Supervising the giants of the seas

Exploring a supervisory interface for a fleet of

of semi-autonomous vessels

Thomas Wahl

Master’s Thesis 2019

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# Abstract

Rolls-Royce has embarked on a journey to develop unmanned surface vessels (USV) which will eventually revolutionize the way in which cargo will be transported worldwide. The USVs, while slower, will make up for the lack of speed with a reduction in crew-related costs. Additionally, being slower, they produce fewer emissions and require less fuel.

This thesis will be exploring a way in which multiple USVs can be supervised from a centralized location. A shipping company or any other instance that owns and operates a fleet of USVs in the future will need tools to keep the fleet under surveillance and control. This thesis does not go to explore the possible ways, in which the USVs can be remotely controlled.

A key factor that was identified during this thesis, was the portrayal of the situational awareness and status of multiple unmanned vessels. The goal of this thesis was to develop a user interface that would enable the remote operators to follow the fleet and address the situations where the automation cannot act on its own.

For this thesis, teachers of maritime navigation and flight control were interviewed together with technical experts and people who are working on building the system that will allow the USVs to be remotely operated and supervised.

This thesis aims to open up the field for the designing of a true centralized supervisory system user interface for unmanned surface vessels and to recognize some key of the possible key features.

Keywords: Unmanned Surface Vessels, User Interface Design,

Tiivistelmä

Rolls-Royce on matkalla, jonka tuloksena pyritään luomaan miehittämättömiä aluksia. Nuo miehittämättömät alukset tulevat mullistamaan tavan, jolla kuljetukset hoidetaan maailmanlaajuisesti. Vaikka miehittämättömät alukset kulkevat hitaammin, korvaavat ne nopeuden puutteen olemattomilla miehistökustannuksilla. Hitaampi vauhti takaa myös pienemmät päästöt.

Tämä opinnäytetyö etsii tapaa, jolla useampia miehittämättömiä aluksia pystytään valvomaan keskitetysti ja yhdestä paikasta. Kuljetusyhtiö, tai mikä muu tahansa taho, joka omistaa useampia miehittämättömiä aluksia tulee tarvitsemaan keinoja näiden alusten valvontaan ja hallintaan. Tämä opinnäytetyö ei tule etsimään tapoja, joilla miehittämättömiä aluksia liikutetaan etäyhteydellä.

Tässä opinnäytetyössä tunnistetaan tärkeäksi tekijäksi useamman miehittämättömän aluksen tilanteen ja tilannekuvan välittäminen käyttöliittymällä. Opinnäytetyön tavoitteena on luoda käyttöliittymä, jolla etäohjauskeskuksessa työskentelevät voivat seurata laivaston tilannetta ja puuttua tilanteisiin, joita automaatio ei kykene selvittämään.
Tätä opinnäytetyötä varten haastateltiin merenkäynnin opettajia, lennonjohdon opettajia, ja etäohjausjärjestelmää visioivia teknisiä asiantuntijoita.

This thesis aims to open up the field for the designing of a true centralized supervisory system user interface for unmanned surface vessels and to recognize some key of the possible key features.
Tämä opinnäytetyö pyrkii tekemään avauksen keskitetyn valvontajärjestelmän käyttöliittymän suunnitteluun miehittämättömien alusten laivastotasolla ja tunnistamaan tärkeimpiä tekijöitä suunnittelussa.

Avainsanat: Miehittämättömät alukset, käyttöliittymäsuunnittelu

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The voyage that was this thesis, was a rocky one. The way was riddled with obstacles that just couldn't be foreseen. But unlike a certain ocean liner steaming ahead on its fateful maiden voyage, this ship has sailed past the perils and reached the end of the unexpectedly long and difficult journey. Unfortunately, not everyone made it. Keijo, Meeri, and Viveca, this is for you.

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Vantaa, 22nd April 2019,
Thomas Wahl

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1.1 Introduction

The goal of this thesis is creating a concept for strategic level navigation and fleet management of unmanned surface vessels (USV). As far as requirements go for this thesis, the end result needs to be Functional – to do what it was designed for, Usable – the user is capable of using the system without usability hindrances, and it needs to be an Experience – The defined UX vision [6,7] needs to be delivered. Functionality needs a further definition, as the goal is practically unreachable, for there are no real infrastructural environments (yet) where the proposed system can be built to be tested or to be used by an individual, or a group– no ships currently sail regularly on a large scale without a crew. However, the industry has sprung from being mere science-fiction into small scale proofs-of-concept and even pilot projects. Soon we will witness the very first unmanned vessel to successfully navigate, for example, across the Atlantic ocean.

1.2 Setting up the problem

Handling a fleet of unmanned surface vessels is no small task. The situational awareness of the fleet needs to be conveyed in an accurate enough state of for the operator(s) to identify potentially hazardous situations and make decisions upon the given information. The overall situation of the fleet needs to be displayed in an easily and quickly absorbable fashion.

2. Literature Review

A set of intermediate concepts are developed to provide insight into various matters, such as input methods, level of automation, and the frequency that human input is needed. To begin my work, I collected a set of scientific articles and books about Interaction Design (IX), Human-Computer Interaction (HCI), User Experience Design (UX), Information Architecture, User Interface Design (UI), Usability, and maritime navigation. With this set of literature, I set up a framework and theoretical base for the thesis. A strong emphasis will be on User Experience and Usability.

2.1 UX and its scope in this thesis

User Experience has a rather wide and hazy definition despite its status in contemporary HCI practitioners and researchers alike. HCI having an engineering-oriented background similar to usability, their emphasis has been on utility and completing tasks. UX is not something that happens by accident in today's products. Modern products no longer provide only functionality – such would not meet any success commercially.

Whilst Nielsen's five components of usability (Nielsen 1993) include Satisfaction (along with efficiency, learnability, memorability, and errors), it does not take users to experience into too deep of consideration other than pleasantness of use in general. Nielsen's heuristics and usability components form a significant part of the framework of this thesis, and I will get to them later in this literature review. Marc Hassenzahl, Forlizzi & Battarbee have made a significant effort in formulating ways to research and construct user experiences. Forlizzi and Battarbee (2004) state that systems that people do their work with benefit greatly from efforts put into improving the user experience from that of base functionality and usability. Hassenzahl (2011) took a look at UX from three different approaches: beyond the instrumental, emotion and effect, and the experiential. Building upon these ideas, I believe there is a potential to improve the employee satisfaction of people who work with supervisory systems - systems that are seldom considered to be the leading edge of user experience design. This would seem to be supported by Roto et al. (2016), stating that in B2B sales, the user experience of the company perceived by its clients, is not increased by improving the user experience of a single product. The overall user experience is distributed along multiple touchpoints.

Nowadays applications that emphasize on the users' experience seem to be more popular than the ones that give it less effort – or provide a lesser experience. Users respond to a poor user experience more often and have even caused popular applications to be pressured to revert their recent updates because of perceived negative effects on the overall user experience. Instagram and Snapchat have both met the public uproar after they had deployed changes to the user interface, which resulted in a lesser user experience. This is, however, a lesser factor in the context of safety-critical expert systems, where the emphasis is on safety, functionality, and reliability.

2.2 The bigger picture of the system

Today's manned vessels are in a way an extension of the crew. Roughly simplified, the vessel only does, what it is commanded to do – based on orders given to it by the crew, who base their decisions on the available information and their collective experience in maritime maneuvering and navigation. An unmanned vessel, whilst not fully autonomous, has to rely only on its sensors to navigate safely and to convey a thorough enough depiction of the situation to a remote operator for decision making in challenging situations. The unmanned surface vessels are to be the pinnacle of maritime technology much like the very first raft ever built was to humanity. Every unmanned surface vessel will be covered with sensors of multiple types from cameras to 3d laser technology, from radar to lidar, and from accelerometers to barometers. The sensors themselves generate an enormous amount of data, from which a situational awareness needs to be formed. The unmanned surface vessels will possess a remarkable computational potential – so they can crunch numbers really hard! And because of this massive potential, the vessel will be able to cope with the amount of data and form its own situational awareness. In other words, the vessel has mapped its surroundings, knows its location and can project its own context forwards. Nevertheless, there are bound to be situations where the onboard decision-making routines cannot come up with a solution to an unraveling situation. Therefore, an external human controller needs to be vigilant.

In these situations, the vessel might be in the open sea – thousands of kilometers away from the nearest high-speed wireless network. And I think it's needless to point out – that the vessel will not be connected to the internet with a cable. So this will raise a number of challenges. The only real connectivity out there in the middle of the blue nowhere, are the satellites. If you think of this situation in terms of web service - A web service has an interface, through which the user is able to access, interact, and use the service. The service itself runs a lot deeper than the front end of it. The service back end is constructed to send and receive data from subsequent service functions and rummage through databases. Carrying out the requested tasks, the back end will give the information in a format that can be displayed in the front end. So -in the case of unmanned vessels, the vessels' sensors are the functions and the databases are the physical data storages onboard, whilst the vessel itself acts as the back end. Having the vessel crunch the data into more manageable chunks, the vessel can contact a remote operating center without the need for a continuous connection. The requirement for a lesser amount of bandwidth will save a pretty penny for the companies – as they are not required spend money on the remarkably expensive satellite bandwidth or to build and manage their own network of satellites. And for the context of this thesis, I will assume that the data needed from the ship is in a form that is needed for this system to be functional.

2.3 Level of Automation, Situational Awareness, and Alert Thresholds

To design a fleet level supervisory user interface, some baseline requirements need to be fixed. The level of automation (LOA) as defined by Parasuraman, Sheridan, and Wickens (2000), describes the level of automation in a ten-step scale, where 1 is considered as a system totally dependent of a human operator, and 10 being totally autonomous. levels two and three are defined so, that the system makes suggestions on possible actions in the situation and the operator then decides whether to accept the suggested action or provide the system with a different solution. A study [2] showed that there would seem to be a bias for trusting the suggestions made by the autonomous system in cases, where the autonomy cannot decide on what action to take. This would even be in cases, where the suggestion made by the autonomous system was erroneous. With this in mind, careful consideration needs to be taken when deciding on what level of automation to use in different levels of the system.

Situational awareness is described to be the perception of surroundings, events, and environmental elements in a correlation of time and location [5]. It also reaches beyond the present moment, as it holds the aspect of determining upcoming events within the perceived environment [5]. An unmanned vessel has it's sensors to provide them a level of situational awareness on the automation level. In this thesis, the most important aspect of situational awareness would seem to be whether a vessel is functioning normally or not. The aim is not to focus too deeply on the status of an individual vessel, but to provide the statuses of multiple vessels at once.

Alert thresholds are events that are triggered in the system once a certain parameter is determined by the shipboard systems to be unsafe or potentially hazardous. These parameters can be, for example, a vessel is tipping too steeply to one side, a vessel is experiencing technical faults, or a vessel is in close proximity to an object that it might collide with. Alerts, that can be safely handled by the automation should, to some extent, be handled by the automation. situations where the vessel might need sudden assignation to remote maintenance, should not be left to wait for a confirmation from an operator when the automation can perform it almost instantly.

Rather than having “a switch” that sets the automation level on a fixed value on the scale, the level of automation could be adaptive according to the situation (woods et al. 2004). If nothing out of the ordinary happens the LOA can stay very high. If a threshold to trigger an alarm is crossed, the LOA would adapt to the situation. In some severe cases, it would be turned off, because of the need for a remote-control intervention.

2.4 Unmanned Ships in general

Rolls Royce Marine unveiled its unmanned ship concept in the year 2015. Since the event, we have witnessed an almost explosive expansion of innovation and advancements within the industry. Unmanned ships will gradually be a reality but the actualization is still years away. Nonetheless, there have been significant breakthroughs in other similar fields, such as the automotive industry. Tesla is a car manufacturer that should not need any introductions today. Tesla’s cars were among the first to have a system that virtually drives itself, but due to legislation in many countries is still in a bit of a grey area when it comes to the actual use of the system. Other car manufacturers are now bringing their equivalent solutions to the market. Volvo, the Swedish car manufacturer well known for making safe cars, is launching a set of self-driving cars to the Swedish roads during the year 2017. In 2016 Volvo made a 1500-kilometer trip from Gothenburg to Rotterdam with a platooning truck convoy[1]. The first truck had a human driver whilst the ones following it, were operated by an automatic system. Whilst not a fully automated and autonomous operation, it is a very big step towards it. Similar steps are likely to be taken within the maritime industry on the road to fully automated autonomous freight ships.

[1] https://www.businesswire.com/news/home/20160318005231/en/Volvo-Trucks-European-Tour-Platooning

It seems highly likely, that these ships will always have a need for human input. To have a “Human in the loop” even as a verifier would keep the system safe and if executed properly, efficient. Prompting too much human input would pose possible functionality hindrances in performance. Placing humans to make decisions in crucial and important steps would leave the computational free to manage repetitive tasks, algorithms, and other things that would take a lot of time if a human was assigned to it.

The means to differentiate between the initial – the intermediate concepts are essential to the whole thesis. After the evaluation of the first concepts is undertaken, each of them will most likely have a set of good and bad features. From these features, a sort of a patchwork concept is taken to be developed as the final concept. The process will not be a random mash of features that are patched together after each of the first stage concepts are disassembled. Careful consideration must be taken into the arrangement so that each of the parts is compatible with the rest of the concept. Features will be reworked to fit within the context of the final concept.

3. Methods used in this thesis

This thesis’ research will be based largely on qualitative data gathered from professionals of different fields such as maritime navigation, engineering, aviation and harbor officials, and teachers in the maritime industry’s respective schools. I will be using the aviation navigation and flight control center operations as a parallel analog for the system's functionalities. The Remote operation and navigation will be conducted from a shore-based control center. The systems, infrastructure, and the ships are still in various degrees of conceptual development. The outcome of this thesis will add to the existing body of concepts and research data on a conceptual and hypothetical level. The aim is not to create a perfect or even a de facto complete model of strategic control of unmanned vessels, but rather to map out viable possibilities that might act as stepping stones or reference to further development efforts.

3.1. Data gathering

During this thesis, a good amount of data will be gathered. Most of it was done by conducting interviews to gather qualitative data. In the feedback phase, the focus will be shifted from interviews to a questionnaire – or better yet – an online prototype paired with a questionnaire. The data will then analyzed and processed into an easily pliable form – an affinity diagram. The following section goes through the specifics of the data acquisition phase.

3.1.1. Interviews

An interview is a conversation between (at least) two people, that digs into the subjective information of the interviewee. Interviews are a standard part of qualitative research that can be undertaken in three different ways: unstructured, semi-structured, and structured. In this thesis, I will mostly be using semi-structured interviews on multiple occasions. The first set of interviews will provide an understanding on a general level that acts as a basis for the intermediate concepts. At this stage, the factors which will differentiate the intermediate concepts are crystallized entirely.

3.1.2. Data analysis

The amount of data gathered during a project can pile up very high. When every tiny bit of information is somehow context relevant and in the end might end up making or breaking parts or even the whole concept that follows. Finding the most interesting and crucial information amongst the heaps of researched data is paramount to success. Building an understanding of the matter at hand needs more than just heaps of data. The data needs to be sorted and analyzed. Interviews provide a massive amount of text transcripts. This body of text needs to read through and coded. Once coded, the data will be easier to apply to an affinity diagram[2].

[2] https://project-management.com/affinity-diagram-kawakita-jiro-or-kj-method/

3.1.3. Questionnaires

Questionnaires are most likely to be used to gather massive amounts of quantitative data. In this thesis, an online questionnaire was used to gather feedback on a low fidelity interactive prototype, where the questionnaire was built as a branching part of the prototype itself.

3.1.4. Affinity Diagram

An affinity diagram is used to formulate a “big picture” of the problem space being solved. It is a cheap, relatively quick, and straightforward method to analyze qualitative data. Sticky notes (or the digital equivalent) are used to consolidate data. Each note has one information item written on it that is then placed on a large surface. The researcher(s) then shift the items around forming groups of notes that describe divisions or sub-groups of the bigger picture. These sub-groups are then named by the researchers according to the overall context of the sticky note cluster that creates it. Beyer & Holtzblatt (1993 & 1999) Bring this method forward as a tool for multiple researchers to consolidate data, but I argue that it works just as fine with a single researcher. As a group effort, the affinity diagram can be used to consolidate all of the researchers’ standing into a unified alignment. For a single researcher, this is not needed.

4. First interview

The first interview session was conducted in Kotka XAMK University of Applied Sciences with three maritime operation instructors. The first objective of the interview was to build an understanding of who plans the voyages and how. Additionally, topics such as unmanned vessels in general, their remote and autonomous operation were discussed. Other recurring topics were safety, crew duties, and the role of experience in navigating a vessel.

It was surprising to hear how easily a vessel, even a large one, can be steered. The operation itself will only require one person to operate. Other tasks will, of course, affect the steering of the vessel, but the actual commanding of the vessel systems that handle the steering can be done by one man alone. This would indicate, that a single remote operator could be responsible for a single vessel if the system provides the operator with enough information to base her actions on. In addition, vessels operating independently only need interacting within special cases, such as possibly dangerous situations, where the onboard systems either do not have instructions on how to operate in the situation, or the system needs confirmation from a human operator. Therefore, it's safe to assume that a single operator can, on a strategic level, maintain a safe operation over multiple vessels.

Being a University of Applied Sciences, they had very little happening in terms of education for the coming of unmanned vessels. The main function of the school is to educate and instruct students to be able to work in the industry and to provide skills needed to work with available applications. The unmanned vessel industry is very much in a concept planning phase, and currently has no large-scale applications within the industry, therefore the need to train people to use nonexistent systems is equally nonexistent.

5. UX Visions and UX goals

5.1. First concepts

Prior to the formulation of the first concepts, a group interview was conducted in the XAMK University of Applied Sciences with three maritime operation instructors. The initial focus was on route planning and the processes involved in it. Additionally, safety in remote operations and the autonomous operation were discussed together with events that take place in the open sea. Based on the gathered knowledge.

The process of making the first concept was initiated with a mentality “experience first”(Source here). To emphasize this side, four UX visions were formulated on the basis of fictive and existing working arrangements ranging from science fiction starships bridge operations to phone marketing companies. Each of the UX visions was named according to the underlying motivators, which were taken from the movie The Matrix, Star Trek, a telemarketing company, and a request based help desk service. The UX visions were broken down into smaller components, UX goals [6,7], which when experienced together make up an experience similar to that of the UX visions [6,7]. The differentiation between the concepts was according to a four-field chart (figure 1.), in which the two axels were named “individual – group” and “passive-active”. The first axis, individual – group, in itself, is quite self-explanatory. It defines if the action of navigating the unmanned vessels requires a group operation, or if it can be executed by a single operator. The second axel, passive – active, on the other hand, requires some further explanation. It defines the way in which the operation is conducted in relation to the unmanned vessels. On the active end of the axel, the operator(s) engage actively with the unmanned vessels, conducting routine checks, preventing possible problem situations, giving corrective orders, and generally upholding the operation on a strategic level. The passive end, on the other hand, relies more on the operators to complete contact requests sent by the unmanned vessels when they need additional decision making support in ambiguous situations that the algorithmic navigation does not know how to handle or it does not have the authority to decide on. In other words, this axel sets the nature of the operators' work and the way they engage with the unmanned vessels. On one end of the axel, the interaction between the operator and the vessel is initiated by the operator (active), and on the opposite end, the initiator in the action is the vessel itself.

These two axels create the four separate segments in which the initial concepts were situated. Each concept occupies a different space and is according to the segments definition. The UX visions are distributed so that the concept inspired by the movie The Matrix, is a passive – single operator concept. The second concept, inspired by the activities of the starship bridge crew in the movie series Star Trek, is in the active – group segment. Third concept inspired by telemarketing worker situated in the active – individual segment, and the fourth inspired by a request based help desk service assigned to the passive – group segment.

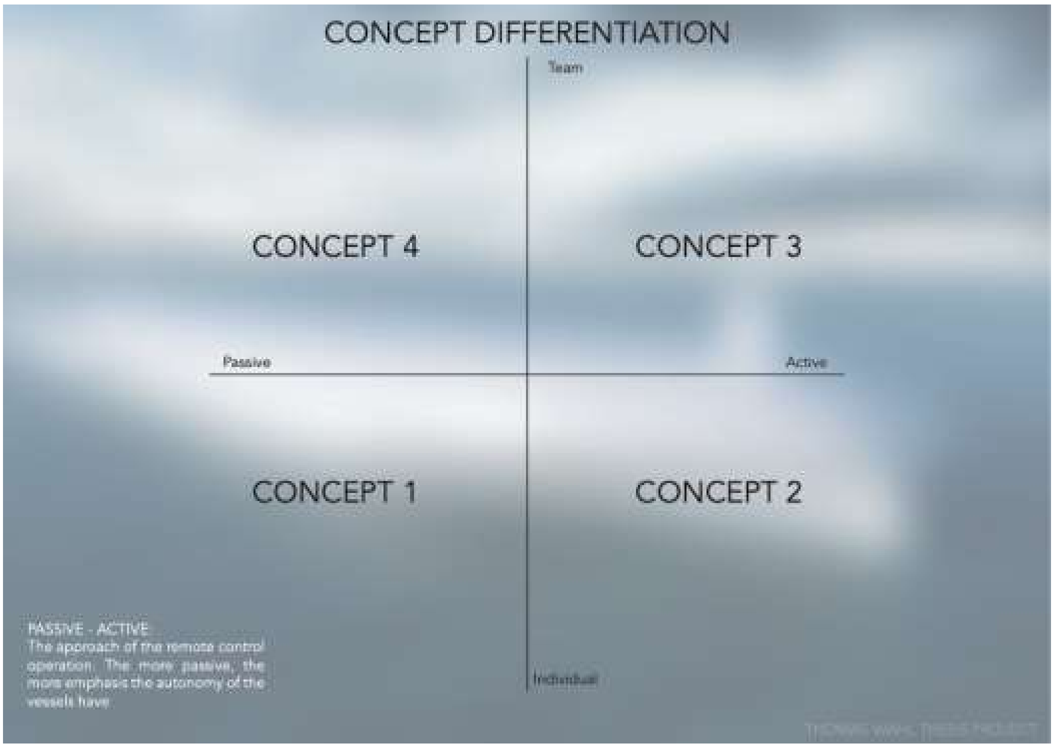

Figure 1. four-field of the ux-vision concepts

These four concepts acted as the basis on which further research would build upon to create a viable concept that could be implemented to the strategic navigation activities of unmanned vessels. The concepts were the basis of the forthcoming interviews with commercial flight control operators, unmanned technology experts, and Rolls-Royce employees working on the unmanned concept in various tasks. The aim of the interviews was to narrow down the options and verify the feasibility of the concepts or certain subparts of them. None of the concepts was considered to be a finished solution in itself to the question. Rather than verifying the feasibility of the concepts as complete solutions, parts of the concepts could be considered separately if needed. The concepts were low fidelity, and thusly it would have been very unlikely that any of them would fit the requirements by itself. They worked as an opener to the conversation, further concept defining, and concept development.

5.2. First concept UX visions

The UX-visions serve as a basis for designing the user interface “experience first”. Firstly the visions are described in detail and are broken into UX-goals. The UX goals

5.2.1. The Matrix, individual – passive

This UX-vision requires some further elaboration of the movie trilogy’s setting. In the focus, is the operator working to guide a group of operatives inside a hostile environment, when a threat comes from every direction?

The Matrix movie is set in the distant dystopian future, where artificial intelligence has enslaved the human race to serve its purposes as a source of power through body heat because the sky was scorched in a nuclear conflict between humans and the machines. To serve as a power supply for the machines, humans are being grown, and at a very early age, they are connected to a vast virtual reality environment called The Matrix. A small group of humans have been disconnected from the virtual reality, and broadcast themselves through pirate signals into the matrix. They operate from small hovercrafts within a network of tunnels while trying to avoid the machines that are trying to locate and eradicate them. Some of the humans are born naturally and don’t have the required input ports installed into their bodies that enable them to broadcast their consciousness to the matrix. These people can act as operators on the hovercrafts. They provide skills, knowledge, weapons, and vehicles remotely to the ones that are inside the matrix. The operators are the lifeline of the people who are trying to free the human race inside the matrix. The operator communicates with the humans inside the matrix via cell phones or regular phones. The operators can only extract the people in and out of the matrix through an old corded phone located around the virtual reality. So every time a human needs to exit the matrix, (s)he needs to contact the operator in order to execute the extraction.

The operators work in front of multiple displays showing the source code of the matrix following the events and acting as “eyes in the sky”. This setup, minus the dystopian desperation, is the UX vision connected to the individual – passive vessel operator. The operator in both setups monitor the situation and act according to requests from the ones that are executing the operation – in this thesis’ context, the unmanned vessel. The operator acts as an on-duty operative, that handles requests incoming from a number of ships that encounter situations that require a human in the loop. I won’t go through the possible situations in too much depth, but they can be for example a situation where the vessel is in a situation in which its automation does not have the information or permission to decide the best course of action.

UX goals

- Feeling of expertise
- Feeing of importance
- The feeling of being trusted

5.2.2. Star Trek, group – active

The movie series Star Trek follows the undertakings of an exploratory starship, The Enterprise” focused on the command crew. The group travels the final frontier encounter strange and mysterious events and beings. The layout of the starships bridge and the collaboration between the crew members in combat situations were key in selecting this exact setting as a UX goal for one of the concepts.

The bridge as an environment is essentially a big circle with the captain’s chair in the center of it. Right in front of the captain is a big screen, that can display anything from telemetry and video communication to visual feed from the ship’s outside cameras. The captain often requests something to be displayed on the screen. The crew operates in cubicle-like stations along the curving back wall of the bridge room. Each of the stations has a specific function assigned to them from weapons, propulsion, and communications to engineering and defenses.

The helm, where the ship is steered from is located directly in front of the captain, facing the same way as the captain.

The captain runs the show, giving orders to the other bridge crew members according to his best knowledge. This set up defines this concept. The captain is the responsible operator, who maintains a multitude of processes simultaneously on a higher level. The other operators are specialists that take care of their specified field of expertise as the situations evolve and unravel. In the unmanned vessel set up, the group actively monitors a number of ships, taking care of any and all situations that need interfering with the autonomous operation. They have the specialists to conduct remote maintenance in case there is a need for it.

UX goals

- Feeling of expertise
- Feeling of belonging
- The feeling of working as a team

5.2.3.Telemarketing worker, individual – active

Telemarketing workers are given a list of potential customers, to whom they call in an effort to sell products or services. The work is individual as the employee proceeds through the list given to her. She actively engages each situation in the same manner, in some cases repeating the same scripted set of phrases during each phone call. Whilst this is considered to be rather intrusive marketing to some (or most people), in the context of this thesis, there does not exist a possibility of angry or annoyed individuals, who perceive this intrusion as a violation of their privacy, as the customers are replaced by unmanned vessels.

The operator is given a list of vessels to actively engage within actions to keep the fleet of ships on schedule and operational. The operator works as a human in the loop, making pre-emptive decisions for the ship to guarantee a cost-efficient and safe voyage.

UX goals

- The feeling of being proactive
- Feeling of readiness
- Feeling of structure

5.2.4. Request-based help desk, passive – a group

Companies sometimes outsource their help/service desk operations to instances that are dedicated to providing those services with consistent quality and sufficient workforce. Anyone facing IT related issues in their work can easily access help desk services remotely through a ticket based system, or simply by calling the help desk service number. In the other end, a help desk worker receives a service request or a call and then proceeds to solve the abnormal situation. In case the situation needs a specialist to solve, the event can be handed over to a member of the help desk team that has a specific set of skills that will help in solving the situation.
The fourth concept was constructed around this principle. A team of operators working "passively", similar to the matrix concept, with requests that are being issued by the unmanned vessels. The team consists of basic operators, that handle the bulk requests, that are not too unordinary. When a request requires further actions, that the bulk operators cannot complete, or they don't have the authority to advance themselves, they will forward the request to an operator with the required clearance, authority or set of skills. The group work is similar to the setting of the Star Trek concept, but in this case, the physical setup does not need to be confined in a single space, where all the operators conduct their work. All of the operators could be situated in a more office-like setup, rather than a single circular control room.

UX-goals

- The feeling of being on call

- The feeling of being organized
- Feeling of predictability

6. Second Interview round

In the second interview session, the UX-visions were subjected to scrutiny. The goal was to determine if anyone or a combination of multiple UX-visions could act as the basis for the user interface concept. The second interview session

6.1. Interviewing aviation control instructors

The analog to unmanned vessel strategic navigation was acquired from the aviation industry. The flight control specialists handle similar situations, albeit the objects are moving with many folds faster and the decisions need to be made much faster. Their knowledge on the more hectic actions is valuable to this thesis, offering a glimpse into a world where similar things are in operation but with many times the speed. A flight from Helsinki to Tokyo takes an excess of ten hours, while a freight cargo shipment takes over a month to make the same trip. Of course, the route is much less straightforward in maritime traffic, the plane beats the vessel every time.

Dealing with safety-critical systems in this context often means that the used technology is often quite old in their basic functionalities, and very few innovations can be implemented at a rapid pace. All systems need to be confirmed as safe and reliable. In this sense, the technology and the practices are very well established. This makes their addition to the field of research essential, as the unmanned vessel traffic is not existing in any real commercial application. Finding good processes, practices, and principles in analogous fields can prove itself crucial.

The interview was conducted in Avia College, near the Helsinki-Vantaa airport, where the to-be flight control operators are being trained. Initially, the interview aimed to create an overall image of what flight control actually does. The topic of flight control, in general, was not discussed in too much detail, but rather to get the big picture clear. Both of the interviewees were instructors in the college, who have been working in air traffic control in Finland.

Air traffic control essentially works like the traffic lights for aerial traffic. Every plane flying in within a country's airspace needs to be under someone's responsibility. As the plane travels from one responsibility area to another, the responsibility of the plane transfers to the air traffic control of the corresponding area.

6.2. Interviewing technical experts

A third interview was conducted to illuminate the technical aspects of the unmanned and remote operated vessels. The people interviewed in this round were technical experts on the system level, who are involved in designing the implementation concept for the unmanned vessels. As a retrospective note, this interview might have been better to be conducted earlier in the thesis project, as it unveiled that some of the aspects from the initial starting point for this thesis had changed. The levels of interaction between the remote operating center and the vessel had been reduced from three to two. In the initial stage, the three existing levels of interaction were strategic, tactical, and melee, from which the tactical level was dropped from the list.

The interview clarified a lot of technical aspects that are essential for a feasible future implementation of the concept. These varied from data transferring to algorithmic reliability and vessels' physical structures to sensor capabilities. These are topics that are not taken into too much inspection, as this thesis is mainly a study into design aspects rather than technical details and system architecture. However, this information defined the vessels' functional behavior for the future. Since the amount of data gathered by the sensors onboard the vessel is quite substantial, there is no point in the consummation of vast amounts of bandwidth, when the vessel itself can crunch some serious numbers. The data can be automatically analyzed and condensed so that the remotely working person will have access to quality information determining the overall state of individual vessels and an entire fleet. The user interface needs to convey this information in a non-ambiguous way, which is also quickly identified.

A control center would have a fleet management unit, into which this thesis's outcome will be addressing. The fleet management keeps a piece of overall status information constantly updated, and deals transferring of vessels into remote operation stations and the remote maintenance department. The fleet management does not, (nor does the system devised in this thesis) perform any remote maneuvering actions, such as docking. Those actions are the responsibility of the remote-control stations, which are a whole different level of the system.

6.3. Interviewing Rolls-Royce staff

The fourth set of interviews was conducted in the Rolls-Royce office in Turku. The objectives for this round was to gain additional understanding about the strategic elements of the unmanned surface vessel operations, what manner of information could be crucial for remote operation centers to effectively and safely maintain a multitude of remotely operated vessels. All of the interviewed were people working for RR on their unmanned concept. One interesting aspect that surfaced in the fourth round of interviews, was all of the actions that are needed to be completed in the port. Such as the loading and offloading, permissions and documentation. The user interface needs to display according to a set of relevant information to the operators.

What information does the user need? This is a very critical question when designing for experiences. Having the user interface flooded with all sorts of data and sensor readings is easily overwhelming to the cognitive processes of us humans. Computers can handle it, because they are built to do just that, and that in turn can be used to lessen the load on the human brain. Let's say I'm trying to find out which of the many libraries in the Helsinki metropolitan area have a copy of the latest book by my favorite author. What I want and need to see is a list of libraries that have it and not a list of libraries that do not have it. Even including the ones without the book makes the search more cumbersome. Filtering out relevant information in all stages is important. Conveying situational awareness from multiple sources, and where a human error might mean very nasty events, lowering the cognitive load of the user needs to be given strong emphasis. This does not mean that everything that can be hidden should be hidden, nor does it imply that the valuable data and sensor readings are not important to the user and should be permanently behind the line of visibility. This could lead to situations, where the root cause of the anomalous situation cannot be identified because the information is deliberately withheld from the user interface by the mandate of simplification.

7. Design requirements

From the data gathered in the interviews, a set of design requirements was drawn up. Some of the listed requirements were given straight on a need basis, whilst others were deduced from the data using an affinity diagram.

7.1. Vessels status indication

The user interface needs to indicate the status of a vessel in a clear manner. The indication needs to be clear enough, for a vessel with an indicated situation is clearly detectable at a glance and without the need to engage in actions that require difficult cognitive work [woods]. In situations that might entail danger, the user interface needs to alert the operator in a clear and understandable manner.

7.2. Fleet level status indication

The user interface needs to communicate the status of every vessel in the fleet at once in a clear manner. Vessels that are functioning properly and are not in any deviant situation need to be represented in a clearly distinguished way so that they do not steal the focus of the operator(s).

7.3. Displaying of necessary information

The user interface needs to display necessary information about every vessel in the fleet. The information needs to be displayed in a way that can be quickly absorbed by human operators.

7.4. Displaying information without overwhelming the operator(s)

Necessary information needs to be communicated to the operator(s) without cluttering their short-term memory. The information architecture needs to be sorted according to the importance of the information in the context of the situation. In emergency situations, the required information is different from the optimal situation. Lesser priority information and detailed information should be available when needed.

7.5. Harbor interfacing

The user interface needs to take into account the vessels that are not currently on their voyage. Vessels that are in the dock ready for departure, or vessels that are ready to dock in the harbor need to be addressed in order to achieve a port-to-port solution. Activities in the harbor, i.e. loading, offloading, paperwork – such as permissions need to be included as mandatory objectives to be fulfilled before embarking or arrival.

7.6. Integration to remote-operating stations, and remote maintenance

The user interface needs to have functions that allow the operator(s) to assign a vessel to remote-operation or remote maintenance. This function needs to be easily accessible. The remote-operation assignment needs to be done in a way that leaves no gaps in the autonomous operation and remote operation. The vessels need to be under control at all times.

8. The first UI draft

The technical interview together with the RR personnel interviews made it apparent, that none of the initial experience concepts were applicable “as is”, but as a combination of some of their parts. Since the remote-control center concept has certain characteristics built into the mental image it portrays and is very similar to the star trek bridge crew concept in this thesis, that concept will work as a basis for the experience design of the further development stages. The star trek bridge crew concept made an assumption, that one crew would be responsible for an entire fleet with specified roles to fulfill. This isn’t straight wrong, but the scale and structure implied in the concept were misleading.

8.1. Interfacing with remote-control stations

The focus of this thesis is in the big picture of maritime navigation and fleet management of unmanned vessels. Whilst most of the time the vessels will be operating autonomously, there are many possible situations, in which human operated remote-controlling is needed. Therefore, the system needs an interface with a human operated remote-control station and vice versa. The two operational environments work independently from each other and transfer command of the vessel once the control is passed from one system to another.

Pilot captains that guide vessels to and from ports need the remote-control stations. Whether the station is in a centralized control center or if they are specific to each port, is still under consideration. Whichever of these two approaches is used, the solution will provide an opportunity for both options to be used. If the systems, fleet level, and remote control, are integrated into the same system, the port-specific pilot captain control stations might be more challenging to implement. A separate interface between the systems needs to be opened up, whereas the fundamental idea of integrating the system is to reduce the number of separate systems.

A question that is raised with the separate remote-control system, is how to ensure, that no unwanted intervention of the other system is possible. Yet, if there is a potential threat or a dangerous situation from the actions of the currently responsible system. This needs to be taken into account when the actual development of this sort of system structure is taking place.

The first UI draft was developed on top of the accumulated interview data. Perhaps the most significant aspect as takeout from the pool of data was the way in which the fleet situational awareness needs to be visualized. Operator(s) need constant up-to-date information on the fleet as a whole, and of the individual USV:s. Practically, the optimal result being a view, from which the operator(s) are able to tell which individual ships from the fleet might need closer monitoring or remote assistance, at a glance. In a case, where all of the USV:s are running optimally and are not experiencing any other difficulties, there is very little need for visual cues. So, by principle, only the individual vessels with the optimal situation are not to be emphasized. Anything deviating from the optimal situation should be communicated in a way that it immediately stands out visually and possibly even with sound.

Additional vessel specific information can be accessed on a separate layer so that the main state of the view will communicate the situation of all the vessels at once. The system needs to have tools to address warnings and deviant situations, such as assigning vessels to remote control stations, or remote maintenance operations. The first UI concept was developed to be tested with an expert evaluator group consisting of RR personnel –(and the individuals involved in the interviews). The tests were targeted to refine the given information to a state, that the most important information is the one that is the easiest available and the fastest to interpret. In parallel, the usability, and user experience undergo testing.

Other information should be available on the user interface based on their importance for the remote-control center. Other fairly relevant information includes vessel name, the port of origin, destination, voyage progress, velocity, weather, etc. Most of the information does not need to be visible in the main view of the user interface and therefore it can be hidden under a separate layer such as an expander or a modal window. Any and all warnings and error messages from vessels need to be communicated in a way, that if the arrangement of the elements on the screen exceeds the bottom of the monitor, it is possible to access it quickly. This can be achieved in multiple ways. Working solutions might be, that any and all vessels with warnings and errors get sent to the top of the vessel lists in each column.

Most of the interviewees on the final interview, that was conducted with RR personnel, regarded a map view as the main view to be a bit cumbersome and difficult extract vital information from. When a control center has multiple vessels deployed, and they are on route to different locations on the globe, getting a coherent overview of the fleet becomes an issue on a map view. This does not mean that the map and location information are irrelevant. It merely receives a lower priority on the information structure. The Location information could be accessible under an expander as an embedded item or opened up as a modal window. Since a control center is equipped with multiple displays, it’s reasonable to assume, that the designing of the interface would not be restricted to one screen. Having a big enough screen with an acceptable resolution could mean that the main view could be divided into a global map view and a fleet status view, that serves as the main view in this concept.

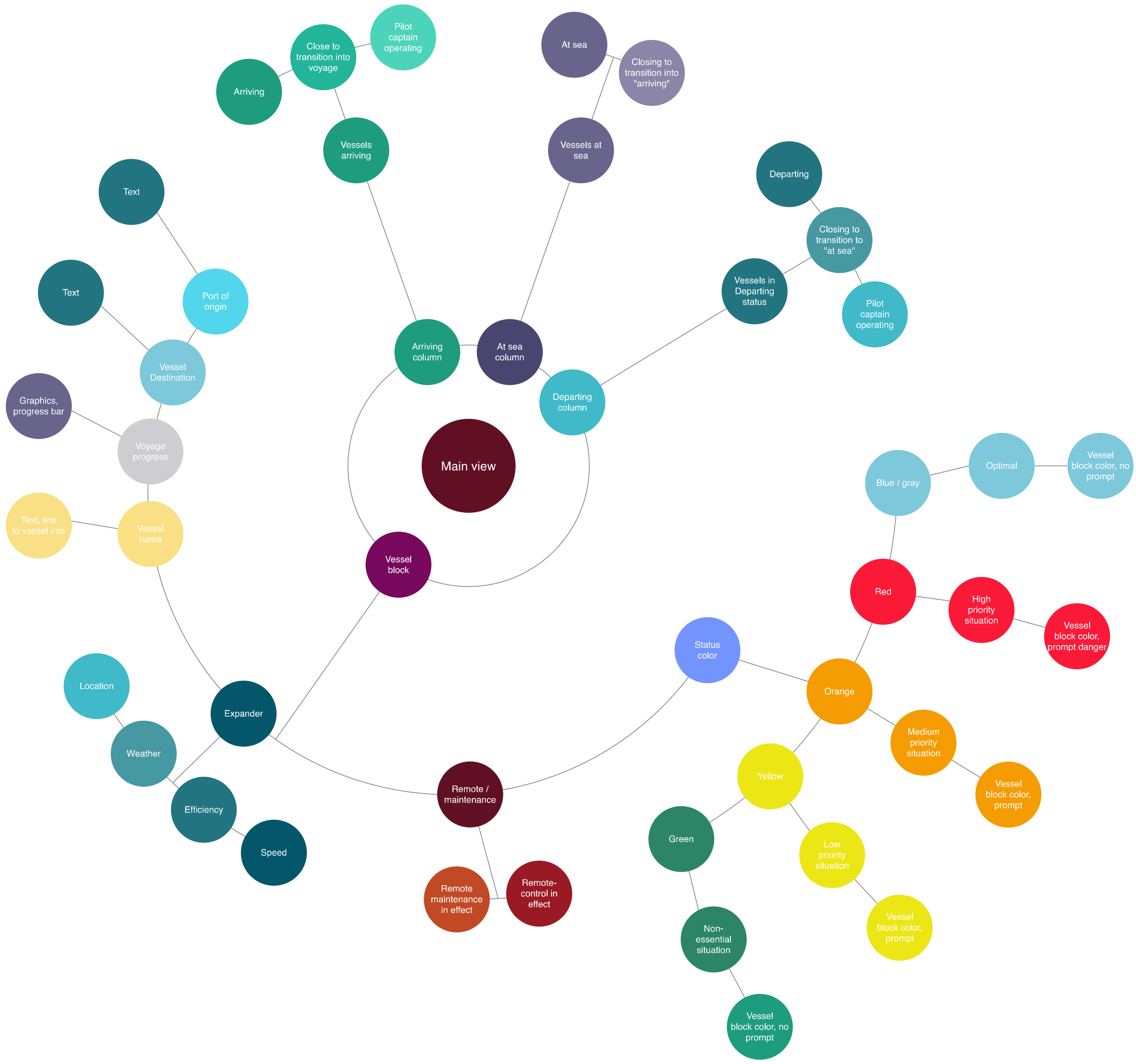

Figure 2. Main view structure mind-map

9. Main view

Because the main view should display multiple vessels at once, some level of separation of vessels is needed. An initial intuition was that all the vessels are divided into three columns as interactive elements, that serve a function of a vessels' voyage timeline from port to port. This is perhaps the most important feature of the user interface on the general level. The columns would be named "At port", "Departing", "At sea", "Approaching" and "Arrived". The "Departing" column would include vessels that are still in the port loading cargo, waiting for permission to leave, in addition to vessels that are still on local waters. At sea, column lists all the vessels that are on open seas, on international waters, and the “Arriving” column holds all the vessels which are approaching a port or are docked and still unloading their cargo.

9.1. Vessel box

The most recurring element in the main view is the vessel element or the vessel box. The element is basically a rectangular block, with a base color that corresponds to the vessels’ status. The block element is expandable and inside the expanded view, the operator can find detailed information about the vessel in question. Rather than taking an approach that would display all the vessels in a selected order in a list, and convey a selected set of information on the first level of the user interface, the decision was made to approach the problem with an expandable element that is placed on the first level of the user interface according to its status on the port-to-port scale. The main view acts as a timeline, where the start line, port of origin, is on the left and the vessel boxes gradually progress from column to column towards the finish line on the right, the destination port. This gives the operator(s) a quick and rough estimation on what sort of situations might be expected with each individual vessel. The unexpanded view shows the vessel name, status in color, a progress bar, and the ports, between which the vessel operates currently. These elements are all derived from the interview data, and given preliminary priority in the last interview session with RR personnel. The color range on the base color goes from a neutral grey or blue in an optimal situation towards the red end of the spectrum in deviate situations. The more in the red end of the spectrum the color is, the more severe a situation is.

Figure 3. Vessel boxes with vessels in various statuses

If the vessel is undergoing a remote operation or remote maintenance, the vessel box will visually convey the information to the operator. In the case of remote operation being in use, the fleet level will maintain observational privileges for the vessel, whilst the actual maneuvering is done from a remote-operation station either in the same control center, or as in the case of a pilot captain services, from the destination port control station if such a setup is implemented.

9.2. Colors

The colors in the main view play a significant part in the main view. They portray the most significant information to the operator(s) in an "at a glance" manner. Using color to differentiate vessels with different statuses serves the purpose very well. As Cooper (2007 p.292) stated, *"Differences in hue draw our attention quickly"*. For the sake of this thesis, I have chosen the scale of visible light wavelength to be the scale of the severity of the situation of an individual USV. This being the case, there is a possibility of misleading information being conveyed on a cultural medium. In the western countries, the meaning of the color red is widely unambiguous – it portrays a warning, an error, a flaw, or even danger. On the other hand, the color red is used to communicate passion and affection. Outside of this cultural context, the meanings may vary dramatically. However, this system will be in expert use, and it will require extensive training from the operator(s) to be allowed to actually operate a fleet of USV:s. Through this training, the meaning of the colors used in the user interface will be thought to everyone who aspires to become an operator. This does not leave the option for customization closed, but for the sake of universal consistency, the scale should remain as stated.

The background color of the main view was originally set to be black. Since the system needs to be operated around the clock, even in multiple shifts, staring at a bright screen will be stressful. Or so common sense would seem to indicate. However, a study [1] has indicated, that a significant amount of people perform better in reading a dark text from a light background than light text on a dark background. In the concept, the user interface communicates a large amount of data via colors, and not in long sections of text. The colors on the dark background seem to be more noticeable that against a light or white background. The benefits and tradeoffs of these visual presentation methods need to be with the operators, once a system is actually being developed.

9.3. Functions

The user interface will incorporate actions that the operator(s) can execute. These actions are mostly utilized in cases, where the automation cannot make decisions or it does not have the permission to do so. in addition, the operator(s) will need to access vessel data and information.

9.3.1. Redirection and assigning

The redirecting and assigning is the main link from the fleet level to remote-control stations and remote maintenance services. Once a vessel is in a situation that needs attention from the human-operated remote operation center (needs remote-control, remote maintenance) the fleet level assigns the vessel to the station that suitable for the situation. Once the task is complete, the vessel is returned to the fleet level from the station level. The main view will show which ones are under remote-control or remote maintenance. In order to achieve this, I constructed a clickable prototype structured that was intentionally made to resemble a tutorial section of a game or an onboarding wizard from a smartphone application.

Platooning?

Platooning in the context of this thesis means the navigation of multiple vessels according to one lead vessel. The following vessels match their maneuvering according to the lead vessel. Lorry manufacturers, such as Volvo have made successful tests on unmanned lorries across roads in Europe and the united states of America. In the tests, a convoy of unmanned lorries successfully navigated among normal traffic.

For the case of the first concept, the platooning aspect was dropped. Platooning would however be an important aspect of USV traffic on the seas. Reducing Co2 emissions and lowering the costs of transportation. In a fully autonomous environment, the platooning aspect could be integrated within the structures that supervise the areas of operation near the shore. Smaller convoys could determine via vessel-to-vessel communication whether to engage in a platoon or not, based on their destinations and shared routes.

10. Testing the first concept

To test the concepts with the participants of the interviews and a group of experts on maritime navigation needed to be planned in a way that would provide necessary data within a reasonable window of time. To achieve this, Inspiration was taken from video game tutorials and smartphone application onboardings.

Modern videogame tutorials tend to make the user go through the basic controls, functions, and possibilities of the game in a closed environment where the stakes of the real game are not yet in play. Thus the user can get acquainted with the basic controls and rules of the video game. Similarly, modern smartphone applications have an onboarding wizard in the beginning that the user needs to go through before the use of the actual app can commence.

So, how does this help the situation at hand? I constructed a low fidelity clickable prototype that was intentionally made to resemble a tutorial section of a game or an onboarding wizard from a smartphone application. An online prototyping tool, named inVision can be used to create simple user interfaces with somewhat limited functionality. To achieve a complete clickable prototype, every screen and state change of the screen needs to be drawn separately and then linked to corresponding display states via hotspots. The hotspots are the functional layer of the prototype, that is linked to other hotspots, making navigation between the screens possible.

Since the tool used doesn't have any means to give direct feedback from the test users, an online survey needed to be linked into key positions within the flow of the test prototype. These key positions needed to be easily noticeable so that the user will not bypass the feedback giving part. This notion gave a basic structure to the prototype. The test user is given four tasks to complete within the prototype. Every task is followed by a link to the corresponding feedback form. Before the test user proceeds to the next task, he will need to answer a series of questions about the task that was just completed.

The link and the password to the test were sent to a set of expert evaluators, consisting of maritime navigation lecturers, aviation control college teachers, Rolls-Royce personnel, and unmanned vessel technical experts.

10.1. The first task

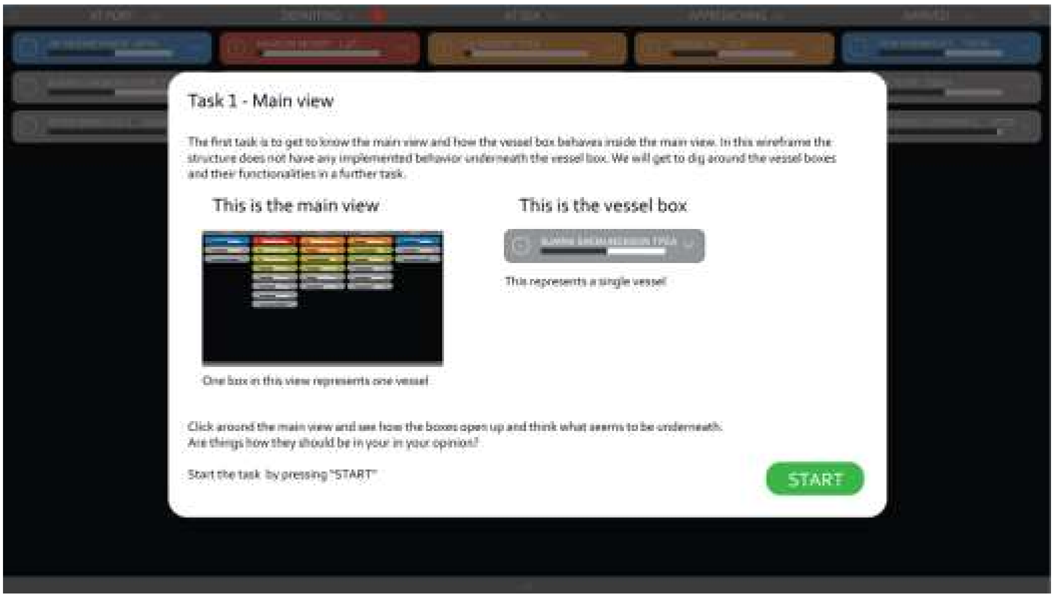

Figure 4. First task briefing in online prototyping platform InVision

The first task in the test was for the user to get acquainted with the main view, and what it would look like when the system would be operational. In this state, multiple vessels would be tracked at the same time. The main view would hold vessels in every column (at a port, departing, at sea, approaching, arrived). The user is instructed to click around the vessel boxes to expand them, and to learn that the expanded vessel box has additional information on the vessel. An info text on the prototype prompts the user to click on the text box to continue to the question part of the task. The user has completed the first task when he presses this button.

10.2. Task 2

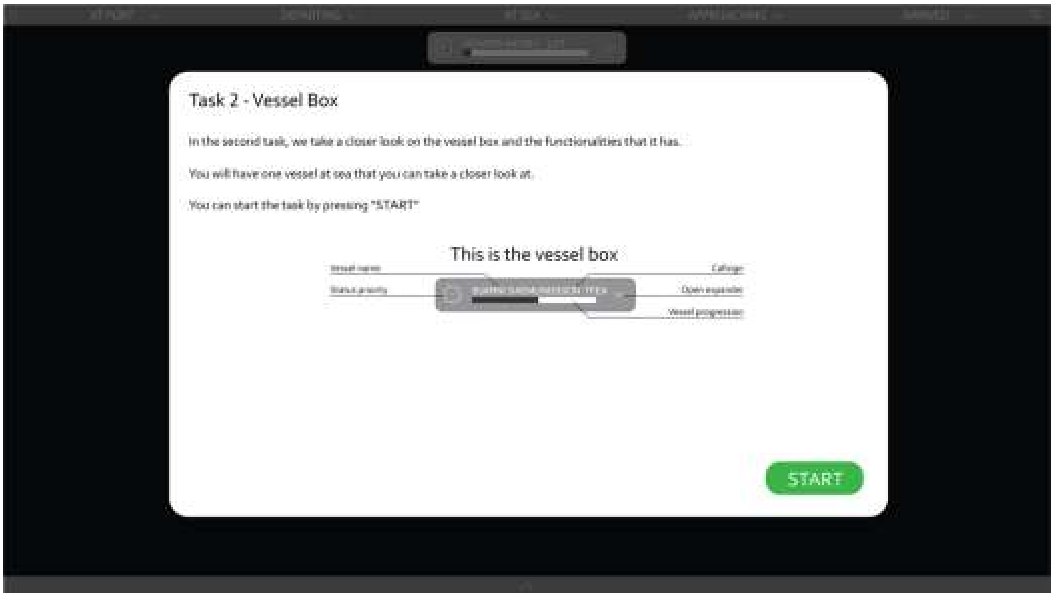

Figure 5. Second task introduction

In the second task, the test user is required to take a closer look at the vessel box. The main view has only one unmanned vessel on it, to give focus on the element itself, the information it holds, and the functionalities that are on the subsequent layers. Controls to change the priority rating (also indicated by the color of the box) of the vessel. The color of the vessel box communicates the overall situation of the vessel to the controller – the priority rating. The more the color is in the red end of the spectrum, the more severe a situation it is in and the more immediate attention it needs, red being priority 1. Once the user reaches the details under the expanded vessel box, an info-box is shown as the means to proceed to questions and the next task.

10.3. Task 3

Remote assigning is one of the key functions in the system, although the actual tasks that the vessels are assigned to are being operated by a separate part of the system, which is not a part of this thesis. The view has two unmanned vessels on the main view. Both vessels are now indicated as red, or priority 1, to the test user. At this point, the user will presumably have accumulated enough information from the previous two tasks to know how to dig deeper into the matter. The situation of the first vessel is described to be a collision warning. A situational depiction is given under the details of the vessel box. The second vessel is described to be experiencing anomalous vibrations and sounds from the engine room. The vessel box gives the user two choices – remote operation or remote maintenance.

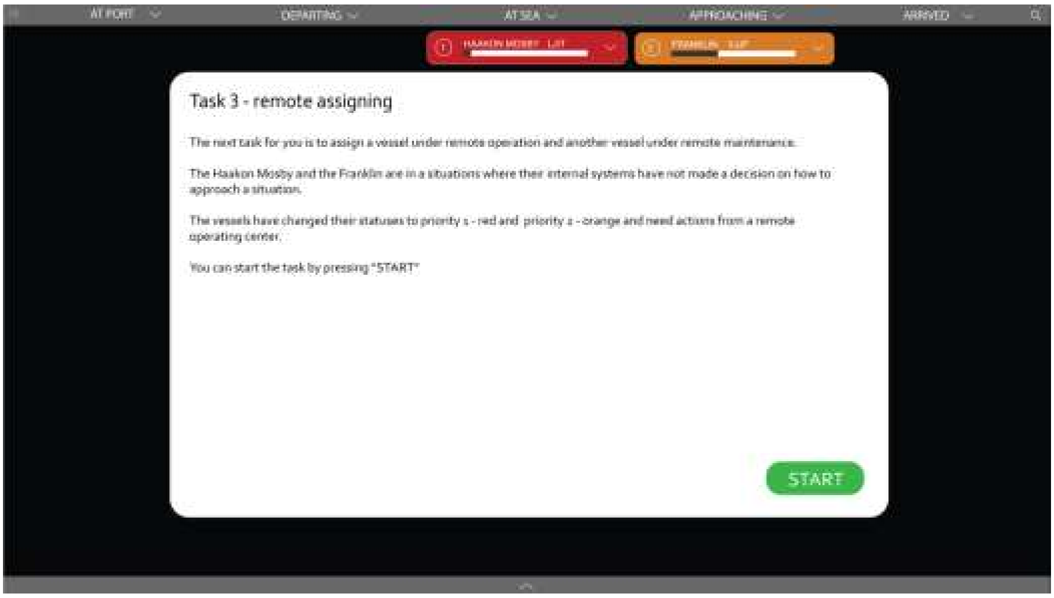

Figure 6. Third task introduction

The vessel with the collision warning is to be assigned under remote-operation, whilst the vessel with the anomalous vibrations and sounds is to be assigned under remote maintenance. Once both objectives of the task are completed, the test user is prompted to continue on to the questions and the final task.

10.4. Task 4

Departure and arrival within the first concept are defined as actions that need to be confirmed by the system operator(s). In this task, the view is once again occupied by two unmanned vessels. One about to depart on its voyage, whilst the other is in the closing meters of its voyage. In other words, The first vessel needs to be given the verification that it needs to leave the port, and the second needs verification to begin docking. The test user is again needed to navigate deeper into the vessel box to verify, that all of the required attributes are met in order to allow the two vessels to execute the required tasks.

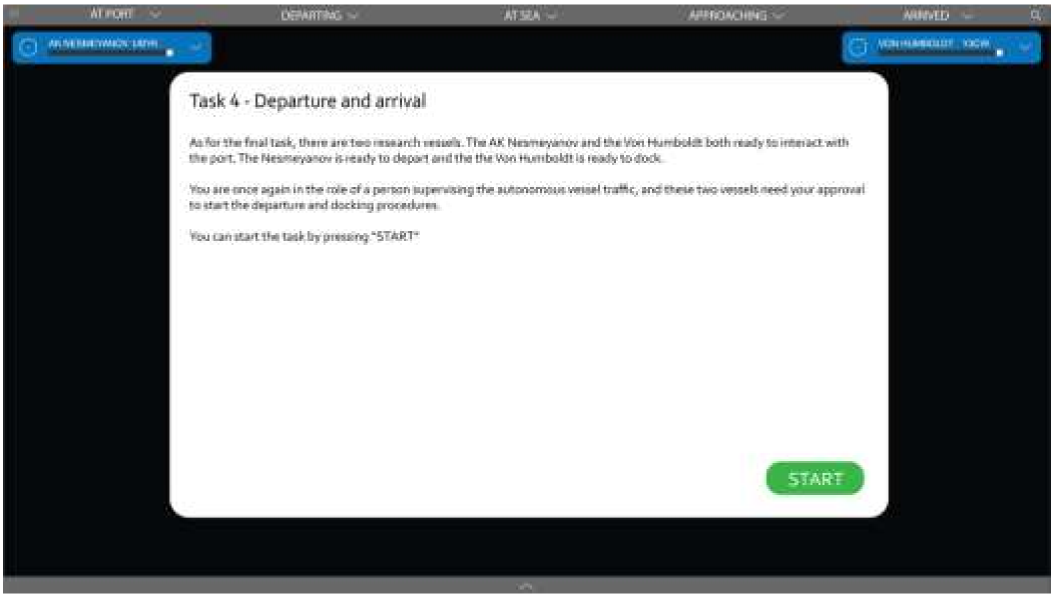

Figure 7. Final task introduction

Once the user has sent the first vessel on its voyage, and the second one has docked, the task is completed and the user is prompted to answer a final set of questions.

The objective of the test was to determine if the selected visual approach gives enough information and available options for the operator(s) to monitor a fleet of USV:s. The vessel box, representing a single USV is a key component in the concept, and its behavior in the main screen is another factor that needed to be confirmed, in order to verify the selected approach to be viable.

10.5 Feedback on the first concept

The gathering of feedback from the first concept did not unravel as suspected. Some of the recipients of the test package seemed to have moved behind very secure email systems, in result of which none of the sent requests ever reached them. Due to this, the contact request ended up returning rather harsh automated messages, saying that all of the sent material was blocked from the

recipients. No reason was given, and every subsequent attempt of contact faced by the same response.
Despite the setback, the questionnaire still received a satisfactory amount of replies from system specialists and Rolls-Royce personnel.

11. The second concept

The test conducted on the first concept gave some interesting results. The test users would have wanted more information about the vessel on a higher layer of the user interface. Information such as: what type of vessel this is, the size of the vessel, vessel radio call sign, and IMO number. Adding more information to the vessel box, which was the main element of the first concept, can be done. The vessel box needs to be revised for the second concept.

11.1. Revised design requirements

From the feedback gathered from the test of the first concept, the design requirements needed to be revised. The largest addition compared to the first concept is the map view.

11.1.1. Vessels status indication

The user interface needs to indicate the status of a vessel in a clear manner, using three easily recognizable colors – for optimal, sub-optimal, and warning situations. Having a reasonable amount of used colors will reduce the visual clutter of the user interface, as stated by Cooper (2007). The indication needs to be clear enough, for a vessel with an indicated situation is clearly detectable at a glance. In situations that might entail danger, the user interface needs to alert the operator in a clear and understandable manner.

11.1.2. Map view

The user interface needs to portray the map of the area of operation. The vessels in the fleet need to be positioned on the map according to the vessels' actual position.

11.1.3. Fleet level status indication

The user interface needs to communicate the status of several vessels at once in a clear manner. Vessels that are functioning properly and are not in any deviant situation need to be represented in a passive enough way so that they do not steal the focus of the operator(s).

11.1.4. Displaying of necessary information

The user interface needs to display necessary information about every vessel in the fleet. identical information on every vessel needs to be displayed in every vessel box to keep consistency. The necessary information at this stage remains an educated guess, and it needs to be determined in further developments where more information is available through possible pilot projects for example.

11.1.5. Displaying information without overwhelming the operator(s)

Necessary information needs to be communicated to the operator(s) without cluttering their short-term memory. The information architecture needs to be sorted according to the importance of the information in the context of the situation. In emergency situations, the required information is different from the optimal situation. Lesser priority information and detailed information should be available when needed.

11.1.6. Harbor interfacing

The user interface needs to take into account the vessels that are not currently on their voyage. Vessels that are in the dock ready for departure, or vessels that are ready to dock in the harbor need to be addressed in order to achieve a port-to-port solution. Activities in the harbor, i.e. loading, offloading, paperwork – such as permissions need to be included as mandatory objectives to be fulfilled before embarking or arrival.

11.1.7. Integration to remote-operating stations, and remote maintenance

The user interface needs to have functions that allow the operator(s) to assign a vessel to remote-operation or remote maintenance. This function needs to be easily accessible. The remote-operation assignment needs to be done in a way that leaves no gaps in the autonomous operation and remote operation. The vessels need to be under control at all times.
In cases where the automation can clearly identify that a vessel is in need of remote-operation or maintenance, the automation should do so, but inform the operators of the incident.

12. A map view

A map view was suggested in the feedback from the first concept testing. This would give the operator an approximate position of the vessel in the area of operation. Since the use of the supervisory system might vary a lot in the size of the area of operation. The area might be a simple cable ferry operating between two fixed points, an inland sea with very little commercial traffic, a certain collection of close-by harbors, a whole continent, or even global. The need for a map view is well justified on the smaller end of the scale, where the operating vessels are in relatively close proximity at any given time. It would, however, need some additional defining to justifiably fit into global operations, where vessels are scattered across vast distances.

12.1. The map in general

The map view needs to primarily indicate the position of a vessel along with an identifier that allows the operator to recognize the individual vessel. Additionally, it needs to display other maritime traffic, at the very least, in the vicinity of the operator's vessels. In the event that the vessels are in such close proximity, and the map is zoomed in a far-away position, the vessel indicators could be merged into one and the indicator is given a quantity indicator or a list of vessel names under the indicator together with the vessel class – which gives a rough estimate of the size of the vessel.

12.2. What the map should be like?

The map should, first of all, display the area of operation, where the focus is on the masses of water and not on the land. Different sorts of overlays can be implemented to display additional information on for example weather, wind, and wave conditions. These overlays could be toggled on or off to reduce the visual cluttering of the map itself and to bring better focus on the vessels when needed. The vessels, being the main interest of the operator(s), should be on the top, i.e. clearly visible at all times.

12.3. Vessels on the map

The position of the vessels needs to be indicated on the maps. This can be achieved with a pointing icon, similar to "point-of-interest" or pin markers in map applications on the web, such as google maps. The route of the vessel can be indicated with a line, with directional indicators, to give the operator(s) the direction of movement. The "minute stick", that the air traffic monitoring systems use, can be utilized to indicate for example the stopping distance, or maximum area of emergency- or evasive maneuvers the vessel can make with its current speed and heading in any given position on its voyage. This would need to be configurable or scalable as the zoom level of the map might render a minute stick almost invisible due to the scale. I would argue that rather than having a minute stick, an hour stick would be a lot more sensible. The minute stick is crucial in flight control systems because of the immense speed that the planes are traveling. The unmanned vessels travel a lot slower.

13. Evaluating success

When it comes to evaluating the success of the concept the focus is turned towards the revised design requirements. If the concept meets the set criteria, the concept can be considered to be successful.

13.1. Vessels status indication

The vessel status indication was based on the design of the first concept. The vessel box. The color scheme and range were simplified to the second iteration because the color green was not widely connected to any issues that needed addressing. Giving only two possible levels of deviating situations made the color indication a lot more clear. Minor and major alerts were still communicated through colors in the red end of the visible light spectrum – commonly associated with alerts and danger in the western countries. The colors could be customizable to cultural context to avoid any confusion of their conveyed meaning.
The detailed information view of the vessel box gives a short description of the vessels' current activity along with a revised set of information.

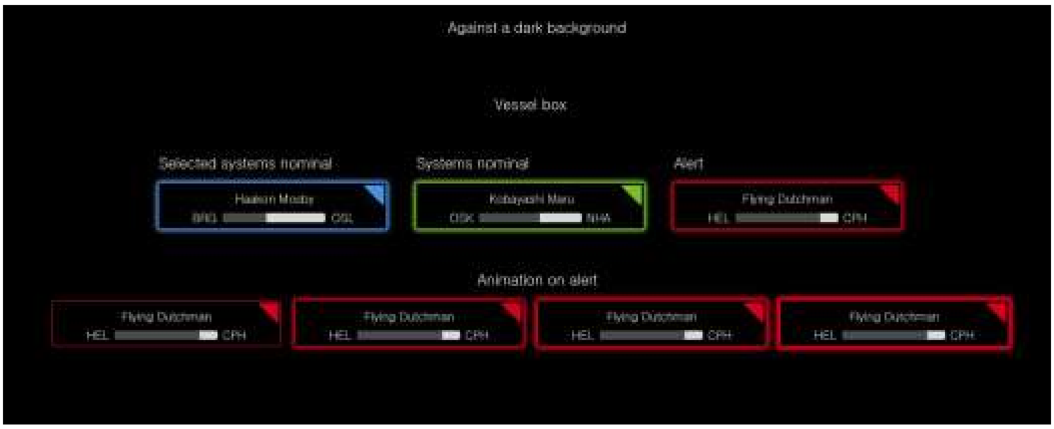

Figure 8. Variable states of the design of the vessel box for the second concept iteration

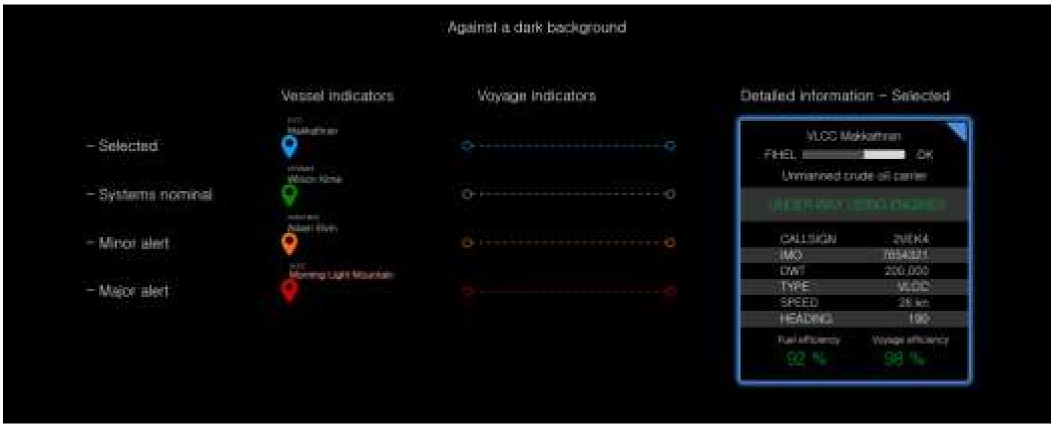

Figure 9. Map elements and their corresponding meanings

13.2. Map view

The map view was by far the largest addition to the concept in the second iteration. Including it was based on the feedback gathered in the evaluation of the first concept. Given that a shipping company or a cruise line company usually operates on a relatively fixed area, the map view got more justification. For example, if the Estonian-Finnish cruise line Tallink was to use the system, their vessels operate in a relatively limited area, and can all be tracked successfully on a projected map view.

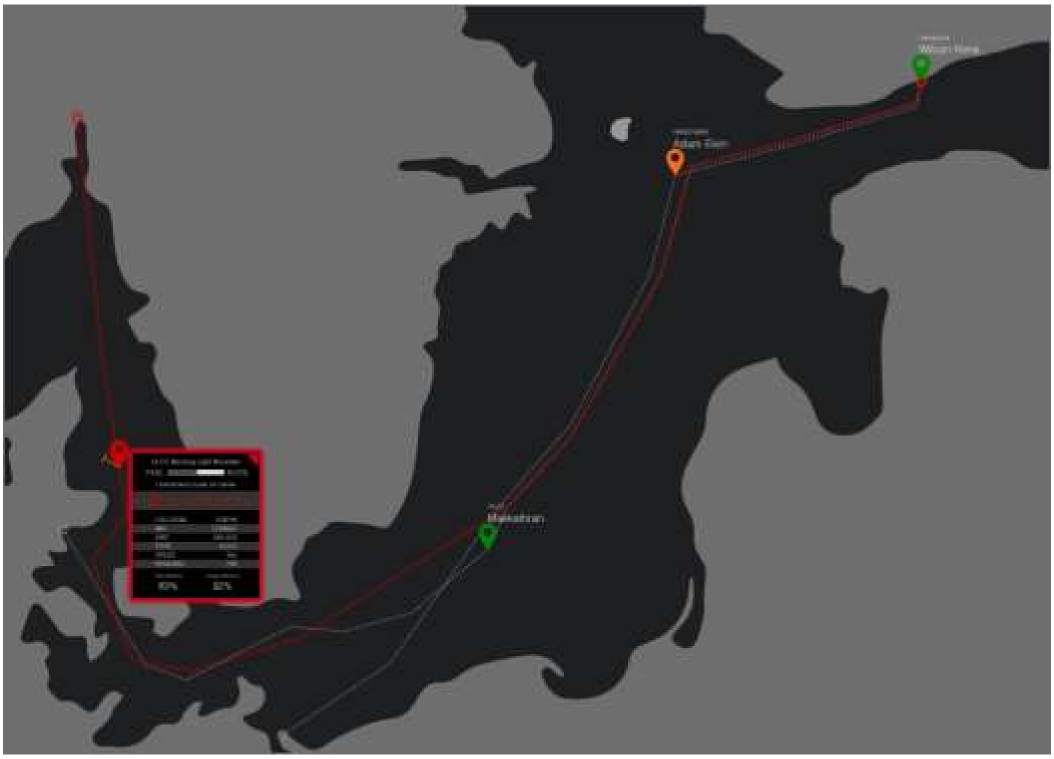

Figure 10. The map view of the second concept iteration

13.3.Fleet level status indication

The fleet view – called the main view in the first concept remains with an unchanged baseline idea. The view gathers all the vessels – their vessel boxes in a single view according to their situation. The fleet level view gives the operators the opportunity to monitor the whole fleet at a glance. This would indicate that the requirement has been met.

Figure 11. Fleet- and map-views side-by-side

13.4. Displaying of necessary information

The necessary information displayed in the vessel box of the first concept was lacking certain items. The revisited set of the required information was derived from the set of the first concept and the feedback that was received in the evaluation.

The “hour-stick” was included in the map view to give additional insight and as a rough depiction of the vessels’ progression in the near future. With the given information, it can be said that the requirement is met.

13.5. Displaying information without overwhelming the operator(s)

In the second concept, the amount of information is increased when it is compared together with the first concept. This could mean that the second concept is heavier on the operators' cognition. Since the second concept did not go through a similar evaluation cycle as the first concept the answer to this criteria is not going to be definitive. The interface concept is designed to be cognitively light – seemingly vital information (not a definitive, since the research made into the required information is not in the focus in this thesis), is displayed in an easily understandable fashion. The information is divided into three levels. The map view provides the operator(s) with an approximate position on the map with an indicator and an overall situational status by color. The fleet list view provides the statuses of all the vessels in the fleet, including their current voyage progression on the four-column progression.

13.6. Harbor interfacing

Harbor interfacing in the second concept is done differently than in the first concept. The vessels that are currently in docked in a port are kept in a reserved column, whilst in the first concept, the vessels that have reached the end of their voyage would have had to be reset to the first column somehow. The "at port" column shows the number of vessels that are currently under procedures before departure or after arrival. This enables the operators to keep track of available assets in terms of vessels. The embarkation process requires less effort from the operators and provides the needed information. It is unclear whether the solution proposed in this thesis will be sufficient to establish the harbor interfacing, or if more complex solutions are required with additional controls and steps. Nevertheless, the function has been illustrated in the user interface concept and can be replaced or added to.

Figure 12. Harbor interfacing controls

13.7. Integration to remote-operating stations, and remote maintenance

The user interface and the system it is displaying should handle the assigning of vessels into separate remote-operating and remote-maintenance systems. The operator(s) are able to assign the vessels to these systems via the vessel box. In alert cases where the automation does not know what to do, it prompts the operator to make the decision.

Figure 13. Alert notifications and remote-operation controls

15. Conclusions

The inclusion of the map view was something that should have been thought to begin with. A somewhat wrongful assumption was made, based on the interviews, that a map view would not be necessary. However, this was later proven to be false with the evaluation questionnaire.

The UX-visions and their corresponding UX-goals proved to be somewhat hard to relate by the industry professionals. This might be because of the peculiar nature of the devised UX-visions in this thesis. The results might have yielded a better result if the UX-visions would have been less fictional and less in the field of fantasy.

The evaluation of the first concept did not receive a desired amount of responses. The inability to reach the flight control teacher interviewed in the data acquisition phase was a very unfortunate and unforeseen aspect. Nevertheless, the questionnaire managed to gather a reasonable amount of feedback, from which the second concept could be built.

The most important takeout seems to be the communication of the fleet status and in a sense – the fleets' situational awareness. Conveying the individual statuses of each of the vessels in the fleet in a quickly absorbable fashion proved to be one of the major challenges. This thesis provided a suggested approach to the problem and it might serve an MVP solution. However, this does not suggest that the approach is to be the new textbook example. The current advances in user interface design would indicate that there will be better, more efficient ways to portray the same set of controls and information.

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