allows keys to be continually refreshed (Kassem et al. 2016). The vulnerability of such systems is defined by that of the devices which it operates through. However, the system Kassem et al. propose is constructed for use in houses, it requires a wired internet connection which is difficult to facilitate in a boat, a vehicle. To enable connectivity in this case, wireless communication is required. Using 4G or 5G internet would be a valid workaround to solve this issue. In this thesis, the concept of a digital key is interpreted as enabling smart devices as keys. Examples are smartphones and smart watches. Products which many people own. As compared to the use of physical keys, digital keys open for more flexibility and easier sharing of keys (Wei et al., 2017). Since there is no requirement of a physical transaction of a key, it can instead be facilitated by transferring a key to a device which the user already owns.

### **3.2.4 Internet of Things**

When researching connected and smart objects, Internet of Things (IoT) is a concept which is often mentioned. IoT is defined by the Oxford English Dictionary (2022) as “a proposed development of the internet in which many everyday objects are embedded with microchips giving them network connectivity, allowing them to send and receive data.”. An important feature of an IoT architecture is that things in the system should be interconnected and

self-configuring (Li et al., 2015). Implying that all things know how they should connect and configure themselves in a system. Allowing for smooth addition and removal of things. Such a system allows for modularity and scalability, thus allowing users to choose the items they deem necessary for their individual application. 4G wireless communication is used in IoT systems today and has been altered to fit the demand of an IoT expansion (Li et al., 2018). Li et al. continues, analyzing the difficulties to overcome to fit IoT applications to 5G networks, which include scalability and safety concerns. However, 5G connectivity would benefit large scale IoT systems with superior speed and low latency. In the case of unlocking marine vessels, reliable connection and system integrity is more important than low latency and high-speed internet access. Thus, opting for an older, proven generation of wireless communication is preferable.

### **3.3 Safety Lanyard and Man Overboard**

Safety lanyard- or Man overboard (MOB) systems are often a prominent feature in marine safety that seek to minimize the risk of harm if the operator would fall off the vessel. A safety lanyard system most often works by automatically stopping the vessel if the operator moves too far from the steering position. This is often done by physically connecting the operator to the steering position, and if the connection is broken it activates as a kill-switch thus disconnecting the throttle of the vessel (Department of Transport, 2019). There are safety lanyards that do not require operators to be physically connected to the boat. These can work by utilizing a wireless transceiver that can identify if a wearable the operator has on them has left the range of the boat and then disconnecting the throttle. A type of functionality found in some of the products presented in the benchmark.

Designing a system with the purpose of unlocking marine vessels, including the drivetrain, could include a digital kill switch. A good procedure to adhere to is to make sure that the vessel can engage after being disconnected by a MOB-system. This could be done by having an extra lanyard in the boat that can replace the one connected to an operator that has fallen off the vessel, since it is often not possible to engage the throttle if no lanyard is connected.

### **3.4 Process and Method**

The design process for this phase of the project aimed to find how a system could support functionality which would cater to the user needs found in the previous phase. First, the process of ideation was conducted, which ended in a wide solution space with many potential solutions. In parallel, a design specification for the system was compiled, which combined user insights with findings from research and ideation. This specification was used to narrow down the solution space into a final system design.

#### **3.4.1 Ideation**

Ideation in this phase of the project aimed to find how desired functionality could be grouped and packaged into a system. Based on user insights and market analysis. The main goal of the ideation process was to find as many potential solutions as possible, to widen the solution space. The process went from unorganized brainstorming sessions to a mapping session to categorize solutions and finally using scamper to generate more ideas from the ones already found. .

##### **3.4.1.1 Brainstorming**

To get started and to generate a large solution space. Brainstorming was used frequently in the beginning of the ideation. The goal of the method was to say anything that came to mind, without criticizing the ideas of one another (Wikberg Nilsson et al., 2016, p.125). All ideas were documented in Figma to be used in further ideation. The brainstorming sessions were all on what functionality the system should include as opposed to how to facilitate the functionality. After each session, an evaluation round took place, where ideas were eliminated based on feasibility and reason. Subjects brainstormed were man overboard/safety lanyard, locking/

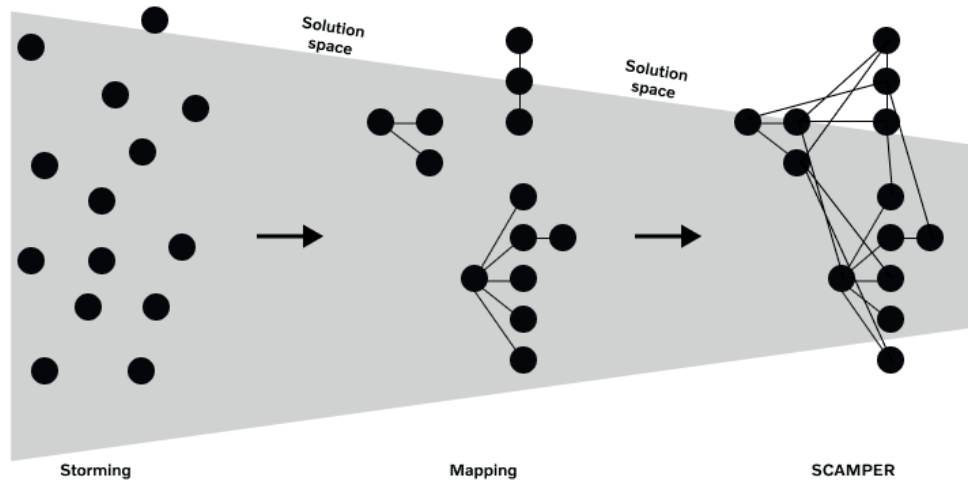


Figure 18: The solution space narrows with each step in the ideation process.

unlocking, key sharing, and starting/stopping the boat. After a couple of brainstorming sessions, there were 40 ideas on how the system should function. Mind mapping, a method used to structure and keep track of ideas and cluster different information together, was then used to categorize the ideas. This created a map where relationships between functionality and potential user interfaces became visible. The map put the 40 ideas into seven distinct categories which were then used in further ideation.

### 3.4.1.2 Scamper

Scamper was used to develop ideas and to apply concepts in creative ways. The scamper method poses the questions: Substitute, Combine, Adapt, Modify, Put to other use, Eliminate and Reverse to support an ideation process. The method has been developed by Bob Eberle and is usually applied to ideate further after a brainstorming session or other similar methods (Wikberg Nilsson, 2016, p.133). Here, the mind map which came from the brainstorming sessions was used as a base and new relationships were formed when distinct functions were combined, or a user interface was substituted by another. New links were drawn in the mind maps between functions and features, across previously defined categories.

The method widened the solution space by introducing more ways to allow certain functionality. Simultaneously, it shone light on features which opened for most compatibility with different solutions. No formal concepts were constructed in this phase of the project. Instead, there was a process of narrowing down the solution space into a system which fit into the user needs by providing desired functionality. To narrow down the solution space, a design specification was constructed.

### 3.4.2 Design Specification

Apart from requirements applied from user desires, new requirements surfaced during ideation. The system goal was to transmit information about authorized access. This goal included prohibiting unauthorized access. Further, it was to increase the usability and usefulness of an authentication method for boats. Which would simplify the boat unlocking procedure relative to current solutions. To concretize the system goal into specific requirements, a specification of requirements on a system and compatibility level was compiled, which also included security requirements.

The system requirements are requirements on the system's functionality. Related to connectivity, the possibility of remote access to data from the boat, and the feature of authorizing users and accessing the boat. There was a contradiction between the wish for a connected system which allows for continuous monitoring of a boat, and the wish for a system with no connectivity for boats which status is sensitive if accessed by the wrong user.

In both cases however, the system must function while offline since coverage of cellular networks is limited at sea (Rao et al., 2016).

The system must be compatible with onboard systems, compatibility with both NMEA 2000 and EVC is therefore vital to the system. To function correctly it would also require functionality to switch onboard electronics on or off, even more important if the boat uses electric propulsion. To bring even more use to the system, it was also desired that it would allow one key to access all areas of the boat. This led to the desired goal of allowing the system to unlock external locks, such as doors and hatches. Even though Volvo Penta does not control how a boat builder installs doors and locks on a vessel as they supply the driveline and its control system. Exploring the possibility of including it in a future system could lead them to gain more control of the boating experience, as it would allow for easier onboarding.

Table 1: System Requirements.

ID	Requirement	Category	Comment
Sys1	System should enable long range access	System	
Sys2	System should enable offline use	System	
Sys3	System should enable vessel sharing	System	
Sys4	System should enable status monitoring	System	
Sys5	System should enable utilities control	System	
Sys6	System should enable geofencing	System	
Sys7	System should function when boat is turned off	System	
Sys8	System should function in any weather condition	System	
Sec1	System should prevent unauthorized use	Security	
Sec2	User interface should prevent accidental unlocking	Security	
Sec3	System should prevent unauthorized access to boat	Security	
C1	System should enable compatibility with smart devices	Compatibility	Phone, tablet, smart watch etc.
C2	System should be compatible with EVC	Compatibility	To access onboard data
C3	System should be compatible with NMEA 2000	Compatibility	To access onboard data
C4	System should enable unlocking and locking external locks	Compatibility	Hatches, doors
C5	System should enable unlocking and locking EVC	Compatibility	

### 3.5 Evaluation

The evaluation aimed to narrow the solution space down into a tangible system architecture. Some evaluation occurred in parallel with ideation since some ideas could be eliminated based on viability and reason. For instance, an idea found was to use biometric identification such as face recognition or a thumbprint scanner. Ideas which were eliminated after attending a boat ride in the rain where it became evident that no outside area on a boat would remain dry enough to consistently support such functionality. Some ideas could be eliminated using the specification of requirements.

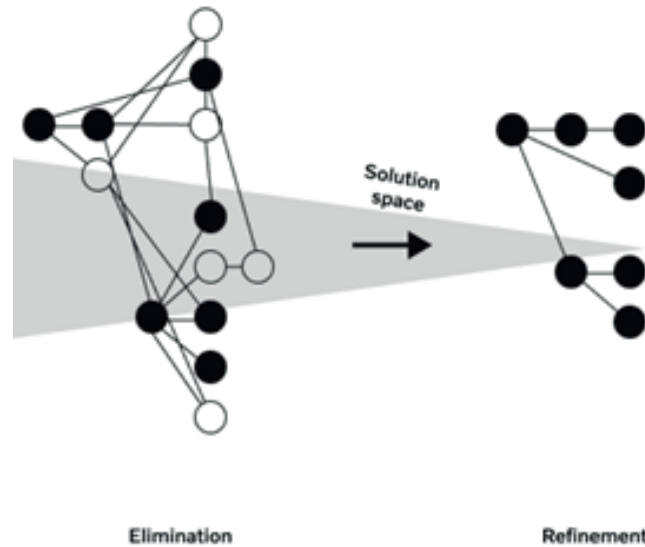


Figure 19: The solution space narrowed down by the evaluation process

As previously stated, there were no formal concepts to evaluate in this phase. Therefore, the evaluation aimed to find a solution in the solution space which met the requirements set and opened for the functionality desired. An action which aided the evaluation process was the co-creation workshop in which a multi-disciplinary group of people at Volvo Penta would state the importance of certain functionality in the system based on the use cases developed in the discovery phase.

Included in the group of participants were one UX-designer, one HMI engineer, two systems engineers, and one IT-security engineer. Each participant was considered to have valuable insight both in their professional expertise, but also as users since most of them had marine vessels of their own. The workshop started with a presentation on the project, the process so far and the results achieved along the way. Part of the proposed system was presented but not the entirety, so as not to lock the participants onto the solution. Also, the four use cases produced were explained. Afterwards, some questions regarding the functionality of the system were posed.

- Could this concept be launched within 10 years?
- Is there anything we have not considered?
- What is important in an onboarding procedure?
- Positive/Negative/Interesting with the concept?

The questions started two main discussions: cyber security and remote start. Cyber security was raised as an issue by the IT-security engineer. Intrusions into a boat are unwanted and delivering a quality unlocking system means keeping unauthorized users out. While the subject had been discussed earlier in the project, it had never been a focus of investigation. The discussion during the workshop granted insights into the importance of system integrity and that secure means of communication between the subsystems would have to be implemented. Remote start was a subject of interest since one of the system engineers had worked on larger boats with several helm stations and explained that drivers often found it annoying to be unable to start the boat from other stations than the main helm.

After the discussion, the co-creation session started. Participants were handed prepared worksheets with both spontaneous use cases, Spontaneous Commercial, and Spontaneous Leisure, from section 2.5. Which were a search and rescue situation and a spontaneous evening cruise. The planned use cases, also from section 2.5, ferries and a family boat vacation, were excluded to provide more focus for the use cases presented with the reasoning that solving the problems of a spontaneous outing on a boat would also solve the problems of a planned one. The worksheets included a description of the use case along with a timeline from the emergence of a need or wish to go boating until the boat can cast off. The goal was to find which information is important for users as well as how they want to receive it and when. Additionally, what parts would be needed in a system to support this? Mediating objects, examples of information needed and functions desired were also provided to the participants which they could place on the timeline. They were also provided with post-it notes to add additional items. The participants were instructed to place information and functionality on the timeline where they thought it was needed. When the desired items were placed on the timeline, examples of elements of a new system were handed out. Participants were then instructed to place elements in conjunction with the functionality it could provide.



Figure 20: Picture taken during co-creation of the system showing the worksheets used.

The session produced ideas of additional functionality and proved the proposed system concept useful. Spontaneous leisure was first to be presented. Participants spoke from experience of their own recreational boating trips. However, their focus and input were also impacted by their professional knowledge from their positions at Volvo Penta. “You just want to know systems checked OK/Not OK and then be ready to go” was a statement by a system engineer who had previously worked as a test boat driver. They pushed for easier monitoring of onboard systems. The idea of a smart route planner emerged from the UX designer, a way to show the user possible and reachable destinations for the trip “[...] connected to live data, find a swimming spot with low activity[...]” The idea of using a personal device as key was also advocated for by the UX designer and well received, since it was considered an object which a user would already carry with themselves. One of the system engineers directed the temporal ordering of information presented. They wanted it organized from the level of decision making the information had on the use case for a go/no-go decision. It started with check weather, being the precondition for wanting to go boating. The other critical deciding factor was range, since low range may abort a trip.

## SPONTANEOUS LEISURE

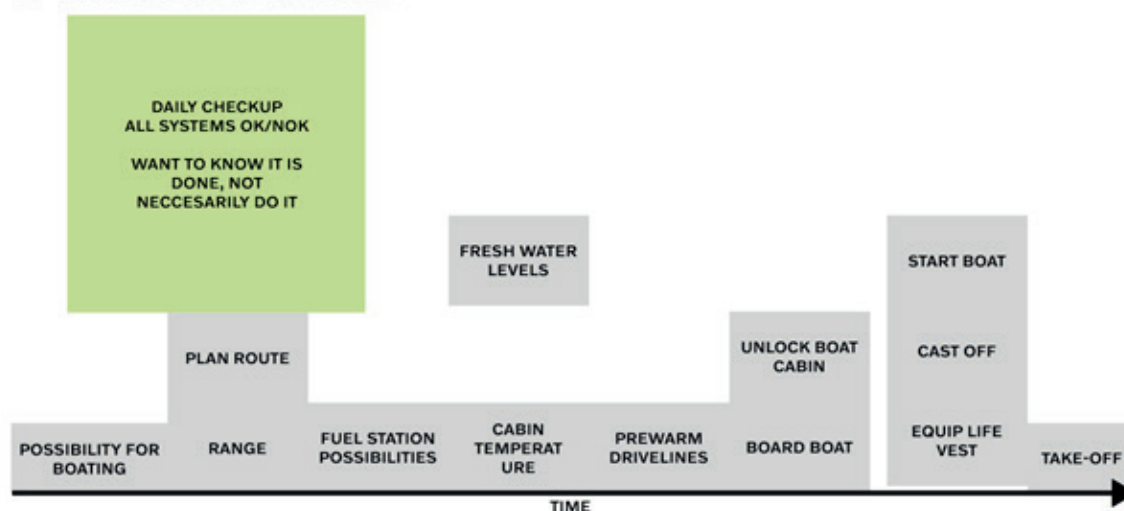


Figure 21: Result from the spontaneous leisure use case during the workshop.

When presented with the second case, spontaneous commercial, the group reasoned that the same information is important. But that the system demands are higher, I.e., that the functions of the vessel should be reliable as it could be in a dangerous situation if something went wrong. A comment from one of the system engineers was that a connected system that relies on Wi-fi or 4g connection must either be secure enough to not lose their connection or that there is a lowest level of system safety that does not require a connection at all. It was noted that an SAR situation is difficult and that there are currently many different things to keep track of for the drivers and that it is difficult to platform all the different systems that they have that assist them in their work. The group remarked that an emergency vessel will perform the necessary preparations and controls upon arrival from an outing, therefore, information status is not a primary need. An emergency response situation will benefit from a system that shortens the timespan from getting the SOS-call to when they take off from the marina. Ideas that occurred were that the new system could start prewarming the drive directly after the alarm or that the new system could connect to another system that could suggest the most suitable vessel in the fleet to perform the SAR mission

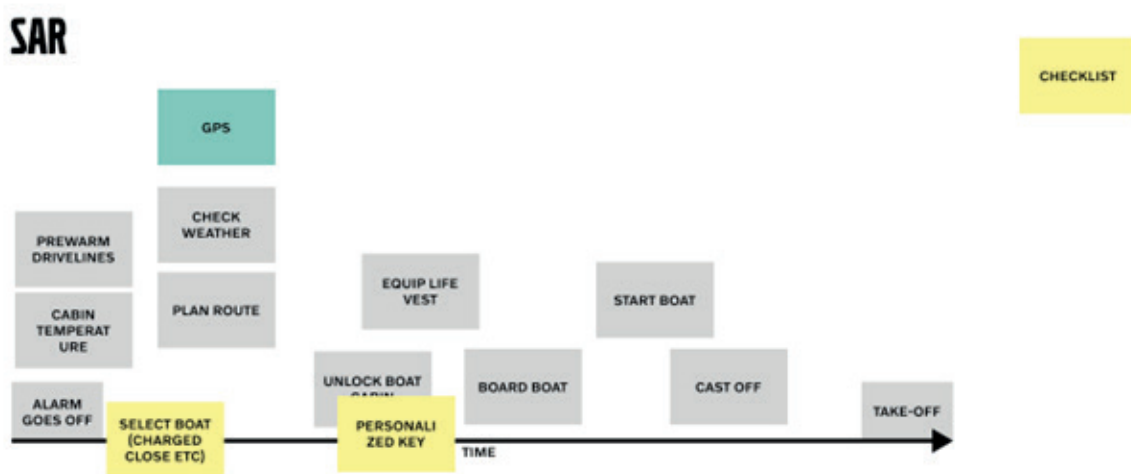


Figure 22: Result from the spontaneous commercial use case during the workshop.

### 3.6 Result

Here the result of the system design phase is presented. The result derived from the finding in the discovery phase that has been explored, iterated and evaluated during this phase. It aims to describe the system architecture and the functions of the system.

The final concept was divided into three parts, a back-end system and two user interfaces for front-end interaction. This was composed of a digital user interface, proposed to be a smartphone application, and a physical user interface consisting of a key fob. The solution was chosen to allow flexibility within the system for the user, and this was significant for service in both customer segments. The concept offers the possibility to continue to explore implementing the extra features while allowing the project to continue to focus on an optimal unlocking experience. Besides a system layout of vital parts of the system, a service blueprint showing user interaction is included in the result to show its intended use.

When comparing the old set of steps of unlocking a marine vessel to the new set of steps that follows the implementation of the new system one can see that the process has been simplified by opting for fewer actions that the user must do. The old method had six different steps to start the boating journey which involves multiple keys and turning on battery switches whilst the new method only requires three different steps with less artifacts.

The new unlocking method uses one of the new unlocking interfaces, either the digital or physical key, to unlock doors or hatches that now use electrical locks that are connected to the system. The same action simultaneously switches on the batteries and EVC system. The

user can choose to use their smart device to do a routine system check on their phone or do it on the vessel. Since the system is directed towards electric propulsion it will not need to engage the ignition hence that step is also eliminated. Thereafter the user can engage the motor and start their journey.

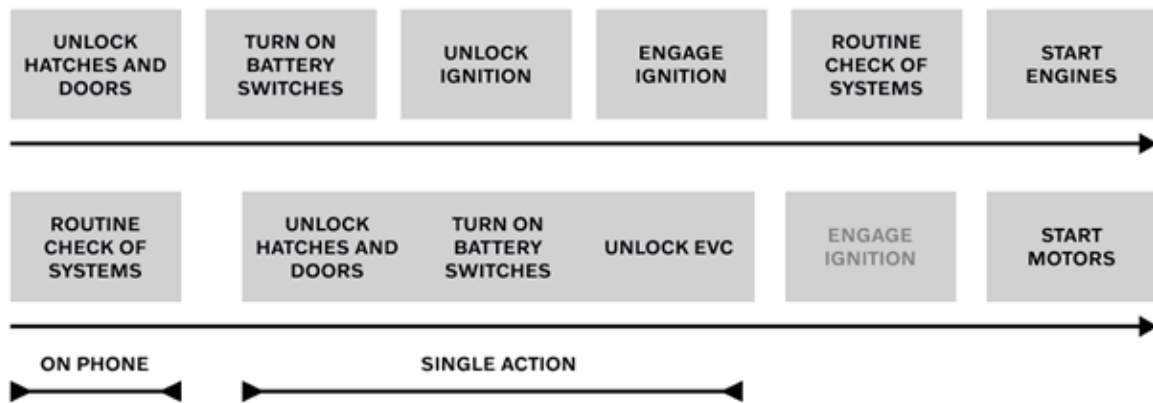


Figure 23: Old contra new steps of unlocking a Volvo Penta boat.

### 3.6.1 System Layout

The system proposed in this thesis was a smart hub added as an addition to the EVC system. Its purpose was to allow connectivity and support communication both internally, with EVC, NMEA 2000, additional sensors onboard connected through local Wi-Fi, and externally with the user’s own smart device. The system supported both a physical key fob and a digital user interface as HMIs. To allow connectivity, the hub required both a cellular network connection for the user to access vessel data remotely, and a local Wi-Fi connection to enable communication with the system in areas where cellular service is unavailable or undesired. Both means of connectivity would be integrated into the hub. To ensure service, the hub required its own power supply which should be charged when other onboard batteries are. This is since it was found to be undesired to use a vessel’s main batteries, however, with an electric drivetrain which incorporates a large battery bank and requires electrical charge for its main function, this might not be the case.

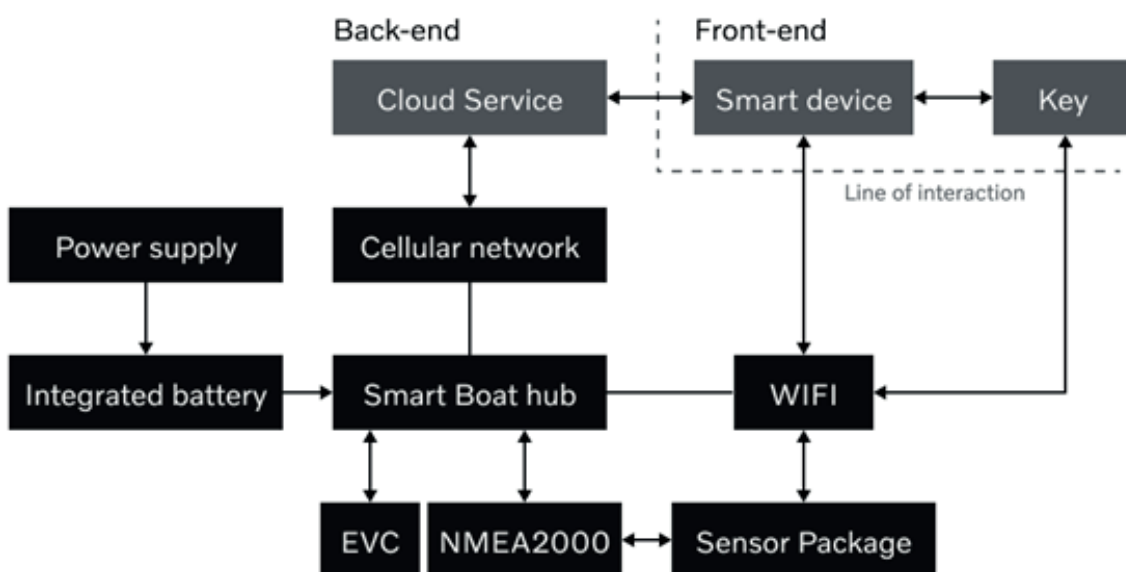


Figure 24: Proposed system architecture.

The system was designed to enable many solutions toward customers, including the variety of users Volvo Penta caters to. It had to consider both users who wanted to utilize a digital key exclusively as well as those who demanded a physical key. Therefore, it was constructed to allow for both or any to be used. This means either a digital key or a physical key could be used exclusively. Yet, a user could also opt for a combination of both.

Raising connectivity through cellular network is a key to accessing onboard data from afar. With a boat that is reachable online, a user can get their hands on live vessel data whenever they wish. Besides this, it can also increase the security of authentication. A connected system can change the authorization message between key and system as often as seem fit, which reduces the risk of key copying significantly (Kassem et al., 2016). This would require both the key and the hub to be connected to the internet. Which makes an independent key fob difficult to facilitate. In this application, the system could update the authorization message when the key is connected.

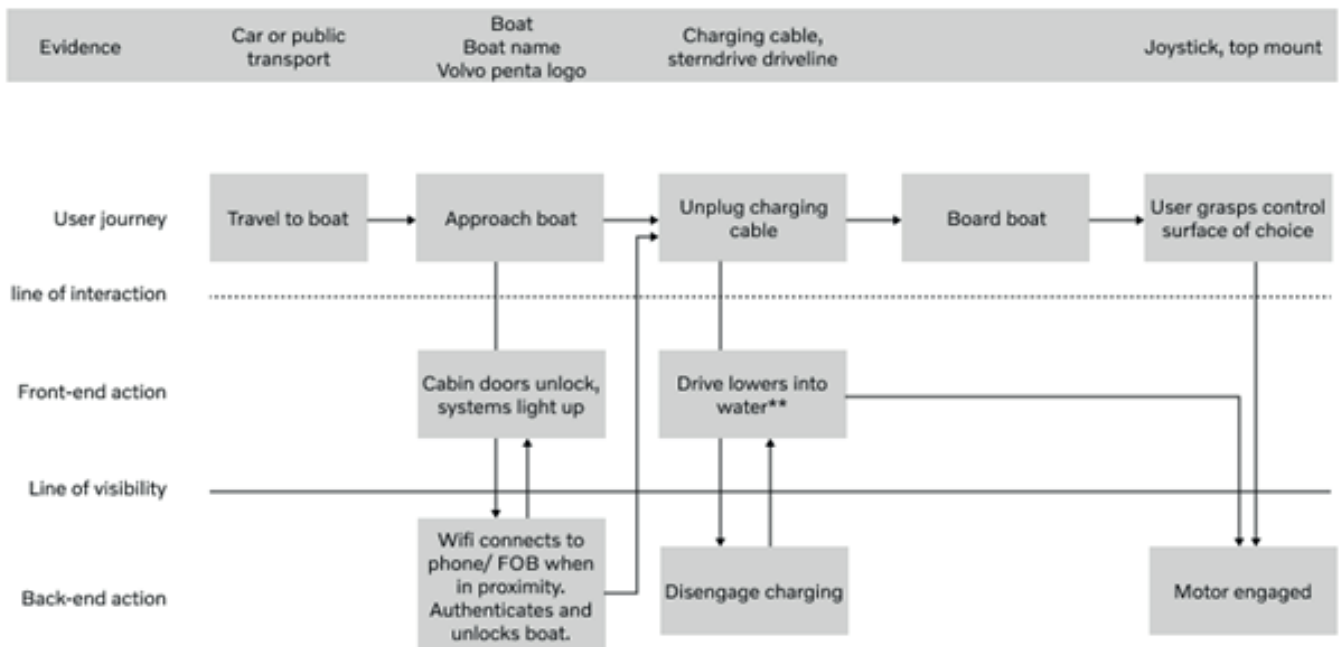
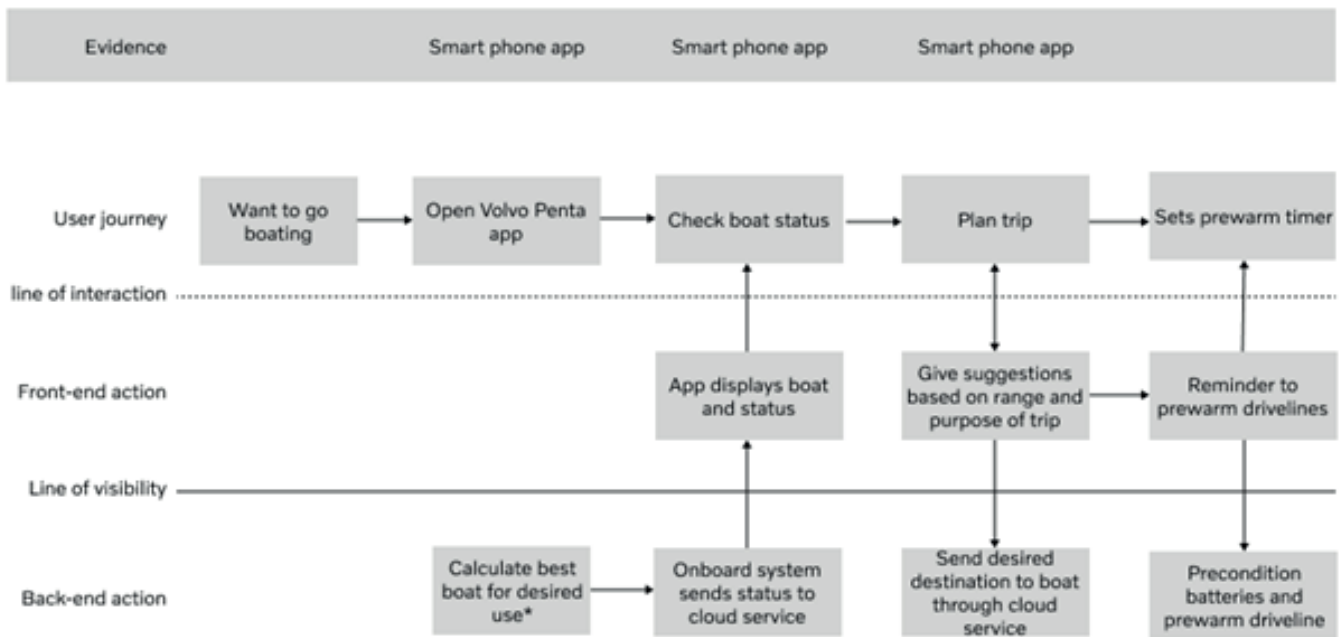
Using Wi-Fi as a means of communication opens many possibilities. Initially, it was the main method of communication proposed for communication between user interface and the smart hub. This is because all smart devices are compatible with the method, and it offers more security than BLE (Bluetooth Low Energy) and RFID (Radio Frequency Identification). Further, it allows for an IoT system, a modular structure where the user can choose which items they want in the system. Implementing more sensors for monitoring boat's status is made simple. Additionally, it makes the addition of smart locks possible for unlocking doors and hatches. The local Wi-Fi network onboard also allows for authentication if the system lacks a cellular connection. Since a Wi-Fi network allows local connection without internet access, a user can connect to the boat to authenticate themselves.

The implementation of a cloud-based platform for users to interact with their vessel granted a way to reach vessel data. Further it allowed keys to be shared. Since the digital key only consists of an authorization message between a personal device and the smart hub onboard, allowing more users the ability to access the boat is made easier. This paves the way for a higher utilization rate of leisure boats, both by peer-to-peer sharing and boating-as-a-service applications. It would remove the need for acquiring a physical key before using the boat. This also helps in commercial applications. In a situation where there are many drivers and many boats, instead of manually accessing and exchanging keys in between drivers, a fleet manager could distribute the keys digitally. The only exclusion being cases where the company or organization opts out of connected boats.

Having a digital platform opens a lot of future possibilities to implement more features connected to the Volvo Penta experience as it could be a hub for further utilities. One probable future function can be if it would be possible to connect a safety lanyard to the system. The modern MOB solutions that were explored during the benchmarking phase worked via wireless transceivers. Something similar might be possible to implement with the new system but that was determined to be outside the project's scope and was not explored further.

### **3.6.2 Service blueprint**

A service blueprint is a method used to define different components of a system and visualize their relationship to one another. It can be used to understand what underlying processes are needed for specific user interactions to occur (Service Blueprints: Definition, n.d.). The service blueprint should be done in relation to the customer journey and mark out customer actions, front-end actions, back-end actions and supporting processes. Customer actions are the steps the user takes to reach the end goal, such as engaging the boat's ignition. Front-end actions are defined as things that occur in view of the customer for example that the systems light up after the ignition has been engaged while back-end actions happen outside the view of the customer in this case it can be that the battery control module is performing



\*Only if marine vessel is acquired through Volvo Penta Boat sharing service.

\*\*Only if the boat has trimmable sterndrive

Figure 25: Service Blueprint for unlocking a boat with the new system.

background processes to make the system work. These elements can also be organized as being in the line of interaction, -visibility or –internal interaction to separate what the user interacts with, is able to see or only gets the effect of.

In this project service blueprint has been used to map out the current way the user journey is and what happens for the user from when they set out to go boating to when they leave their vessel at the harbor after they come back from their journey. That has then been used to spot weaknesses in the sequence of events and to map out a new system which improves the customer journey without losing track of important customer pleasure points. The making of a new service blueprint in this project has been a way to map out important points of interaction between the user and the system to see where feedback is important and to see what supporting processes and interactions need to be in place both behind the line of interaction and the line of visibility to ensure a smooth and pleasant user journey.

The service blueprint for onboarding ranged from the desire or need to use a marine vessel, labeled as want/need to go boating to when the motor is engaged, and the user can cast off. The blueprint included all actions a user can make, however, not all actions are required for every case. The upper blueprint consisted of all the actions a user could complete before travelling to the marina. It shows how the system allows for monitoring of the boat's status before planning their trip. In cases where the boat is shared, in a boat pool, or part of a commercial fleet, the system could allow for an automatic selection of a boat with sufficient range and features for the desired trip. For an individually owned boat, the system could provide route planning suggestions based on the features and range of the boat. The ability to check system status before arriving at the boat saves time for any user, since a routine checkup of the boat is included in many boaters' start-up sequences. Here, trust in the system was deemed important, as the feature would be redundant if users chose to do their routine checkup regardless of an automated one.

In the lower half, the blueprint (Figure 25) for arriving at the boat and boarding it is shown. As proposed, the system would utilize passive keyless unlocking to start onboard systems as the user approaches the vessel and their phone or key fob connects to the onboard Wi-Fi. This would unlock the boat such that it is ready to go as soon as the user has boarded it. If the boat used electric propulsion, the user would have to disengage the charging cable manually. Otherwise, they would be ready to cast off as soon as they came on board.

As the system aimed to enable as many desires as possible for all customer segments. A holistic solution was required. The system proposed is a ground for increased usability across all segments, providing easier access to the boat, both from afar, and on the way from the dock out on the water. Additionally, it increases Volvo Penta's control of the onboarding user experience by enabling the user to complete the entire onboarding procedure through a Volvo Penta user interface.

### **3.6.3 Intended use**

This section aims to convey how the system will work in practice through highlighting certain features and how they will function in real life. A phone can be used to interact with the onboard system at all ranges through cellular networks. However, the function of unlocking should have some limits to ensure both security and safety. First, the unlocking action should only be able to be completed if the user is within the Wi-Fi range of the onboard system. Thus, the boat cannot be accidentally unlocked if the user is not present at the boat. Further, if the boat is left unlocked when the user leaves the Wi-Fi range, the user should be notified. Since people could still be onboard when the key leaves the boat, locking is not always desired upon leaving. However, locking up should be possible from wherever, but not if the boat is being driven. This prevents the driver from being locked out of the controls of their boat while out at sea. A user can use both the digital key and the physical key to unlock their boat exclusively. Additionally, the digital key should allow for the sharing of keys between people.

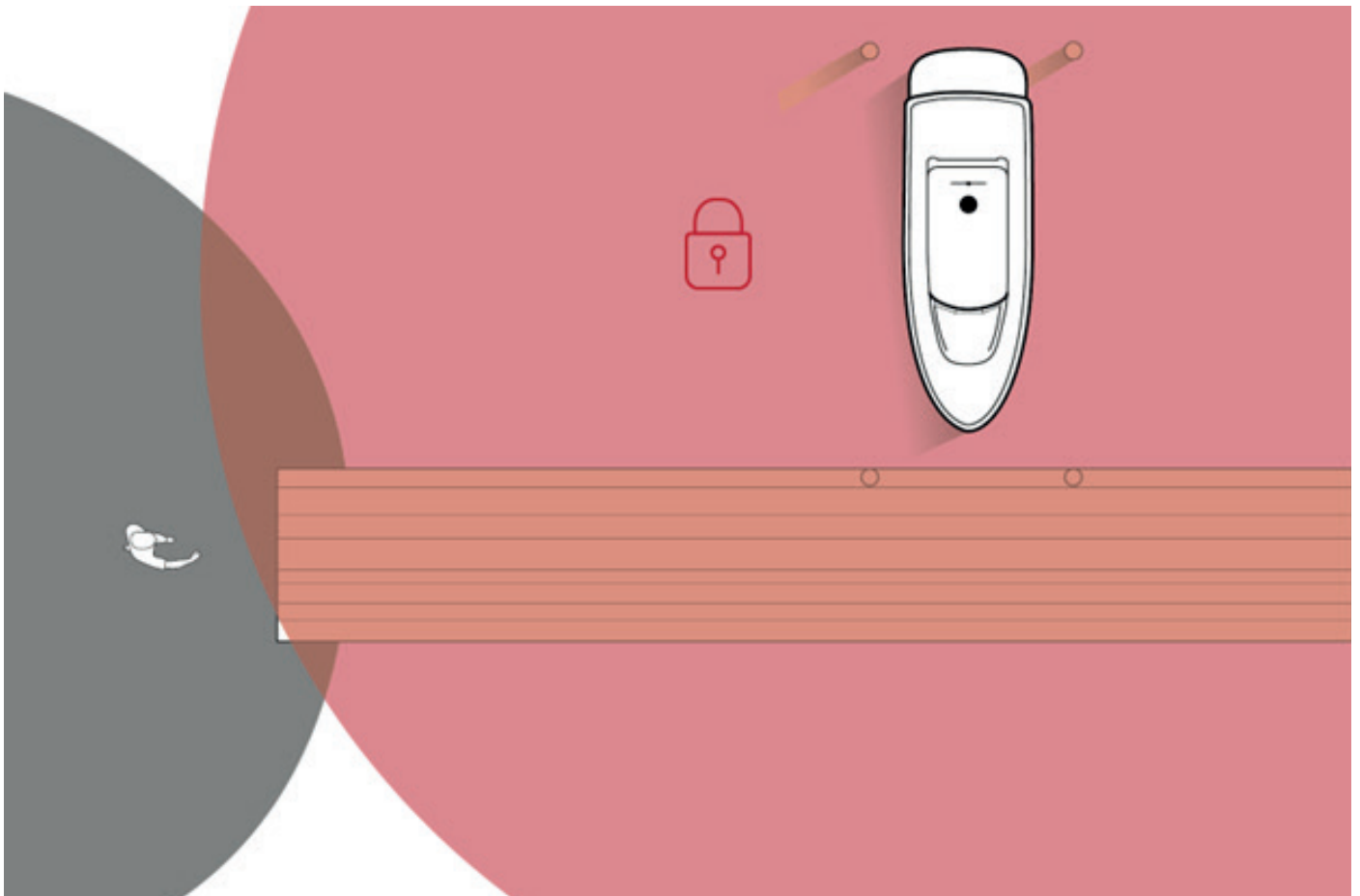


Figure 26: Unless the user with their unlocking device is within the Wi-Fi range of the boat it is not possible to unlock the boat. The user can however use the app to control amenities such as prewarming the drivetrain..

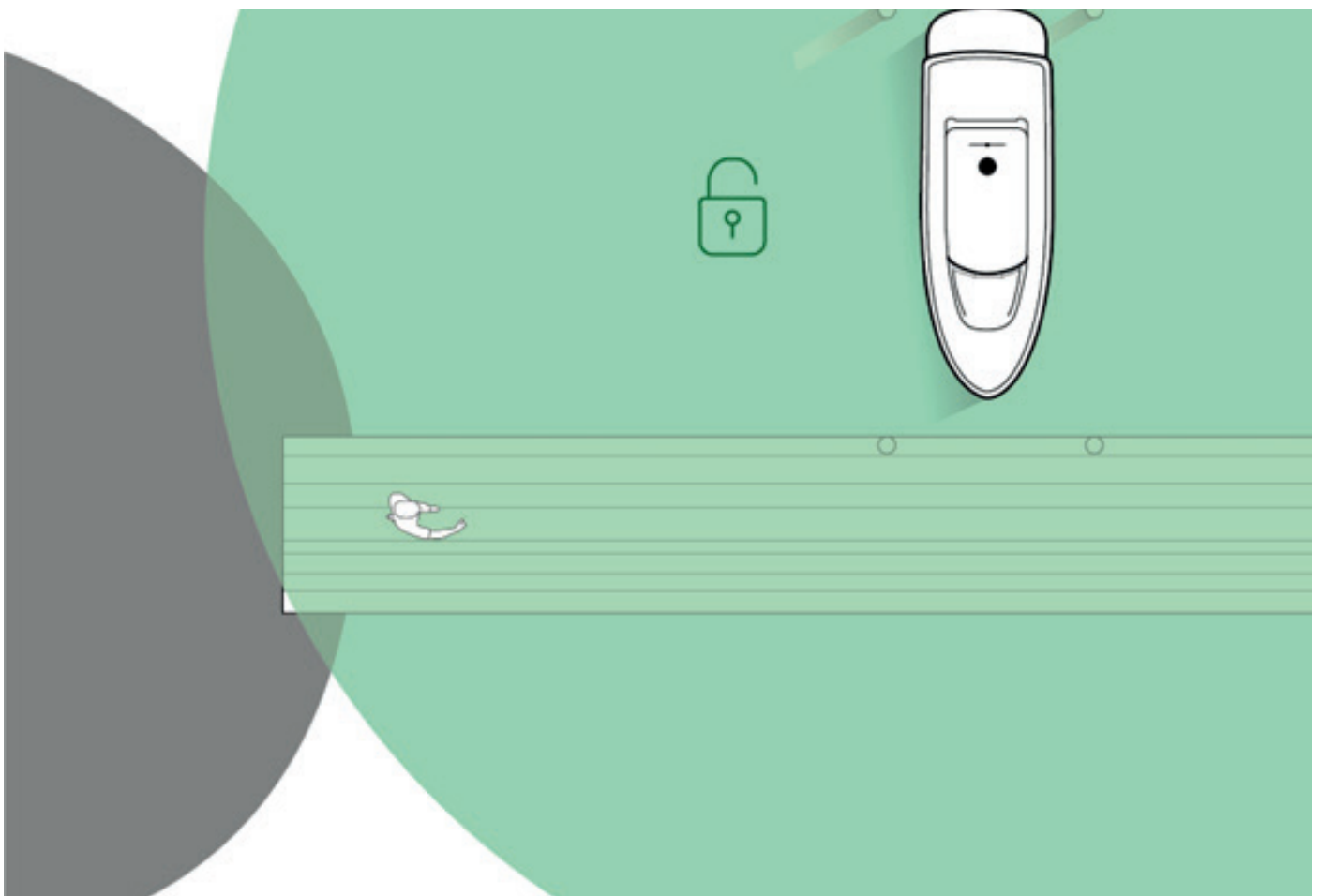
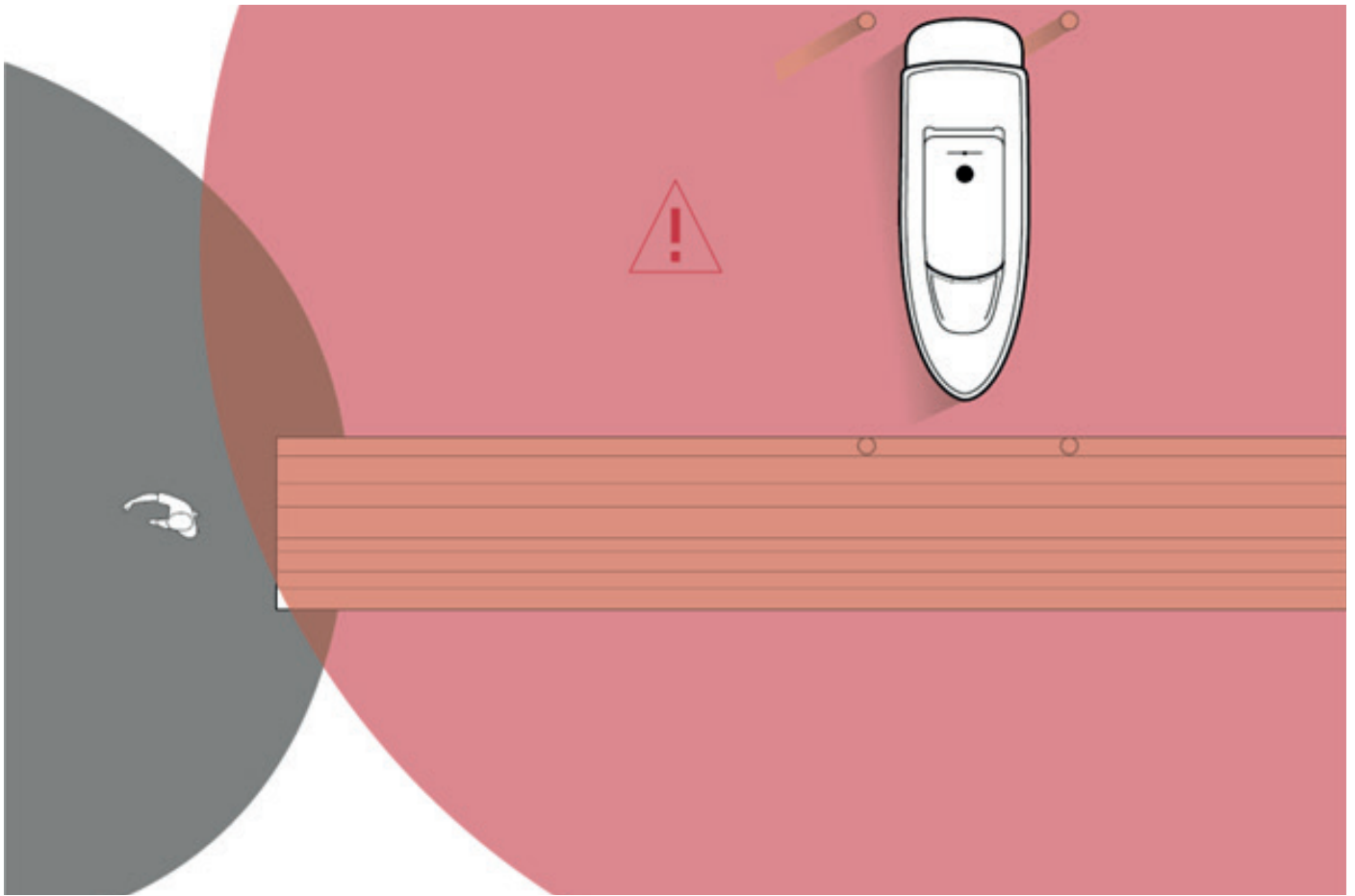


Figure 27: Within a vicinity of the Wi-fi, it is possible to unlock the boat with the app or the key. The boat's system will operate as normal if the unlocking device remains within the Wi-Fi range.



*Figure 28: The system should recognize if the user leaves the vessel unlocked and passes beyond the Wi-Fi range. If this occurs the system should send an alert to the user's smart device to notify them as a precaution to not leave their boat unattended.*

### 3.6.3.1 Intended use: Scenario

To demonstrate how the system is intended to be used scenarios were made to emphasize how the new system can help alleviate user pain points. Scenarios are a method that can be used to describe a user interaction and a user's internal motivations (Wikberg Nilsson, 2016, p.141). Two scenarios were constructed to highlight how it can work in different ways for the two main customer segments: Leisure and Commercial.

#### **Scenario: Leisure**

Hannah does not have a boat of her own, but she has always loved going out on the ocean. People in her family have often had boats and she would like her own someday, but now she just does not have the time for it. During the times that she does have time for an outing at sea she can ask to borrow her sister Emilia's boat. Emilia has a Volvo Penta system which makes it easy to share access to the boat.

Emilia has the Volvo Penta app on her phone which she uses as her boat key. Hannah also has the app on her phone, but without having a boat of her own. When Emilia wants to share her boat, she can share her access with Hannah within the app. Emilia can choose how long she wants Hannah to be able to access the boat and during that time the boat is available to Hannah. Hannah can then use her smart device to access the boat in her phone and see the boat's status and has the possibility to pre-warm the system if she wants.

When Hannah has started the system on her phone Emilia is able to see status updates on her phone if she wants, but she cannot use her app to affect the vessel while it is Hannah's possession. While Hannah is operating the boat, she can be confident that she has control of the vessel as long as she is out at sea, even if she would be late to return it. If she would be late with returning the boat both she and Emilia will get a notification from the Volvo Penta app. Hannah's will suggest that she heads back to the harbor, and Emilia's will notify her of the late return with a status report of the vessel's current location.

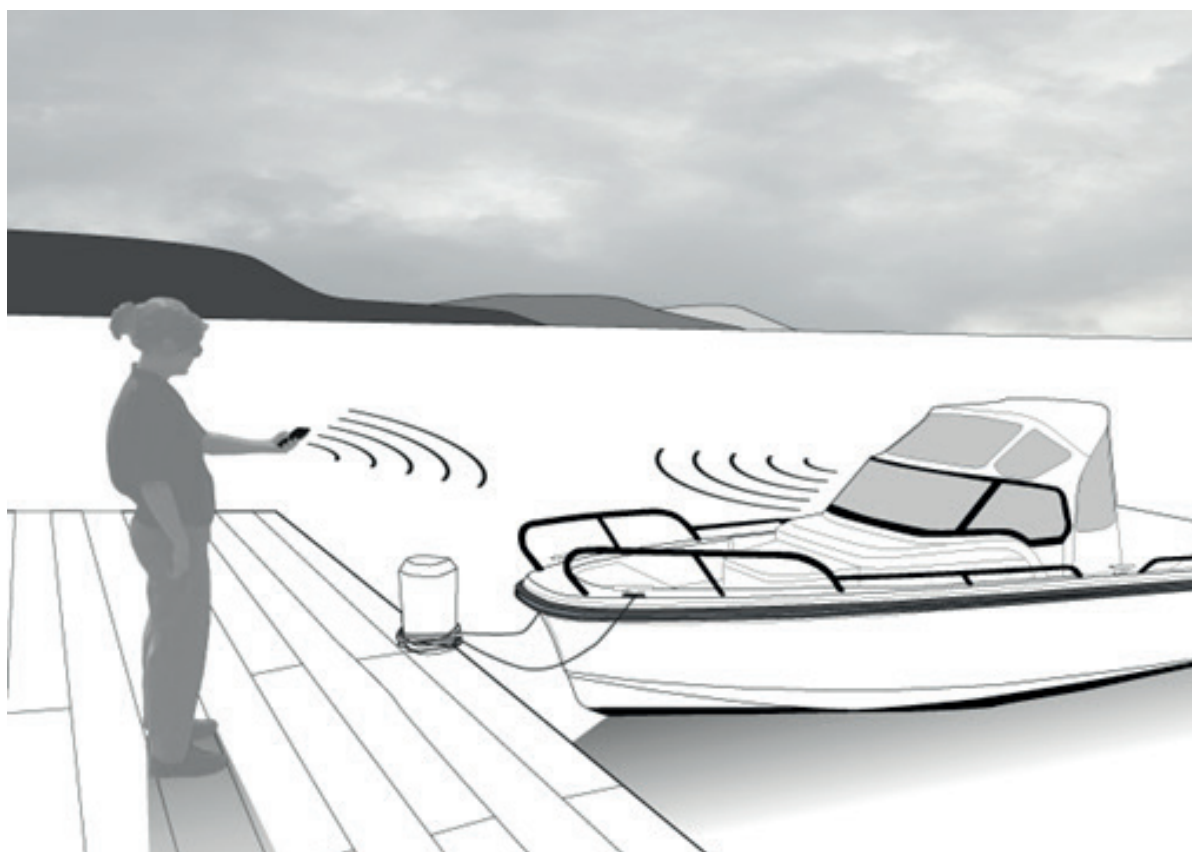


Figure 29: Illustration depicting the leisure scenario

**Scenario: Commercial**

Otto is a pilot captain for a large industrial harbor where large ships arrive many times daily. While some ships can be planned for, some call for pilot aid on arrival. Therefore, the pilot station has to be ready at all times to depart. To minimize the time from station to the sea, all pilot boats have been equipped with the Volvo Penta system. Before, because Otto and the other pilots at the station shared the boats in-between, key handling had become such a nuisance that they left the keys onboard at all times. Now, no physical key is needed. All pilots have access to all boats through the Volvo Penta app, yet the station also carries physical key fobs as backups.

When Otto receives a call from a freighter, he quickly checks the status of all boats in the application on his work phone. He picks the one most suitable for the trip he is about to make and goes down to the dock. Once he unlocks the boat, it is his to control until his trip is complete. While he is out, all other pilots may access the status of the boat but not change its lock status. When Otto eventually returns to the station and has locked the boat again, his session is over, and the boat is ready to be unlocked by another pilot.

The constant possibility to receive live vessel information makes it easy for the pilots to maintain their boat fleet. The ability to see eventual problems before going onboard cuts the time it takes to conduct routine check-ups of the onboard systems.

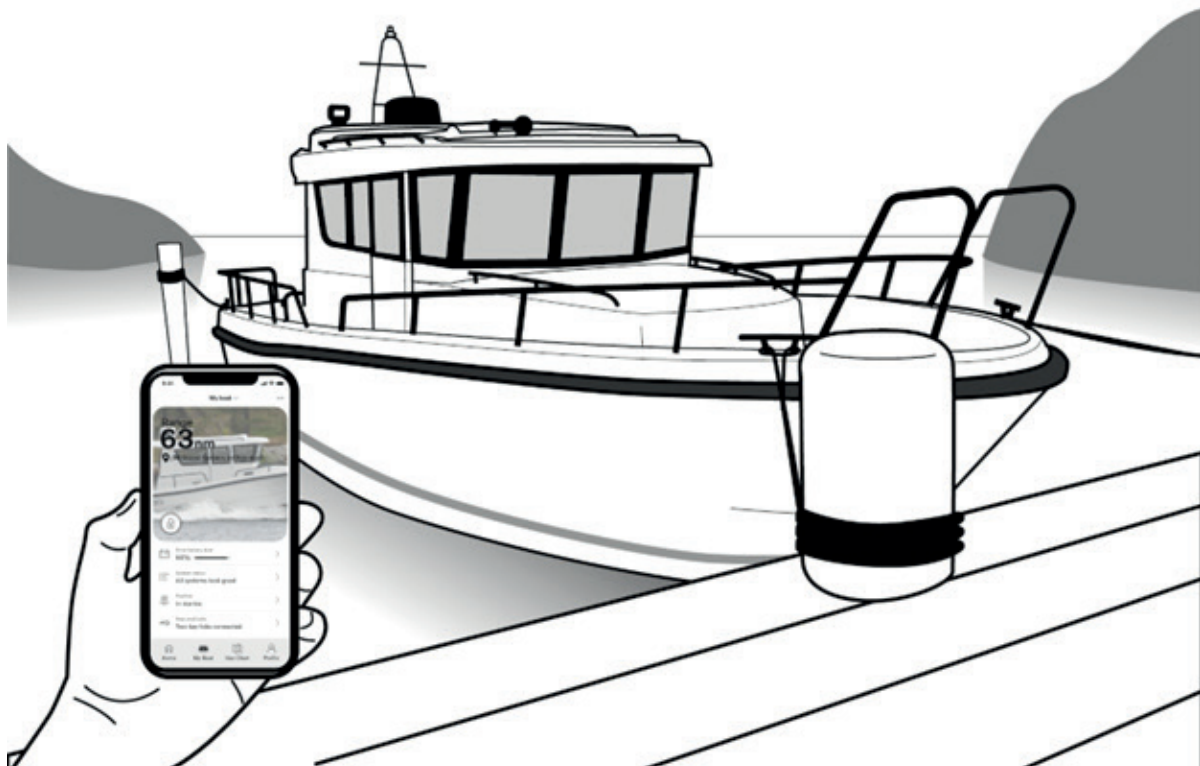


Figure 30: Illustration depicting the commercial scenario



# 4. Phase 3 - Front-End Design

This chapter describes the design process applied when designing the front-end artefacts in this project. It also includes design theory applied throughout the process. The two artefacts were a digital user interface, and a physical key fob, both with the main function to unlock marine vessels. First, common information regarding the design process of both interfaces is presented. Then the process of designing the digital key, and the design process for the physical key. To finally present the results of both processes.

## 4.1 Usability Theory

Decisions made throughout the design process have been grounded in design theory on usability, and product emotions. This section aims to define and describe terms later used by providing a background on the theories used. Usability is defined by the International Organization of Standardization (ISO) as the “extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (ISO, 2018). User experience (UX) design is closely related to usability which targets the perception the user has of the interaction (Usability.gov, 2023). Facilitating good usability is a process of understanding user needs of a system since the artefacts within it will have their unique rendition of usability because the goals of each system are different. Yet, there are some principles applicable in most cases. Jordan (1998) compiled a list of ten factors to consider in usability design. The ten factors are presented below with a brief explanation, applied from Jordan’s book.

- **Consistency**  
Designing products such that similar operations are conducted in similar ways.
- **Compatibility**  
Designing products such that they operate in ways which users expect in relation to other products and systems they know of.
- **Consideration of user resources**  
Designing products such that the user can conduct operations without exhausting their resources, neither physical nor cognitive.
- **Feedback**  
Designing products to provide the user with appropriate feedback that their actions are validly conducted.
- **Error prevention and recovery**  
Designing products to minimize the risk of error and aid the user in fixing the error if necessary.
- **User control**  
Designing products to enable the user to control their use in their advantage.
- **Visual clarity**  
Designing products in a way which makes information easy to read and understand.
- **Prioritization of functionality and information**  
Designing products which easily provide the most essential functions and information.
- **Appropriate transfer of technology**  
Designing products with technology that enables ease of use.

- **Explicitness**  
Designing products which show their intended use.

The importance of these principles lies in the user's ability to understand and predict the outcome of their actions. These are all enablers for other terms explained by Jordan, guessability, learnability, experienced user performance (EUP), and re-usability. Guessability according to Jordan is a measure of the effectiveness, efficiency, and satisfaction which a user can perform a task with a product for the first time. For guessability, it is important that the user can predict the outcome of their actions, without having learnt how a product functions. If a product is inconsistent, a user would be confused with the procedure to complete actions. However, if similar actions always behave similarly a user can predict how to conduct tasks and what the result will be. This coincidentally improves learnability as well since learning one function helps the user to learn how similar functions work. Compatibility with other products also aids in guessability, by enabling users to use proof from external products to predict how a product will behave. Green usually means go and red means stop, therefore, using them in an opposite manner will confuse a user. People interact with many products daily and construct models based on their previous interactions. A prominent issue when designing products which co-exist with other products on the same platform, such as smartphone applications which can be seen as their own product. However, the user of a smartphone application also interacts with many other applications on the same platform, thus being concise with other applications makes an application easier to understand.

Jordan explains learnability as the measure of effectiveness, efficiency, and satisfaction a user can complete a task with a product their second time using it. To facilitate learnability feedback, either positive or negative, is important to enable an understanding of what has happened, thus learning from what the user has done. Many factors which aid guessability will also coincidentally aid learnability. EUP separates from guessability and learnability since an experienced user requires more user control. They need to be able to modify the product to their specific use to maximize ease of use in those tasks.

Nielsen (1994) also lists a set of factors to consider that are associated with good usability while designing software systems. They advocate that these five factors are good to target to achieve satisfaction in the user.

- **Learnability**  
The system should be easy for a novice user to understand so that any user can be proficient in using the system within a brief time. If possible, prior knowledge of similar systems should aid the user and allow them to be more efficient. Characteristics of such a system can be easy-to-understand error messages, possibility to use the program for useful tasks prior to mastering it, ability to undo and confirming questions before doing risky commands.
- **Efficiency**  
Efficiency in the system relates to the user's ability to perform at an elevated level of productivity once they have gotten an understanding of how the system works.
- **Memorability**  
That the system is memorable is especially important for a casual user of the system. Even if they are not frequent users of the system, they should be able to quickly regain their ability to be efficient after being away from the system for some time.
- **Errors**  
The system should ensure there is a low error rate. If a user makes an error, they should be easily able to recover from them. Therefore, the system should not allow catastrophic errors to occur.

- **Satisfaction**  
The user should think that the system is nice to use, and it should be pleasant for them to interact with the system. Factors to consider can be that the user should feel that they are in control of the system and that the user should not feel intimidated by perceiving the system as too complex.

These factors are wise to try to accommodate to achieve user acceptance. The new system sought to create with this project will mean a substantial change in the procedure of which unlocking is done, and this will mean that the system might meet some resistance from conservative users. Therefore, it will be vital to ensure user satisfaction for users to adopt the solution.

In literature on human-machine interaction, many authors agree that emotions are a huge controlling factor as to why a person chooses to use a product and their performance while doing so (Brave and Nass, 2007; Desmet, 2003; Norman, 2002). Desmet constructs a model for how products convey emotions. It consists of four objects, appraisal, concern, product, and emotion. Appraisal refers to the assessment or perception of the product. Appraisal is where emotion derives from. Concern is most closely related to the goal of using a product but can also include attitudes and standards, such as social norms or personal preferences. Emotion is the goal of interaction in Desmet's model. If one expects a product to be efficient, their concern is for the product to be efficient. During appraisal, if the product is not efficient, their emotional reaction would be dissatisfaction. The goal for a product can also be to be aesthetically appealing, then the concern takes on a role based on attitude, or personal preferences. It can fulfill its goals for some, providing them with pleasant emotions, while others with contrasting preferences will look at it with disgust. The model produced by Desmet is useful when designing products to provide emotions and evaluate them.

Brave and Nass (2007) discusses the effect of affect when interacting with human-machine systems, specifically the effects emotions have on attention, memory, performance, and assessment. They found that users tend to be more attentive toward tasks and interfaces which convey positive emotions, and that in tasks that demand high attention, an aroused emotional state is positive. Also, a user interface which annoys the user is more likely to divert attention toward other stimuli. Regarding memory, they write that it is easier for a user to remember their mood when conducting a task than to remember how they did it. Also, a slight increase in positive emotions showed a significant increase in performance. Further, user interfaces providing positive emotions made users less likely to take risks. Norman (2002) discusses this from the perspective of human perception. He explains three levels of processing stimuli, where he writes that visceral processing, the quick and automatic response to stimuli, is what helps us assess if a situation is harmful or not. If a situation is perceived as threatening, the response must be quick. If, however, the situation is pleasant, slower processing methods, behavioral or reflective, can be used. Thus, providing a well thought through assessment.

Jordan (1998) discusses how to design for usability. The overall procedure requires an in-depth understanding of users who will interact with the product. Therefore, he states that creating a specification of user characteristics is important. This specification must be more detailed than a demographic. If there are physical ergonomics to consider, anthropometric factors must be considered. Cognitive factors are also important. If the users of a product are proficient in certain areas, the user interface must take their knowledge into account.

### **4.1.1 Information Processing**

Top-down- and bottom-up-processing are terms related to how the user processes stimuli from the surrounding environment and reacts based on either what clue they are given from the stimuli or their prior knowledge and experience. Regarding design it is important to consider this in relation to how the user is set to manage a task given through the object

or system that the designer is set to create. Wickens (2012) uses these terms to distinguish if a user is using the provided stimuli in real time without needing to interpret the data further which is considered as being bottom-up-processing or if the user is using their prior knowledge and experience to process the stimuli to understand the context as they do in top-down-processing.

In relation to the scope of this project, it is important to understand that the amount of knowledge and prior experience of operating a marine vessel will differ between users. The frequency of which these users interact with the context will also vary. Therefore, the design will benefit from utilizing stimuli which helps the user understand their task in a way that is in line with bottom-up-processing so that they can use the product or system correctly while using minimal prior knowledge. This type of design also benefits users without any knowledge of boating which is in line with the notion of boating for everyone.

#### **4.1.2 Mental Models**

A user's mental model of how a system, interface or artefact works can be described as their preconceived notion of how they expect to be able to interact with it and subsequently how it will react. The mental model is based on their previous experience with perceived similar interactions. To design in line with users' mental model can help mitigate potential mistakes as one can either fit the design to the users' mental model or one can clarify and educate the user if the design deviates from equivalent products (Nielsen, 2010).

This project has sought to keep the design in line with user's mental models through keeping the designs simple and consistent with similar systems. New additions for users should be thoroughly and clearly communicated to ensure a successful system.

### **4.2 The Marine Environment**

It is important to keep the environmental context of the project in mind during all phases of the design. The marine environment is harsh in many aspects, and it will affect the solution space in both systematic and material ways. Volvo Penta does adhere to the international Ingress Protection rating of IPx7 with most of their current EVC system accessories (Volvo Group, 2016). This classification has been developed by the International Electrotechnical Commission (IEC) to classify how water- or dustproof an electronic device is as these elements can cause damage if they penetrate this type of product (International Electrotechnical Commission, n.d.). For a product to be classified as IPx7 it needs to be able to withstand temporary immersion in water according to IEC standards. Furthermore, the marine environment exposes the products to water, salt, harsh winds, and blazing sun, all which must be considered when developing solutions. Especially when deciding on materials that should be used in this environment.

### **4.3 Process and Method**

This project's process has been iterative and used various methods for generating ideas and evaluating designs. Since two different interfaces were designed in this project, this section is split into three major subsections. The section starts with the process of finding a common expression for both the physical and the digital interface. Then the design process of the digital interface is presented and last the process of designing the physical interface.

#### **4.3.1 Finding the Products' Expressions**

A product should ideally convey the company's identity and desired expression. To ensure the design of the two interfaces followed the same original expression several different image boards were constructed. The image board is a common tool used for design projects. The method is a visual communication tool that can have many purposes such as generating ideas, conveying a tone of voice for a product or to give inspiration (Nielsen-Norman Group, n.d.-a). In this project several different image boards have been created for varying purposes.

### 4.3.1.1 Mood board

The project has primarily worked with two mood boards to convey the two primary customer segments that Volvo Penta caters to: Marine Commercial and Leisure Boating. The two segments have unique needs and uses for their marine vessel; therefore, two mood boards were made to correspond to each of the segment's expression. Both segments are important to cater to in the final solution and using a mood board to represent their needs visually was used during both the conceptual stage of development as well as the refining of the design.

The mood board for the Leisure Boating segment is meant to convey Wanderlust, Freedom, Community, Warmth, Happiness, Spontaneity, Adventure, Ease and Content. Which are words that center around the desired user experience.

The mood board for the Marine Commercial segment is meant to convey Pride in work, Comfort, Cooperation, Utility, Unity, Safety

The boards were used to communicate the intended target of the solution. Both as a guide to aesthetic choices and what environment the solution should fit into.

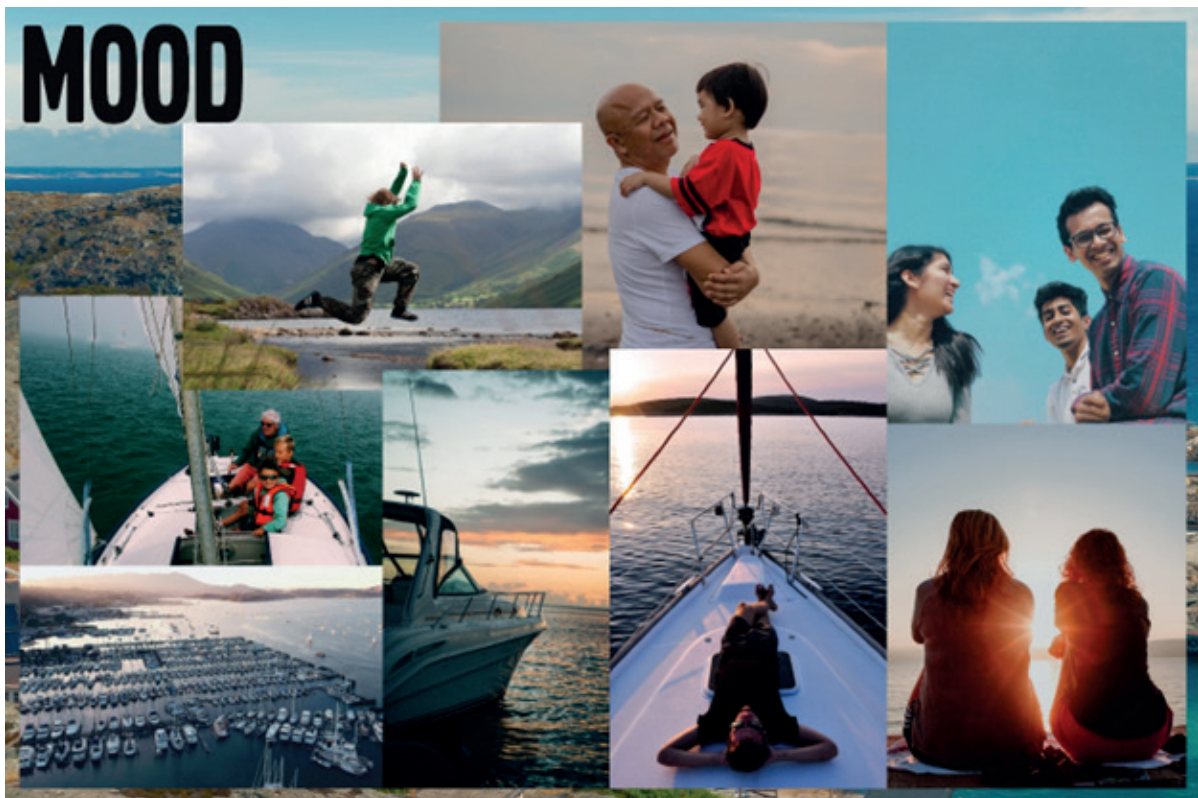


Figure 31: Mood board for the leisure segment. Images reproduced with permission, left-right, top-bottom, Heaton (2016), Murti (2020), Manoj (2019), Ballad (2018), Rondon (2021), Block (2017), Tozour (2020), Uematsu (2017).

### 4.3.1.2 Inspiration board

An inspiration board is like a mood board but instead of using it as a medium to evoke emotions or a tone of voice it uses the chosen images to take direct inspiration from. In this project it has been used as an internal communication tool for form exploration. It can help bridge the gap between the intent behind the sketch and the rough result.

The inspiration board for this project was made through exploring webpages which promote modern and trendy design projects such as lemanoosh.com and behance.com and gathering appropriate samples of design details to achieve a contemporary design. These details were things such as angularity, smoothness of edges, tolerances, and material transitions.



Figure 32: Mood board for the commercial segment. Images reproduced with permission, left-right, top-bottom, Boran (2020), Dumlao (2018), BMPower (2006), IsawRed (2022), Einerhand (2020), Billeasy (2018).

### 4.3.2 Design Process – Digital Key

The process of designing a digital key consisted of two parts. First, how to present vessel data and finding which vessel data was most important. Second, implementing a method of unlocking which provided most value to the user. Lastly, to pack these two into a consistent user interface which was pleasing to the user.

#### 4.3.2.1 Ideation

Sketches made for the digital key were exclusively produced in Figma, a digital design tool which is used to make vector graphics and interactive prototypes. The first iteration aimed to explore how to present vessel data. It ended up presenting an overwhelming amount which made the interface appear cluttered and unappealing. It was hard to perceive differences in information because of the lack of hierarchy and order which rendered the interface inexplicit and unclear. The cluttered design was discarded while some elements remained. A revision of what information was vital in a go/no go decision was conducted, aided by the result from the co-creative workshop (3.5 Evaluation).

The next iteration had to use a more explicit interface where a user could easily find the information needed without having to sort through large amounts of data. The most important visual element in the interface was the range of the vessel, since it was deemed a necessary point of information. The interface also used distinct colors to communicate the state of charge, to enable the information to be

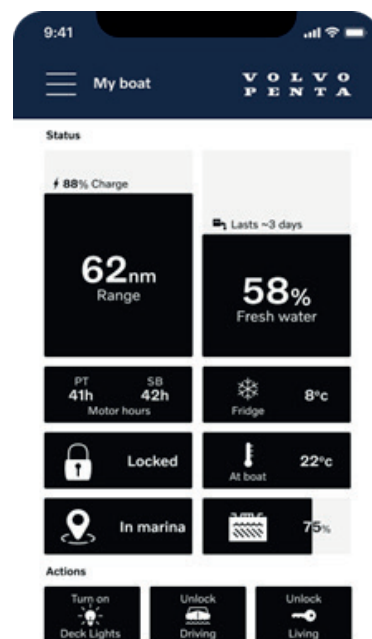


Figure 33: First iteration of digital user interface

perceived briefly. This iteration also included different methods of unlocking, with buttons for different unlocking states, or a slider. At this state, the concept was still at a low-fidelity level. While the way data was presented was not optimal, the type of information and its hierarchy was thought through. The method of unlocking included the states of living, meaning being onboard without enabling driving, and driving, which referred to unlocking the drive too. The unlocking states were an idea which came from the user desire to access their boat without using it for driving but was perceived as difficult to understand. Further, the exact meaning of living and driving was difficult to interpret. Meaning it was difficult to guess the outcome of a potential action. The exact function of unlocking was also tedious in this stage since there were different buttons for each state which made the operation of unlocking awkward. Thus, the next iteration aimed to explore how the unlocking could be made more intuitive.

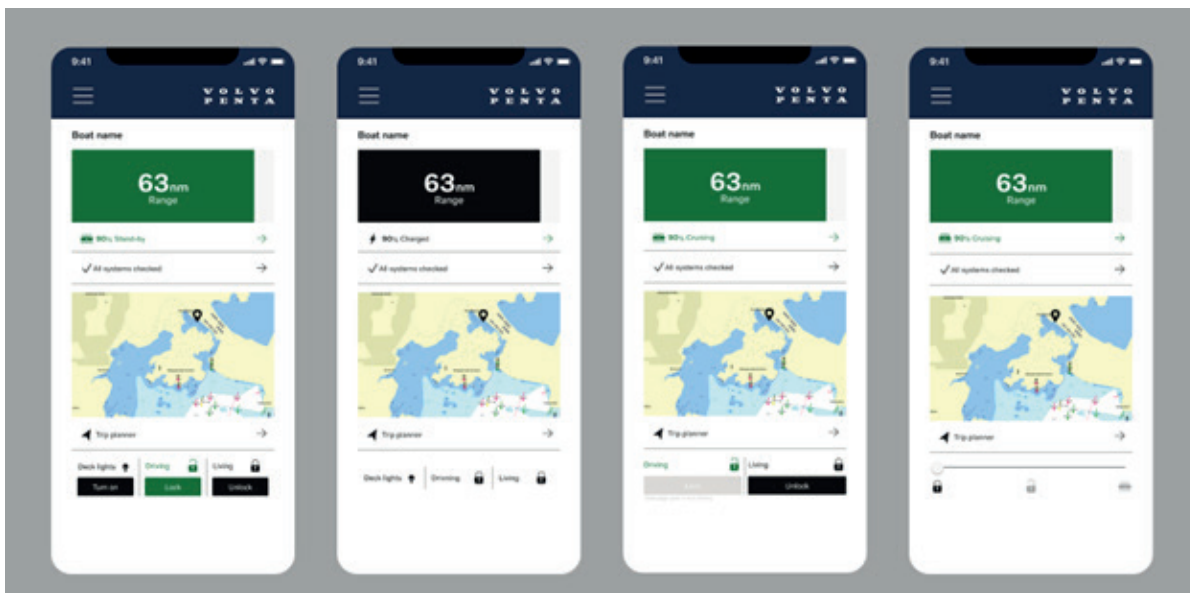


Figure 34: Second iteration of digital interface design

Iteration three resembled the previous one in layout but tested new types of unlocking interaction. However, it still incorporated the three different states of locked, living, and driving. The new interactions were either a floating action button (FAB) or a segmented switch see Figure X. The FAB button was inspired by Google’s material design guidelines, while the segmented switch was inspired by Apple’s design guidelines. Since the two are the major actors in the mobile operating system market, being consistent with them could make the user interface easier to navigate for users. Interactive prototypes were made for both types of unlocking and tested briefly. The response given was that FAB was good since it provided good visual feedback, but it looked too playful to fit into the rest of the interface. While the segmented switch was more in-line with the interface but more difficult to understand and provided little feedback to the users.

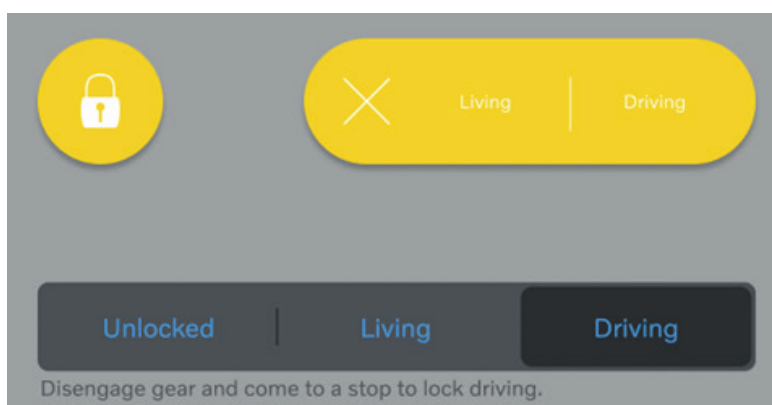
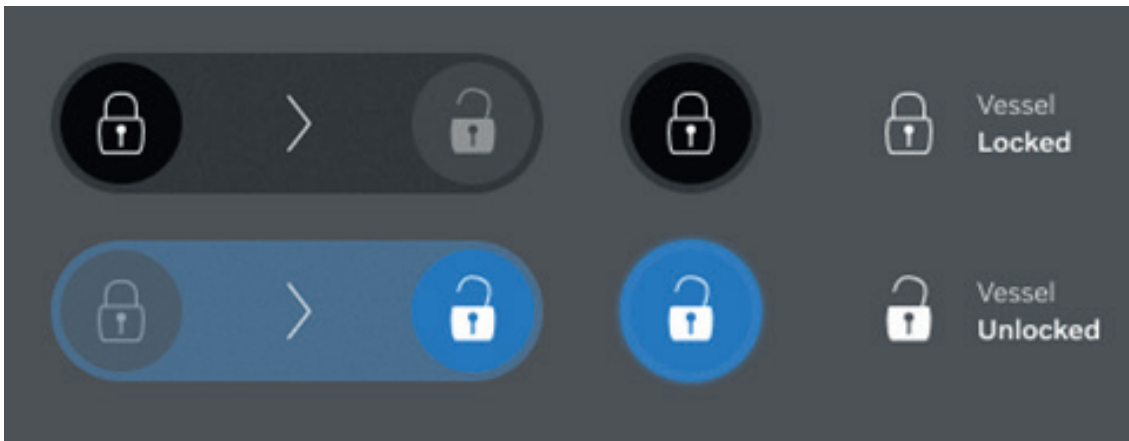


Figure 35: First concepts for methods of unlocking, FAB on top, segmented button below.

At this point, it became evident that a living and driving mode in the interface was too difficult to implement in a usable way. Also, the function was considered unnecessary since a user would not want to enable driving without being present at the boat either way. The concept was excluded in further iterations. With the insight of using other means onboard to engage driving. This way, the future concepts could focus on providing a user-friendly unlocking experience. With the findings from previous iterations, three concepts for unlocking methods were constructed. A button was the first concept, a clickable surface with a lock icon which when pressed would unlock the boat and provide feedback through a change in color and an unlocked icon. The second concept was a slider which demanded the user to complete more than one action before the boat was unlocked, increasing security at the cost of convenience. The last concept was a button with text, providing readable feedback to the user's actions.



*Figure 36: Final concepts for methods of unlocking.*

Ideation of the whole interface continued with the aim to find how vessel data could best be presented and how to communicate the desired emotions to the user. The methods of unlocking were implemented into different user interfaces with distinctive designs. One more utilitarian, with much data visualization, and two with a more minimalist approach, where only the required data was displayed discreetly in the context. The new iteration also included more personalization where the user would be able to incorporate pictures of their boat into the app.

### 4.3.2.2 Concepts

The ideation process culminated into three final concepts, all with the same functionality. Locking and unlocking boats, as well as providing some vehicle status. Each concept was made in a version which incorporated each of the presented unlocking interactions. They are presented below in the order of most minimalist, to most utilitarian.

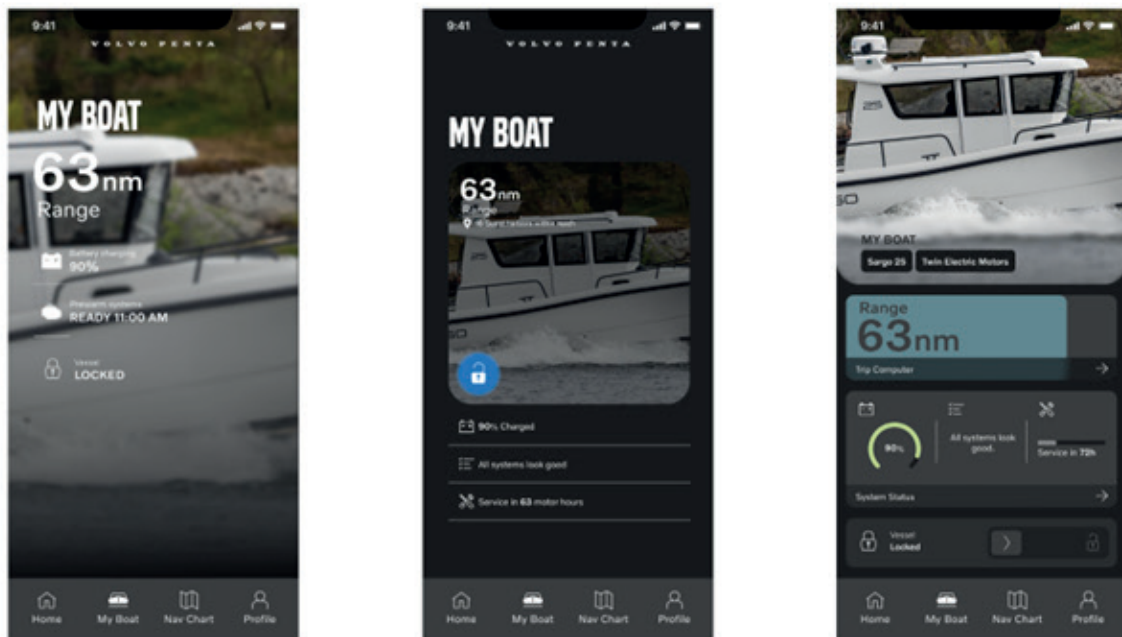


Figure 37: Final concepts for the digital interface. Image of boat adapted with permission CC BY 2.0 from Nyman (2020b).

The leftmost concept (1) aimed to use the entire screen as an image backdrop where the user could upload and insert an image of their boat to personalize the experience and provide inspiration to use the boat. The information displayed was range, battery level, preheat status, and lock status. The status icon for lock state was also intended to be interactive and the means for unlocking the boat. The center concept (2) provided a card view of an image of the boat. On the card, range, and an indicator of reachable docks within the range was displayed along with an interactive lock status display which could be used to change the lock state. Then, below, a list of valuable information, such as battery level, system status indicator and service status were displayed. The rightmost (3) consisted entirely of different cards. On top, an image of the boat with some vessel information, then a range indicator with an entry point to more information when clicked. Below that important system status indicators with an entry point to a full list of information about the vessel's status. Last a slider to lock and unlock the boat.

### 4.3.2.3 Evaluation

To decide which concept to develop further, an evaluation of the three was conducted. It consisted of a semantic, an emotional, and a usability assessment. The remainder of this section presents the methods used and their outcome.

#### Hierarchal Task Analysis

A hierarchal task analysis (HTA) has been used as a method of evaluation and system understanding during the project. The HTA method breaks down a task into sub-tasks which makes the entirety of the process more perceivable as the hierarchy breaks the tasks down in detail. The result is typically presented in a tree diagram with the task goal as the starting point and thereafter the sub-tasks that must be achieved to get to the end goal (Sandom & Harvey, 2005).

Two HTA analyses have been done for the evaluation of this project, one for the physical key fob and one for the digital key app with the task goal being Access Boat. There are not a lot of steps to reach the goal but by breaking down the task into sub-tasks it is more apparent to see how they relate to each other. From the HTA analysis one notices that awaiting feedback is an important sub-task that the user needs to get before they can know that they have achieved their goal. Therefore, it was noted that the type of feedback they receive should be well communicated and clear. The analyses were also used as a basis for further evaluations with other methods such as Enhanced Cognitive Walkthrough (ECW) and Predictive Error User Analysis (PUEA).

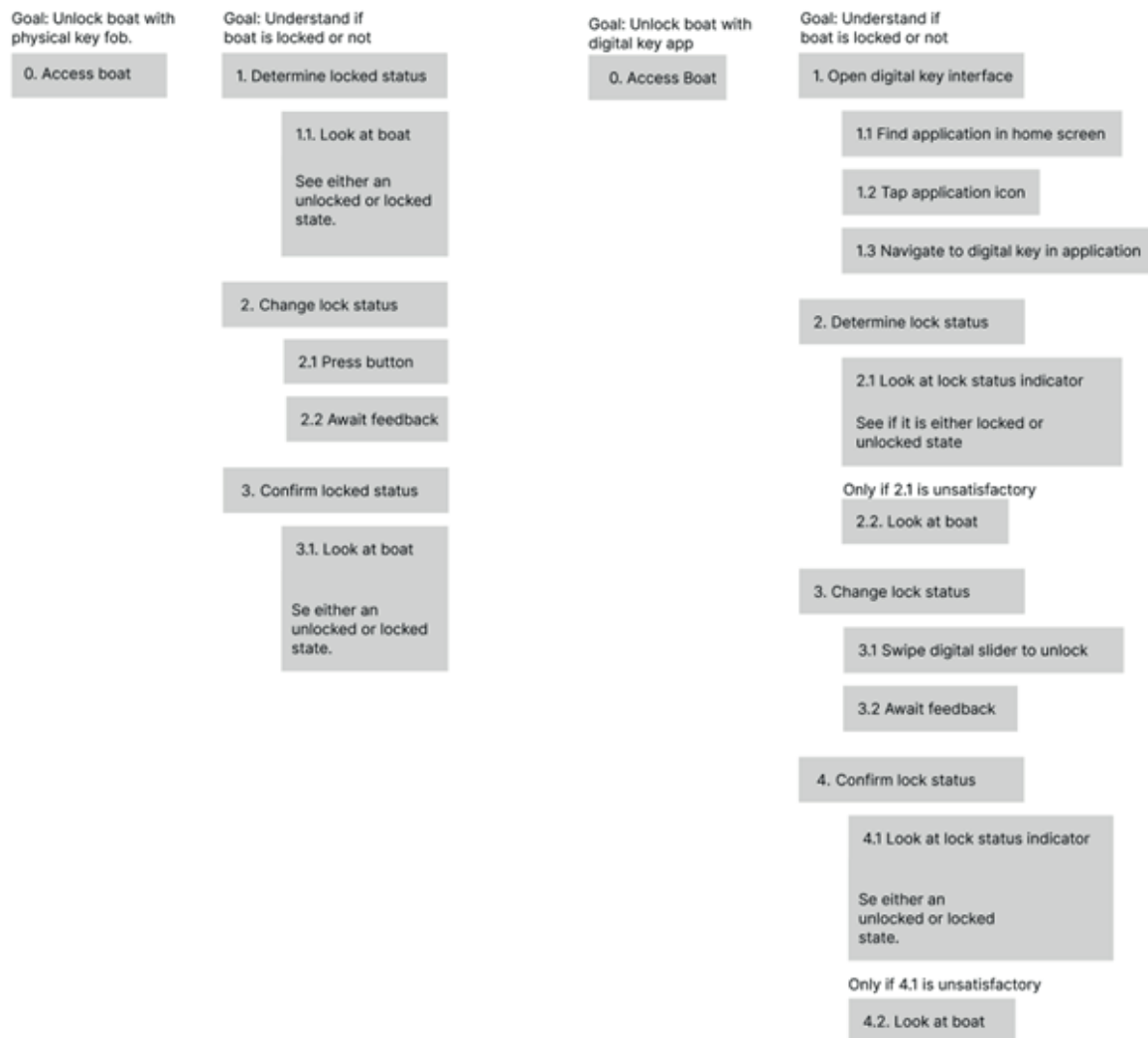


Figure 38: HTA of accessing a boat using either the physical key fob or the digital key app.

### Enhanced Cognitive Walkthrough & Predictive User Error Analysis

Enhanced Cognitive Walkthrough (ECW) and Predictive User Error Analysis (PUEA) are methods to evaluate errors that can occur during a use situation. Bligård and Osvalder (2013) describes the ECW part of the method as:

“ECW uses a detailed procedure to simulate the user’s problem-solving process in each step of the interaction between user and interface. It is continually checked whether the user’s goal and knowledge can lead to the next action being correctly executed.” (Bligård & Osvalder, 2013)

To use the method, one needs to specify the tasks that are important to evaluate for the user-interface interaction. Simplified one then should answer several specified questions about the user’s interaction with the task, for example: “Will the user know that the evaluated

function is available?” and determine the likelihood of user success. If it is determined that an error is likely, the error should be categorized as what problem type they are.

Table 2: Examples of problem types, from Bligård and Osvalder (2013).

Problem type	Explication
User (U)	The problem is due to the user’s experience and knowledge, possibly because the user is accustomed to different equipment
Hidden (H)	The interface gives no indications that the function is available or how it should be used
Text and icon (T)	Placement, appearance and content can easily be misinterpreted or not understood
Sequence (S)	Functions and operations have to be performed in an unnatural sequence
Physical demands (P)	The interface sets too high demands on users’ physical speed, motoric skill and force
Feedback (F)	The interface gives unclear indications of what the user is doing or has done

The PUEA part of the analysis is also done by following a set number of steps and by applying a questioning procedure where the analyst should aim to predict any use error that can occur during the given scenario (Bligård & Osvalder, 2007). The items of investigation should all be considered to complete the method.

Table 3: Items of investigation in a PUEA, from Bligård and Osvalder (2007).

Items of investigation	Explanation
Type	What is the type of use error? (categorisation)
Cause	Why does the use error occur? (description and categorisation)
Primary consequence	What is the direct effect of the use error? (description)
Secondary consequences	What effects can the use error have that lead to a hazardous situation for the user or other people, or to risk of machine damage or economic loss? (description and judgment of severity by a grade)
Detection	Can the user detect a use error before it has any secondary consequences? (description and judgment of probability by grade)
Recovery	Can the user recover from the error before any severe consequences arise? (description)
Protection from consequences	Which measures does the technical system employ to protect the user and the environment from the secondary consequences? (description)
Prevention of error	Which measures does the technical system employ to prevent occurrence of use errors? (description)

These set of steps were employed on both the digital and physical user interface to determine how good the system was to prevent and mitigate error. A good system should primarily prevent errors or allow the user to recover from those errors so that no catastrophic consequences will occur to stay in line with Jordan's (1998) and Nielsen's (1994) usability factors for good system design. Through answering these questions regarding the system, it was determined that the systems held up to these factors and that suggests the system has good usability. Out of the possible errors found, all were due to slips and user error (U). A slip can be described as a mistake that occurs when the person has had the correct assessment in a situation but still fails to do the task correctly. Shortly it can be described as 'Good plan, bad execution' (Bligård & Osvalder, 2014). These types of errors indicate that the system is not the primary cause of issues, which is a good indicator of the success of the system. On the grading scale of error severity, they were also deemed negligible.

An example of a typical error found in the system through the ECW and PUEA method could happen when trying to unlock their vessel and failing to do so. One cause could be if the user determined the lock status wrong and therefore, they might then change to the wrong lock status because of their faulty assumption about the locks status the vessel was in. The primary consequence of this is that the vessel is changed to an unwanted lock status and the secondary consequence is that the user either must repeat their intended action if they realize their mistake or be made aware of their mistake to avoid unwanted consequences. An unwanted consequence in situations involving locks is typically leaving the vessel unlocked and unattended for a longer time. This makes the vessel vulnerable to theft or trespassing. To avoid this occurrence the system is equipped with preventative measures. The primary hindrance for this to occur is prevention through having the lock status indicators be significantly different from each other, therefore, this situation is unlikely to occur in the first place. The secondary prevention method is through recovery since the action is easily reversible when the user notices their mistake. Lastly there are protection measures if the user were to leave their vessel unlocked. If the user leaves the range of the vessels Wi-Fi connection the system should recognize that it is unlocked without having connection to the authenticator devices (smart devices or key fob) it will then send an alert to the users' smart device to notify them of their mistake.

Through utilizing this method, one could be sure that the system had measures to mitigate errors that have a possibility of occurring in this type of system. It is possible that certain errors that can occur in use situations were not covered by the method, but it is likely that many catastrophic consequences were caught and could be discussed and solved through discussing them with ECW and PUEA methods. All the ECW and PUEA cases can be found in Appendix C.

### ***Experience Evaluation***

To evaluate affective responses to a design's expression a semantic differential scale can be applied. The method uses two bipolar adjectives on a scale from one to the other to evaluate user's perception of an object, which could be both a product and an experience (Bradley and Lang, 1994). The rating should be conducted by potential users, and if the rating matches the desired value that is a good estimate that the semantics of the design has achieved its desired purpose. In this project a semantic differential scale was used to evaluate what unlocking method was preferred semantic differential scales were used. Potential users were instructed to try out the different methods of unlocking a boat through a mockup version of the app constructed in Figma. The potential users consisted of three people without any previous boating experience, four experienced boaters, and six employees at Volvo Penta and Volvo Group Design. They were then instructed to rate the versions on the scales vulnerable-secure, old-modern, boring-exiting, dull-inspiring, stale-interesting, untrustworthy-reliable, confusing-straightforward, mellow-uplifting, ugly-beautiful and do not want-want.

The scales were introduced to participants without a numbered scale, not limiting them to picking a certain discreet number. The results were then gathered and digitalized to find an average answer and the spread of answers.



Figure 39: Result from the semantic differential scale evaluation.

The rightmost statements were the desired result of the evaluation. The unlock slider was placed best in average response, and stood out clearly in security, but lacked since it was considered more confusing than the other methods. Still, it was the most desired solution. Mostly, since it required a more advanced operation than a single tap to unlock, which innately provided prevention to accidental unlocking. The low straightforwardness was a guessability problem but after one use, participants understood it, thus, it was considered easily learnable. The slider was therefore chosen as the main unlocking method but required some further development to minimize confusion in its interaction.

The semantic evaluation of the entire interface was conducted by utilizing a method called the Repertory Grid Technique (RGT). RGT is a method which can be applied in UX evaluations to gain qualitative insights into the perceived experience of technical artefacts (Fallman and Waterworth, 2005). By comparatively weighing artefacts against each other on scales between two opposing statements, it provides a comparative scoring of the artefacts. In this case, the same statements used in the semantic differential scale were used. They were put on a scale of one through five. The RGT study provided both qualitative and quantitative insight on how a user might perceive a new user interface as the subjects were instructed to think aloud and explain their choices while they filled in their data sheets.

The study was conducted over a period of three weeks with the same sample as the semantic differential scale plus three more inexperienced boaters. It yielded a lot of feedback on the interfaces which had been created. This feedback was used to modify the prototype and create a large variety of interfaces that were then subject to be in the next iteration of evaluation. The target of working with iterations of the interface made it possible to put the feedback received to the test to see if incorporating the feedback yielded more positive results for the next iteration of tests.

The early evaluations featured one of the interface prototypes (Concept 2), a connected boat app that featured unlocking possibilities, two connected car apps that featured unlocking possibilities, and Volvo Pentas own app Easy Connect. The interfaces were all different stylistically and featured different functionality. These differences created a broad baseline to compare the prototype interface to. In the table below, the average score for each interface in each scale is presented.

From the quantitative data gathered it was found that one of the connected car apps for unlocking personal vehicles was favored in most categories. It scored the highest average in all categories except two where it was tied the new interface. The interface of concept 2 was found to have polarizing scores with the subjects both expressing affection or dislike

Table 4: Results from the first round of repertory grid evaluations.

	Concept		Other applications			
	2	Boat	Car	Car	Boat	
Vulnerable	3.5	2.8	3.8	3.3	2.2	Secure
Old	3.3	1.8	4.0	3.3	2.8	Modern
Boring	3.2	2.3	3.7	2.8	1.7	Exciting
Dull	3.0	2.3	3.5	2.7	1.3	Inspiring
Stale	3.0	2.3	3.8	3.0	2.0	Interesting
Untrustworthy	3.7	2.8	3.7	3.5	2.3	Reliable
Confusing	3.7	3.2	4.0	2.8	2.7	Straightforward
Mellow	3.3	2.3	3.3	2.8	2.2	Uplifting
Ugly	3.8	1.7	4.0	3.2	2.2	Beautiful
Don't want	3.3	2.2	4.2	3.3	1.5	Want
	33.8	23.8	37.9	30.9	20.8	

for it. An interesting finding from the qualitative data was that the prototype interface was convincing as a genuine application from Volvo Penta as it was convincing enough to make employees at Volvo Penta believe that the interface was taken from a launched Volvo Penta application.

The second round of evaluations included all three concepts, 1, 2, and 3, as well as the favored connected car unlocking interface and the connected boat app. Again, the average of each response is presented.

Table 5: Results from second round of repertory grid evaluations.

	Concepts			Other unlocking apps		
	1	2	3	Car	Boat	
Vulnerable	2.8	4.0	3.8	3.5	1.5	Secure
Old	4.3	2.8	2.7	4.7	1.2	Modern
Boring	3.5	2.7	2.8	3.5	1.2	Exciting
Dull	3.3	2.7	3.0	3.8	1.2	Inspiring
Stale	3.3	2.7	3.2	3.7	1.7	Interesting
Untrustworthy	2.8	3.7	3.5	4.2	2.5	Reliable
Confusing	3.2	2.8	3.2	4.5	2.2	Straightforward
Mellow	3.5	2.5	2.5	3.8	1.3	Uplifting
Ugly	3.7	2.3	2.3	4.0	1.2	Beautiful
Don't want	3.3	2.3	4.2	4.3	1.2	Want
	33.8	28.5	31.2	40.0	15.0	

When presented with all concepts, the comparative rating of concept 2 fell. However, it rated highest in security and reliability. Both concept 1 and 3 scored well, yet not as high as concept 2 did in the first round. The sum of averages of concept 1 was the highest. Yet, during the evaluation some deemed it too minimal, and had a challenging time seeing what functionality it offered. There were also concerns regarding images which would not contrast the text as well as the image in the prototype. While it scored well, participants would afterwards express worries regarding the minimalist approach. Especially in the commercial market.

Concept 2 got the response that it felt robust, but boring. Some participants found the information difficult to interpret since there were no clear labels, and it lacked clues toward

its interaction. Also mentioned was that some visualization of the presented data was missing from the concept as opposed to the favored connected car app and concept 3.

Concept 3 was rated highly, and the most wanted of the three. Most participants found the interface too cluttered. Yet some enjoyed it while some regarded it too technical. One major finding was that the lack of visual hierarchy made people confused with the parts of the interface which were interactive, and which were not. One participant was unable to find the unlocking function before it was explained to them.

#### 4.3.2.4 Refinement

It was deemed that a secure and reliable unlocking interface was more important than an exciting, modern, and interesting one. This was proposed only as one screen of an entire application as opposed to the whole solution. Thus, it was decided that concept 2 would be subject to further development, in consul with experienced HMI engineers at Volvo Penta. However, it would require the implementation of clearer communication of its functionality. Therefore, some elements from the other concepts could be applied to the concept.

#### 4.3.3 Design Process – Physical Key

The design process of the physical key consisted of finding what exact function the physical key would house, as well as how it would be shaped. In the process, sketching and modelling were used to produce variations.

##### 4.3.3.1 Sketching

Sketching has been a consistently used tool for the project. Sketching provides a platform to explore a concept both in how it will look aesthetically and how functions can be applied to a product. The medium is suitable to use to communicate ideas between stakeholders even if the sketch is low fidelity and provides support for discussion. The fast pace of which sketches can be produced also gives many ideas to explore and keeping the sketches rough makes it more painless to discard ideas that are less favorable (Lipson, 2000). Many iterations of sketches were produced as a part of the process of evaluating what would constitute a suitable solution for the key fob. Both physical and digital mediums were used to create sketches. The different tools have different strengths. With physical sketches, it is easier to experiment with the design and try out more organic shapes while digital sketches can be copied to produce varieties of concepts.

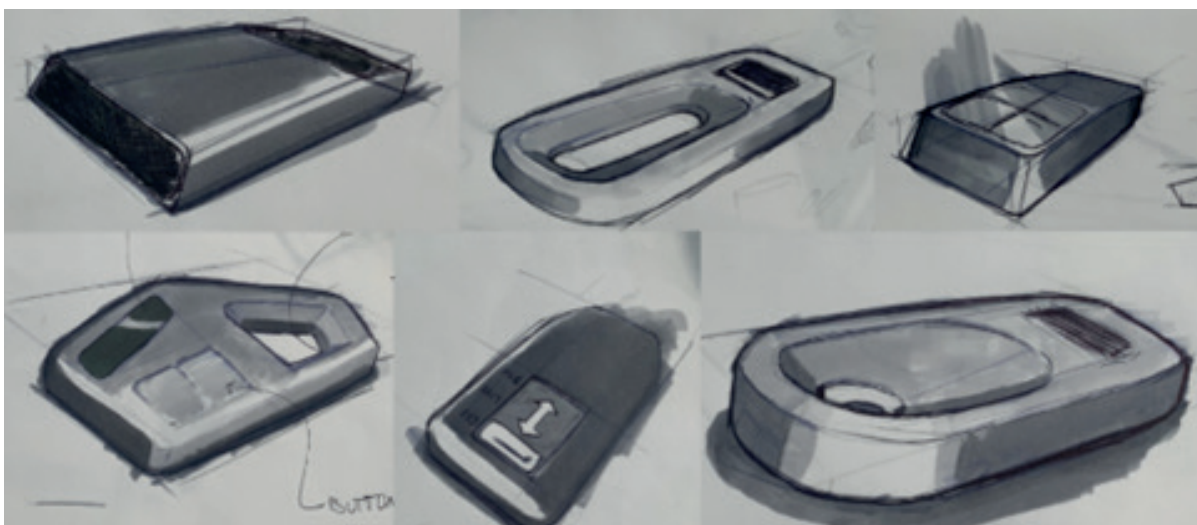


Figure 40: A selection of paper sketches made during ideation.



Figure 41: A selection of digital sketches made during ideation.

In the sample of digital sketches, 1, 3, and 4 were supposed to function only as a means of unlocking, and 2 was an idea of an extended MOB (Man Overboard) fob which allowed for unlocking together with a MOB function. The idea of 1 and 2 was to allow wearability, to enable the user to always keep the key close. In a review, clip-ons were discarded by the note that they easily wear down. The slot on fob 2 was also discarded since its oblong profile was susceptible to fracture.

One important feature of the physical key was physical buttons. To explore different buttons, an exploration of button designs was conducted. Through digital sketching, a type of morphological chart was made with different possibilities for button options for the fobs. The morphological chart is a method that utilizes combining different components of what is being ideated on to create a range of creative solutions (Wikberg Nilsson, 2016, p.147). In this part of the project, the scope of the function of the buttons was wide so the charts' main purpose was to generate a lot of different ideas how the buttons could be shaped. Characteristics used were soft-hard edges, raised-sunken, flat-rounded, and circular-angular.

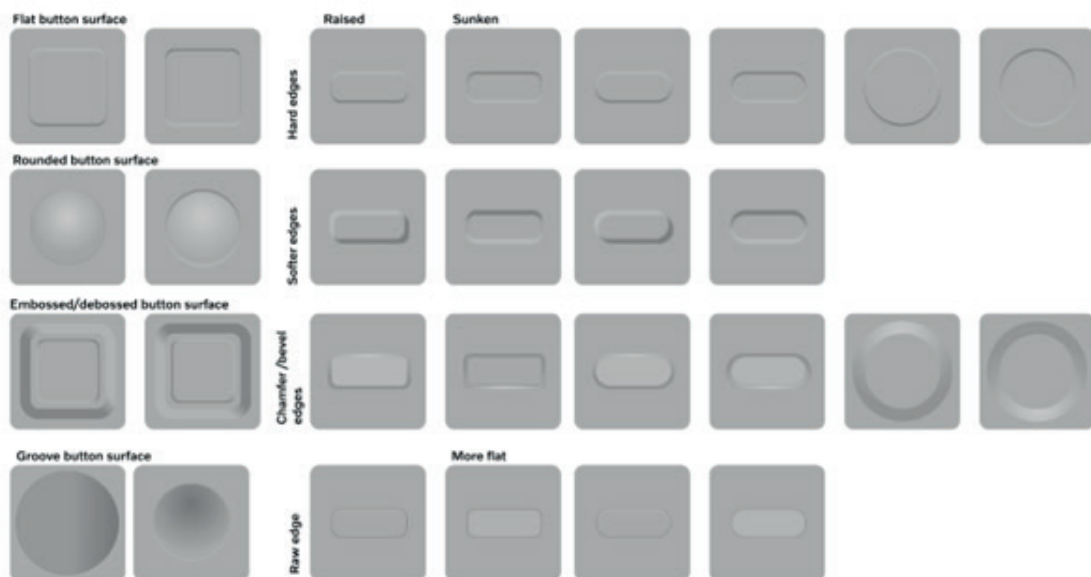


Figure 42: Chart of different button types from the morphological study.

#### 4.3.3.2 Physical models

Making physical representations of a concept provides the opportunity to further understand a design. A product that is made to be handled should be evaluated accordingly which makes it essential to create physical representations where haptics such as touch and weight can be explored.

Iterative model creation was primarily done with wood as the chosen material. The material was suitable for its solid properties, and it worked for the purpose of a rough evaluation for the shape of the new key fob. A range of different wooden fobs were created that sought to imitate designs from the sketching phase. New shapes were also made through combining different elements from old designs. The process consisted of making several different fob models that were then evaluated based on their appearance and feeling. The ones that were liked were further evolved in the next round and models that were not found to be lacking were either discarded or modified. This process was done until one concept was left, then converted into a 3D CAD (Computer Aided Design) model.



Figure 43: All wooden physical models made throughout the project.

Some of the wood models were photographed and taken into Figma where the pictures were sketched upon to explore how the interface on the fob should look like. The placement of buttons was explored, dividing lines and materials and what parts of the fob should have active surface areas. The number of buttons that the fob needed to have not yet been decided at this time of development, therefore, the numbers of functions for the fobs differed a bit. Some of the sketches feature screens and trackpad solution, these were however deemed as too complex features to have in a fob as they would require more power than necessary for a standard fob to sustain their functions. A decision was made to put two of the different sketches into CAD software for them to be 3D printed later. During the CAD modeling some tweaks were made to the models to make them closer to the shape that was desired.



Figure 44: Sketches layered upon one of the wood models

The first 3D printed model featured four buttons on the top surface. This concept was chosen since it featured the same amount of functionality as the e-key remote, which also has four buttons. The second 3D printed model featured two buttons placed on the surface of the fob. The thought process around having two buttons was that it could either be two buttons with assigned ON and OFF functions, I.e., one function for each button. Another option was that the two buttons could both have binary options where one of the buttons would be designated as ON/OFF and the other could be used for another function.

The concepts were evaluated with a design lead at Volvo Penta. Out of the two models, the second model received the most positive feedback as four buttons were considered too many. It was also commented that it seemed like it was easy to accidentally access the buttons as they easily could be reached inside a pocket which was undesirable. The second 3D printed model also had a smaller size which was appreciated. Lastly, the design lead thought the second model resembled the desired expression better. Therefore, it was decided to continue developing the second concept to refine it further, both regarding its appearance and functionality.



*Figure 45: 3D-printed models made in the project.*

## 4.4 Result

In this section, the results from both the development of the digital interface and the physical key are presented. Going through the features of them both.

### 4.4.1 Digital interface

#### Design

The final interface design incorporated a large image card where the user would be able to insert an image of their boat. Present on the card was an indicator of range. In a leisure application, suggestions of reachable locations could be presented, and in a commercial application, a calculated time until refueling. The unlocking is also placed within the card to separate it from other data. Below is a list of data, from most important to least. Each list item also contains navigation toward a more detailed view.

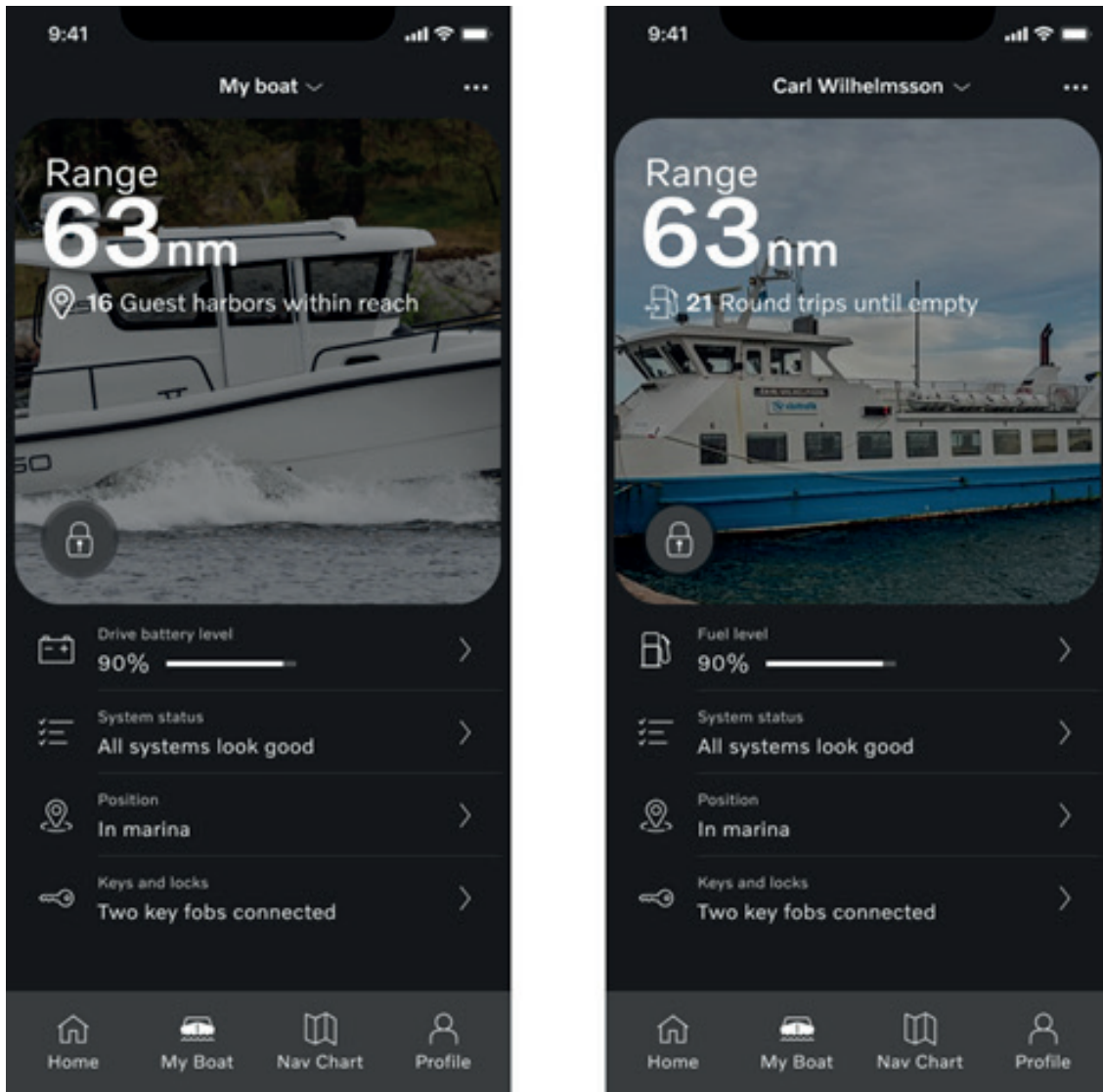


Figure 46: Final interface design. Left boat image adapted with permission CC BY 2.0 from Nyman (2020b), right boat image adapted with permission CC BY-SA 4.0 from Carter (2022).

The interface was designed with prioritization of functionality and information in mind. Presenting range first in large text, followed by an indicator of lock status, deemed to be the most important pieces of information. When planning a trip, range is essential, and when a user wants to make sure their boat is locked, being able to see the locked status briefly is useful. The remaining information is listed below, and to not overwhelm the user, most data is only accessible if the user desires it, providing visual clarity.

The method of unlocking was a slider; however, it was designed to be hidden when not interacted with. When the lock button was pressed, the slider would emerge and after

unlocked, retract again into a smaller icon. This method combined a button with a slider to add an extra step to the unlocking. The color of the element changes when entering the unlocked state, and the icon is filled rather than outlined to display a change in state. The contrast between the states provides clear and visible feedback that the action has been taken. The change in color also eased the ability to see the locked status briefly. Using the slider as a means of unlocking was to prevent the error of accidentally unlocking the boat which was interpreted as too easy with just a button. The method also allows the user to have more control over the unlocking procedure.

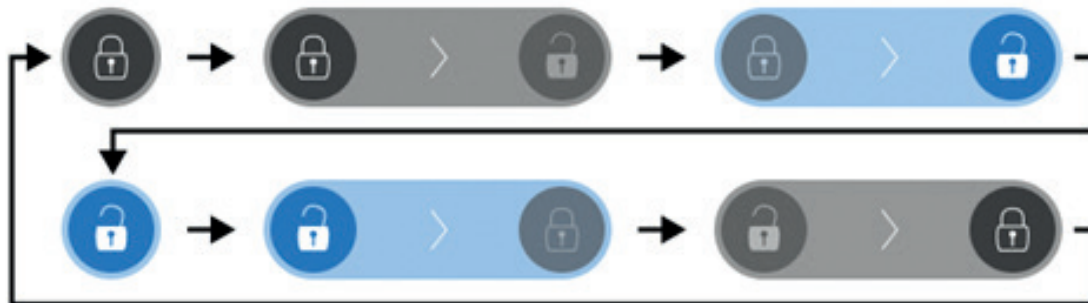


Figure 47: Flow of unlocking interaction.

The list items below all followed the same pattern. An icon, a small headline, and a larger information text, along with a chevron to indicate there is more information if pressed. They are both internally consistent toward one another, and externally consistent since many applications use chevrons to communicate navigation. Information which could be visualized, such as the battery level, was visualized but in a more discreet way than in earlier concepts. This was to stay in line with the Volvo Experience System, which aided in constructing an interface compatible with users' mental model of a Volvo application. Since the need for driving a boat can occur anytime of the day, the interface was designed both in a bright theme and a dark theme. This is a feature supported by most devices and is a performance requirement in most digital interfaces.

To provide the appropriate user experience, the design was aimed at being perceived as secure and reliable firsthand. It was also desired that the interface would inspire and excite users, as a part of the boating experience. Allowing the user to insert their personal picture of their boat was one of the means to provide a more inspiring interface. The entire user experience is however based upon the usefulness of the interface's main functionality, thus the desire to design an experience had to be grounded in the base functionality.

### **Enabled Functionality**

The secondary focus of the project has been to use the application as a platform for the user to gain valuable information regarding their boat to decide if the boat is ready for take-off. The new interface tries to convey that information in a way where the most essential information takes priority to make it as easy as possible for the user to understand. Having more hierarchy in the information presented could also help a novice user better understand what information is most important. Having easier access to vessel information will make boaters more prepared before taking off.

Boating as a service has been a point of interest in this project, even if it has had little to no part in the overall system design. To facilitate boating as a service it is reasonable to speculate that there will be a need to have a digital platform where users can browse, rent, and access a marine vessel of their choice. The application that has been developed during the project has thus far been focused solely on unlocking vessels, but it is likely that it could have further uses in the future. Since the application will facilitate access to marine vessels one could entertain the possibility of the application to also facilitate renting possibilities in the future.

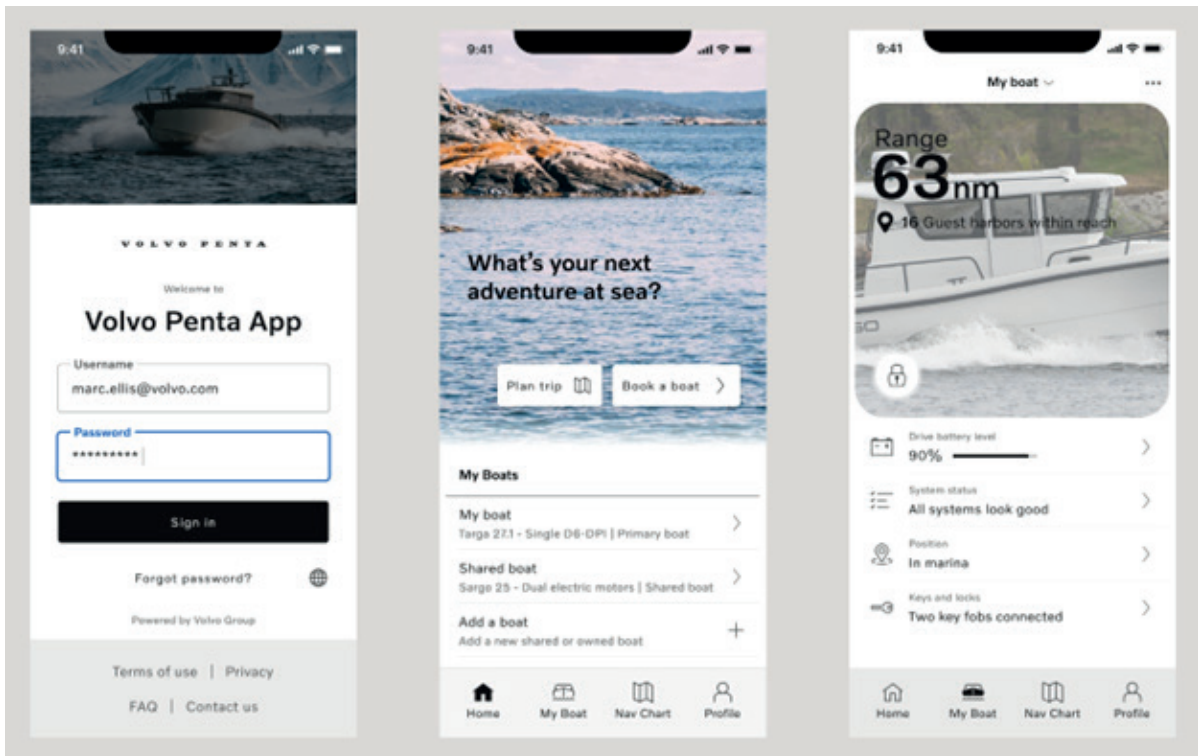


Figure 48: Collage of screens from the final digital interface for the leisure segment.

This can also be applied in a commercial setting, where many users share many boats. Then, instead of a boat sharing platform, it can be packaged as a fleet management platform. Providing easier planning and access, since a manager could have access to an entire fleet of vessels and distribute digital keys to users as needed. In the case of spontaneous commercial, such as an emergency response vessel, this could be taken to another level. If the system were to receive information about the emergency, it would enable the system to choose the best vessel for the emergency.

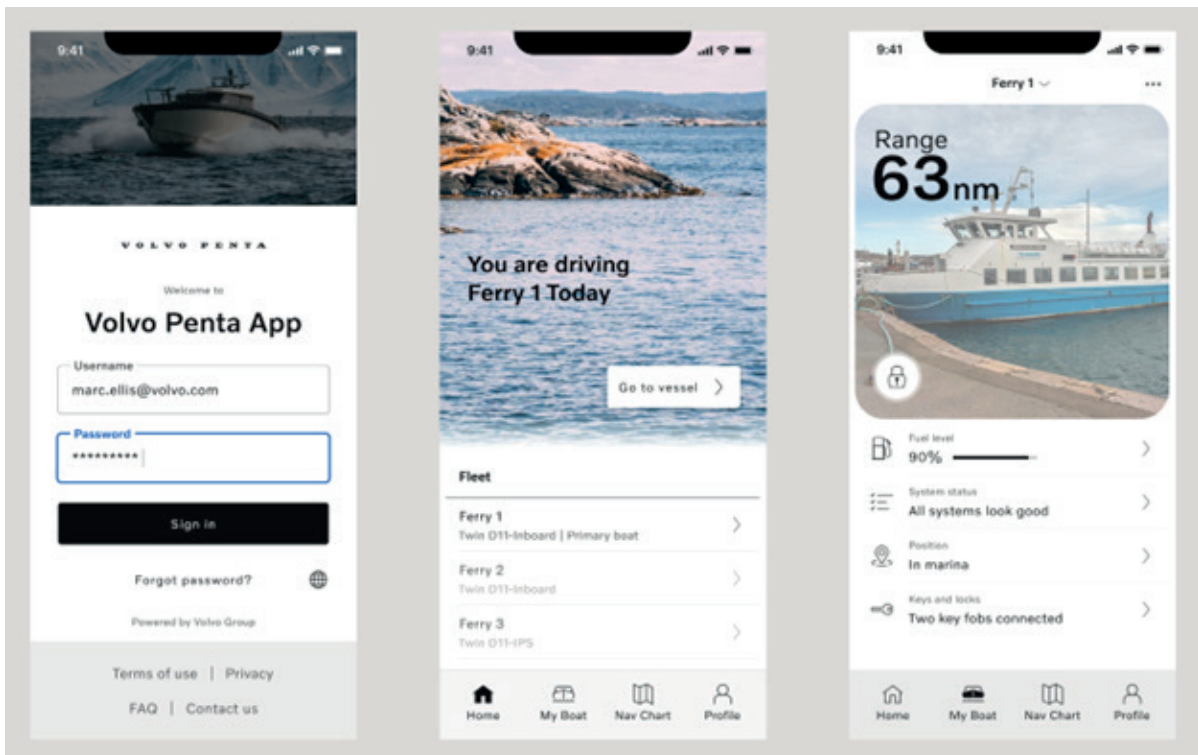


Figure 49: Collage of screens from the final digital interface for the commercial segment.

## 4.4.2 Physical key

### Design

The new physical key for the system is simple and has similar qualities to its predecessor. It can unlock the system from a distance through pushing the button with an unlocked padlock symbol. The key fob is easy to use due to its simple interface with basic functionality. The two modes are indicated through symbols a locked and an unlocked padlock which is consistent with Volvo Pentas' other systems. The unlocked symbol also contrasts with the locked symbol by being filled in, making it easier to spot which mode is engaged. Since most boats have their unique installation of accessories, it was uncertain whether the boat itself could provide feedback of a user's action when changing the lock state. Thus, the key fob itself would benefit from providing feedback. This is made possible by a small LED (Light Emitting Diode) which lights up when the key fob receives input that the lock state corresponding to the button pressed has been applied. Which is possible since it connects to the onboard system with Wi-Fi enabling two-way communication.



Figure 50: Digital sketch of key fob.

The opening on the key fob serves a function and can be used to fasten it to an attachment such as a key chain or a belt. This functionality is good to have in a marine environment since there is always a risk of dropping items in the water, which can be a nuisance to retrieve. The risk of the key fob ending up in water also led to it being important that it floats on its own. Due to the risk of the key ending up in water and being close to water, the design is made to be waterproof according to IEC IPx7. The key fob was designed for cases where users do not wish for a connected system or a digital key, or the implementation thereof is impossible. Thus, it only provided the base functionality of locking and unlocking, since all other functionalities can be accessed from the helm environment.

### ***Usability***

The choice to simplify the product to its minimum viability comes from the finding that the users currently often simply use the current product in its simplest form. Keeping the product simple and close to most users' mental model of what a key is and how they work is good for consistency purposes. Clearly communicating the keys simple functions through buttons with icons is good when keeping users' information processing in mind as presenting the user with clear stimuli is a part of designing for bottom-up processing. Keeping the key fob as a part of the solution where it can be used exclusively as the point of interaction with the marine vessel also removes the issue of considering how a new solution could impact how a commercial vessel operates. They will be able to keep their routines as they are if they choose to. The only practical difference will be that there are less steps during the unlocking process and a small-scale change on the key fob interface



## 5. Discussion

This thesis aimed to develop new means of onboarding marine vessels, and to create a concept for a future means of unlocking them, with a focus on creating a good user experience. Through a human centered design approach, where user studies and market analysis laid the foundation for iterative concept development, it was found that a new system would be needed to support desired functionality. The main finding of the thesis was the system layout explained in section 3.6, it was proposed to implement existing technology which had not before been used in the marine industry.

Since the system was on a conceptual level it was deemed difficult to holistically evaluate the user experience. The system proposed aimed to provide a backbone for the functionality found desirable, but the way the system would function remains unexplored. What is known is the artifacts that users will use to interact with the system. Throughout the project, requirements regarding the provided functionality of the system were specified, without specifying hardware, software, or other methods of implementation. Therefore, more UX analysis has focused on details of the entire system I.e., the new key fob and the UI (User Interface) of an unlocking application. These were designed to provide an understanding of the system's functions and to explore how the front-end interaction could become a good user experience. The front-end of the system has sought to conform to relevant theory regarding UX and adhere to the theoretical guidelines to ensure a pleasant interaction.

The struggle of not being the only brand in control of the user experience makes it difficult to understand where the design should focus on standing out and coding the solution as a strictly Volvo Penta product and when to focus on working seamlessly and integrating with other components that are all a part of the same vessel. The user experience of unlocking a marine vessel has previously been scattered throughout many subsystems and artefacts. Ranging from cabin keys to battery switches. Creating a system which can access and control more subsystems was a way to cluster them all, allowing higher control of the user experience. This way, Volvo Penta can be present in more stages of the planning and onboarding process of vessels which incorporates this system. Which also means the Volvo Penta brand gets more recognition as a primary boating facilitator. In this thesis, the result was limited to the unlocking of the EVC system and onboard electronics. To streamline the process of onboarding further than proposed, allowing for the unlocking of doors and hatches would be beneficial. The system should be compatible with this functionality with its internet-of-things capabilities, however, the market for marine smart locks is limited. Either, Volvo Penta would have to supply their own locks, or partner up with a lock supplier which could provide locks which enhance the experience.

As a parts manufacturer, Volvo Penta battles the problem of not having full control over the exact installation of the user environment which has been challenging for the project in some respects. Since the user experience is in many ways connected to how and what the user interacts with it is difficult to both simulate an accurate user experience as well as predict how a future solution will be implemented in practice. This will make it difficult to implement many of the more radical and forward-looking concepts from the ideation-phase. The chosen solution works to close this gap between Volvo Penta's lack of control of the user environment and the user's perception that the boating experience is linked to the Volvo Penta experience.

During the ideation phase of the project there were interesting ideas regarding more futuristic solutions which had a certain relevance from a user experience point of view. They were, however, discarded for being unrealistic even though it is possible that future innovation could make them more plausible. Working towards a future solution involves a

continuous tradeoff between the utopian solution and plausibility and this project opted for a solution that could be viable with today's technology to ensure the possibility of success. A more radical authentication method would also be more difficult to evaluate, therefore, the project excluded them from further development.

The limited access to boat builders throughout the project makes it difficult to do more than speculative guesses if this type of system would be something that they would purchase. The biggest evidence for this is that there are aftermarket solutions that aim to alleviate the same type of pain points for users that this type of system fixes. That strongly suggests that this type of system is something that boat buyers want and since boat builders want to please their customers they can sell a boat with a new Volvo Penta solution with an integrated connected boat system. That other similar business areas also move towards IoT-solutions, such as the automotive and housing, suggests that connectivity and connected unlocking methods are sought after in more parts of life.

## 5.1 Reflection

The project process has sought to be iterative and as considerate to feedback and user needs as possible. However, the access to end users has been limited. While user studies on end users provide solid information, a good user understanding can be facilitated through other methods. Other creative means were used to gain user insights. Like field studies, both on a boat fair, and on a test run. The boat fair provided quantitative insights into the leisure segment, while the test run was a qualitative study of the commercial segment. Another way to gain user insights was to hypothesize use cases and evaluate them iteratively and access previous user studies. From this, pain points for users were found and use cases were constructed to gather all the user insights found. The use cases aimed to present four opposites to together cover the entire user group and their respective user needs. They were both an effective way of compiling the user needs and effective in communicating them to others.

There were three distinct ideation processes present throughout the project. One for the system design and two for the front end, one for each interface. The ideation for the system design was based around finding suitable elements to provide certain functionality. This process consisted of exploring many possibilities to then eliminate those which were unreasonable or unrealistic. The final design was not chosen based on user testing, but rather on the found user insights, and technology. This was because the system was never implemented, so it was unreasonable to try and test it in its entirety. Ideating the digital user interface was a process of trial and error, followed by many iterations. Different orders and ways to present data were tested and reviewed until three final concepts were tested more in-depth. Both an evaluation of the usability and the semantics of the interfaces were conducted. The ECW and PUEA method used to find potential errors in the use of the interface was difficult to apply, since the framework is constructed for human-machine systems where the outcome of errors is more severe than the system proposed in this project. The method provided an understanding of potential risks and their cause; however, it could have been beneficial to apply another severity scale to the framework. In the semantic evaluation of the digital interface, qualitative insights were weighed higher than quantitative data. The final concept chosen was not what scored highest but what participants saw as the concept with most potential and most in line with the brand identity. Elements which received positive feedback from the study were also kept in the final iteration.

## 5.2 Conclusion

The main issue regarding the user experience of boat onboarding is that it is fragmented. While there are products available which gather some functionality. There is no system which controls the entire operation from the dock to the sea. Users lack live information from their boat which hampers planning of both long and short trips. Some boats require an entire

keychain to allow access, making the key difficult to bring along in daily life. This makes a spontaneous boat trip difficult to accomplish. Moreover, marine vessels are complex since they all have a unique installation catering to the user's needs. The use cases of different boats also have implications on the desired unlocking method.

Through thorough design processes it is possible to achieve a well thought out system. The system proposed in this thesis aimed to alleviate the issues of onboarding by providing a flexible and holistic solution which could cater to many different user needs. It is suitable for the leisure segment for accessing boats remotely to receive status updates, as well as providing a digital key, present in a device which is always in the user's possession which allows for spontaneous outings. In the commercial segment, the system would make the onboarding procedure more efficient, saving valuable time. The user experience improves by increasing the amount of vessel information available to users without needing to access the boat and decreasing the number of actions required before they can cast off.

### **5.3 Recommendations for future work**

This project has sought to create a baseline for how Volvo Penta should approach their unlocking process and their user experience. To implement the suggested solution the system will have to be built and tested to ensure that the intended technology works without unintended consequences. This project has provided a specification of requirements for its intended functionality from which the system can be built with room for technological aspects to be changed if they are deemed to suit better for the intended purposes.

Future work also includes further prototyping and testing of both front-end solutions presented in this project. Out of the two the digital interface will need the most work to be able to be implemented. As of now the digital interface is on an early conceptual level since it consists of wireframes that make up the current interactive prototype. Further work on the digital interface would include deciding on what functionalities to include in the application and to further iterate how information should be prioritized and building it to be more interactive so it can be tested more thoroughly. The new key fob will also need some work to be operational. Firstly, the key fob should go through another evaluation process, as the newest model did not go through quite as many evaluations as previous iterations. A comprehensive model or prototype should also be made to evaluate the feeling of having the key fob in the user's hand and to evaluate how the button interactions seem. Since it is such a simple product it is, however, likely that only small changes will be needed on the key fob to achieve user acceptance.

Given that access to other stakeholders of this project such as users and boat builders has been limited it would be recommended to include them in future user studies to see if their perspectives have any important insights. It is important to keep in mind that this project has only explored a small portion of the possibilities which could be included in the system. Meaning the potential of the system is larger than presented in this thesis. Future work on this project should try to investigate the full system limit, that is, how much of the boating experience Volvo Penta wishes and can be responsible for. The full scope of a Volvo Penta wirelessly connected system remains unexplored since its possibilities are larger than this thesis has had the opportunity to explore.

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# Appendix

A. Interview Template .....	1
B. ECW and PUEA .....	1

## A. Interview Template

Interviews conducted in Swedish. Template translated.

- Do you own a boat?
- If yes, what type of boat?
- Does it have a cabin?
- How many engines?
- Are they Volvo Penta?
- How many keys do you need to operate your boat?
- If Volvo Penta: eKey tag or eKey remote?
- How does the process look for you from want/need to go boating until you can cast off?
- Does any action feel unnecessary or especially necessary?
- What information do you wish for when planning a trip?

# B. ECW and PUEA

## Template ECW and PUEA – Functions Authentication

		Rank	Success/fail Story	Usability problem	PS	PT	Notes
	1. Will the user know that the evaluated function is available?		Yes, the user will know of this		N/A	N/A	
	2. Will the user interface give clues that show that the function is available?		Yes, the interface will show icons that guides the user that authentication is required to operate vessel.		N/A	N/A	
	3. Will the user associate the right clue with the desired function?		Yes, the symbol is commonly associated with changing locking status.		N/A		
	4. Will the user get sufficient feedback to understand that the desired function has been chosen?		Yes, by a change in icon and color to show another state is active.	5			
	5. Will the user get sufficient feedback to understand that the desired function has been performed?		Yes, by a change in icon and color to show another state is active.	5			
Error & Type	Error Cause	Detection	Prim. Consequence	Sec. Consequence	Prevention	Recovery	Protection
P4	Unlocking action was performed before the key fob entered the range of boat WIFI.	4 Key fob interface does not change status.	Vessel lock status unchanged.	5 If vessel was unlocked, integrity issues.		User needs move closer to vessel and repeat action.	Locked -> unlocked N/A Unlocked -> Locked: If fob and connected smart device leaves wifi connection > 1 min systems lock and notification of locked systems is sent to smart device.
A11	Lock button pressed unknowingly	3 Icon changes	Vessel lock status changed if in range	If user stays within range of vessel w/o supervising if the vessel might be susceptible to theft. If outside range, vessel stays unlocked.			Locked -> unlocked: Action requires button to be pressed with some force. /Accidental action will need specific circumstances. Unlocked -> Locked: If fob and connected smart device leaves wifi connection > 1 min systems lock, and notification of locked systems is sent to smart device.

## Template ECW and PUEA – Operations Determine lock status

	Rank	Success/fail Story	Problem Type	Notes			
1. Will the user try to achieve the right effect?		Yes, they will try to understand the lock status		Determining lock status is easier on application as the UI is more bright and glanceable than the key fob. That means that struggling to determine lock status will primarily be a key fob issue.			
2. Will the user be able to notice that the correct action is available?		Yes, they will have enough clues to know that they can determine lock status					
3. Will the user associate the correct action with the desired effect?		Yes, there will be sufficient clues during the operation for the user to understand what action they need to take.					
4. Will the user get sufficient feedback to understand that the desired handling has been performed correctly?		Yes, they will know when they have received their desired information.					
Error & Type	Error Cause	Detection	Prim. Consequence	Sec. Consequence	Prevention	Recovery	Protection
A 6 User presses wrong button	S User error, or lack of other than visual feedback	If the user accidentally locks the system they will know when they see that the UI does not light up. On Key fob - none	Vessel may be put in the non desired lock status.	Unwanted locking -> User needs to use correct button on Key Fob again Unwanted unlocking -> look at other example of this occurring.	Different buttons should prevent this but slips is still a possibility	Unwanted locking -> perform correct action again. Unwanted unlocking -> Vessel locks after keys loses connection to onboard Wi-Fi	None
R 2 Misread the lock status indicator. Less likely on digital interface.	S Saw wrong icon Unlikely on digital user interface since it provides both changes in icon and a change in color which is easily glanceable.	If the user accidentally locks the system they will know when they see that the UI does not light up. For putting it in undesired unlocked status alert will be sent to authorized users smart device after some time	Vessel is not put in desired lock status	Unwanted locking -> User needs to use Key Fob again Unwanted unlocking -> look at other example of this occurring.	Icons look different and are placed in different places so user should reasonably not have this problem.	Unwanted locking -> perform action again. Unwanted unlocking -> Vessel locks after keys loses connection to onboard Wi-Fi	Alert on smart device

### Template ECW and PUEA – Operations Change lock status

Rank	Success/fail Story	Problem Type	Notes				
1. Will the user try to achieve the right effect?	Yes, the user will do this.		Changing the lock status requires more coordinated effort to do on the digital UI than the physical key fob, therefore, it will be more likely that a user accidentally changes the lock status with their key fob. The key fob is however only operable while in the range of the vessels Wi-Fi which limits the range where the error can occur.				
2. Will the user be able to notice that the correct action is available?	Yes, with the user interface, there is only one action available which also is the correct one.						
3. Will the user associate the correct action with the desired effect?	Yes, the user will receive feedback that shows that their action has had the desired effect.						
4. Will the user get sufficient feedback to understand that the desired handling has been performed correctly?	Yes, the user interface provides feedback after an action has been conducted	User					
<ul style="list-style-type: none"> <li>What can the user do wrongly in this operation?</li> <li>What happens if the user performs this operation at wrong time?</li> </ul>							
Error & Type	Error Cause	Detection	Prim. Consequence	Sec. Consequence	Prevention	Recovery	Protection
P2 If the user determined the lock status wrong the user might change to the wrong lock status.	S Wrong assumption of what lock status the vessel is in.	The outcome of the user's action is not what they expected	Vessel lock status is changed to an unwanted status.	Unwanted locking -> User needs to use Key Fob again Unwanted unlocking -> look at other example of this occurring.	Lock status indicator should be clear enough for most to not have this problem.	Repeat action to undo change occurring.	Alert on smart device if unwanted unlocking and leaving wifi connection.
A9 User swipes too short on the unlock slider.	S Failure in action, knows what they should do but fails to complete the task because of a loss of attention	User will not receive feedback from the UI that indicates a change in lock status.	Vessel is not put in desired lock status	User needs to repeat action correctly to achieve desired effect.	Slider is not difficult to swipe, but difficult enough to make changing lock status accidentally not happen often.	Repeat complete action	



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