Thomas Colin Guo Kaland

The Digital Fire Central

Design of a firefighting resource management center for critical situations aboard RoRo-ships.

Master's thesis in MTDESIG
Supervisor: Thomas Porathe
June 2020

Master's thesis

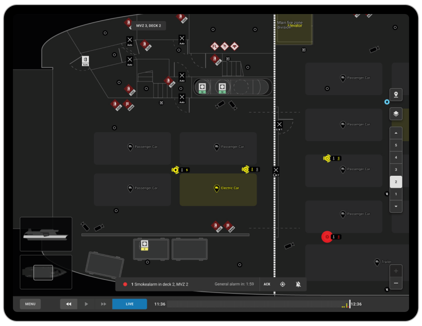
NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

NTNU
Kunnskap for en bedre verden

Thomas Colin Guo Kaland

The Digital Fire Central

Design of a firefighting resource management center for critical situations aboard RoRo-ships.



Master's thesis in MTDESIG
Supervisor: Thomas Porathe
June 2020

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

NTNU
Norwegian University of
Science and Technology

NTNU
Fakultet for arkitektur og design
Institutt for design

Masteroppgave for Thomas Colin Guo Kaland

Design av et brannslukking-ressurssenter for bruk i kritiske situasjoner ombord roroskip.

Design of a firefighting resource management center for critical situations on RoRo-ships.

Currently, fire situations and firefighting onboard RoRo-ships are handled using archaic support systems and methods. Some examples are the use of several paper maps, miniature figurines and large alarm panels to detect, assess, plan and act on a fire situation. All of these physical support systems and methods could probably be combined into a central digital management center and benefit from this digitalization.

The task for this thesis is to investigate and design a firefighting resource management center (FRMC) for RoRo-Ships that helps in accelerating time sensitive tasks and provide a more comprehensive and effective decision support. The FRMC should also be designed for ease of use and reduced human error under critical operations (e.g. in case of fire).

The overarching tasks are:

- Research how firefighting is done onboard RoRoships today and the need for a FRMC
- Design and test prototypes of a FRMC with a focus on UX
- Evaluate the FRMC compared to traditional methods

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

Ansvarlig faglærer (hovedveileder IPD): Johannes Sigurjonsson
Faglig veileder: Thomas Porathe

Utleveringsdato: 09.01.2020
Innleveringsfrist: 04.06.2020

Trondheim, NTNU, 08.01.2020

Thomas Porathe
Faglig veileder

Ole Andreas Alsos
Instituttleder

Abstract

In recent years, there has been a significant number of fires aboard ro-ro-ships, i.e. a type of vehicle ferry. The consequences of these fires could have been reduced had there been a better fire management system aboard.

This thesis explores how fire is detected and firefighting is planned and executed, with a focus on upper command and situational awareness. The exploration shows that a more unified system, a system that combines information from relevant firefighting equipment and systems aboard and presents it to the user, is needed aboard ships. The research also shows that a portable fire management system might streamline firefighting planning by making information available to crews not situated on the bridge.

Further, different prototypes of a portable fire management system are tested. The tests unveil several improvement potentials with the prototypes, but they also show a very positive attitude towards the concept from ship crew.

In the end, several recommendations and thoughts on what such a unified firefighting system should contain is presented.

Sammendrag

I de siste årene har det vært flere brannhendelser ombord ro-ro-skip, en type bilferge. Konsekvensene av disse brannene kunne ha vært redusert dersom skipene hadde hatt et bedre system for håndtering av brann.

Denne oppgaven utforsker hvordan brann er detektert ombord skip, og hvordan brannbekjempning er planlagt og utført med et fokus på øvre ledelse og situasjonsforståelse. Ut fra utforskningen finner man at et mer samlet system, et system som kombinerer informasjon fra andre relevante brannbekjempnings utstyr og systemer ombord, trengs ombord skip. Utforskningen tyder og på at et bærbart informasjonssystem kan effektivisere brannbekjempning og planlegging ved å spre informasjon til mannskap som ikke befinner seg på broen.

Videre er flere prototyper av et slikt bærbart system testet. Testene viser flere mangler og forbedringspotensialer ved prototypene, men de viser også en veldig positiv holdning til konseptet fra skipsmannskap.

Til slutt er flere tanker og anbefalinger delt rundt hva et samlet brannbekjempnings-informasjonssystem burde inneholde.

Takk til Thomas Porathe for
super veiledning igjennom et litt
annerledes semester, og takk til
alt av hyggelig skipsmannskap
og rederier som har vist meg
rundt på skip og delt sine tanker
og meninger rundt prosjektet.

En ekstra takk går til Mari
som har vært evig tålmodig
og støttende, til tross for min
maniske Post-it-tapetsering av
leiligheten.

Contents

1 Introduction

On the 15th of September 2011, the first engineer and an apprentice engineer aboard MS Nordlys was working on changing an oil separator. They were in the workshop, adjacent to the main engine room, to adapt a pipe for the new oil separator. Suddenly, the apprentice engineer notices thick black smoke and flames emerging from one of the main engines. The first engineer and apprentice escape the workshop through the main engine room. The room was filled with black smoke and the first engineer tripped and fell over. He quickly got up again and escaped the main engine room. He does not remember seeing how the apprentice escaped.

At 09:13, a fire alarm on the bridge sounds and the system shows fire and smoke development in the main engine room. In addition, the system shows smoke rising to the decks above. To extinguish the fire, a water-based sprinkler system in the main engine room was remotely activated. The extinguishing system did not start. The system had accidentally been set to manual mode in the engine room, making it impossible to remotely activate. Eventually, both main engines stopped working and the lights went out. Shortly after, the emergency generator started, keeping vital equipment and systems aboard powered. The electrician aboard was concerned about the emergency generator as there had been some problems with the air vents feeding the generator with fresh air. He tries to make his way up to the emergency generator room, but due to heavy smoke, the emergency generator was inaccessible. After a little time, the emergency generator stops working and the ship is now in full blackout.

The preceding narration is a rendition of the events described in the report on the fire aboard MS Nordlys (fig. 1.1) during its approach to Ålesund (Accident Investigation Board Norway, 2013). The apprentice engineer was found lifeless a few decks above the main engine room.

Figure 1.1
Photo: (Brano Beliancin/Nytt i uka, 2011)

Photo of MS Nordlys during the 2011 fire incident.
.

1.1 LASHFIRE

In recent years, there has been a significant number of fires in ro-ro ships. A few examples are the Norman Atlantica incident in 2014 (Ministry of Infrastructure and Transport, 2018) where a fire in the car deck resulted in several deaths and complete destruction of the ship, an incident aboard Pearl of Scandinavia in 2011 where an electric car ignited and set fire to surrounding cargo (Danish Maritime Authority, 2011) and an engine fire in MS Nordlys in 2011 that resulted in two crew deaths (Accident Investigation Board Norway, 2013). Many of these fires, and their following damages, is a result of malfunctioning or poor equipment, systems that didn't respond as anticipated and ill-defined routines. The fires might not have been prevented altogether had there been better systems and routines in place, but the damages and consequences of the fires could have been greatly reduced. This is the goal of LASH FIRE.

LASH FIRE is a EU research project (RISE, 2020) whose goal is to research, develop and test new systems and routines that makes fire protection and extinguishing more effective aboard Ro-Ro ships. Hopefully, with the new systems and routines the project produces, incidents like the ones mentioned above will not happen again, or at least have less severe consequences. The LASH FIRE project looks into and investigates six sides of fire protection; effective manual operations, inherently safe design, ignition prevention, detection, extinguishment, and containment. In this thesis, I will explore the ”inherently safe design” aspect of the LASH FIRE project in context of how fire alarms are detected and dealt with. More accurately, I will look into the research and development of a “firefighting resource management center”, or FRMC, with a focus on HMI design. The goal of the FRMC is to make fire detection and response easier and quicker while also reducing human error.

1.2 Ro-ro ships

Broadly speaking, ro-ro ships are a type of ship used to transport vehicles such as cars and trucks. The term “ro-ro” stands for “roll on, roll off” and originates from how the cargo is loaded aboard the ship, i.e. the cargo is rolled/driven on and off the ship via a ramp from the ship to the quay. This way of loading and unloading cargo has made ro-ro ships one of the most successful type of ship operating today. According to the IMO, the global regulating authority when it comes to safety, security and environmental performance of international shipping industry, the success of ro-ro ships is mostly due to its flexibility and ability to integrate with other transport systems while maintaining a high speed of operation (IMO 2020).

Figure 1.2
Photo: Stena line (Stena line)

Stena Estrid is an example of a ro-ro-pax, or ro-pax , ferry on the Dublin - Holyhead route.

1.3 What about other ships?

As this thesis is in collaboration with the LASH FIRE project and builds upon one of the research-tasks that they have defined, the thesis focuses mostly on ro-ro ships and the design and development of a FRMC for that specific ship type. However, a fire doesn’t distinguish between ship types, and a fire aboard a ro-ro ship is pretty similar to a fire aboard a passenger ferry or any other large ship. The systems needed to effectively deal with a fire situation aboard any type of ship is also very similar. Because of this, the findings in this thesis will be applicable to any other ship type with little or no modification. There is, however, a few more considerations to take into account when it comes to the car/trailer space of a ro-ro ship.

1.4 Initial project brief

When I was first introduced to the LASH FIRE project and the task of designing a new firefighting resource management center, I was shown two pictures from a ship my supervisor visited. These pictures show some of the equipment the crew aboard this specific ship use to both detect fire and plan and execute fire extinguishing.

In the first picture (fig. 1.3) two system panels can be seen. The leftmost panel is the fire alarm panel. This panel lights up if a fire detector is triggered. The panel consists of a plaque with a ship-map and several small LEDS positioned on the map. These LEDs show the location of all the fire detector "loops" in the boat. A loop is essentially a group of fire detectors that is connected together. Normally these loops will be naturally defined by the rooms or sections of the boat, so one loop might include all the detectors in the stern car deck. If one of the detectors in a loop gets triggered, the entire loop shows up as activated/triggered on the fire panel. This is indicated in the form of a blinking or lit LED. The rightmost panel is a fire door and fan control panel. Through this panel, the crew can close fire doors and start/stop ventilation fans.

The two other pictures (fig.1.4 and 1.5) shows a special table that is used to plan and execute fire extinguishing. The table consists of a large laminated map of the ship with information about fire extinguishing equipment and systems aboard. In addition to the map, several small labels are used to "place" fireteams and mark where there is a fire (fig. 1.5). During a fire situation, the bridge crew will use this table to keep track of where the fire is, what extinguishing systems are available in the area of fire and where the fire extinguishing crew are situated.

As you can see, the systems aboard the ship is quite primitive and manual and the systems does, at first eyeglance, seem to have a lot of improvement potential. Even so, I must admit that I find the planning table very elegant in its simplicity. However, because the planning table is separate from the fire panel and fire door panel, there are many possibilities for human error. For example, one could mark the wrong placement of fire in the planning table and thereby sending the fireteams to the wrong room, or one could start the wrong extinguishing system simply because of an error in translating the position of the fire to the right sprinkler zone. This last example actually happened in the Norman Atlantica accident in 2014. In the investigation of the accident, it was found that the water extinguishing system was activated on the wrong deck (Ministry of Infrastructure and Transport, 2018). In another accident, at MS Pearl of Scandinavia, the fire detector system/panel simply didn't function because of the massive amount of alarms triggered by a burning electric car, thus making the crew blind as to whether their fire extinguishing efforts were working (Danish Maritime Authority, 2011)

The pictures (fig. 1.3–1.5) created the foundation for my thesis and posed the question; can the fire panel systems be improved by creating a unified digital panel that combines the alarm panel with the planning table? This unified panel would reduce human error by putting all the needed information into close proximity. In addition, the panel could have several digital helping functions that could help the crew in making quick decisions in stressful situations. This digital panel could become the firefighting resource management panel, or FRMC, that LASHFIRE is working on.

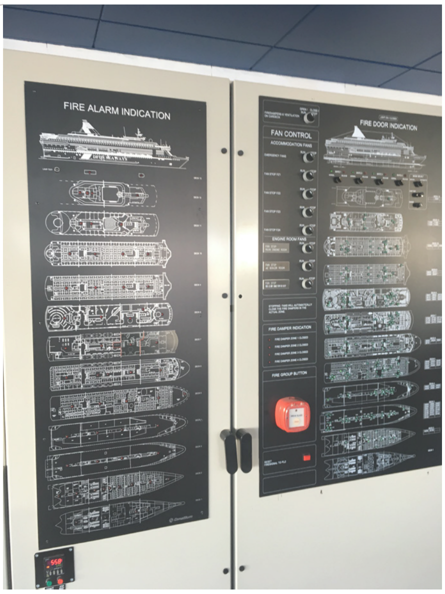


Figure 1.3
Photo: Thomas Porathe

Left: Fire detector panel
Right: Fire door and ventilation control panel

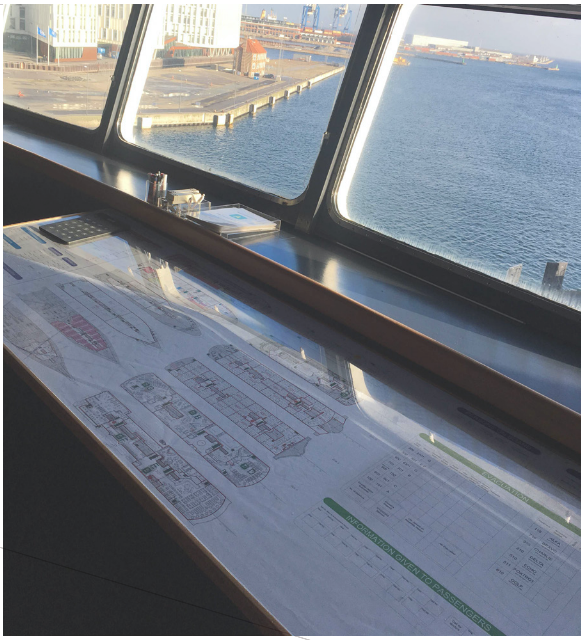


Figure 1.4
Photo: Thomas Porathe

Fire and evacuation control table. It is used as a whiteboard to note down information about fire response and evacuation.

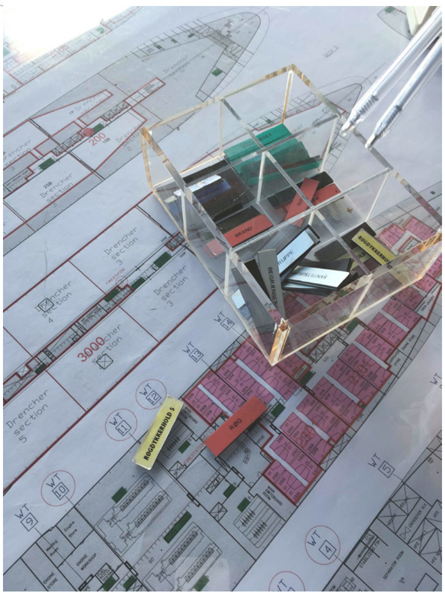


Figure 1.5
Photo: Thomas Porathe

Markers used to quickly note down location of crew and fire.

2 Insight

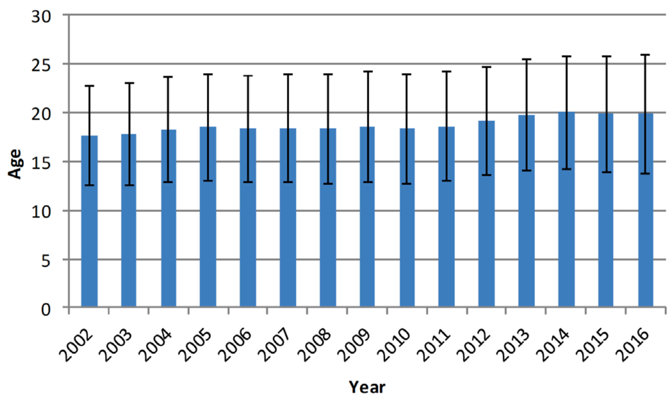
2.1 Ship visits

To get a better understanding of the situation aboard ships today and the problems the crew are faced with during a fire situation, five ship visits were made. Two of the ship visits were arranged by LASH FIRE and our shipping company contacts, and the remaining three visits were arranged by me. The ships were operated by three different major Scandinavian ferry companies.

Since this thesis revolves around developing a new fire detection system panel, it makes sense to visit new and modern ships. By visiting these state-of-the-art ships, one would get an accurate image of what the problems with the modern fire panels are and what kind of extinguishing systems new ships use. It is, however, important to remember that ships are expensive to build and have a long lifespan. The average age of ro-ro-pax vessels was found to be 20 years in 2016 (fig. 2.1) in a report done by Bureau Veritas, RISE and Stena (Bureau Veritas, RISE & Stena, 2018). In the same report, the life expectancy of ships in 2002-2016 was estimated to be 39.2 years. Since most ships are around 20 years old, and the life expectancy of ships are so high, it became important for me to design a system that not only would make fire detection and extinguishing easier in new built ships, but also give an added value to existing ships as a retrofitted system. This system would then not only improve fire safety aboard new and state-of-the-art ships, but also on older ships through retrofitting.

Figure 2.1
Graph: Firesafe II (2018)

Average age of ship by year.



The notion of designing something that would come to benefit existing ships meant that I could not only visit state-of-the-art ships, but also ships that represented the average age of already existing ships. In total, I visited five ships. Four of these were average ships; meaning they were built around the year 2000 and have had one or more refurbishments over the years, and one of the ships were a state-of-the-art ship that was launched this year. Ideally, I would have wanted to visit more modern ships, but modern ships are a rare find and I had to settle for just the one in the short timespan I had for this thesis.

Following is a short description of the ship visits I made. The ships will not be referred to by name because of anonymity of interviewed crew members. Instead, I will use aliases that reflect their type of vessel so that referring to a specific ship becomes easier. Instead of presenting the separate insights from each ship visit, I will present the insight as a whole in the next chapter.

2.1.1 MS Large RoPax

MS Large RoPax was the first ship I visited, and it was board this ship my supervisor took the pictures in fig. 1.2-1.4. The ship is a somewhat large ro-ro-pax ferry with 12 decks. It was built in 1988 but was thoroughly refurbished in 2005. The visit was arranged by LASH FIRE and several persons from the LASH FIRE project attended.

During our visit we got to observe a fire drill. The scenario for the drill was a fire on the car deck. During the fire drill, I was situated on the bridge and observed how the bridge crew used the fire planning table (fig. 2.2) to plan and execute fire extinguishing and evacuation and keep track of where the crew was and how the extinguishing and evacuation progressed. The fire drill focused only on the execution of fire extinguishing and evacuation, and they did not rehearse the moments leading up to the extinguishing, i.e. fire alarm, check whether there is actually a fire and muster the teams. During the fire drill we did, however, talk to the captain and got a walkthrough of the fire equipment panels on the bridge and how they are used when a fire is detected and during fire extinguishing.

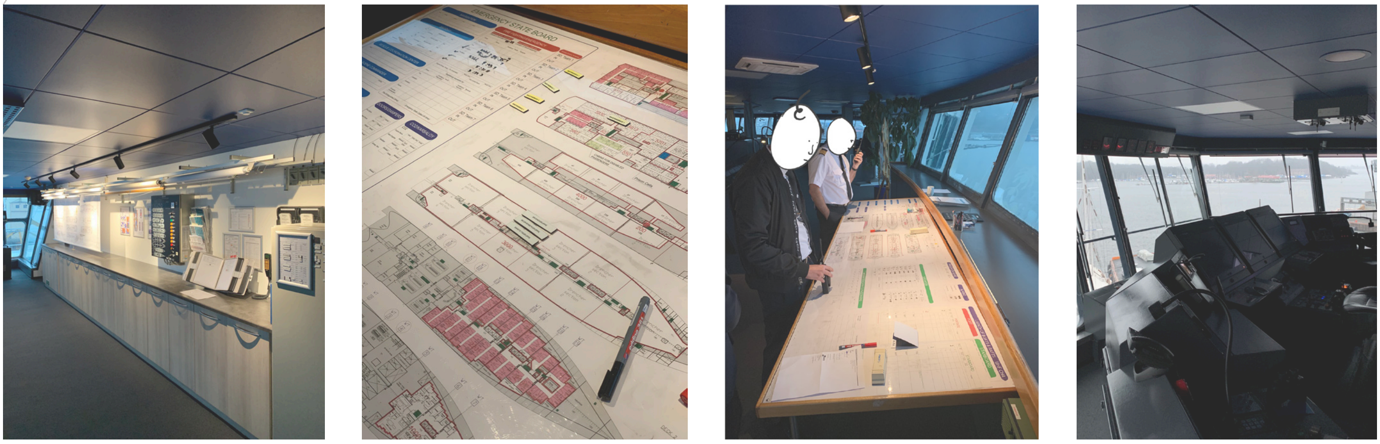


Figure 2.2

Images from the bridge of *MS Large RoPax* during a fire drill. Faces are covered for anonymity.

After the fire drill, I also got the change to attend an interview of the chief mechanic and security officer aboard. The interviews were planned by the other LASH FIRE team members, so I was mostly just listening in on the interview. Nevertheless, the interviews unearthed a few interesting things that I will come back to later.

The notes from the visit can be found in appendix A

2.1.2 MS Medium Ferry

MS Medium Ferry is by definition a ro-ro-pax ferry, but the car deck is very small and not much used since most of the passengers do not bring a car. The ship was built in 1993 but was refurbished ca 20 years later after a fire incident aboard. Because of this, many of the system panels aboard was retrofitted as a part of the refurbishment.

During the ship visit I got to interview the ship's security officer about fire routines and what happens in the event of a fire. In addition, the security officer walked me through the fire equipment and panels on the bridge. The ship was on a route, so I did not have a very long stay aboard the ship.

The notes from the visit can be found in appendix B

Figure 2.3

MS Medium Ferry's bridge. Faces are covered for anonymity

2.1.3 MS Sister

MS Sister is *MS Medium Ferry*'s sister ship. This means that the ships are almost identical when it comes to hull design and the major features of the ship. This ship, however, never suffered from a fire incident and has not gone through a refurbishment as its sister ship has.

The visit started on the bridge where I interviewed one of the crew members about their fire routines and the equipment they have aboard. Most of the info from the interview was identical to that from the interview aboard *MS Medium Ferry*. After the interview, I was given a tour of the ship to see the ship's fire stations (closets for fire equipment) (fig. 2.4), safety room (a dedicated room where you can shut down the engines, close watertight doors and more) (fig. 2.5) and the engine control room (fig. 2.6).

The notes from the visit can be found in appendix C

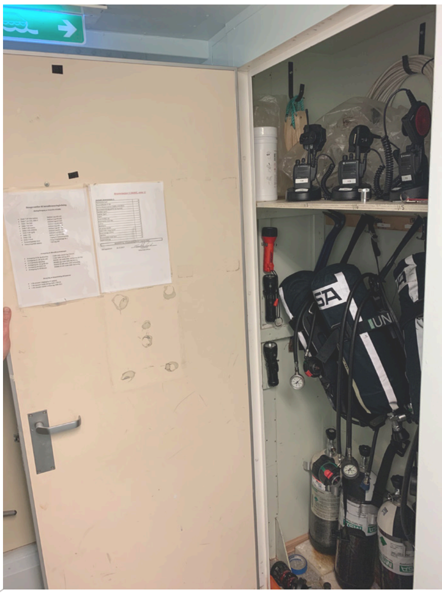


Figure 2.4

A fire station aboard *MS Sister* with smoke diving equipment

Figure 2.5

MS Sister's safety room. Here you can shut down the engines, close watertight doors and control other systems relevant for firefighting.

Figure 2.6

The engine control room aboard *MS Sister*. Not a single ray of daylight in here.

2.1.4 MS Newbuilt Explorer

MS Newbuild Explorer is a brand-new ship launched this year. The ship is purely a passenger ship and does not have a car deck. Even so, the ship is very relevant for this thesis as it contains state of the art fire detection and extinguishing systems and gives a good picture of the state of modern extinguishing systems and the potential for improvements.

The visit started at the bridge with an interview of the security officer and a walkthrough of the fire equipment on the bridge. At this point in time, the design concept for this thesis was already semi formed, so after the interview a few loose thoughts around the concept and what the officer would want in a better system were discussed. After the bridge, the tour continued towards the safety room and the engine control room.

The notes from the visit can be found in appendix D

Figure 2.7
MS Newbuilt Explorer's bridge. Very fancy indeed
.

Figure 2.8
The safety room on *MS Newbuilt Explorer*. Essentially the same as on *MS Sister*, but much more modern.

Figure 2.9
The engine control room aboard MS Newbuilt Explorer. Similar to the control room onboard *MS Sister*, but with more touch screens.
.

2.1.5 MS Generic

My last ship visit was arranged by LASH FIRE and one of our ship-company-contacts. This was a longer visit where I got the opportunity to sail with the ship on a 24h roundtrip. The ship, *MS Generic* is a ro-ro-pax ship that has been classified by LASH FIRE as a generic ship design. This means that *MS Generic* is a ship that represents the majority and average of the ro-ro-pax ships that LASH FIRE looks at. *MS Generic* was built in 2008 and has had equipment retrofitted since then. Because of this retrofitting, the ships fire extinguishing systems bears much similarity to a patchwork, with some type of extinguishing system in one room, and a different type of system in another room.

During my visit, I got to observe the loading and unloading of cargo (fig. 2.11) and follow one of the crew members while he did a fire round (fig. 2.12). The fire round is done once every 30 mins by a crew member and it is basically a round tour of the ship to check for fires. In addition to this, we got a guided tour of many of the fire extinguishing systems and equipment on the ship, interviewed the crew about routines and what happens in the event of a fire and I talked to the bridge crew about what they wanted in a unified fire detection system in a co-design interview.

The notes from the visit can be found in appendix E

Figure 2.10
The bridge at *MS Generic*. It is quite spacious

.

Figure 2.11
Watching the unloading of *MS Generic*. We are easily entertained.

.

Figure 2.12
Walking a fire round through the cargo deck. The trailers are pretty tightly packed.

.

2.2 Insights from visits and literature

In this section I will present the joint insight from my ship visits and read literature and explain in a little more detail how the fire systems and routines aboard ships function. Much of the technical details of how the fire equipment aboard ships work are from the book Ship Knowledge (van Dokkum, 2016).

2.2.1 Fixed vs portable systems

Figure 2.13
Photo: Forbrukerrådet (2019)

A portable CO2 fire extinguisher

Generally speaking, there are two types of fire extinguishing equipment aboard ships; fixed and portable equipment. The portable equipment is much like the fire extinguishing equipment one would find in residential homes (fig 2.13). These portable fire extinguishers are spread across the entire ship and allows crew and passengers to extinguish small fires by manually spraying the fire with a suppressant. This suppressant can be foam, powder or CO2. In addition to the small handheld extinguishers, ships often have bigger wheeled fire extinguishers. These extinguishers functions exactly the same way as handheld ones, except they have a bigger capacity. Exactly what kind of handheld extinguishers ships have aboard varies greatly. On *MS Generic*, a mixture of CO2, powder and foam equipment were used. The different types of equipment were placed where it was most needed, for instance CO2 apparatuses were placed on the car decks and in the galley, while powder apparatuses were placed in the passenger areas (appendix E).

Fixed fire extinguishing equipment are permanently installed systems aboard the ship and usually consists of several nozzles hanging from the roof on each deck. These nozzles can then be activated and sprays the entire room with a suppressant. There are several types of fixed extinguishing systems and the major difference between them are what type of suppressant they spray and the nozzle they use. The most typical ones are sprinklers, drenchers, water mist systems, Co2 systems and other inert gas systems.

SPRINKLER

Figure 2.14
Photo: Vanguard (2019)

Water sprinkler head with a red sealing pill.

Maybe the most commonly known fixed fire extinguishing equipment is the sprinkler system. If you are familiar with sprinkler systems in buildings, the sprinkler systems on ships works and looks the same (fig. 2.14). A sprinkler system consists of pipes running along a ceiling with several nozzles attached at regular intervals. The pipes are pressurized with water and the nozzles are sealed with a special pill that ruptures if the surroundings reach a preestablished temperature (Purpura, 2019). When the seal ruptures, water flows out of the nozzle and is diverted by a rosette into an umbrella shaped water spray. At the same time, the pressure drop in the pipes causes a pressostat to activate a fire pump. The fire pump provides the sprinkler system with constant water flow. This pressostat also triggers the fire alarm.

Since the sprinkler systems have a sealing pill on each nozzle, it is not possible to activate the sprinkler system manually or remotely without physically removing or damaging the sealing pill. It is, however, possible to see which sections of the sprinkler systems have been activated and stopping the flow of water to entire sprinkler sections on demand.

Sprinkler systems are often used in passenger areas and other areas where the temperature is expected to be stable at normal use and where there is little machinery or other flammable materials.

DRENCHER

A drencher is a type of sprinkler system that, contrary to ordinary sprinklers, do not have water filled in their pipes when the system is idle. Instead, the drencher system is manually activated by a crew member by turning on a dedicated water pump and opening valves to feed water to the right drencher section. When a drencher section is turned on, all the nozzles in that section releases an umbrella shaped water spray (fig. 2.15). Drencher systems have a much higher capacity than normal sprinklers and moves a lot of water. Because of this high volume of water, the areas protected by drencher systems needs to have draining holes in the floor. These holes are called "deck scuppers" and need to be open so as not to cause ship instability due to water sloshing around. Drenchers are normally only used in car decks (also known as ro-ro-spaces) since a burning car or truck is much more difficult to extinguish than a burning cabin. (Dokkum, 2016)

In some modern ships, it is possible to turn on drencher sections remotely from the bridge or from other places in the ship through electronic valves. In all the ships I have visited though, the drencher sections and pumps had to be manually turned on in a dedicated drencher control room (fig. 2.16) (see appendix A, E). When asking a chief engineer about manual activation vs remote activation of drenchers he said that some prefer manual activation as it makes it easier to "feel" the flow of water and be sure that the drencher-system is activated (see appendix A). Personally, I do not see any disadvantage in having the possibility to remotely activate drenchers.

Figure 2.16
Photo: Nasatyas (2019)
Image of an activated drencher system. When the system is activated, the deck quickly fills up with water if the scuppers are not open.

Figure 2.15
Photo: Nasatyas (2019)
Image of an activated drencher system. When the system is activated, the deck quickly fills up with water if the scuppers are not open.

Figure 2.17
Photo: Marioff (2020)

A water mist sprinkler head. The green "pill" will melt away when it reaches a specified temperature, thus activating the water mist system.

WATER MIST

Water mist systems are a newer type of fixed extinguishing system. The system works somewhat similar to sprinklers and drenchers except with much higher pressures and a special nozzle that essentially atomizes the water into a fine mist. This mist then suppresses or extinguish fires by cooling the flame and surrounding areas, displacing oxygen by evaporation and attenuating radiant heat (Marioff, 2020).

Water mist systems have two main advantages. The first is that they fill the entire room with water mist very rapidly, contrary to sprinklers who just splash things with water from above. This makes water mist good for protecting both large and small rooms and can be installed anywhere from engine rooms to car decks to passenger areas. The second advantage of water mist systems are the minimal amount of water needed to create the mist. This means that the system can run longer on smaller water tanks and the crew doesn't have to worry as much about ship stability when activating a water mist system.

There are two ways of configuring water mist systems, either like a sprinkler with physical melting valves on each nozzle (fig. 2.17) or like a drencher system (also known as a deluge system) with manual and remote activation of an entire zone (fig. 2.18). Water mist systems can also be activated automatically if two or more fire detectors detects heat or smoke (provided its configured as a deluge system). In MS Newbuild Explorer, the water mist systems in the machine rooms was a deluge system set to automatically activate, while the water mist system in passenger areas was configured with melting valves (see appendix D)

All of the ships I have visited have had a water-mist system. The older ships have had water mist systems retrofitted to protect some select machinery spaces, while the MS Newbuild Explorer used water mist to protect the entire boat (see appendix D).

Figure 2.18
Photo: (Marioff, 2020)

A water mist deluge head. The section with drencher heads is turned on remotely, either manually or through system automation.

CO_2

A different type of fixed extinguishing system works by simply flooding the entire room with CO_2 and thus choking the flames. These systems can only be used in closed compartments and, although very effective, is very dangerous to people (Dokkum, 2016). A large number of fatal accidents has made CO_2 systems less frequently used in new ships. An example of this is MS Newbuild Explorer who exclusively uses a fixed water mist system to protect the entire ship (see appendix D).

The activation of a CO_2 system is done manually through a valve outside of the protected room. Before activating a CO_2 system, the crew needs to be certain that there is no one inside the room. In addition, all hatches and doors has to be closed, effectively sealing the room. In a fire aboard MS Nordlys, the main engine room caught fire but the CO_2 system was never activated because the captain did not know where all of his crew was situated (Accident Investigation Board Norway, 2013).

Because of the many hazards with CO_2 systems, other less harmful alternatives have been developed. Two of the alternatives are Novec 1230 and FM200 (Dokkum, 2016). These gasses do not displace the oxygen in the room and is safe to breathe, thus making them much safer than CO_2 systems. One of the ships I visited was retrofitted with a Novec 1230 system to protect the engine control room (see appendix C). This was, I think, a relief to the crew working in the engine control room.

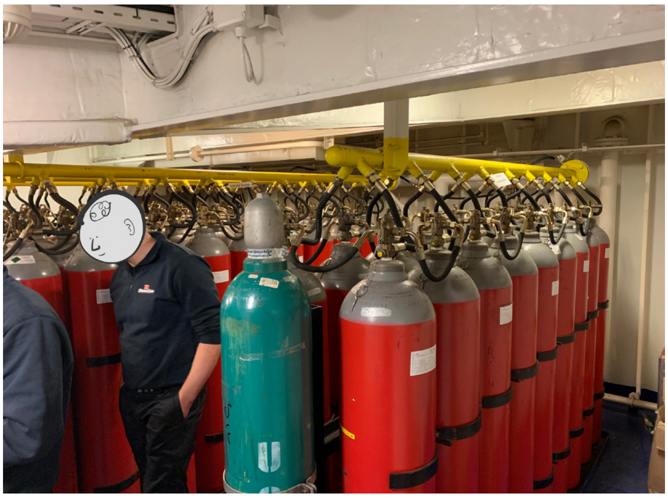


Figure 2.19
The CO_2 storage/battery aboard *MS Generic*. From here, the crew can flood some select machine spaces with CO_2

2.2.2 Firehose

In addition to the portable equipment and the fixed equipment, the firefighters aboard ships also have firehoses available throughout the ship. That is, reels of watertight hoses with spray nozzles that can be connected to a water hydrant to spray water on a fire. These firehoses are the most versatile, easiest and cheapest medium available for extinguishing a fire and, when hoses are connected to the appropriate hydrant, the entire ship can be reached.

2.2.3 Passive fire extinguishing

In addition to the many ways of actively extinguish fires (described above), several passive ways exist. These passive extinguishing methods basically suppresses the fire or prevents it from spreading further by closing spaces or by creating fireproof barriers in the ships design.

FIREWALLS

Firewalls are walls in the ship that's made in such a way that it can prevent fire or heat from getting through the wall. There are three types of firewalls: class A, B and C.

Class A firewalls are constructed from steel or other equivalent material and they are capable of preventing smoke and flame from penetrating the wall for one hour. Class A firewalls are also insulated with approved materials such that, in the event of a fire, the temperature on the unexposed side will not rise more than 139°C above the original temperature within a given timespan. This time span is indicated by the subclass of the wall, i.e. a A-60 wall will be able to prevent fire, smoke and heat from spreading for 60 mins.

Class B firewalls are walls constructed from nonflammable materials capable of preventing passage of fire for 30 mins. In addition, they have an insulation similar to that of an A class firewall, although rated for less exposure of fire.

Class C firewalls are walls constructed from nonflammable materials, but they have no requirements as to how long they have to prevent the passage of fire, smoke or heat. In my ship visits, only class A and class B firewalls were color-coded on maps of the ship and in some ships, only class A firewalls were indicated (see appendix A-E). The reason why some ships only indicated class A firewalls are unknown, but it might simply be because all of the other walls was class B or C, thus making it unnecessary to indicate.

MAIN VERTICAL ZONES

Much like buildings, ships are divided into vertical fire zones (fig. 2.20). These fire zones are divided by a class A firewall (often A-60) and prevents a fire from spreading from one fire zone to the next. Often there are at least one stairwell running through the entire vertical fire zone so that it is possible to get to the lifeboats even if two of three fire zones are completely on fire (see appendix C-E)

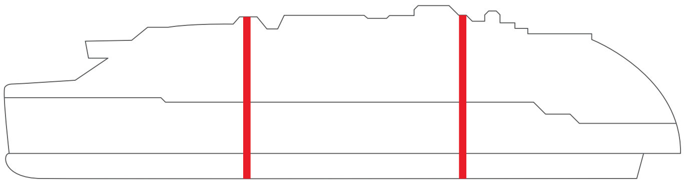


Figure 2.20
Main vertical fire zones split the ship into several vertical sections. Illustrated here by the red line.

DAMPERS

Dampers are special devices that is fitted to vent ducts that penetrate class A firewalls and main vertical firewalls. These vent ducts run throughout the entire ship and becomes a corridor fire can spread through if they are not sealed. This is what dampers do (fig. 2.21). If there is a fire in a room, a crew member will close the dampers to that room, thus sealing off the room from the rest of the ship and depleting the fire from fresh oxygen.

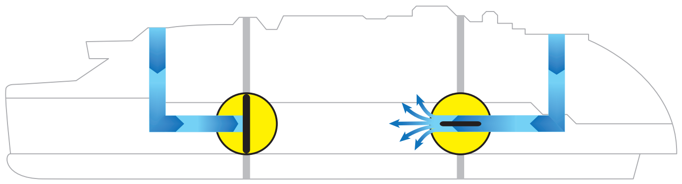


Figure 2.21
Dampers closes the vent ducts to a room. Illustrated here as a yellow circle. When the damper is open (left) fresh air can circulate, otherwise (right) it is blocked by the damper.

VENTILATION

Similar to closing the dampers, the ventilation for different sections of the ship can be turned off to prevent a fire from spreading (fig. 2.22). It is also possible, in some ships, to deliberately turn on and off ventilation sections in order to create a higher air pressure in stairwells, thus preventing smoke from traveling into the stairwells and spreading vertically to other decks. The ventilation can be controlled remotely from the bridge and other dedicated rooms (like the safety room). In some ships, the ventilation turns off automatically if the fire alarm sounds, but the ventilation in stairwells are deliberately turned on (see appendix A).

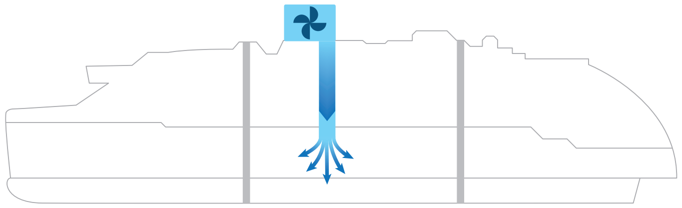


Figure 2.22
The ventilation controls the climate onboard by circulating warm or cold fresh air to sections of the ship. On ships, the crew can purposefully activate and deactivate ventilation zones to prevent smoke or fire from spreading.

FIRE DOORS

Whenever a doorway goes through a firewall, a fire door is fitted. A fire door has the same fire class as the wall it is attached to, i.e. a class A-60 wall will have class A-60 fire doors. There are several types of fire doors, but the most common ones are hinged and sliding fire doors. The hinged fire doors look like a normal door, except it has an electromagnet to hold the door open when needed. A hinged door can be closed remotely, but it cannot be opened automatically. A sliding fire door slides open and closes by sliding on a rail. The movement of the door can be done pneumatically or by releasing an electromagnet that in turn allows the door to slide close. Pneumatically controlled fire doors can be made semi watertight or completely watertight and can (technically) be opened and closed remotely.

On the ships I have visited, the fire doors can be remotely closed from the bridge, but not individually. Instead, the crew has the option to close all fire doors within a main vertical zone (fig 2.23). Often, the state of all fire doors onboard are shown on a mimic panel, but it is not possible to individually control the doors (See appendix E). Normally, fire doors will be closed by default in machinery spaces, cargo spaces and stairwells, but open in passenger areas. In some ships, the fire doors are configured to automatically close in the event of a fire alarm (see appendix C-E).

WATERTIGHT DOORS

Watertight doors are pneumatically sliding doors that becomes watertight when closed. These doors are usually found in decks underneath the waterline and are normally closed when at sea.

The watertight doors can, similarly to fire doors, be closed remotely from the bridge (fig. 2.24 and 2.25). In the ships I have visited, the only option is to close them all, but you can see which one is open or closed on a mimic panel (see appendix D, E).

Figure 2.23
Bridge remote control of fire doors (marked in yellow) on *MS Newbuilt Explorer*. The doors are configured to automatically close in the event of a fire alarm. The crew can remotely close all fire doors in a specific main vertical fire zone, or all fire doors onboard.

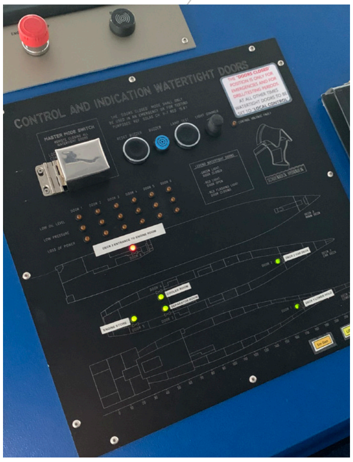


Figure 2.24
The watertight door control panel onboard *MS Generic*. The only option is to close all of them.

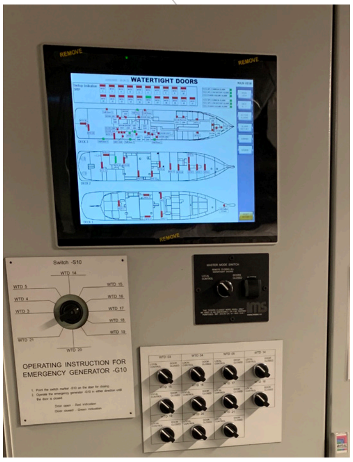


Figure 2.25
The watertight door control panel onboard *MS Newbuilt Explorer*. Here, the crew can actually open and close individual doors.

2.2.4 Detection of Fire

Fires aboard ships are detected by either a type of automatic detector or manually through radio or a manual call point.

AUTOMATIC DETECTORS

Generally, there are three types of fire detectors used aboard ships; smoke detectors, heat detectors and flame detectors. Smoke detectors and heat detectors monitors the level of smoke and heat where the detector is situated. Normally a combi detector is used, which both monitors heat and smoke simultaneously (fig. 2.26).

Flame detectors (fig. 2.27) works by either detecting the UV-radiation emitted by fires and expl7osions or by detecting the infrared (IR) patterns emitted by fires and hot gasses. These types of detectors are good for detecting fires outside, since they don't rely on detecting particles or heat that can blow away.

MANUAL CALL POINTS

Manual call points are switches that can be manually triggered (fig. 2.28). When triggered, the fire alarm on the bridge is activated. These call points are identical to the ones you find in public buildings. To have as effective fire detection as possible, manual fire rounds are routinely performed aboard ships (see appendix E). If the crewmember performing the fire round stumbles upon a fire, it is routine to extinguish the fire with portable extinguishing equipment or notifying the bridge through radio or a manual call point.

Figure 2.26
Photo: Autronica (2020)
A combi fire detector. This one monitors both heat and smoke levels.

Figure 2.27
Photo: Autronica (2020)
An IR flame detector.

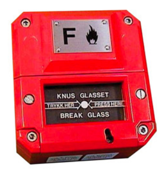


Figure 2.28
Photo: Autronica (2020)
A manual call point for use in harsh environments.

2.2.5 Fire central

The fire central is the "brain" of the fire detection and alarm system. It is responsible for monitoring all the detectors aboard as well as activating alarms and controlling some systems.

Before, the fire central only monitored fire detectors in groups (loops) and if one fire detector within a loop was triggered, the fire central will show an alarm for that loop. However, a regulation change in 2010 made it mandatory to have addressable fire detectors on passenger ships (Leroux & Mindykowski, 2017). This means that the fire central not only monitors groups of fire detectors but also monitors every single fire detector individually. This makes it possible to know exactly which fire detector is triggered in the event of a fire alarm. This new regulation does, however, only demand that the detectors must be addressable, and not that it should be graphically presented. Because of this, some ships have a fire central that simply shows or prints out fire alarms in the form of a line of text or code (fig. 2.29). In *MS Generic*, the crew had to look up the text-code from the fire central in a book to find the location of the triggered detector (see appendix E).

Figure 2.29
The fire central aboard *MS Generic*. It actually prints out a physical paper log of fire alarms.

Most of the ships I visited, however, had a graphical UI connected to the fire central. This graphical UI allows the crew to graphically see and check the state of individual detectors and other connected systems (fig. 2.30). The system also shows the alarm thresholds for the different detectors and the current sensor value for each detector. It is interesting, however, that the system does not give any timeline information about the sensor values. This will make it much more difficult for the user to predict future events and inhibit what Endsley and Jones calls "level 3 situational awareness" (Endsley & Jones, 2016).

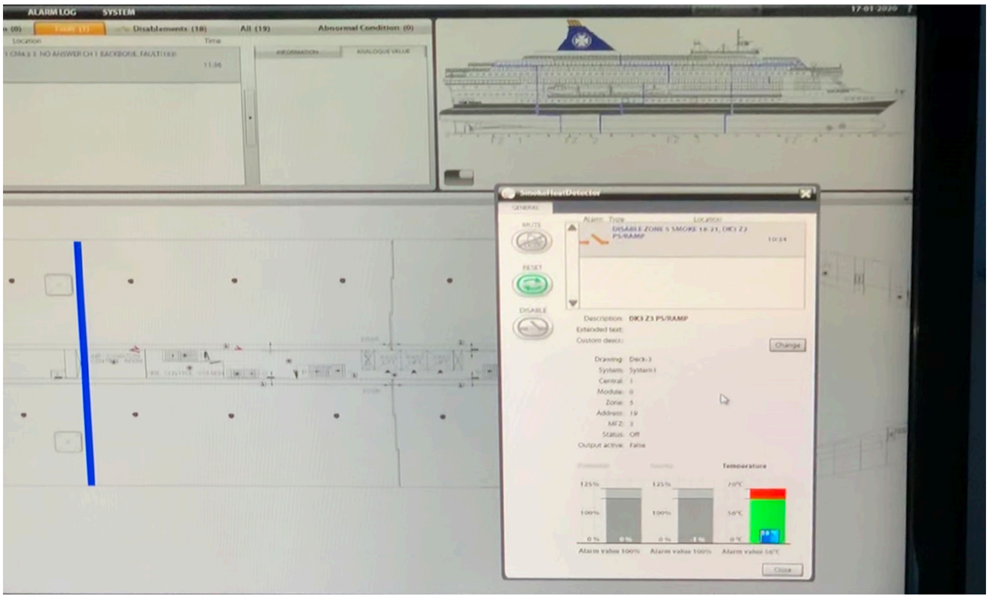


Figure 2.30
A graphical fire central aboard *MS Large RoPax*. The bar chart shows sensor values for a specific detector.

MULTIPLE FIRE CENTRALS

Not until my third ship visit did I realize that the fire central on the bridge is only one of many fire centrals aboard a ship. In most ships, there are three fire centrals; one on the bridge, one in the safety room and one in the engine control room (fig. 2.31). These rooms are, by design, spread across different main vertical fire zones, so that a fire central will always be available even if two fire zones are on fire. In addition, the safety room usually stores a lot of firefighting equipment and several remote-control panels for watertight doors, fire doors, emergency valve for fuel and other controls relevant for firefighting.

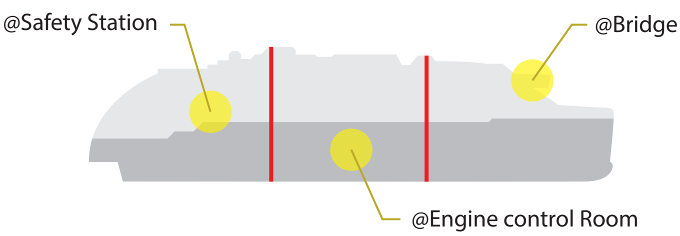


Figure 2.31
The location of the different fire centrals aboard *MS Newbuilt Explorer*. The red lines indicates the main vertical fire zones.

At any moment in time, one of the several fire centrals will be configured as the "master". It is only the master fire central that will sound alarms. The other fire centrals will graphically show alarms and they essentially become a pure information display without much interaction possibilities. It is possible to change which fire central is set to master. Any of the fire centrals can change which is master. During my visit at *MS Newbuilt Explorer* the bridge fire central started as the master. Eventually, the bridge crew sent the master control to the engine control room as there was little personnel on the bridge (see appendix D).

2.2.7 CCTV

CCTV, or Closed-Circuit TV, is a video surveillance system that most modern ships use (fig. 2.32). The system is normally used to monitor the ship and check that no one is doing something stupid or illegal. The CCTV system can also be used to get a better overview of a fire situation. For example, the crew can quickly check and look for smoke development through the CCTV system when a fire alarm sounds. Modern CCTV systems also records 30 mins (or more) back in time. In a more severe fire situation, the CCTV system can then be used to get an understanding of how the fire started and how it has developed by scrolling back and forth in time. This is very easy to do in a CCTV system, but cameras are very vulnerable to smoke and a large fire will quickly make the video feed unusable (see appendix A).

In MS Newbuild Explorer, the CCTV system is even connected to the fire central and all the CCTV cameras aboard the boat is placed on the same map as the fire detectors are. Here, the crew can click on a CCTV camera on the map, and the video feed from that camera will pop up (see appendix D).

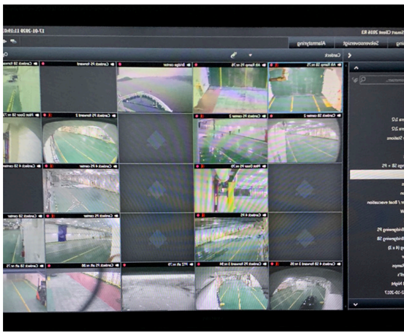


Figure 2.32
The CCTV station aboard *MS Large RoPax*

2.2.8 Fire locker

Other equipment used for firefighting, i.e. clothes, masks, tools and such, are stored in several fire lockers around the ships (fig. 2.33). The fire lockers are often dedicated to a specific fire team. For example, fire locker 1 contains equipment for fire team 1 and so on (see appendix C).

Figure 2.33
A fire locker aboard *MS Sister*. This one contains fire clothes specifically for fire team nr 1 aboard the ship.

2.2.9 Fire control plan

Page 21

On the bridge, and throughout the ship, printed fire control plans are available. On the bridge, this fire control plan is usually laminated and hung on the wall or recessed into a tabletop as with MS Large Ro-Pax (fig. 2.2). The fire control plan is a map of the ship where all of the fire-equipment, fixed fire extinguishing zones, fire lockers, dampers and other information related to fire is graphically marked (fig. 2.34).

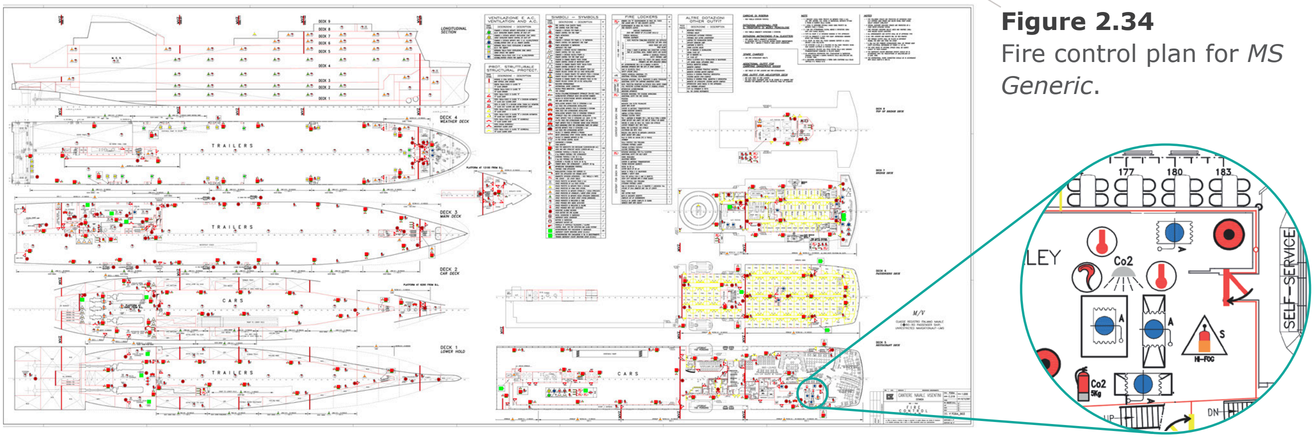


Figure 2.34
Fire control plan for *MS Generic*.

During a fire scenario, the crewmember in charge of firefighting (usually the chief engineer or safety officer) will plan the fire fighting and keep track of the fire scenario by using the laminated fire control plan on the bridge as a whiteboard (fig. 2.35). On this board, he has all the information about fire equipment and systems on board. Also, he can mark where the fire teams are mustered and write down important notes on the fire control plan. Typical things that would be marked on the fire control plan is where the fire is, when sprinklers were activated, where the fire teams are, where other crew teams are and when and where a smoke diver team entered a room. The last one is especially important in order to prevent the smoke divers from forgetting the time and running out of air. In MS Large Ro-Pax, a thumb rule was to radio the smoke divers after 10 minutes to remind them to come back (see appendix A).

At MS Large Ro-Pax, the fire control plan in the table was also meant to be rolled up in the event of an abandon ship order. This fire control plan would then become a kind of log of what has happened before abandoning the ship.

The fire control plan contains a lot of information about the ship. This information is very valuable for planning the firefighting, but also for the crew that actually performs the fire fighting. In one of my ship visits, the security officer said that he would have liked to have all of the information in the fire control plan available for the fire teams, who is not necessarily located near one (see appendix D). This is so also the fire teams can get a better overview of where the fire is and how they are going to attack it.

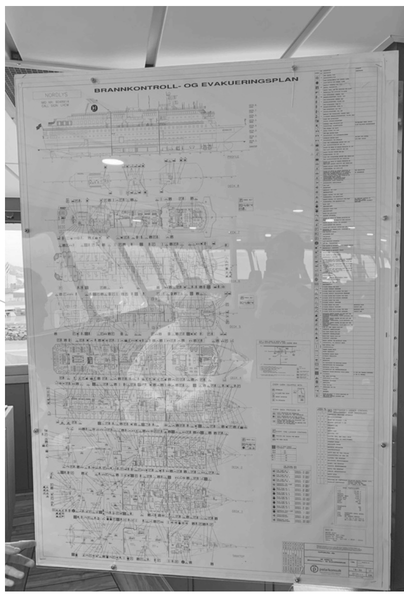


Figure 2.35
The fire control plan aboard *MS Medium Ferry*. It swings open from the wall to save space.

2.2.10 Bridge layouts

In my ship visits I have spent most of the time on the bridge. This is because there is a fire central on the bridge, the bridge is a quiet and good place to perform interviews and since the bridge is the command center during a fire scenario. In all of my visits, I have been surprised at how spacious the bridge actually is. The bridge size varies, of course, with the size of the ship, but since the bridge needs to be as wide or wider than the ship itself, there is usually quite a lot of floor space. So much so that in many of the bridges I visited had a dedicated sofa and coffee table installed! This is interesting as it indicates that the concept I come up with does not necessarily need to be very small to be able to fit into an already existing bridge.

Figure 2.36 shows schematics of three different ship bridges. The bridges are from three of the ships I visited, and they have been drawn by eye measure and are not to scale. The yellow areas in the figures indicates equipment relevant to fire fighting. i.e. fire central, fire control plan, sprinkler/drencher/water-mist activation/panel, ventilation control, door control and CCTV system. All of this equipment needs to be monitored during a fire scenario. The equipment is, however, very scattered in most bridges. This makes it difficult to get a good overview as you have to turn or walk around to get to the different equipment panels. Even in the newest ship, *MS Newbuilt Explorer*, although all of the fire systems panels are gathered in one place, the fire control plan is on the complete opposite side of the bridge. This naturally makes it much more difficult to plan the firefighting while also having an eye on how the fire is developing.

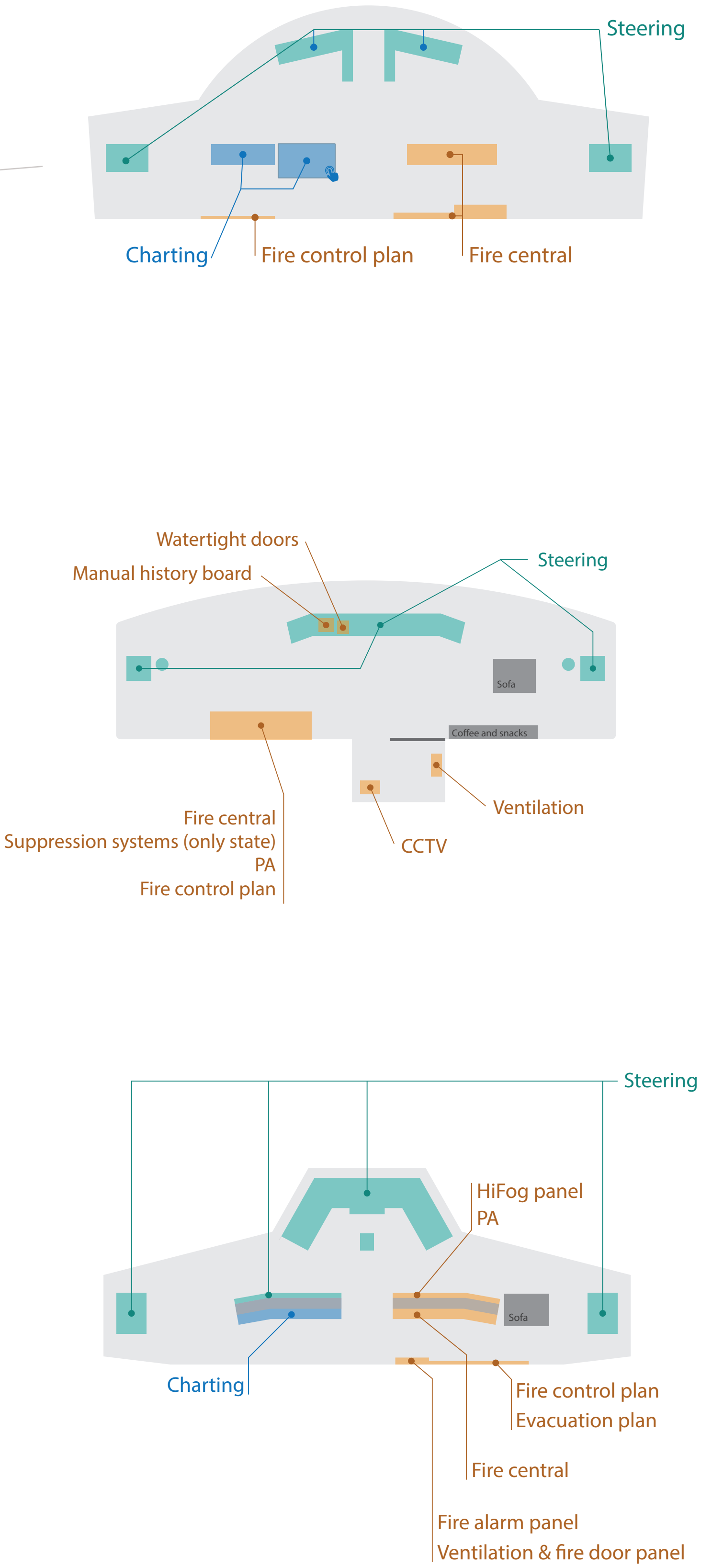


Figure 2.36
Bridge layout of three different ships. The orange is equipment relevant for firefighting.

2.2.11 So, what happens when a fire is detected?

Exactly what happens when a fire alarm sounds varies from ship to ship. There are some similarities between all of the ships I have visited though. Figure 2.37 shows the events from a detector triggers an alarm to the fireteams actually extinguishing the fire.

When a fire detector detects either a particle value or heat value above a certain threshold, a fire alarm sounds on the bridge. When this fire alarm sounds, the crew have two minutes to acknowledge the alarm. If the alarm is not acknowledged, the general alarm will sound aboard the entire ship.

When the alarm has been acknowledged, the next step is to verify that there actually is a fire. Usually this is done by sending a "runner", a person to run and visually check if there is a fire or if there is just something wrong with the detector.

If a fire is verified and it is too big for the "runner" to extinguish with a handheld apparatus, a muster signal is sent to the crew and the crew musters at their predefined places. Here, the crew usually splits into three team categories; bridge team, fire and damage teams and evacuation teams (fig. 2.38). The bridge team has overall command with the captain as leader, the fire and damage teams are the ones actually performing the damage control and fire extinguishing and the evacuation teams makes sure that the passengers are at a safe place.

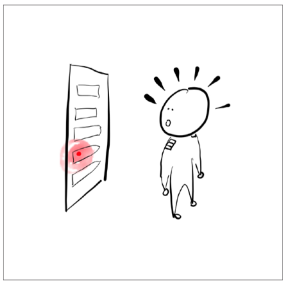
These teams are at completely different places aboard the ship and they communicate through VHF. This VHF communication is sometimes a little problematic as interference and dead zones can happen (see appendix A, E).

When it is time to send in the fire teams and extinguish the fire, one of the fire team members are always outside of harm's way. The person who is not actively extinguishing the fire has the task to keep up radio communication with the bridge and make sure the rest of his fire team members are safe.

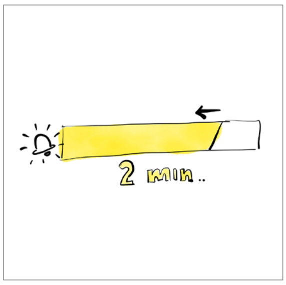
VHF ?
VHF, or very high frequency, is a type of short distance radio communication.
In ships, VHF is used to contact other ships, call the international emergency channel and communicate internally between persons and teams.

The VHF band has a limited number of channels, and most of them are reserved for specific use. Aboard ships, they usually have one channel for communicating with the bridge, and a few other channels for communicating with specific teams.

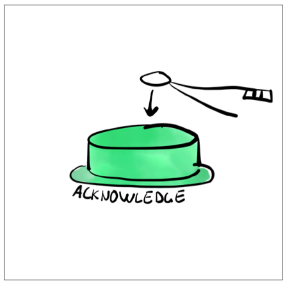
Smoke triggers a fire detector



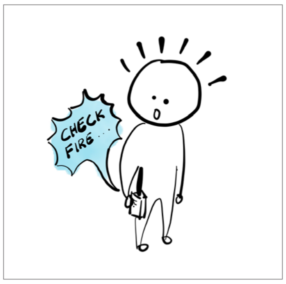
Alarm on bridge sounds



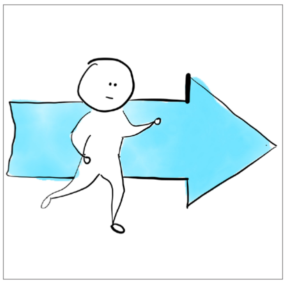
2 mins until general alarm is triggered



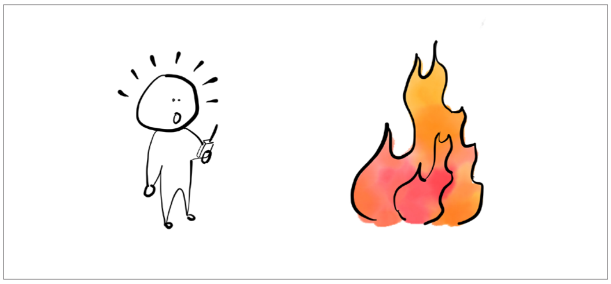
Acknowledges alarm to stop general alarm



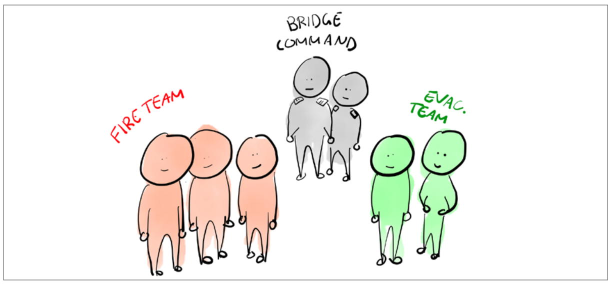
Send someone to check if fire



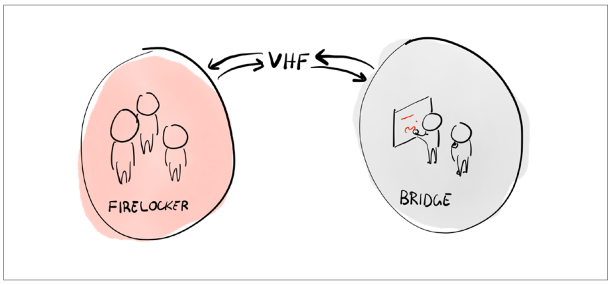
The runner runs to the triggered detector



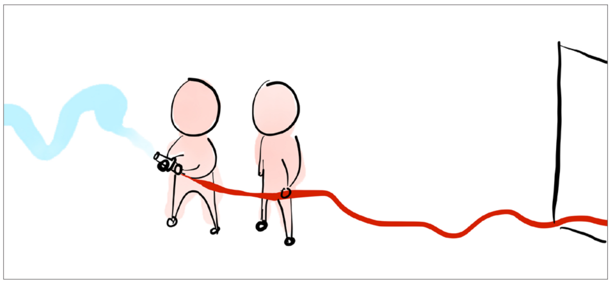
Runner confirms fire and reports back to the bridge



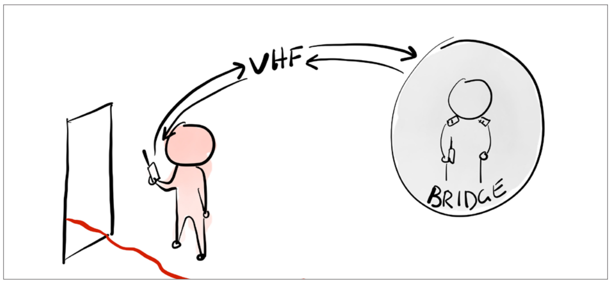
Muster teams and brief situation



Teams communicate with bridge through VHF



Fireteam start fire extinguishing



Designated bridge contact in fireteam

Figure 2.37
Events from alarm trigger to fire extinguishing.

2.3 System blueprint

To get a better overview of how the crewmembers and teams interact with each other and the ship's systems, a system blueprint was made (fig. 2.39). This blueprint is based on the previously mentioned fire scenario aboard Pearl of Scandinavia and shows how the bridge crew get information from the fire systems and how this information is relayed to the fire teams.

An interesting discovery from the blueprint is the massive information sharing happening between the bridge and the fire teams (marked in yellow, fig. 2.39). This communication is happening over VHF, which often can have much interference and be hard to understand. Much of the information sharing is also simply relaying information from the ships systems, through the bridge and down to the fire teams.

Figure 2.39 →
System blueprint showing the communication between teams and systems during a fire scenario.

"System blueprint"

A fire scenario based on the Pearl of Scandinavia incident

2.4 The problem today

Based on my ship visits and interviews with ship crew I have synthesized ten problem statements. The problem statements are divided into three categories; (1) system integration, (2) higher level situational awareness and (3) interaction (fig. 2.40).

1 System integration

Information and system panels are scattered
Fire control map is large and cluttered with information
Fire control map is decoupled from the fire detection system
Fire teams don't get info directly from system, but via bridge over VHF

2 Higher level situational awareness

It is not possible to keep an eye on several detectors at the same time
Fire central does not help in level 3 SA
Hidden automation

3 Interaction

Modern fire centrals are difficult to use
Symbols are the same color as alarm indicators, thus making alarms less salient
Fire central UI is very bright

Figure 2.40
Overview of problem statements.

2.4.1 System integration

INFORMATION AND SYSTEM PANELS ARE SCATTERED

As mentioned earlier, the panels for the different systems aboard are scattered. This is especially true for older ships that have been retrofitted with new equipment. In this case, it is natural to just install the new system panel wherever there is space. When interviewing crew aboard these ships, they all say that a system that could gather all the info in one place would be great (see appendix B-E).

Even in newer ships, where the system panels are relatively gathered and with some integration with a fire central, the fire control plan is still only a piece of paper that is hung on the other side of the bridge.

FIRE CONTROL MAP IS LARGE AND CLUTTERED WITH INFORMATION

The fire control plan contains all static information that is relevant in a fire scenario. The plan is printed on a large piece of paper in order for the map-scale to be reasonable. This makes the fire control plan very large and cluttered with different symbols for all the different fire equipment aboard. In addition, the symbols are hard to differentiate and remember, thus making the plan tedious to search through.

FIRE CONTROL MAP IS DECOUPLED FROM THE FIRE DETECTION SYSTEM

The fire control map is, as it is an analogue piece of paper, decoupled from the fire detection system. This might be a problem when dealing with a large fire as the focus is on the fire control map, but the detector and system state information is on a different panel. In several interviews, the crew has complained about how the information in the fire control map is not available in the fire central (see appendix D, E).

Fire teams don't get info directly from system, but via bridge over VHF
The fireteams communicate with the bridge through VHF and get updated sensor information from the ship systems through this channel. The sound over VHF can have much interference and can be difficult to understand. This might cause confusion, delayed fire extinguishing or faulty information. Another problem can be dialing in the correct channel, thus loosing valuable information and time.

2.4.2 Higher level situational awareness

IT IS NOT POSSIBLE TO KEEP AN EYE ON SEVERAL DETECTORS

On the fire centrals I have seen (see appendix A-E), it is only possible to get information from one detector at a time. This makes it difficult to track the fire and get a proper situational awareness as one has to click around and remember detector values. This is actually something that came up in a later user test (see appendix G, I, J).

FIRE CENTRAL DOES NOT HELP IN LEVEL 3 SA

The fire centrals I have seen (see appendix A-E) does not give any graphical historic information. That is, timelines showing last 10 mins of sensor values or the ability to go back in time and play back the scenario again. The systems do have detailed timelines showing in text what happened when, but these are quite abstract and does requires a lot of mental capacity to deduce out any useful information about the future.

HIDDEN AUTOMATION

What the system will automatically do in a fire scenario is hidden and, as a crewmember said, “we just have to trust that the system does what it is supposed to do” (see appendix E). This might lead to “out of the loop” syndrome, as Endsley and Jones (2016) calls it, where the system doesn't do as one expects. Reasons might be because the automation is hidden and unknown to the operator, or because the operator is unaware of a turned on/off automation protocol. In the engine fire aboard MS Nordlys, the fixed extinguishing system was turned to manual without the operator knowing, thus leading to delayed activation of the extinguishing system (Accident Investigation Board Norway, 2013).

2.4.3 Interaction

MODERN FIRE CENTRALS ARE DIFFICULT TO USE

The fire centrals I have seen, does seem a little finnicky and difficult to use. In *MS Newbuilt Explorer*, two fire centrals were crammed in between four other computers, each of which with a dedicated screen, keyboard and mouse (fig. 2.41). In total, the desk had six separate keyboards and six separate computer mice. Imagine finding the correct mouse for the fire central when the ship is burning.

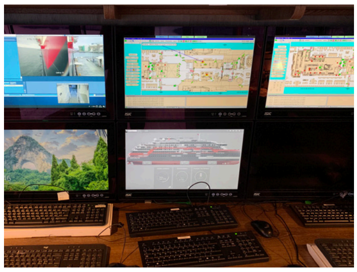


Figure 2.41
The fire central, ventilation control and CCTV systems aboard *MS Newbuilt Explorer*.

In addition, the UI seems difficult to navigate and, in one of my ship visits, the crew member showing me around have had some difficulties demonstrating a few higher-level functions on the alarm central (see appendix E).

SYMBOLS ARE THE SAME COLOR AS ALARM INDICATORS, THUS MAKING ALARMS LESS SALIENT

During my ship visit to *MS Newbuilt Explorer* a fire alarm went off (see appendix E). The reason was a technician doing some work on the detector, so it was a false alarm. When the alarm was triggered, I noticed that the graphical alarm indicator had the same color as many of the map symbols in the fire central. This makes the alarm less salient and a little difficult to find.

FIRE CENTRAL UI IS VERY BRIGHT

Another detail I noticed on *MS Newbuilt Explorer* was a curtain surrounding the alarm central (fig. 2.42) The purpose of the curtain is to block out screen light from the alarm central and other equipment when sailing at night. This could be problematic if an alarm is triggered at night as the light from the screen will blind the user. It is important to point out that during night, the bridge is completely black so as to make light signals from other ships or buoys visible (fig. 2.43). A fire central, I think, should therefore emit as little light as possible during night sailing.

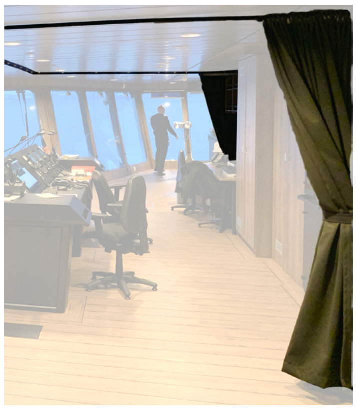


Figure 2.42
Curtains on *MS Newbuilt Explorer* to obstruct the light from pc-screens. The image is edited to highlight the curtains.

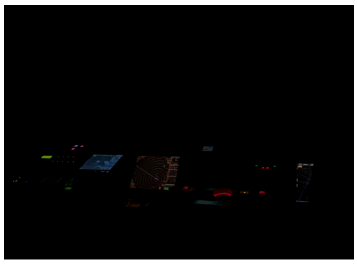


Figure 2.43
No, it is not a black square. An image of the navigation panels aboard *MS Generic* taken during night sailing.

2.5 Codesign at ship

When I was visiting the *MS Generic*, I had the opportunity to talk a little more with the bridge crew around what they wanted in a more unified fire central and how it could be designed. Instead of just a normal interview, which I have done in several of my other visits, this became more of a codesign interview where I could share my ideas as well as theirs and thus co-designing a concept for a new fire central. The idea I vented was simply a digital fire control map with detector information integrated.

It is worth noting that the crew aboard *MS Generic* are used to very primitive fire extinguishing systems with little to no digital elements or automation. I think it explains enough that the fire central onboard prints out the alarms on a roll of paper and has a very basic ascii LCD display to show messages. Even so, I think the co-design yielded some useful insights (see appendix F).

The crew was very positive to the idea of integrating control of fire doors, dampers, drencher and other suppression systems into a unified fire central. They would like this info to be graphically available on a large digital map of the ship. This way they can zoom in on what is important at the moment and get a better overview. They also wanted the system to show potentially dangerous things around a fire. For example, the map can color code the cargo or other systems based on how flammable/dangerous it is.

The crew was positive towards a touch screen, as long as it is a good touch screen. They have some equipment aboard with touchscreens, but the touchscreen quality and sensitivity vary a lot. They also wanted a big screen, for example 50 inches, so that it would be possible to see CCTV while looking at the map. They also stressed that they have to be able to use the system at night, so it cannot be too dim or too bright.

On all of the ships I have visited, the crew uses a folder of checklists as a decision support in the event of a fire. This checklist just contains a few different things that is important to remember or check if there is a fire in a specific room. This checklist can become digital and integrated into the fire central. The crew aboard *MS Generic*, however, was hesitant to this idea. They did say that it could be good, but that they had to try it out to be sure.

The most important information they wanted from a system like this was what kind of alarms are active (fire, smoke or heat), the location of the alarms, how the fire/alarms are spreading, state of watertight- and fire-doors and information about dangerous objects. The captain also wanted information about which fixed suppression system was where and their zones.

2.6 Concept

From the interviews, co-design and visits I have had on ships, it seems a fire central in the form of a large touch screen or touch table will be very useful for the ship crew in helping them detect and respond to fire alarms quickly. It does also seem like a portable digital fire central could be helpful in reducing communications over VHF and for the fireteams to directly get a better situational awareness.

The touch screen will incorporate information about the fixed and portable extinguishing systems aboard as well as giving the possibility to drop notes/pins on a map so that it can be used to note where a fireteam is or where the fire is. It should also be possible to activate fixed extinguishing systems and control doors and dampers from this system.

The concept consists of two parts; the digital fire central on the bridge (and safety room and control room) and one or more portable tablet like fire centrals (fig. 2.44).

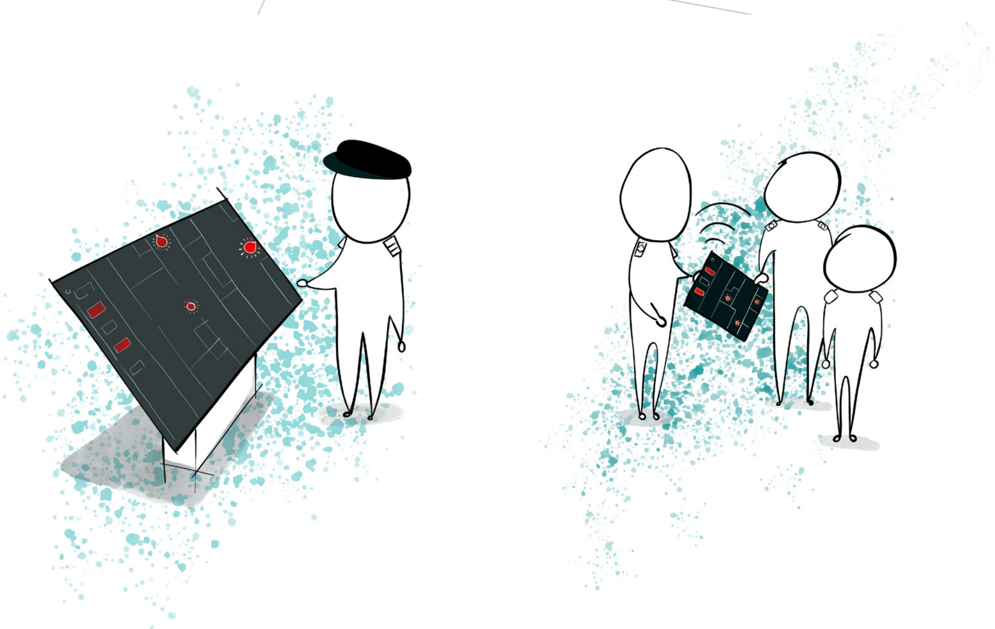


Figure 2.44
Concept drawing of a large fire central on the bridge (left) and a small portable fire central for fire and evacuation teams (right)

The digital fire central on the bridge consists of a large touch screen and is essentially a "google maps" of the ship. On this map you get all the information you would find on a fire control plan, as well as information about system states and the ability to directly control systems on the ship. The map also works as a cognitive aid, where you can "drag-and-drop" fire teams onto the map much like the crew at MS Large Ro-Pax did with physical labels.

To make the fire teams less dependent on the bridge and to free up the VHF line, a portable fire central can be used by the fire teams. This way, the fire team gets real-time info about where the fire is and how its spreading wherever they are. The portable fire central is not meant to be taken with when the fire team is actually performing the extinguishing, but it is meant as a planning/briefing tool that can be used right before they start the fire extinguishing.

This portable tablet can also be used as a tool for the evacuation teams. Not only will it be useful to see real-time info about smoke and heat development when evacuating passengers, the tablet can also be used to check/mark which rooms/areas that has been evacuated. Currently, this is done manually by the evacuation team and reported back to the bridge once an entire section has been evacuated. With the tablet solution, the bridge panel will get real-time info about what has been evacuated, without being overwhelmed with VHF communication.

The digital fire central can incorporate a lot of information that would benefit the evacuation crew. The evacuation crew does have many of the same problems that the fire crew has, and the evacuation plan (similar to a fire control plan, only for evacuation) can easily be incorporated into the digital fire central. In order to limit the scope of this thesis however, I will not focus on the evacuation side of the digital fire central.

2.6.1 Touch display

For many, touch is a love it or hate it kind of thing. When compared with traditional navigation with a mouse, falls short when it comes to speed (Forlines, Wigdor, Shen, & Balakrishnan, 2007; Noah, Li, & Rothrock, 2017). As it is important to act quickly during a fire situation, going with a touch display for the concept might seem counter intuitive. However, even though Forlines et al. (2007) showed that mouse input is quicker than touch, they also showed that touch input is superior when it comes to multiple users. The stationary fire central on the bridge might have several users interacting with it at once. For example, the captain and the chief engineer might discuss how to best approach a fire with the fire central. In addition, touch devises might feel more natural to interact with and to use as a cognitive aid (e.g. a digital whiteboard) (Grinschgl, Meyerhoff, & Papenmeier, 2020). Because of this, touch is probably a good input method for a fire central, even though it might be slightly slower than mouse input.

Another approach, that is very normal for dedicated hardware aboard ships, is to have physical buttons together with a touch display. This could be a valid solution for the digital fire central as well. The display could, for example, have several hardware buttons for important or frequently used functions. It is important to remember, however, that the fire central will mostly be idle and not used. By only having the touchscreen as an input method, and no physical hardcoded buttons, the hardware becomes much more versatile and can, for example, be used for other things during normal ship operation.

2.6.2 Connection to MRCC

A benefit of a digital unified fire central, that is outside the scope for this thesis, is the opportunity to stream ship information from the fire central to the MRCC. The MRCC, or Maritime Rescue Coordination Center, is a search and rescue facility that can assist in emergency situations, e.g. by sending external firefighting teams to a ship on fire. The information from a fire central can be very important so that the external fire teams can prepare properly for the fire situation.

2.6.3 Users

The users of the static fire central will primarily be the bridge crew as they have the overall command during a fire scenario. The portable fire central, however, can be used by any member of the fire teams or evacuation teams. For the sake of simplicity, I have defined three user personas (fig. 2.45).

Figure 2.45
The fire central users. From the left: captain, chief engineer and fire team member

CAPTAIN

The captain has overall command of the ship. During a fire situation, the captain is situated on the bridge and keeps an overview of the situation and what the fire teams, evacuation teams and navigation are doing. She relies on autonomous teams during a fire situation, but have the final say in decisions.

CHIEF ENGINEER

The chief engineer is the leader of the fire teams. During a fire situation, he monitors the ship's systems and is responsible for the fire teams aboard. He plans how to best extinguish a fire and commands the fire teams to execute the plan. He is normally situated on the bridge, but he might also muster closer to the fire if needed.

FIRE TEAM MEMBER

The fire team perform the actual fire extinguishing and are led by the chief engineer. The fire team members are not professional fire fighters and have other duties during normal sailing. They do, however, train on fire scenarios, smoke diving and fire extinguishing.

2.7 Notes on physical design

The physical design of the concept is not the focus of this thesis. I have, however, a few notes about the digital fire central's physical design that is worth exploring in further work.

2.7.1 Size of display

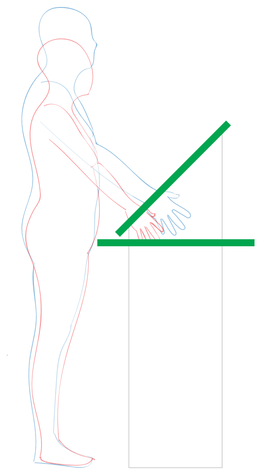


Figure 2.46
A 50″ display (green) in flat and tilted position with man and female figurines based on ANSUR II data.

From some very quick testing by marking out screen sizes on a table and testing reach, it seems that screens bigger than 55″ becomes too big. At 55″ it is still possible to reach the edge farthest away from the operator when the display is in a touch table position. To reach the edge, you have to lean over the table a little bit though. Over 55″ and it is noticeable more difficult. A tilted display seems to be quite comfortable at 55″.

If we look at the average height, shoulder height and arm reach of males and females in the ANSUR II survey, a anthropometric survey of over 6000 US army personnel in 2012, it seems that a ≈50″ table display will be comfortable for an average man and a ≈43″ display for women. This will of course vary from height of the display and whether the display is tilted or in a horizontal table position (fig. 2.46). At *MS Generic*, a digital charting table was installed (see appendix A). This table could be adjusted in both height and tilt by pressing buttons. This adjustment opportunity should be a part of the digital fire central as well.

2.7.2 Display position

As mentioned above, the display should be adjustable to suit the need of the user. It is, however, not always practical to have a display table. Instead, it might be better to mount the screen vertically on a wall with a mechanism that allows for moving the screen into a lower tilted position when it is in use (fig. 2.47).

The wall-hung position might be better for retrofitting the system into existing ships as it takes up less space, while the table might be better for new builds.

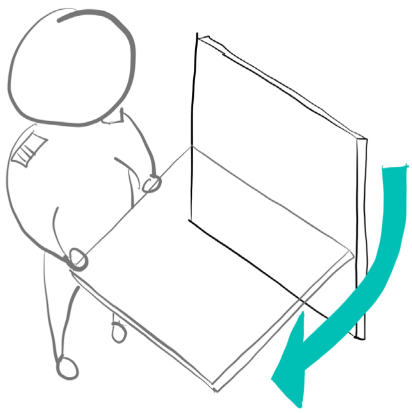


Figure 2.47
The display can swing down from a wall position to a tilted position more suited for touch interaction.

2.7.3 Handles

Since the display is quite big and aboard a ship, it should be sturdy and have handles on the side so that the user can grab ahold during rough sea (fig. 2.48). This will make it easier to use, as the user can grab ahold of the display and thus make more precise clicks with their other hand.

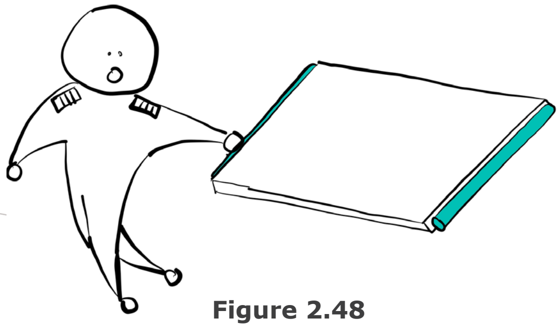


Figure 2.48
The fire central should have handles and be sturdy enough to hold onto.

2.7.4 Power supply

The display and computer for the fire center needs to have an uninterruptable power supply capable of powering the system for a few hours. This way, the system can still be used as a fire control plan and help in planning and executing fire extinguishing even if the entire ship has blacked out.

2.7.5 Logging

Since the fire center essentially logs what happens on the entire ship fire wise, it should log the last few hours onto a removable hard disk. This hard disk should be easily removable from the fire center in a swift motion in case of an abandon ship (fig. 2.49). The hard disk will then become a log of what happened on the ship before it was abandoned, which could be useful for investigations and reports.

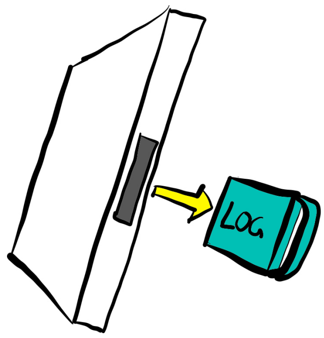


Figure 2.49
Quickly remove the log from the fire central on the event of abandon ship.

2.7.6 Detectors

During my visits at ships, I noticed that the fire detectors have very small indicator lights and are often very hard to see. It might be useful to add a larger indicator lights so that the "runner" has an easier time finding the correct detector. The indicator light can either be off when everything is good and light up when an alarm is triggered, or constantly lit in different colors dependent on the state of the detector.

3 Prototype 0

3.1 Goal Directed Task Analysis

To get a better understanding of what information needs to be available on the digital fire central, I created a “goal directed task analysis” (GDTA). This analysis is based on the GDTA described by Endsley and Jones in Design for Situational Awareness (Endsley & Jones, 2016) and it is created from my insights from ship visits and interviews.

A GDTA is basically a way of mapping out what kind of information an operator needs in order to complete a goal. It is created by dividing goals into sub goals and in the end defining the information needed to complete that sub goal. When finished, you get a tree-like map of goals and information point (figure 3.1).

From the GDTA, we can easily see what kind of information needs to be available in order for the crew to make good decisions regarding a fire situation. The GDTA also includes the evacuation of passengers, even though this is not the main focus for this thesis. It shows, however, that much of the information needed for evacuation is also needed for effective fire extinguishing.

Figure 3.1 →
A GDTA of the fire and evacuation goals during a fire situation. Information points are marked in red.


Act efficiently on fire alarm
Determine if legit fire alarm
Find data to check alarm
Does the data correspond to legit alarm?
• Location of triggered detector
• Type of alarm (smoke, heat...)
• Previous data from detector
Get visual confirmation
Is there fire or smoke develop ment in the area?
• Location of triggered detector
• Type of alarm (smoke, heat...)
• Feedback from runner
• CCTV video feed
Prevent general alarm activation
Can I acknowledge the alarm?
• Location of triggered detector
• Type of alarm (smoke, heat...)
Extinguish fire
Deploy fire teams
Ensure safety of crew
Activate fixed extinguishing system
Activate extinguishing zones
Which can/should I activate?
• Type of extinguisher system
• Crew location
• Place of fire
• Growth of fire
• Fire walls
• Main vertical zones
• Temperature
• Smoke
Find the correct extinguishing zone
What extinguisher systems are available?
• Supression system map
• Place of fire
Esure safety of passenger
Get passengers out of dangerous areas
Are there passengers in "fire areas" ?
• Area of fire
• Area of smoke
• Spread of fire
• Spread of smoke
• Type of area
Check rooms in dangerous area
Are there any passengers in the rooms?
• Checked rooms/areas
• Location of rooms
• What is being checked now
Evacuate passengers
Ready lifeboats
Which lifeboats can be used?
• Location of fire
• Smoke development
• Wind direction
Deploy life boats
Can lifeboats be deployed?
• Passenger count true
• Passenger count now
• Crew count true
• Crew count now
• Go signal
Muster passengers
Are all passengers here?
• Evacuation progress
• Passenger count true
• Passenger count now
Deploy fire teams
Muster fire teams
Where should they muster?
• Location of fire
• Type of fire
• Teperature development
• Smoke development
• Active extinguishing systems
• Dangerous objects
• Firewalls
• Fire doors
Plan fire extinguishing
What is the best way to extinguish the fire?
Understand fire scenario
How is the fire now and how will it be in the future?
• Available extinguishing equipment
• Place of fire
• Development of fire/smoke/temp.
• Temperature level
• Smoke level
• Available extinguishing systems
• Active extinguishing systems
• Dangerous objects
• Firewalls
• Fire doors
• Main vertical zone
• Dampers
Ensure safety of crew
Understand fire scenario
Keep crew safe
Are the crew still safe?
• Location of crew
• Time spent smokediving
• Crew actions
• Fire development
• Smoke development

The GDTA also illustrates just how much information is needed to develop a good situational awareness over a fire situation. This can be problematic as it can lead to information overload if we show all of the information simultaneously. Luckily, as both Endlsey & Jones and Ware (Endsley & Jones, 2016; Ware, 2013) points out, the process of creating an awareness of any situation will naturally alternate between a “bottom up” and “top down” processing (fig. 3.2). This means that, at some points, you might notice something new and need to process what this new information is (bottom up), and sometimes you might search for a specific information, so you tune your visual pattern finding mechanism to quickly find the desired information (top down). In the context of a fire central, this means that it doesn’t have to show all the information from the GDTA at once, but only the information that will be processed bottom up, i.e. when an alarm is triggered, or a sprinkler system activates. This, of course, doesn’t mean that all the other information should be hidden away and be hard to find, but the information can be somewhat hidden as long as it is easy and quick to find with a visual search.

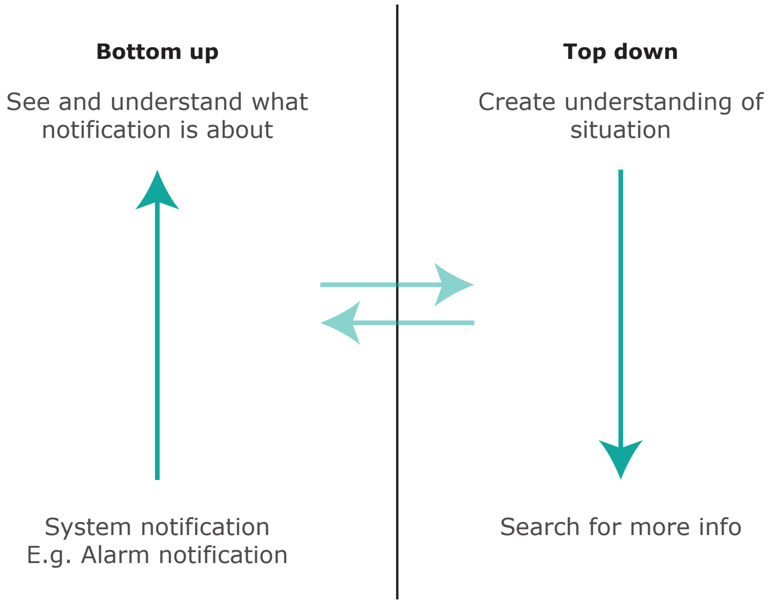


Figure 3.2
Bottom up and top down processing will alternate in any situation.

3.2 Input and output overview

In addition to the information gotten from the fire central, it would also be good to control some relevant ship systems from this fire central. The modern fire centrals today can already control some fixed extinguishing systems, but from my interviews and ship visits, it seems that it would be very helpful to also control doors, dampers, ventilation and other systems used for firefighting.

A simple input & output overview was created to map out systems into two categories; input & outputs and inputs (figure 3.3). The input category consists of systems that purely give an input to the system and cannot be controlled in any meaningful way. These are mostly fire detectors and CCTV. The input & output category consists of systems that can be controlled remotely from the bridge and gives an input to the bridge as to what state they are in. There is no pure output category as any system that can be remotely controlled will also need to have some feedback as to what state the system is in.

Figure 3.3
A quick overview of the inputs and input & outputs found on ships

3.3 Sketching

To verify the concept, I started sketching screens for the portable tablet fire central. The sketches were meant to communicate the concept of having a "google maps"-like map over the ship with options to activate systems and see the state of the ship through data from fire detectors as well as fusing sensor data into heatmaps and smokemaps. I would then bring these sketches with me on ship visits and discuss the concept with the crew aboard.

I decided to start sketching for the small screen portable fire central as this would be easier to bring on ship visits. In addition, it is generally easier to scale designs up for bigger screens than scaling them down.

3.4 Covid-19

Unfortunately, before I had finished my sketches, the Covid-19 pandemic hit Norway and it became impossible to visit any relevant ships. In addition, the ferry company I was planning on visiting shut completely down, thus making it hard to get into contact with ship crew over internet. Luckily, through one of LASH FIRE's contacts, I managed to plan a video interview/user test with a chief engineer working on a ship from a major ferry company operating in the Nordics.

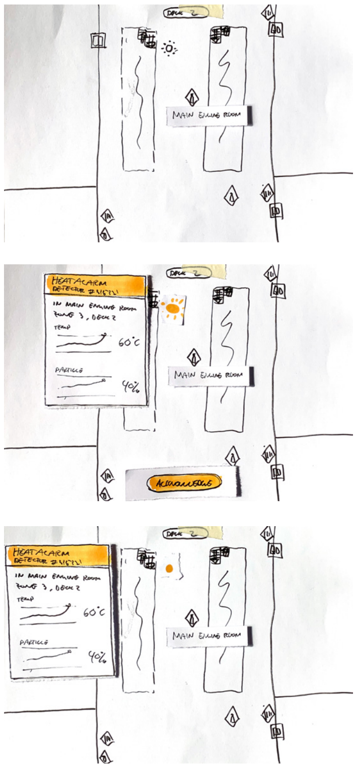


Figure 3.4 ↑
Sketches for a paper prototype to be tested on ship visits.

Figure 3.5 ↙
Some exploratory sketches for the concept.

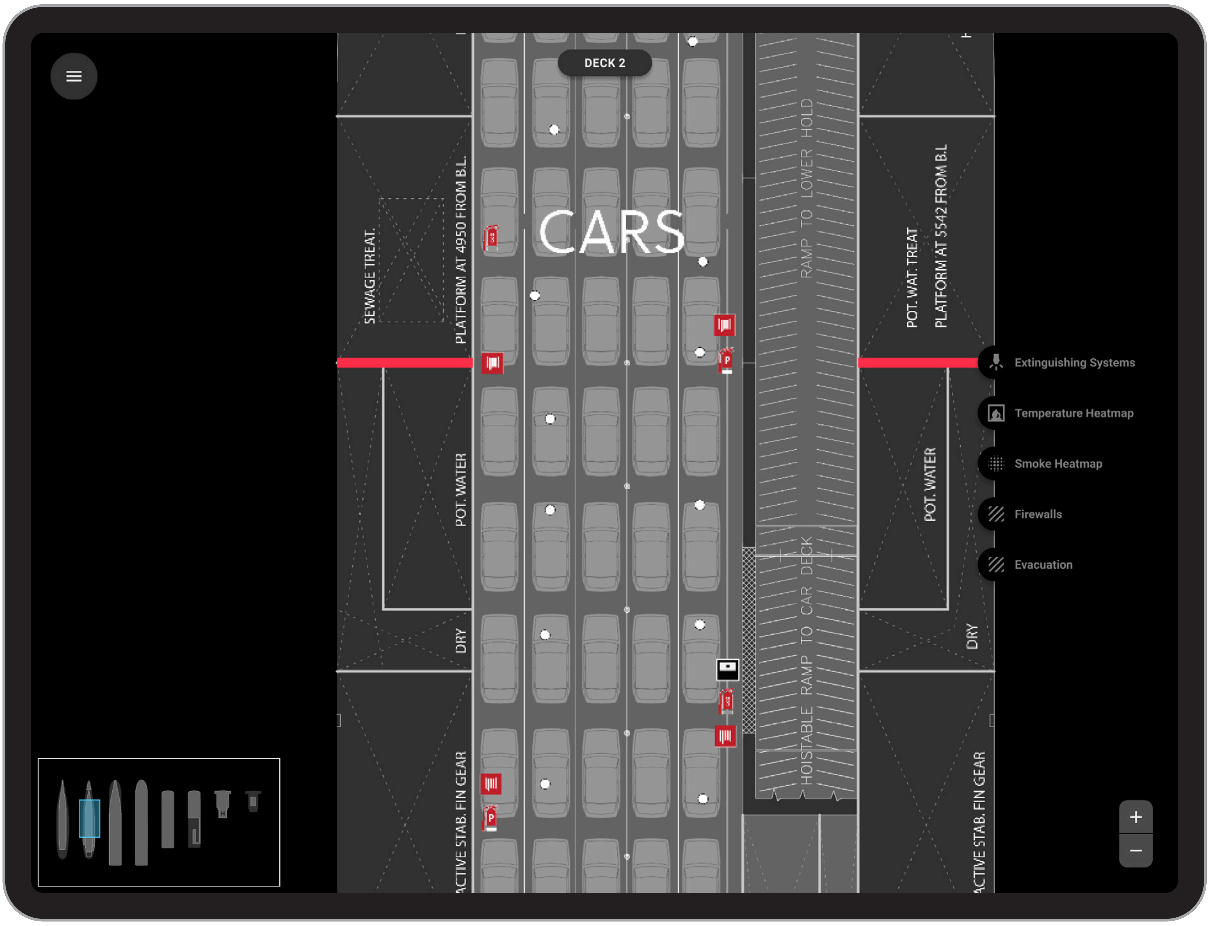
4 Prototype I

I quickly realized that showing paper sketches and prototypes over video chat would become problematic. Mostly because of poor video quality, but also because the paper sketches and prototypes would not do a great job in explaining the concept on its own and would need some explaining and demonstrating, which is not very easy over video. Because of this, I decided to skip the paper prototype and rather make a quick digital prototype. This digital prototype did take a little longer to make, but it also explains the concept much better.

The prototype was created in Figma and the map and systems layout are taken from the fire control map and general arrangement file of *MS Generic* (see appendix E). To make the prototype as quick and easy to create as possible, it is restricted to only one deck.

Figure 4.1 shows the starting screen of the prototype. It consists of a main map, a small overview map, buttons to toggle layers, zoom and open a menu.

Figure 4.1
Starting screen of prototype 1



The main map covers the whole screen and functions much like “google maps”. You can drag your way around the map and zoom out and in to show more/less detail. On the map you find symbols that shows the location of different extinguishing equipment and all the detectors and manual call points on the ship. By clicking on the symbols, you get some more info regarding the equipment/component, for example temp and particle levels for a specific detector (figure 4.2a). On this prototype, however, the zoom doesn’t work and many of the symbols cannot be clicked, as this would add a considerable jump in complexity and make the prototype too refined for the current design stage.

Figure 4.2b shows an example of the information shown when clicking on a firehose. Here, the length of the firehose is not only written in text, but also shown graphically with a green circle.

Figure 4.2c and 4.2d shows examples of map layers. Here a fixed extinguishing systems layer (figure 4.2c) and both a heatmap and smokemap layer (figure 4.2d). The extinguishing systems layer shows which areas are protected by which extinguishing system through colored and textured overlays and labels. The different types of fixed extinguishing systems aboard are also color coded, and a color key is displayed at the bottom of the screen.

The heatmap is discretely color coded from blank to blue to yellow to red and the smokemap is discretely coded with varying density textures. This way, both maps can be read at the same time, since one uses texture and the other uses color. The semantics of the colors are also important, and it seemed fitting that the heatmap goes from blue (cold) to red (warm) and the smokemap with varying densities of black particles. The blue-yellow-red color gradient also has the happy side-effect of being able to be perceived by people suffering from the most common forms of color blindness (Ware, 2013).

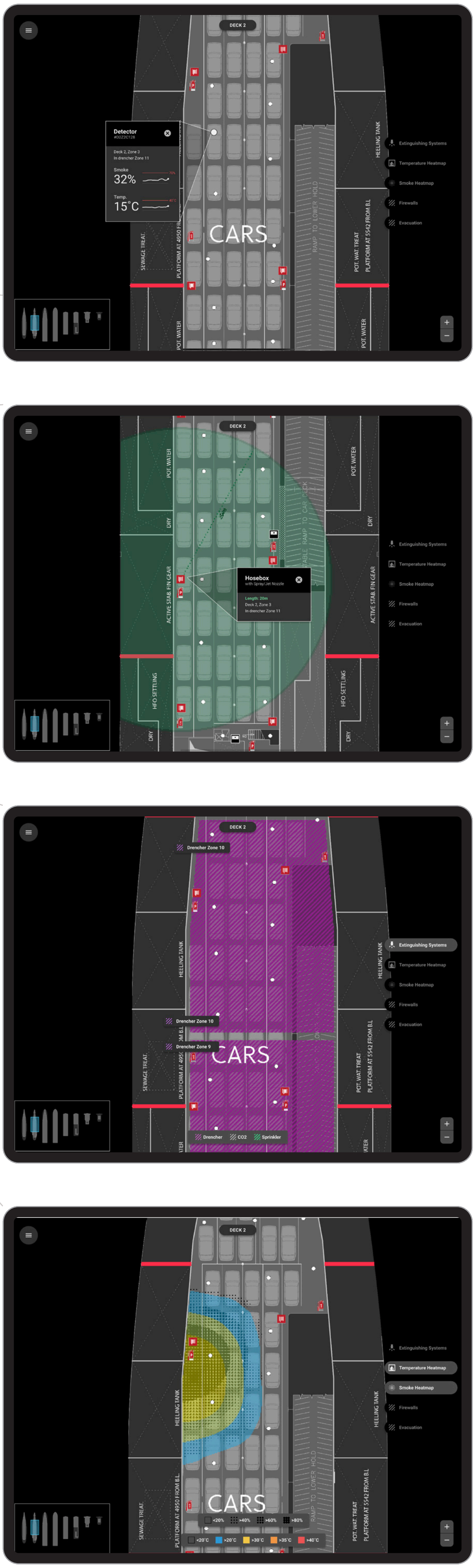


Figure 4.2 a-d
From top:
a: Detector info
b: Firehose info
c: Fixed Extinguishing
d: Heat- and smoke- map

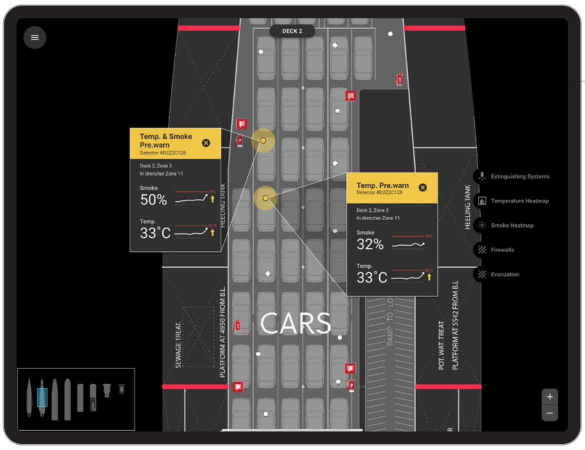
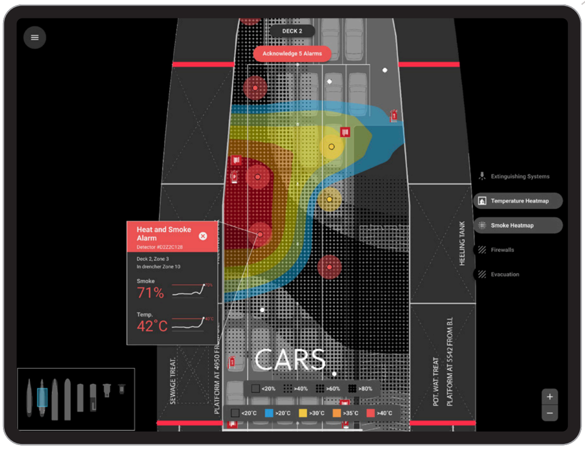


Figure 4.2e and 4.2f shows various stages of alarms. Figure 4.2e shows two temperature increase prewarnings and figure 4.2f shows several temperature and smokealarms.



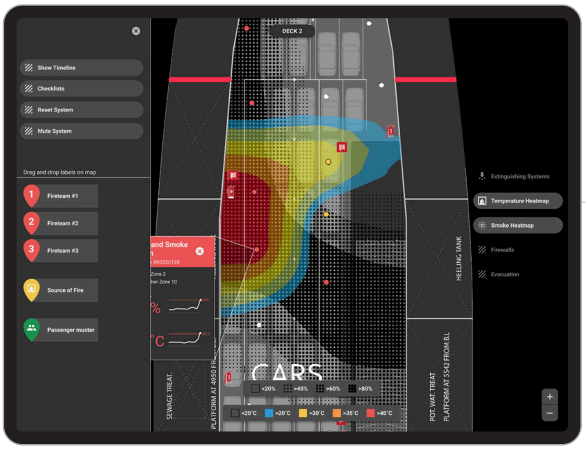


Figure 4.2g shows the concept of dragging and dropping tags/labels onto the map, so that the person in charge can mark where fire teams are or where the fire actually is.

Figure 4.2h shows a timeline of alarms and events that has happened. The concept is that the user can scroll through the timeline and the map will go back in time to where the timeline is scrolled. In this way, the user can scroll back and forth to get a better understanding of how the fire situation has evolved.

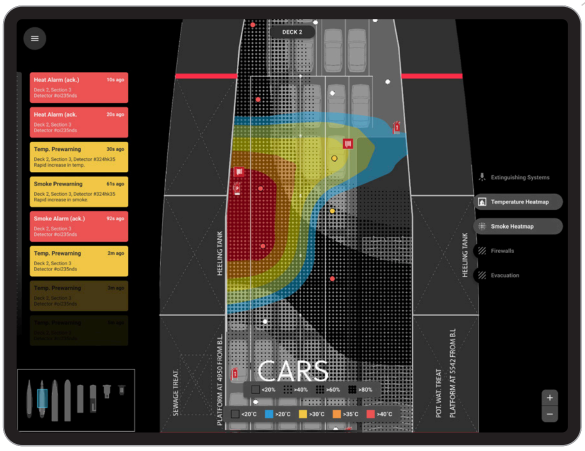


Figure 4.2 e-h
From top:
e: Two pre-warnings
f: Several alarms
g: Drag and drop markers
h: Alarm timeline

4.1 Dark colors

Several studies have shown that positive text contrast, that is white background with dark text, outperforms negative text contrast regardless of ambient light conditions ((Buchner & Baumgartner, 2007; Dobres, Chahine, & Reimer, 2017). This might also be true for graphs, where a light background with dark graphs is easier to read accurately (Shih, Huang, Lu, & Shih, 2013). The reason might be that a light background makes the overall screen lighter, which makes your pupils contract and consequently makes objects a bit sharper (Piepenbrock, Mayr, & Buchner, 2014). Whether the increased accuracy and performance of positive contrast makes any difference outside of a laboratory is uncertain. The studies do make a strong case though, and it might seem smart to have a light UI with positive contrast on a digital fire central.

On the bridge, however, it is simply not practical to have a large touchscreen with a light UI. This is because the bridge is completely dark during night sailing (see figure 2.43), so as to make faint light signals and navigation lights visible. It would, of course, be possible to just dim the display at night, but this will make the display very hard to use at night since dimming also decreases the screens contrast. Another option is to have a negative contrast UI, or a “dark” UI. Such an UI has an overall brightness much lower than positive contrast UIs while still having a good text to background contrast.

Page 47

It seems like having a UI that can change between a dark and a light UI dependent on the room-brightness (or even by just clicking a button) would be the best. Then the bridge could switch over to a dark UI during night, while the control room and safety room can have a constant light UI as these rooms are solely lit by artificial light. This function is already implemented into electronic chart displays, or ECDIS, and seems to work very well.

To make my life easier, I decided to focus on a dark UI for this thesis. A dark UI might be slightly less efficient and accurate than a light UI, but at least it can be used in both night and day scenarios.

4.2 Testing and co-creation

The prototype was tested through a video call with a chief engineer from a major Nordic ferry company. The prototype was sent to the chief engineer prior to the video call, so that he could click through it before the call. The call was used to discuss the concept in more depth and see if the concept is something that would help and be used in a fire situation.

In general, the chief engineer was very positive to the concept and the prototype. He especially liked the way you could navigate around and toggle different information layers. He also liked the concept of having a large touch panel on the bridge, but he would like two displays; one for fire management and one for evacuation. The portable fire central was not an instant sell though, and he said that it would maybe be better for the evacuation team. On the other hand, he also said that the portable fire central could make reporting between teams easier.

Figure 4.3 is a list of what was good with the concept and what had improvement potential.

Figure 4.3
Summary of key insights from usertests

🎉 **Good:**

Easy navigation
Layering information
Drag and drop markers (fireteams and fire location)
Heatmap and smokemap
Histogram and trendlines
Radius on firehose (graphical)
Prewarning for increasing temperature and particle
"Google map" like map

🛠️ **Improvement potential:**

Wants sideview of ship. Can use as quick navigation
Pressure on fixed extinguishing system
Info about scuppers. Especially if all is open
Info about firewalls
Info about doors
Highlight trash chute and elevator when fire (or other risk objects)
Better, more accessible timeline
Looping play function
Show frame numbers
Timer to suppress detectors in car deck
Pop-up overload when many alarms

5 Prototype II

After the positive feedback on prototype no 1, I started creating a more interactable prototype. At first, I planned to just iterate on prototype 1. However, prototype 1 was not created to be fully interactable, because of this, it was easier to create a new prototype from the ground up.

5.1 User scenarios

To get a better overview of how a digital fire central will be used, two user scenarios were created (fig. 5.1). The scenarios are created from insights from my ship visits and interviews and they show two different possibilities when a fire alarm is triggered. The two scenarios are opposite of each other in terms of severity, where the first is a falsely triggered alarm and the second is a legitimate fire alarm.

Together with the user scenarios, I also sketched a few corresponding screen sketches. The purpose of the screen sketches was not to accurately show how the screens will look like, but rather translate the scenarios into how the system might respond to them.

Figure 5.1 →
Two scenarios with screen sketches. Blue is false alarm, red is fire in car deck.


Scenario
An alarm sounds in fire central
Operator sees alarm location
A runner is sent to check
Screen
System shows alarm
Runner confirms false alarm
Operator mutes the alarm
Business as usual
System shows alarm in passenger room
Mute alarm for x minutes
Muted alarms are clearly visible
Runner confirms fire
Operator sees more alarms triggering
Activates extinguishing systems
Fire team gets ready
Operator plans manual extinguishing
Fire team is sent in and extinguishes fire
Alarms are going away
Fire is extinguished and operator disables broken detectors
System shows alarm in car deck and highlight el- car
More alarms in different zone and system highlights dangerous objects
System starts general alarm unless acknowledged
System activates extinguishing automatically
Drop marker and keep track of smoke diver timer
Alarms are going away. A few detectors are broken
Select broken detector and disconnect
When all alarms are gone, unmute detectors

5.2 Fictional ship

The last prototype was based on technical drawings and fire control map of an existing ro-pax ship. I was planning on continuing using this ship as the basis for the prototype as it accurately describes how most ships are today. However, the work involved in converting all 8 decks into something that I could put into Figma proved to be too much. Instead, I decided to create a fictional ship and a fictional map for that ship. This made it easier to create the prototype in Figma later on, as the fictional map is smaller and much more light weight.

The fictional ship is based on *MS Generic* and *MS Newbuilt Explorer*, but much smaller with only 5 decks. The fictional ship is a modern ro-pax ship with a small closed car deck in deck 2. The entire ship is protected with a water mist system called Hi-Fog, except for the battery room, where a chemical system is installed. The ship has a restaurant, kitchen, a reception, several passenger rooms, dedicated crew space, machine rooms, workshops and even a sauna. Throughout the ship there are placed fire detectors, CCTV cameras, fire doors, watertight doors and dampeners.

The ship is, of course, not very realistic (as I am not a ship designer), but the map of the ship does contain most of the systems and equipment one would find in a real ship. The map is certainly real enough to be used in a clickable prototype.

Figure 5.2 shows a few of the decks on MS Fictional. The entire ship map can be found in appendix Q.

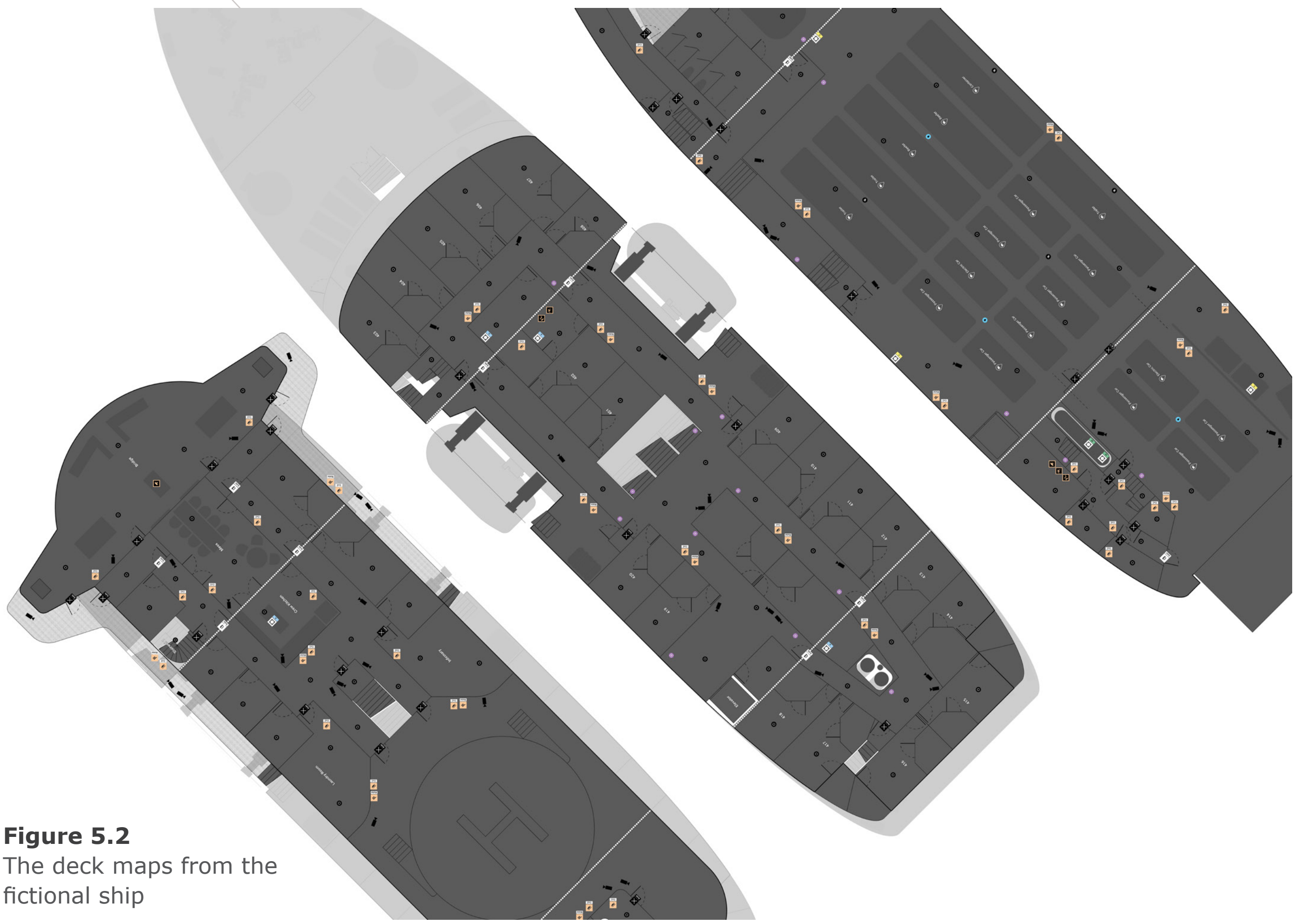


Figure 5.2
The deck maps from the fictional ship

5.3 Color choices

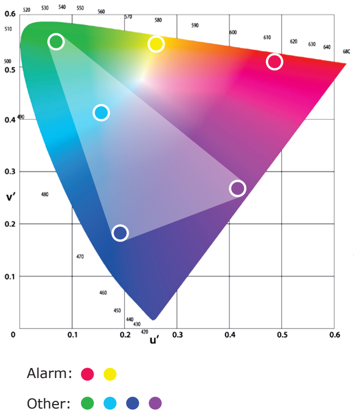


Figure 5.3
Red and yellow reserved for alarms. The other color's convex hull does not engulf red and yellow. This makes red and yellow stand out.

As with any information display it is important to make alarms and warnings as salient as possible. This is, of course, so that alarms will be seen quickly by the operator. Normally, I would just reserve red and yellow as alarm and warning colors and make sure that the other colors in the UI does not interfere with red and yellow. More technically speaking, I would make sure that the convex hull of the other colors does not engulf the designated alarm colors (Ware, 2013) (fig. 5.3).

Unfortunately, the marine industry has a lot of standards when it comes to color-coding equipment and symbols. In the case of a digital fire central, the IMO has set a standard that fire equipment (and basically anything to do with fire) shall be colored in bright red (IMO, 2017). This is fine when color coding signs that hang over the equipment, but it quickly becomes cluttered on maps that show all of the fire equipment on the ship (e.g. a digital fire control map). In the case of a digital fire central, the red symbols for fire equipment will mask alarms and make them less salient.

To work around the alarm saliency problem, one could simply change the colors of the alarms to yellow or blue and make sure that the other colors in the UI does not use these colors. The color red and yellow are, however, very culturally connected to alarms and warnings (at least in the west). This cultural connection might make alarms with untraditional colors less effective than alarms with traditional colors.

Luckily, hue is only one color-dimension and I can use luminosity and saturation to make the alarm color more salient. This way, I can reserve 100% saturated yellow and red for warnings and alarms, while still using darker and less saturated red and yellow for other symbols and UI components. To get this to work, I have to be sure that the three-dimensional convex hull of the other UI colors does not engulf 100% saturated yellow and red (fig. 5.4). I have also purposefully kept the color use in the UI to a minimum, so as to make alarms and warnings more salient.

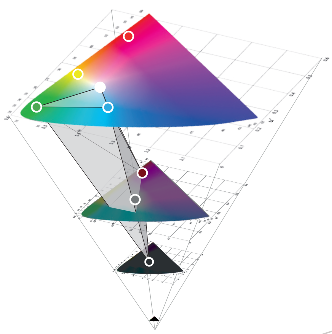


Figure 5.4
Saturated red and yellow reserved for alarms and the 3d convex hull of the other colors plotted in grey.

In this prototype, I actually tried to shift the color of fire extinguishing equipment to orange. The thought was that orange might be close enough to red to still be read as fire equipment while making alarms more distinct and salient. This did not work though, as a chief engineer pointed out, because orange is used for color-coding chemicals (see appendix I).

5.4 Symbol creation

On prototype 1 I simply used some arbitrary symbols to mark the different equipment and detectors on the map. The IMO have defined several symbols for use in ships, and 52 of those symbols are specific for fire control plans (figure 5.5) (IMO, 2017). However, the symbols are intended for printing and they are not very easy to visually search through.

Figure 5.5
The IMO symbols for use in fire control plans

I decided to create new symbols for the different equipment and systems on the ship. The goal of creating new symbols is to optimize the map for visual queries, that is, making the map and symbols easy to visually search through. To do this, the symbols needs to be distinct from each other in shape and color. It is, however, impossible to make over 50 symbols distinct from each other while also making them easy to remember and search through. To work around this, I sorted the symbols into categories and made each category with a distinct form language. In this way, it is easy to search for a specific category, then search for a more specific item within that category.

To create the symbols, I started by sorting the IMO symbols into ten different categories (fig. 5.6). I also added detectors, CCTV, manual call point, cars, cargo, dangerous things and charge station as part of the categories.

Next page

The charge station and cargo are another LASHFIRE project. The project looks at automatic screening of cargo and digital surveillance of the charging of electrically cooled or warmed trucks/containers (aka reefer). This info is very valuable to have in a digital fire central, as it can show where there is dangerous cargo and whether a reefer has a charge error (which might indicate an origin of fire). In addition, I decided to add the actual charging station as a point of interest on the ship map. This charging station can then monitor the charging of connected vehicles and trigger an alert if there is a charge error. This could be useful in the future when more and more electric cars are getting charged aboard. In this case one does not necessarily know the exact position of the car itself but seeing an error in a charge station will give a strong hint to where the erroneous car is located.

As the digital fire central is, well, digital, it is not necessary or very user friendly to show everything as small symbols on a map. Instead, many of the systems can be visualized with larger color-coded graphics and layers. An example of this is the fixed extinguishing zones. In the paper fire control map, the fixed extinguishing zones is shown wither by a small symbol or a line indicating the area of a sprinkler zone. In the digital fire central, it is better to show the sprinkler zones with colored overlays that can be toggled on or off, as shown in prototype 1. Because of this, some of the symbols are simply put into a category named “color, texture, graphically coded”. This category contains the symbols/systems that will be shown in a more substantial way than just a symbol.

After sorting the symbols into categories, the categories where then again sorted into triggers, primary and secondary (fig. 5.6). Triggers are things that can trigger alarms or warnings, i.e. detectors, primary are things that will need to be easily differentiated from each other and secondary are less important systems and locations that doesn’t necessarily need to have their own type of symbol. Broadly speaking, the primary categories are systems and equipment that is frequently used in fire extinguishing or evacuation, while secondary categories are systems installations that doesn’t need to be as salient as the primary categories since they are not actively used in fire extinguishing or evacuation.

After dividing the different categories into three, I started sketching and designing the different symbols for the different categories (fig. 5.7). The designs use the standard symbols from IMO as a basis but diverges in several different ways to make them better for visual queries.

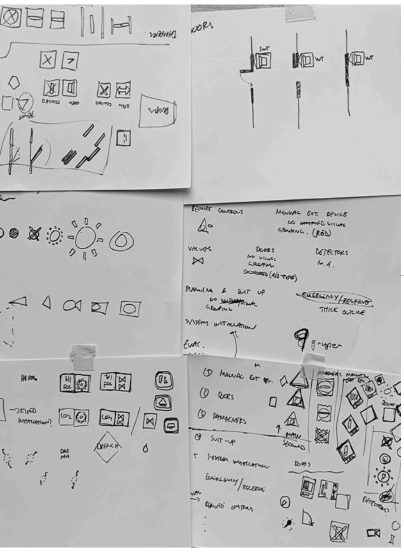


Figure 5.7
Some exploratory symbol sketches

Figure 5.6
Symbols sorted into categories, and then into triggers, primary and secondary.

5.4.1 Triggers

The triggers are perhaps the most important element in the digital fire central as they graphically indicate warnings and alarms. As there are very many detectors and manual call points in a ship, the triggers need to be quite discrete when there is no alarm or warning but become very salient when a warning or alarm is triggered. Because of this, triggers are designed as small circular symbols with an icon in the middle (fig. 5.8). The icon indicates what kind of trigger it is, i.e. a detector, a manual call point or a charging station. When an alarm/warning is triggered, the symbol changes in both shape and color to become a lot more salient.

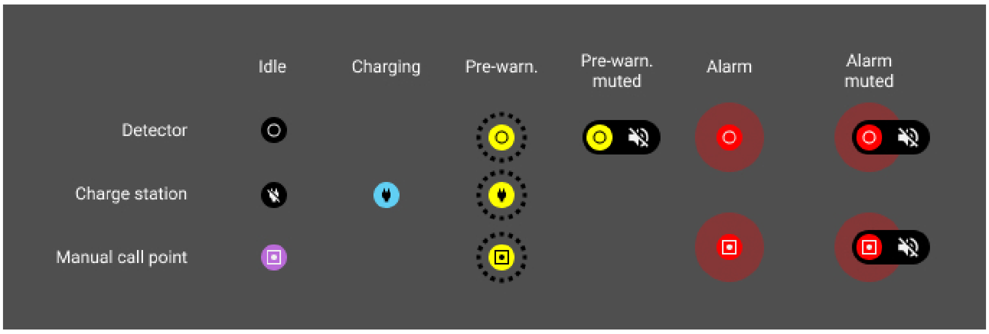


Figure 5.8
Overview of trigger symbols and their states.

5.4.2 Primaries

The primaries are differentiated from triggers in both size and their cornered and square shape. The categories within primaries are differentiated in both shape and color. This makes it easy to perform visual searches for a specific "primary category", as you can either search by shape or color.

The evacuation equipment (fig. 5.9), fire equipment (fig. 5.10) and planning and suit up equipment (fig. 5.11) are designed with similar outer shapes. This is to group together all handheld/manual equipment and differentiate them from doors and dampers. In addition, the equipment types are redundantly differentiated by color, lightness and/or shape and each equipment has its unique symbol. This will, hopefully, make it easier for the operator to perform visual searches either for a category of equipment, e.g. fire equipment, or for a specific equipment, e.g. a fire hose.

Figure 5.9
Examples of evacuation equipment symbols.

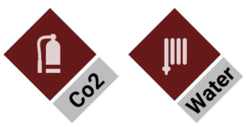


Figure 5.10
Examples of manual fire equipment symbols.

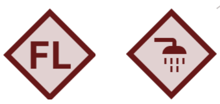


Figure 5.11
Equipment used for suit-up and planning.

DOORS & DAMPERS

The doors and dampers are perhaps the most important of the primary's symbols. They are important because a key part of firefighting is to close fire doors and dampers to both prevent the fire from spreading and cut off its oxygen supply. It is therefore paramount that the state of the doors and dampeners around a room (i.e. open or closed) is easy and quick to see.

In current graphical fire centrals, the state of doors are normally shown by either a red or a green arbitrary symbol, where green means closed and red is open. This might seem counterintuitive at first, but it makes sense because a closed door is good in the context of firefighting. In the context of evacuation, coloring an open door red does not make any sense. In addition, the red-green color coding is not very friendly for color blind people and it does interfere with the color of the alarms (figure 5.12) and makes alarms less salient.

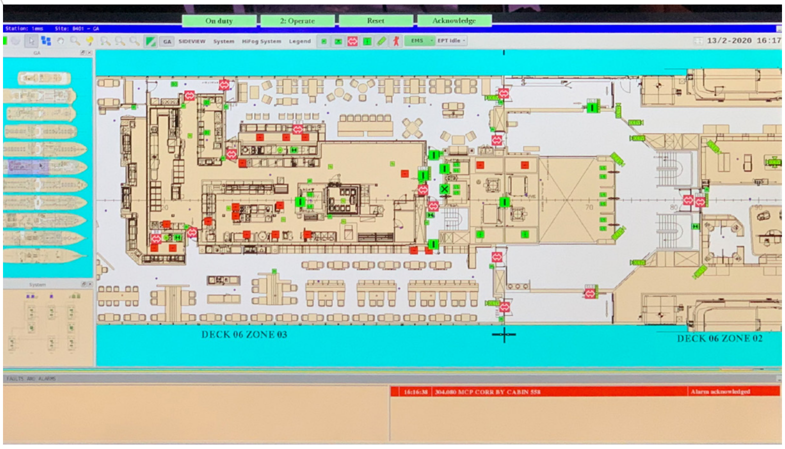


Figure 5.12
The fire central aboard *MS Newbuilt Explorer*. It is difficult to distinguish between alarms and an open door.

To fix the problems a red-green color-coding poses, I decided to change the colors completely. My first thought was to shift the color coding to blue and purple (fig. 5.13). These colors do not have any significant cultural meaning attached to them (except for blue is cold maybe) and could perhaps work equally well for both fire teams and evacuation teams. In addition, blue and purple lies on what is called a tritanopic confusion line, making them differentiable by most colorblind people (Ware, 2013).

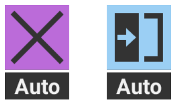


Figure 5.13
Blue and purple to color code an open and closed sliding door

The blue and purple marker does fight a little for attention though, and it quickly becomes a bit cluttered when there are multiple open and closed doors and dampers in one area (fig. 5.14). This clutteredness comes from the fact that the color-coding is paired with a symbol describing the equipment, i.e. damper or door. In addition, the markers incorporate coding for what kind of door it is (auto, semi watertight or watertight) and what kind of space the damper is closing (cargo space, machine space or accommodation space). The color-coding for the damper space is defined by the IMO, but whether this is something that truly needs to be incorporated into the marker or not needs more testing.

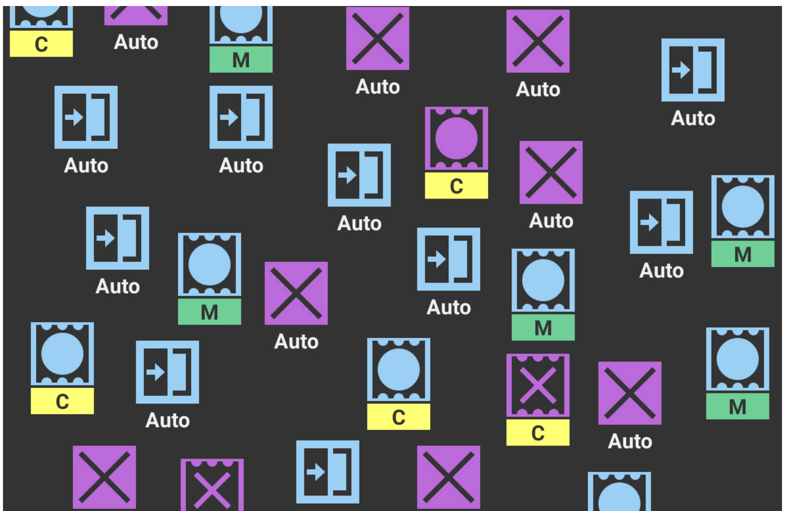


Figure 5.14
Several open and closed doors and dampers next to each other.

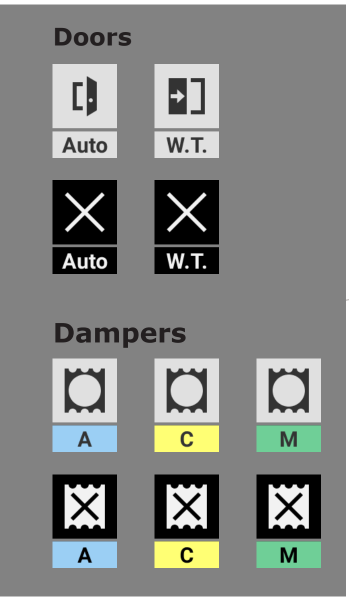


Figure 5.15 ↑
Symbols for fire doors and dampers, color coded white or black for open or closed.

An interesting phenomenon mentioned by Ware (2013) and showed by Theeuwes and Kooi (1994) shows that it is possible to do a conjunction search pre-attentively by using luminance polarity in contrast with the background as one dimension. That is, if I instead use white-black color coding and put the markers on a grey background, the shape of the symbols will be easier and quicker to find and search through. Inspired by this, I decided to use white for open and black for closed (fig. 5.15 and 5.16). This also have the effect (dependent on the darkness of the background) of making open doors a little more salient than closed doors. This is actually good, as it is important to notice an open door when dealing with a fire as well as when evacuating.

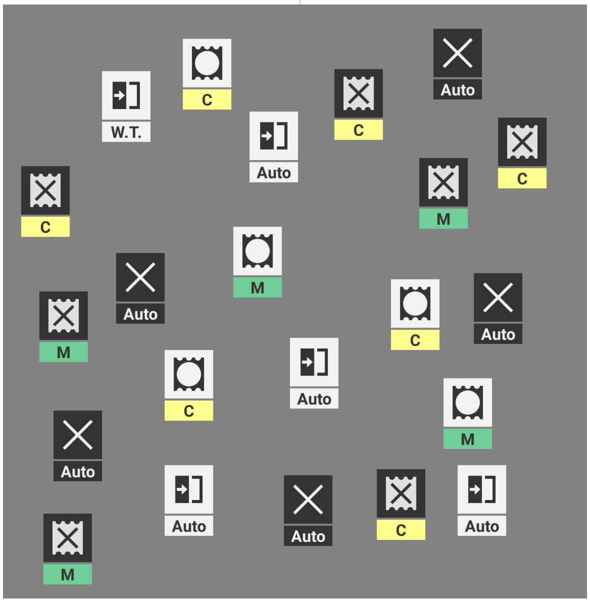


Figure 5.16 →
You see, much better. Several open and closed doors and dampers with black and white color coding.

REMOTE CONTROLS

The markers for remote controls are a bit redundant, as the control will be available through the digital fire central. In older ships, however, it will be useful to mark where the remote controls for different systems are. The marker is basically just a redesign of the symbols standardized by IMO. The marker consists of a triangle with a white outline, grey background and a descriptive symbol inside of what is being remotely controlled (fig. 5.17).

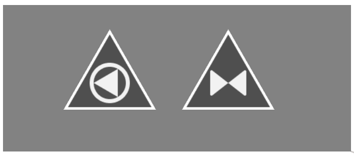


Figure 5.17
Symbols for remote control. The icon is specific for the thing being controlled and the outer triangle is in accordance with the IMO symbols.

CCTV

The CCTV marker bears more resemblance to the detectors as it needs to be quite understated to prevent cluttering the UI. The reason is the sheer amount of CCTV cameras aboard a ship, which quickly creates clutter if the markers grabs the operator's attention.

The marker is, in many ways, just a stylized image of a CCTV camera (fig. 5.18). It is also quite unique from the other markers in that it has a stronger directionality. This directionality is used to show where the camera is pointing. In addition, the marker is outlined to create a sufficient contrast with the background regardless of background luminosity or color.

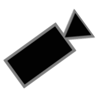


Figure 5.18
The CCTV symbol shows both location and direction of the camera.

5.4.3 Secondaries

The secondary markers are simply modelled after the classic map markers one finds in any other digital map. They are designed to live a little bit more in the background so as to not clutter the map. The map markers are mostly used for system installations and, since it is impossible to remember what every symbol means, it should be combined with an explanatory text (fig. 5.19).

Figure 5.19
Two secondary markers. One with text and one without.

SYSTEM INSTALLATION

The secondary map markers can also be colored to add a bit more attention to important systems or highlight a specific marker. This is done with reserve/emergency equipment (figure 5.20), but can also be done with other equipment as long as the colors does not interfere with the alarm colors.

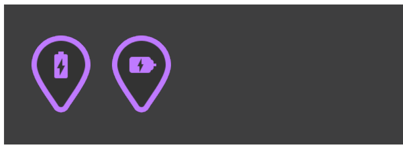


Figure 5.20
Markers for emergency equipment is highlighted in purple and with a thicker outline.

5.5 Alarm animation

To increase the salience of alarms, the triggers are animated when they go into an alarm state. The animation is in the form of a sinusoidal pulsating circle growing out of the detector marker (fig. 5.21, see appendix O for animation links)

The movement of the animation increases saliency and grabs attention by triggering your visual cortex cells that is tuned to local motion (Ware, 2013). In addition, it has been shown that the useful field of view is larger for moving targets (Petersen & Dugas, 1972). Basically, this means that the alarm animation will have a better chance of grabbing the operator's attention when he is focused on something else on the screen.

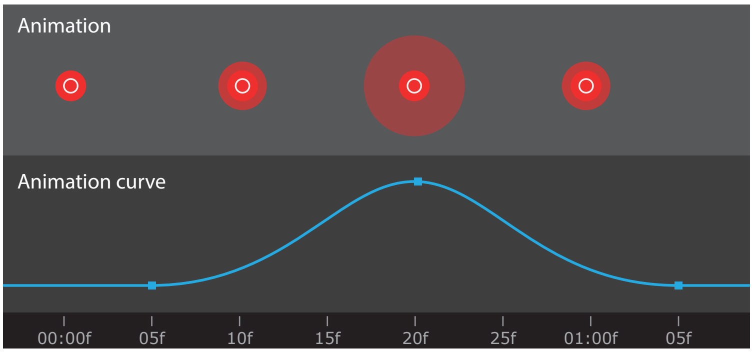


Figure 5.21
The figure shows the alarm animation at different keyframes. The blue animation curve shows the animation movement.

5.5.1 Time of events through animation

In addition to grabbing attention, the pulsating animation also creates an opportunity to show the chain of events at which the different detectors got triggered. The idea is to pulsate the alarms in a sequence that correlates to when the alarm was triggered in relation to the first alarm. From prototype 1, we already know that the system should include a timeline that can be scrubbed through to get an understanding of the chain of events. The pulsating animation can function as a supplement to the timeline by subtly indicating the order in which the alarms got triggered without needing the operator to actively seek for the information.

For prototype 2, the alarm animations were linearly shifted by 0.25 seconds to indicate the order in which the alarms were triggered. That is, the first alarm pulse at 0 sec, the second alarm pulse at 0.25 sec, the third alarm pulse at 0.5 sec and so forth (figure 5.22). This creates a wave of alarm pulses that starts at the first triggered alarm and ends at the last triggered alarms.

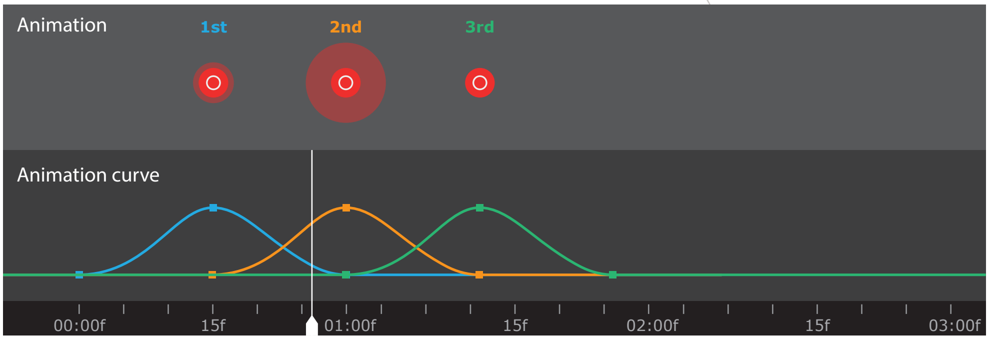


Figure 5.22
The figure shows three alarms and their animation sequence in relation to each other. The 1st alarm blinks first, then the 2nd, then the 3rd and so on.

For the sake of simplicity, only four different "pulse-timings" were created, and the alarms were grouped into these timings to show the chain of events. That is, all alarms triggered 0-1 mins after the first alarm will pulse after the first alarm all alarms triggered 1-2 mins after the first alarm will pulse third and so forth. This way it will always be possible to see which alarm got triggered first, and then follow the animation to see how the alarms are spreading.

5.6 WCAG

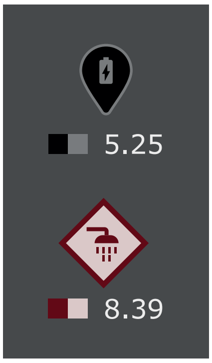


Figure 5.23
Two symbols and their internal contrast rating. Both are over 4.5 relative contrast.

As with any user interface, it is important to have sufficient contrast in order for information elements to be legible. I have already explained how the color-coding is chosen to be friendly for most color-blind people and how I use redundant and dual coding in both shape, color, luminosity and animation to make the system more user friendly. In addition to this, I have strived to keep a good contrast on text and symbols relative to the background. Text and symbols have at least a contrast of 4.5 relative to the background, but often the contrast is much higher. This gives an AA rating in the WCAG standard and meets the requirements of ISO-9241-3 concerning contrast and visual display requirements for office work. By and large, the text and symbol contrast should be enough to be legible for most people.

At some points in the UI, the contrast is deliberately kept quite low so as to not cause clutter. In these instances, an outline is used to create a sufficient contrast and ensure legibility.

5.7 The prototype

When the storyboards, all of the symbols and animations were in place, the creation of the second prototype started. The prototype is put together in Figma and to create it, I first created a makeshift design system (fig. 5.24). The design system splits everything down into components that I can use throughout the prototype. The main benefit of using a design system (at least for this prototype) is the possibility to change a master component and all of the components based on the master will change accordingly. From the components in the design system, the prototype was assembled.

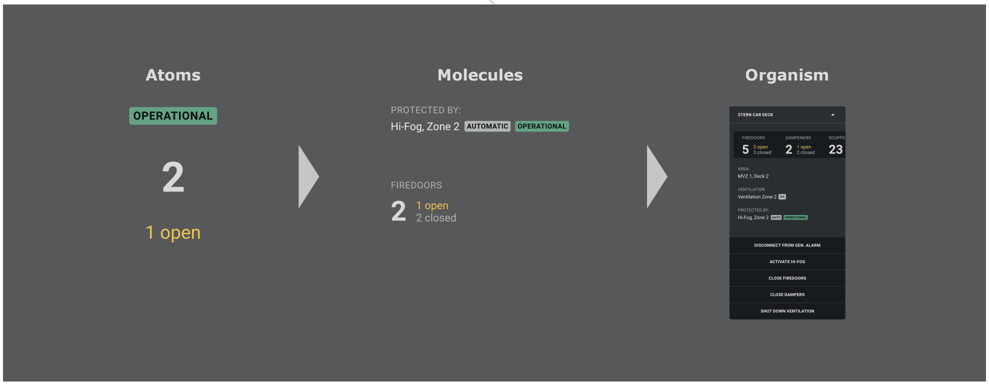


Figure 5.24
The design system defines building blocks ("atoms and molecules") on which I can create UI elements from ("organisms").

5.7.1 Overall layout

The overall layout of the prototype is very similar to prototype 1. It consists of a large map of the ship, with a small overview map in the lower left corner (fig. 5.25). A side view of the ship is also included in the lower left corner as suggested from codesign session of prototype 1. Other new things include a floor selector and navigation buttons on the right edge of the screen, as well as a timeline at the bottom of the screen.

Figure 5.25
Overall layout of prototype 2

5.7.2 Zoom

The prototype includes three zoom levels that can be switched between by using the plus and minus buttons in the lower right corner of the screen (fig. 5.26). Ideally, the zoom should be continuous by either scrolling with the scroll wheel on a mouse or by the “pinch to zoom” method. Unfortunately, this is not possible to prototype in Figma.

The three zoom levels also change the detail level of the map. This is to prevent information overload and cluttering when zoomed out, but still having the information readily available on a quick zoom in. When zoomed out, only markers for doors, dampers and ongoing alarms/warnings are shown in addition to room names. When zooming in, the map gradually changes to show more and more markers until everything is shown. At this point, the information overload is not as big a problem, as the map is so enlarged that the information density is manageable.

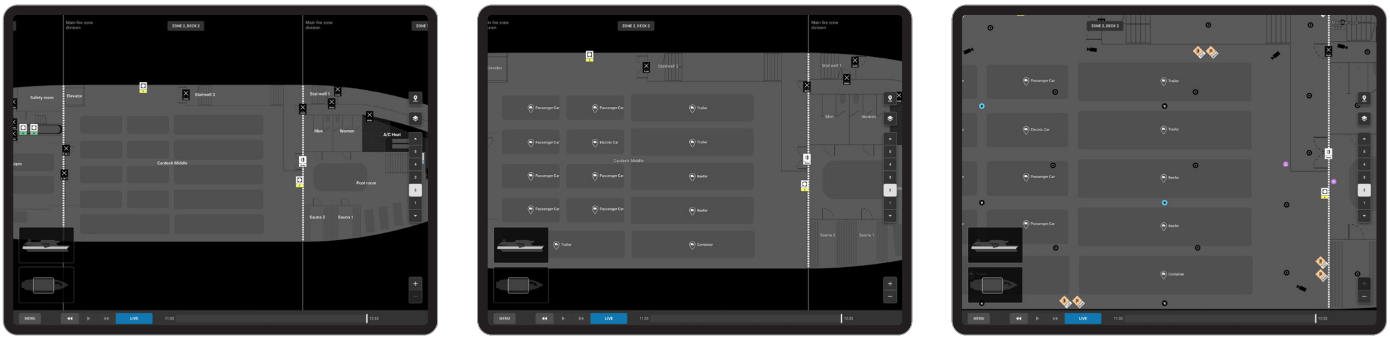


Figure 5.26
Three zoom levels with different information density

5.7.3 Panels

The markers on the map can be pressed to open an overlay panel with information on the specific component/equipment/system (fig. 5.27). In addition to the specific information for the clicked marker, I also added a panel with information and options for the room in which the clicked marker is situated in. This way, the operator can quickly close all dampers and doors to a room or area and even activate fire suppression systems without clicking excessively around in the system.

As this prototype is made for a ≈13” portable fire central, it is only possible to open one panel at a time. This is to not overcrowd the screen. On a bigger ≈55” fire central on the bridge, it should be possible to open several panels at once. It should also be possible to drag the panels around on the map and place them wherever the operator wants (as is prototype 1).

Figure 5.27
Figure of overlay panels. The panels are accentuated. More information and actions regarding the room/ area is readily available under the map-marker-panel.

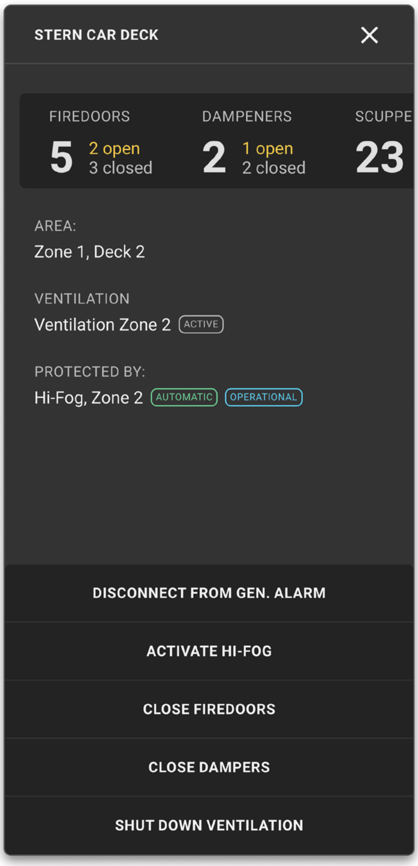


Figure 5.28
When clicking on a room, more info and actions about that room is available through the overlay panel.

ROOM

The room panel (fig. 5.28) can be opened by clicking on the name of the room on the map, but it is also available directly from any other panel as explained earlier. This panel includes information about the number of doors, dampers and scuppers inside the room and whether they are open or closed. The panel also includes info about where the room is (in which vertical fire zone and deck), the ventilation zone connected to the room and the fire suppression system installed.

Through the room panel, the operator can also activate the suppression system, shut down ventilation, close all fire doors and dampers to the room and disconnect the room form general alarm. The last option will basically mute all of the detectors/triggers in the room. This is useful for when dealing with larger fires so that the operator does not have to constantly acknowledge new alarms.

When clicking on a room, more info and actions about that room is available through the overlay panel.

DETECTOR

The detector panel has simply gone through a slight refactoring from prototype 1. It contains the same information, except it now also has a mute button. The mute button will stop the detector from triggering a sound alarm or the general alarm, but the alarm will still show visually in the system. When clicking mute, the operator can choose to mute the alarm for a specific time span or permanently (fig. 5.29).

The detector panel, and several other panels throughout the prototype, uses small pill markers to indicate whether the detector is connected to the fire central or if there is a connection error.

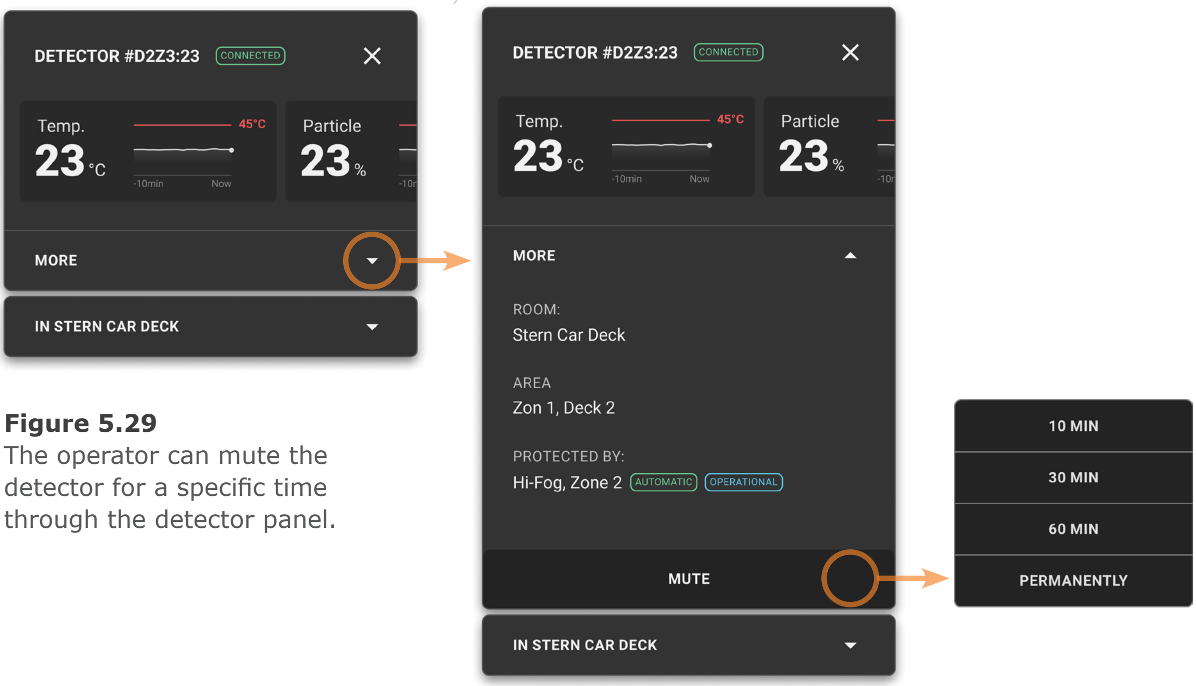


Figure 5.29
The operator can mute the detector for a specific time through the detector panel.

HOSE BOX & PORTABLE EXTINGUISHER

The hose box and portable extinguisher panel shows the same information as in prototype 1, with the addition of information about last service (fig. 5.30). The "last service" information is added to test out the idea of additionally using the fire central as a service system. In this use case, the portable fire central can be used to find the equipment in need of service, servicing them and updating this in the system. This whole service-aspect of the fire central is a thesis in itself and I will not focus much on it. It is, however, important to test if this information is useful when dealing with a fire.

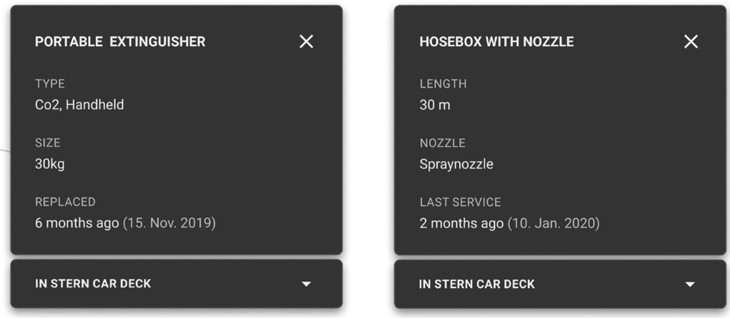


Figure 5.30
The hosebox and portable extinguishing panel

DOOR

The fire door panel can be used to close the selected fire door (fig.5.31). In the case of a sliding fire door, the fire door can also be remotely opened. In addition, the panel includes information on door type, fire class, state and connection status. The door state (open/closed) and connection status is shown through pill-markers.

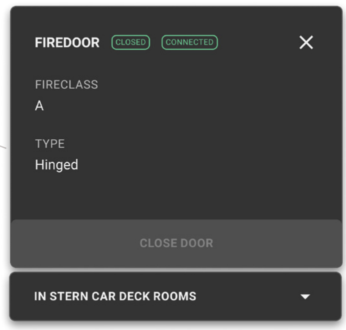


Figure 5.31
The fire door panel. From here, the operator can close a specific door.

DAMPER

As with the fire doors, the operator can open and close the damper from the damper panel. The panel (fig. 5.32) shows the connection to the damper through a pill marker. The panel also shows which room the damper is for. This is useful as the damper might not always be at the same deck or right next to the room it is connected to.

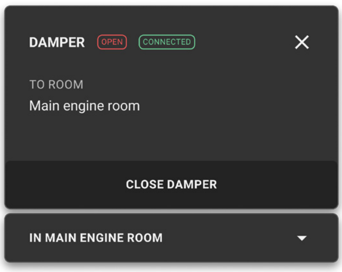


Figure 5.32
Damper panel

FIRE LOCKER

A fire locker panel was created but never used in the prototype (fig. 5.33). It was not used simply because it was not relevant for the scenarios during user testing. The fire locker panel simply contains a list of the equipment in the locker.

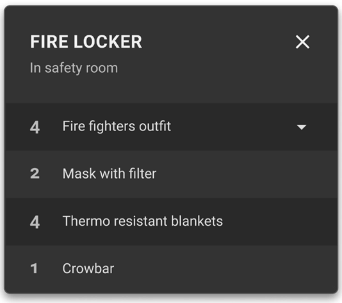


Figure 5.33
The fire locker panel shows a list of what the locker contains.

CHARGE STATION

As mentioned earlier, the screening of cargo and charge monitoring of reefers is another LASH FIRE project. Further on, I will simply refer to this project as “the charge project”. As the charge project is a separate project from the FRMC project, I will not get into too much detail around the technicalities of charge monitoring here.

In the charge project, the idea is to put information of cargo location, whether the cargo is dangerous or not and charge/power telemetry into a cargo monitoring system. In this system you can click on a truck or reefer on a map and get all of the cargo and charge information on that specific cargo. This seems like something that would be useful to show in a fire central as well, especially since reefers are likely fire starters.

A version of the monitoring system in the charge project has been incorporated as a layer in this prototype (see 5.6.4 Layers, page 82). In addition, I have added the possibility to get information on a specific charge station/power connection by clicking on the corresponding map marker. This charge station panel (fig. 5.34) shows information on power usage and temperature for each of its plugs and can trigger a warning if there is a charge error.

The charge station panel has several horizonal scroll sections where the operator can scroll through all of the different charge telemetries of a power connection. In addition, if the location of the cargo is known, the cargo and the connector is highlighted to show this connection (fig. 5.35).

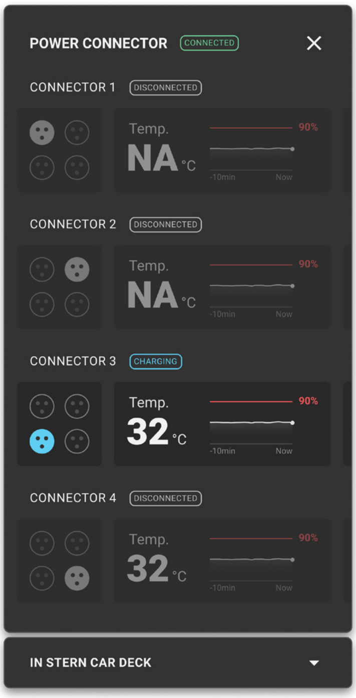


Figure 5.34
Power connector panel with one connected electric car.

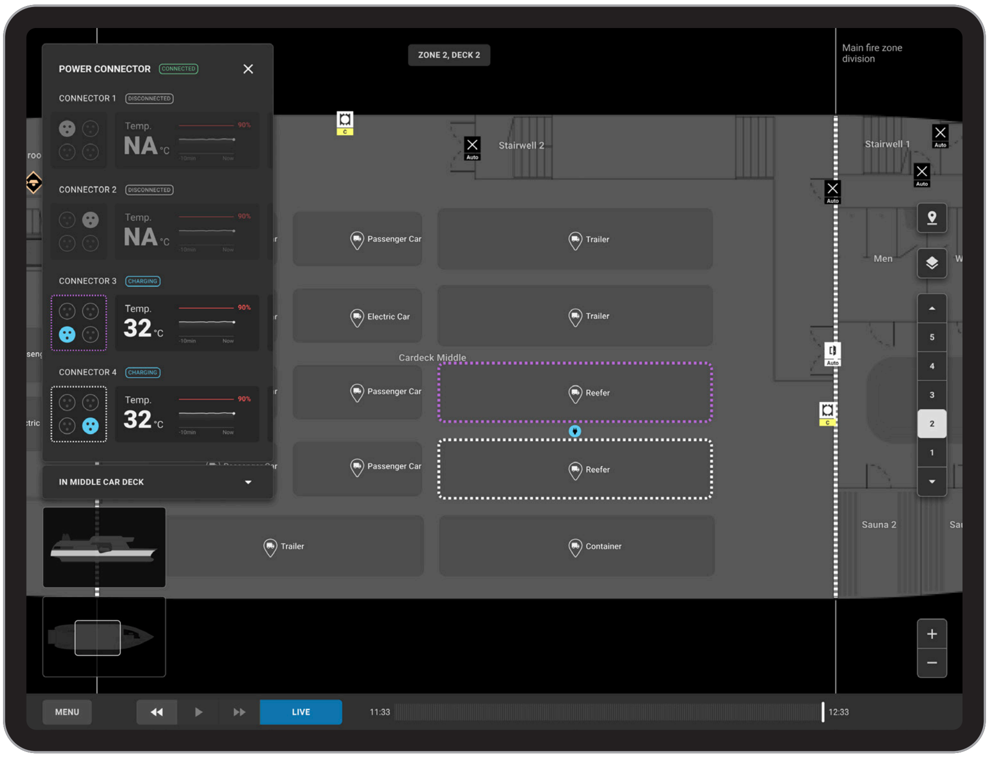


Figure 5.35
Power connector panel when two reefers are connected. The connected reefers are highlighted with stapled lines on the map.

CARGO

It is also possible to select a specific cargo/truck/car and get specific cargo information. If the selected cargo is charging, the charge telemetries for that specific cargo is shown in the cargo panel. Otherwise, simple static information about the cargo is shown. Exactly what information is shown varies from cargo type (fig. 5.36).

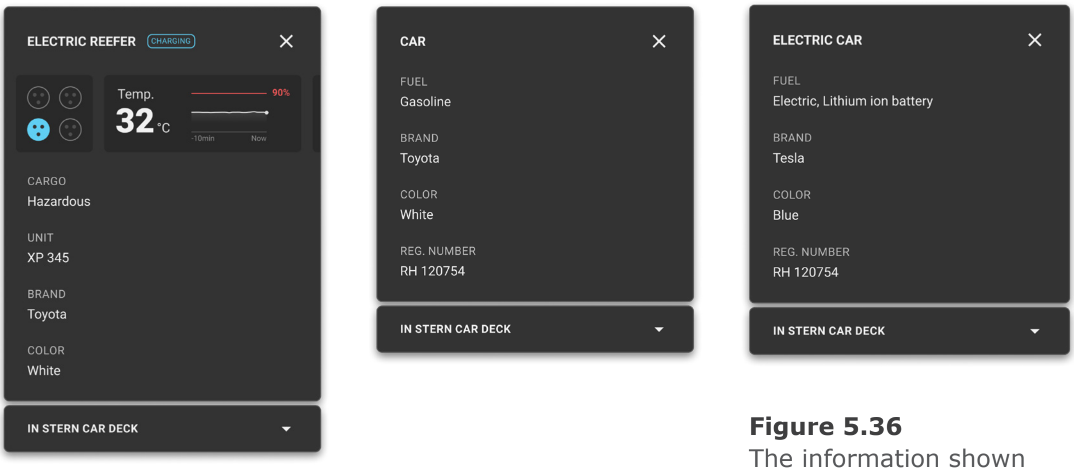


Figure 5.36
The information shown when opening a cargo panel depends on the type of cargo. Private passenger cars have little info, while cargo containers or reefers have more info.

CCTV

To open a CCTV feed, the operator can click on a CCTV marker and the video feed will open in a panel. The video feed can be expanded and scrubbed through. This is useful to check if a fire alarm is legitimate or to find out where the fire started.

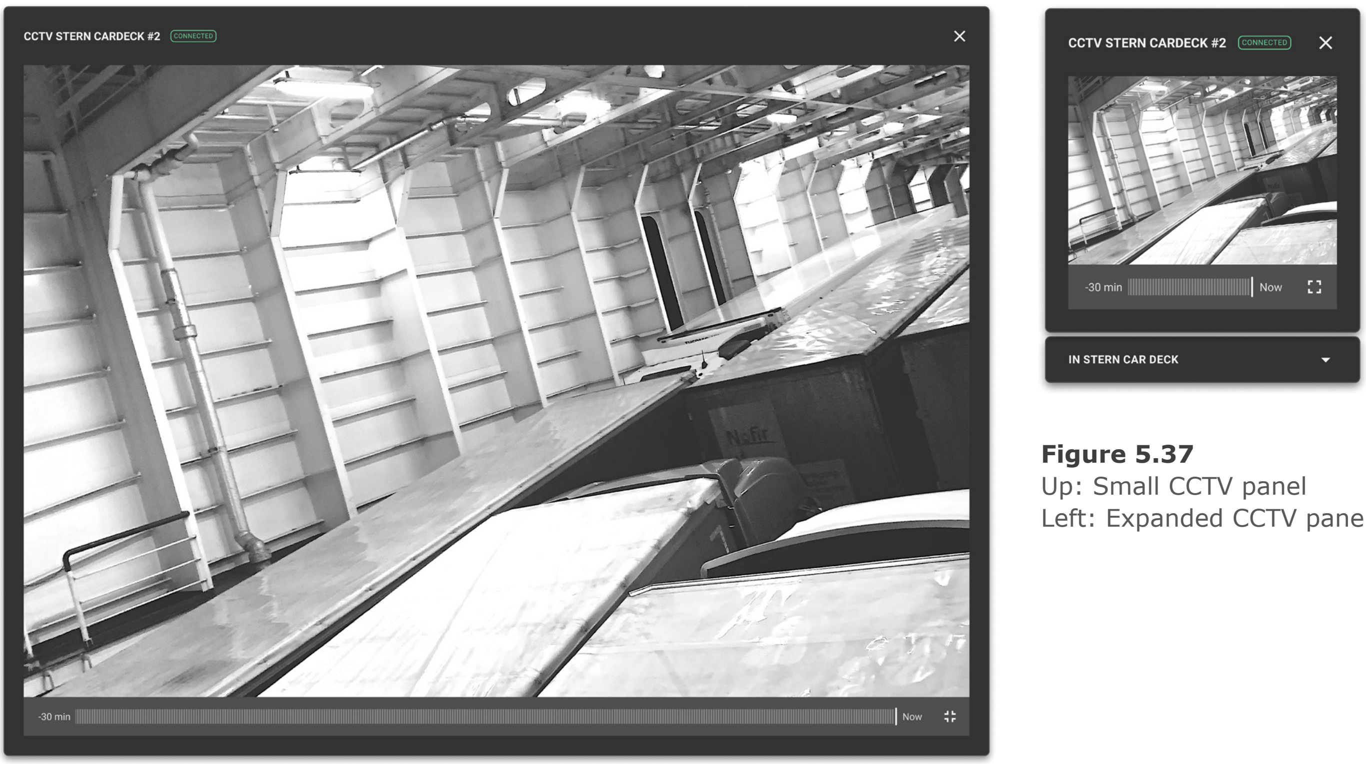


Figure 5.37
Up: Small CCTV panel
Left: Expanded CCTV panel

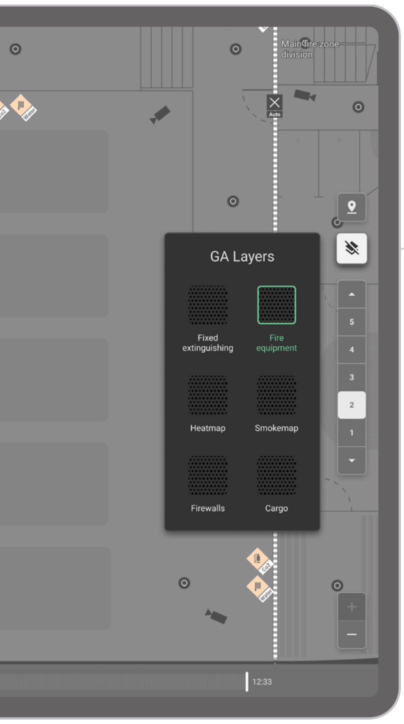


Figure 5.38
The layers can be toggled on/off through an expanding menu.

5.7.4 Layers

As in prototype 1, it is possible to toggle the visibility of different information layers. This toggle menu is now moved into an expanding menu on the right to preserve space (figure 5.38). Most of the layers in this prototype is similar to prototype 1, with the addition of fire walls and cargo layers.

The firewall layer (fig. 5.39) shows the firewall class for different walls throughout the ship. Normally, the firewalls are color-coded with red for A-class and yellow for B-class and nothing for C-class. This will, as explained earlier, interfere with alarm saliency. Instead, the firewalls are coded with thick white stapled lines for A-class and thinner stapled orange lines for B-class.

The cargo layer (fig. 5.40) color codes the cargo into how dangerous it is. In addition, it indicates what is charging and whether there is a charge error by using stapled and color-coded outlines.

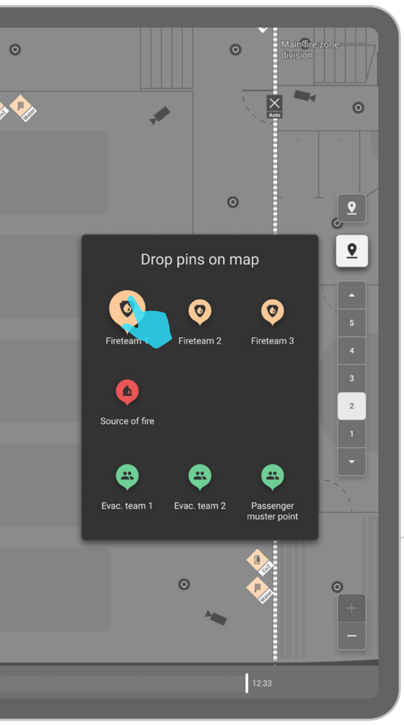


Figure 5.41
Through the "markers" menu, the operator can drag and drop markers onto the map. The markers function as a cognitive aid.

5.7.5 Drag and drop map markers

The drag and drop markers have been moved out from the menu and into an overlay expandable menu similar to the layer menu (fig. 5.41). This is to make it easier to quickly drag and drop fireteams or location of fire onto the map.

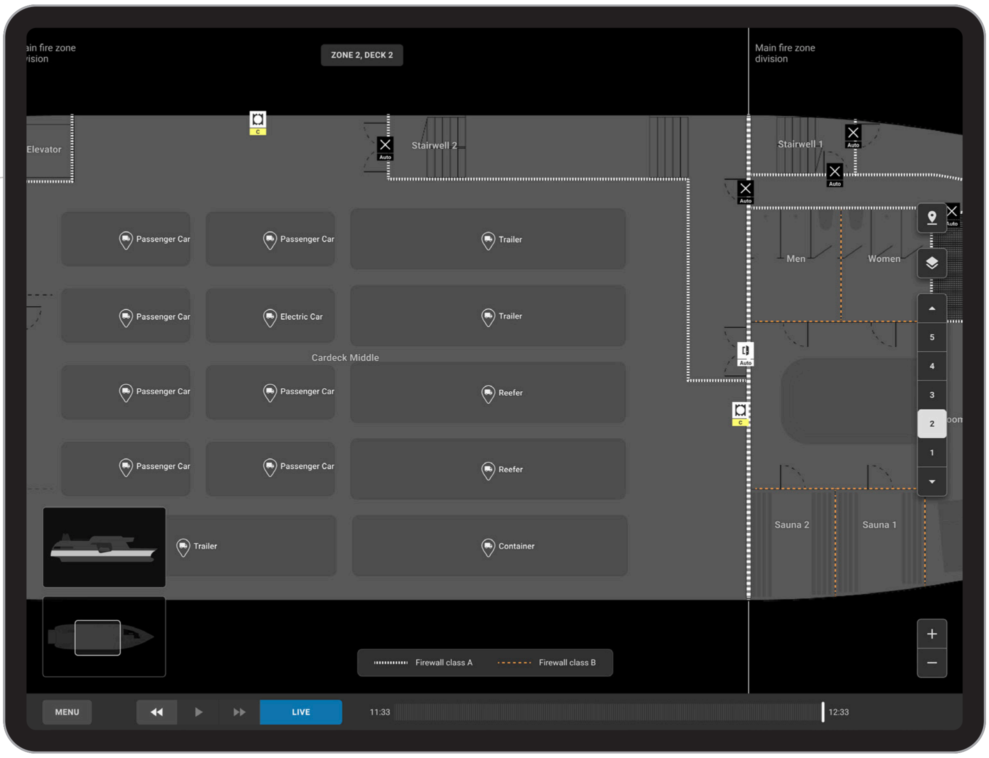


Figure 5.39
The fire central with the firewall-layer turned on.

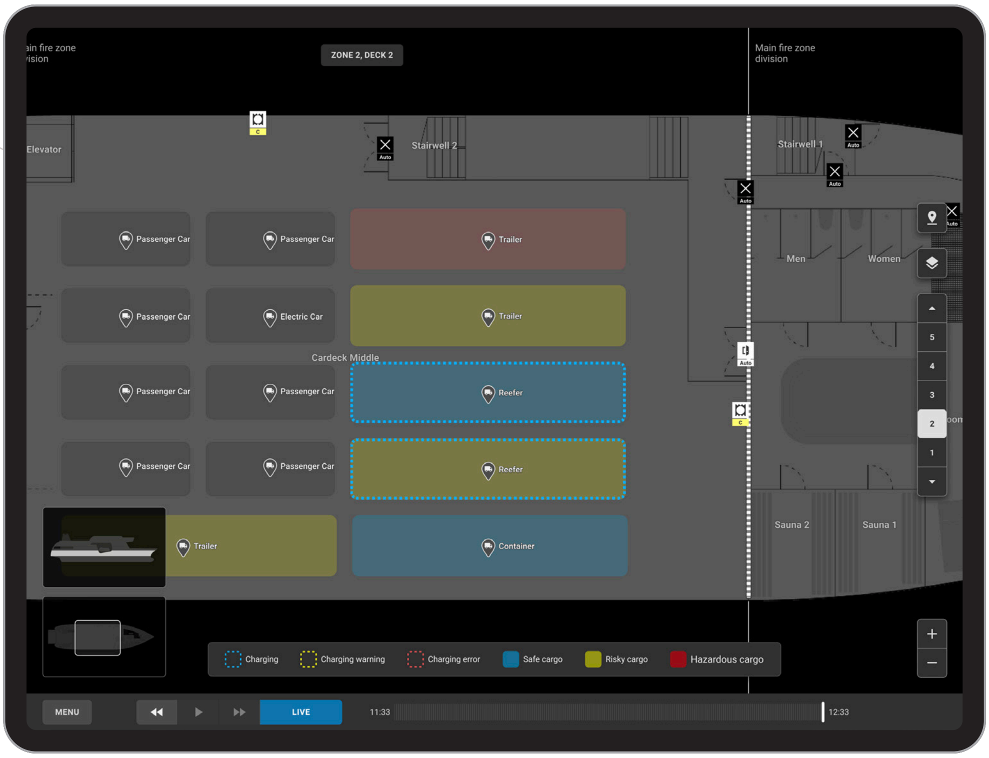
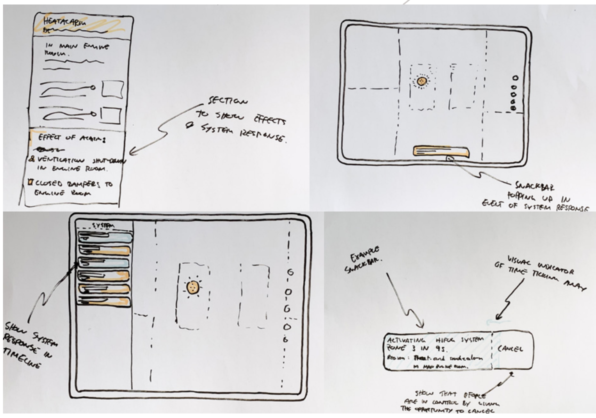


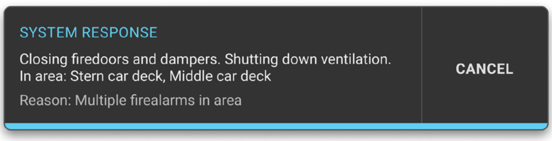
Figure 5.40
The cargo layer shows information about cargo danger levels and reefer charging.

5.7.6 Prevent out of the loop syndrome

In some of my visits (see appendix B - D) the systems aboard was partially automatic. Here, the system would respond to a fire alarm automatically by either starting the suppression system, closing fire doors or shutting down ventilation. This could lead to out-of-the-loop syndrome for the operator and might hurt the development of a good situational awareness. As Endsley and Jones (2016) calls it; a situational awareness demon .

In order to prevent out-of-the-loop syndrome, the system should be transparent in its automation. Exactly how to make the system transparent is difficult to figure out. It could simply show the system response in a detailed timeline, but then it would be hidden until the response is performed by the system. Another way is to give a sneak peek to what the system will do in the nearest future and how the system is dealing with the current alarms. In the end, I settled on a simple "snack bar", a small overlay bar that pops up when the system is about to do something and gives the operator the option to cancel the system response (fig. 5.42).





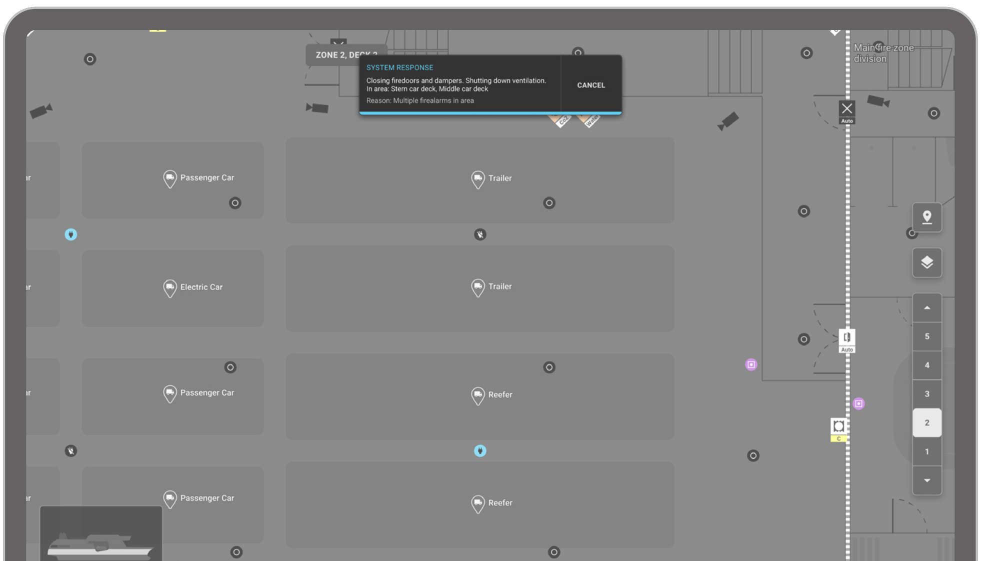


Figure 5.42
Some exploratory sketches of how to prevent out-of-the-loop syndrome and the design I used for testing.

5.7.7 Timeline

To accommodate the need to go back and forth in time (see 4.2 Testing and co-creation) a timeline was added to the system. The timeline gives the operator the possibility to scrub back and forth in time to see how a fire has developed. In addition, the timeline incorporates fast backwards and fast forwards buttons as well as a normal speed play button. This way, the operator can quickly peruse through some time period of interest.

The timeline has a large indicator indicating if the system is live or if the timeline is scrubbed back. When the system is not live, the edges of the screen start glowing yellow to further grab attention and indicate that the system is not in real-time (fig. 5.43).

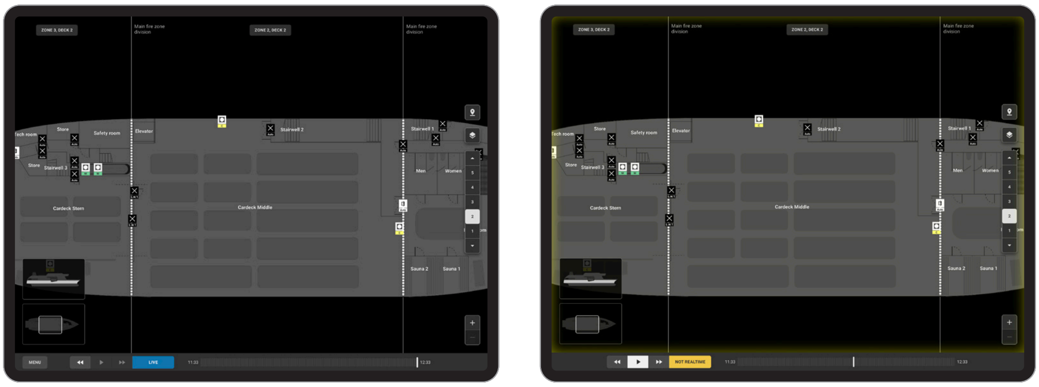


Figure 5.43
The timeline in both real-time and scrubbed backwards in time.

Figure 5.44
The timeline marks when a prewarning or alarm happened by adding small red or yellow circles to the timeline.

Triggered alarms and other events get marked on the timeline as small red or yellow circles (fig. 5.44). This is to help the operator scrub efficiently through the timeline to a point of interest. It also helps in indicating the severity of a fire situation as many alarms triggered over a short period of time will show as several small red circles packed into a small spot on the timeline.

5.7.8 Activated extinguishing system and deactivated ventilation

When dealing with a fire scenario, it is very important to easily see where a fixed extinguishing system is activated and where the ventilation is off. This should be shown graphically on the map in order to prevent a similar scenario as on Norman Atlantic, where the wrong drencher was turned on (Ministry of Infrastructure and Transport, 2018).

To show where a fixed extinguishing system is turned on and where the ventilation is turned off, an outline is used (fig. 5.45). The outline is meant to be as little intrusive as possible, while also clearly indicating the system state. This outline is only shown when a fixed extinguishing system is on or if ventilation is off. The outline uses a “Cornsweet edge” (Ware, 2013) to make it clearer what is the inside or outside of the contour. In addition, the lines have explanatory text, so that the operator does not need to remember any color coding.

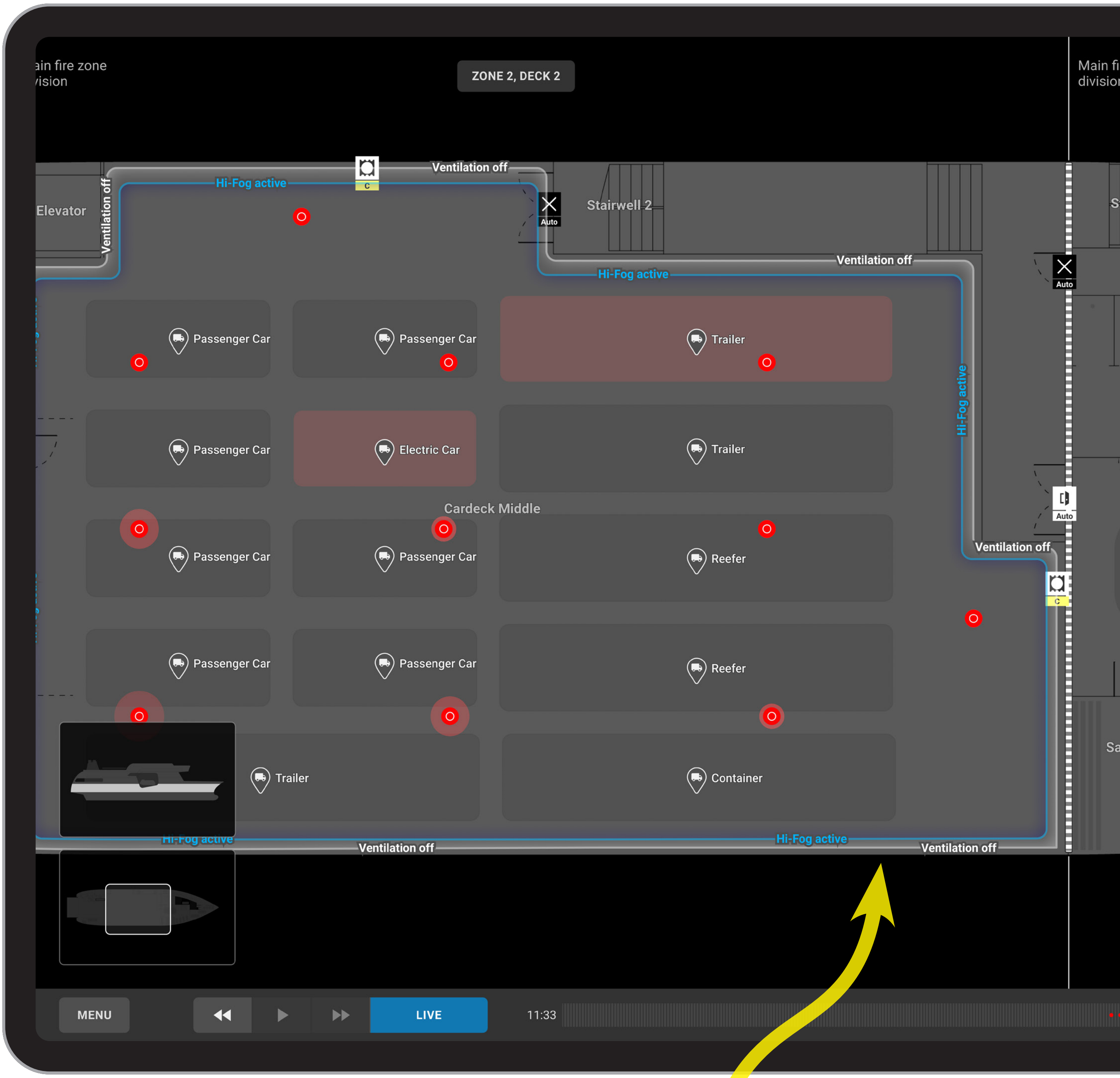


Figure 5.45
Active water mist system and ventilation turned off in middle car deck during a large car fire.

5.8 User tests

The prototype goes through the two scenarios shown earlier in this chapter (see 5.1 User scenarios). The first is a false particle alarm in room 420 on deck 4, while the second is a more severe fire in the car deck. The fire scenario is modelled after the Pearl of Scandinavia accident, which is a fire in an electric car that spread to other cargo through sparks and flying debris.

The prototype was tested twice. The first was a user test followed up with a small co-creation discussion with the same chief engineer as participated when testing prototype 1. The second user test was with a captain and a chief engineer working on a Dutch ship operated by a large Nordic ship operator. It is worth mentioning that the second user test had several technical difficulties and the user test was ended a little bit prematurely because of this. See appendix I and J for detailed notes from the user tests and appendix K for link to prototype.

The user test was divided into three parts. The first part was an exploration part, where the users were free to click around the prototype and comment on what they saw. After the free exploration, the system triggers a pre warning in room 420 and the user has to mute the detector. This scenario is mostly to test the prewarning indicators and the mute function. Lastly, the full fire scenario is activated, and the user has to deal with a massive fire. Here, both the alarm indication, highlighting of dangerous goods, alarm acknowledging, and system automation is tested.

The user tests did, despite much technical difficulties, yield some interesting results. Generally, the users are positive to the idea and the system. The alarm and prewarning indicators work well. In some cases, it is difficult for the user to find the alarms as it is outside of the viewed area. This is of course natural, and the system is supposed to center the alarm, but this is not possible in Figma. It did, however, bring up the need to have an edge marker to indicate where there is an alarm/prewarning. In addition, the mute/disconnected/acknowledge functions and wording were very confusing for the users. This was mostly because they were used to the words meaning something else. As it will take too long to go into full detail, the major findings from the user tests is summarized in figure 5.46.

🎉 **Good**

Dangerous cargo highlighting
Prewarning indicator is intuitive
Layers
Layer color-coding and keys
Timeline, scroll and dot-indicators are intuitive and useful
Charge station is quickly understood and useful
CCTV in fire central is an excellent function
The possibility to control other systems aboard, e.g. sprinkler
Overall system idea and usefulness of system
Alarm blinking to get attention

🛠 **Improvement potentials**

The word “zone” is confusing when referring to main vertical fire zone. Use MVZ.
Car outline looks empty when zoomed out
Add option to manually activate General Alarm
“Connected” pill tag is misleading and users think it means the detector is not muted
Disconnect zone is not intuitive
Users don’t like automatic system response, would rather have decision support or intelligently suggestion of actions
Horizontal scroll indicator on charge station and detector telemetries
Option to disconnect charging station
Animation on sprinkler and ventilation activation
Open water-mist panel when pressing water-mist zone
Press sideview to get large side view
Orange color on fire equipment is misleading
Alarm blinking sequence is difficult to catch
Would like frame numbers as a layer
More info about dangerous cargo and what extinguisher to use

Figure 5.46
Key takeaways from user test of prototype 2.

6 Prototype III

Even though prototype 2 was only tested twice, I decided to iterate on the prototype in order to get the most out of future user tests. Ideally, prototype 2 should have been tested on 4-6 users, but as Covid-19 makes it difficult to get in touch with users, this was simply not possible.

Prototype 3 is an iterative improvement over prototype 2 and deals with many of the improvement potentials found through user testing. Most notably is the changes done to how alarms are handled by the system and the operator.

Figure 6.1
Prototype 3 in idle and alarm state

6.1 Animation refactoring

The alarm animation worked very well to grab attention in prototype 2, but the animation sequence was not very apparent for the users. The sequence at which the alarms pulsed were not very clear simply because the timing was too quick. In addition, since the pulse movement is sinusoidal, the second alarm pulse starts pulsing before the first alarm pulse is finished (fig.6.2). This makes it less clear which alarm pulsed first.

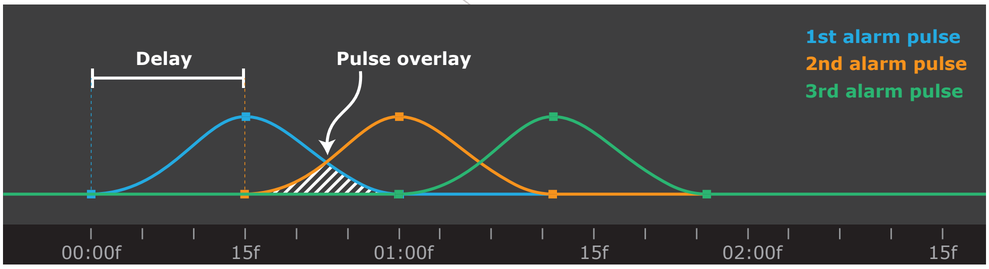


Figure 6.2
Figure of alarm animation sequence and the delay and overlay between pulses.

6.1.1 Pulse delay

To make the pulse sequence more apparent, one could simply increase the delay between each pulse. However, the pulse sequence will quickly become very long if there is many alarms and we allow for a sufficient delay between the pulses and a delay to indicate the end of the sequence (figure 6.3).

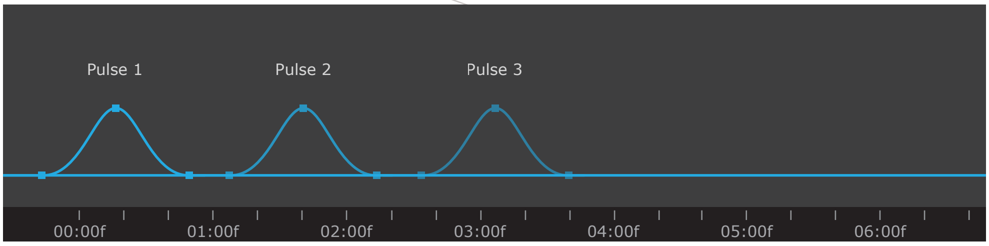


Figure 6.3
Pulse sequence timing chart. Pulses with longer and equal spacing in-between and a long pause at the end to signify sequence end.

Instead, I opted for a pulse delay that decreases throughout the animation sequence (fig. 6.4). That is, the time between the first and second pulse is 1 second, the time between the second and third pulse is 0,75 seconds, the time between the third and fourth pulse is 0,5 seconds and so on. At the end of the pulse sequence, a long delay indicates that the animation end.

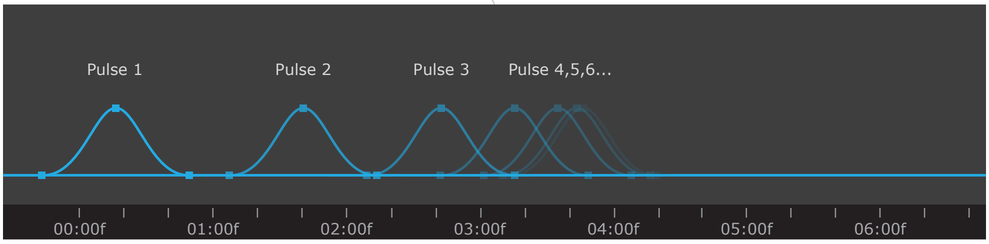


Figure 6.4
Pulse sequence timing chart with decreasing spacing between pulses.

This way, the pulse sequence has a fixed maximum length, while also making the trigger sequence of the few first alarms apparent. The pulse timing will become more difficult to distinguish throughout the pulse sequence as the delay approaches zero but seeing as the sequence of the first alarms are the most important, this is a feasible tradeoff.

6.1.2 New animations

In addition to the pulse timing and the interval time, I also believe the animation in itself made it more difficult to distinguish the pulses in prototype 2. The animation is composed of a circle that increases and decreases in size in a sinusoidal way (fig. 6.5). I believe, that this makes it more difficult to see when the animation starts as it begins so slowly and ramps up until the circle reaches its full size.

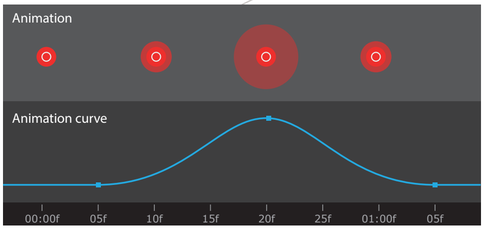


Figure 6.5
Old animation and curve of the pulse animation.

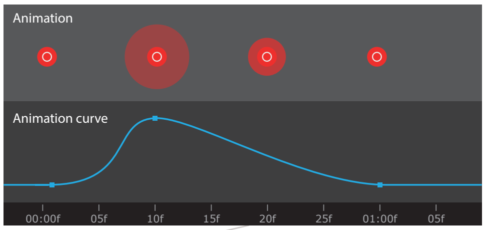


Figure 6.6
New asymmetric animation curve creates a more distinct pulse beginning.

To create a more distinct pulse, the animation curve was adjusted and skewed forward (fig. 6.6). This makes the pulse have a more distinct start, thus making it easier to follow the alarm pulse sequence.

PRE-WARNING

Even though the prewarning symbol worked pretty well in the user tests of prototype 2, I believe that the prewarning symbol should be animated as well. This is to draw attention from the operator quicker than what a static symbol does.

Figure 6.7
The new pre-warning symbol. The three lines slowly spin to grab attention.

The prewarning animation is a simple rotating animation that is quite easy to notice while also being less attention grabbing than the alarm animation (fig. 6.7).

NON-ACKNOWLEDGED ALARM

To distinguish non-acknowledged alarms from acknowledged alarms, a new animation for non-acknowledged alarms were created. Several animation alternatives were created (see appendix O). The final animation uses several expanding concentric circles to grab attention and has a rhythm that (I personally think) feels important without causing much stress (fig. 6.8).

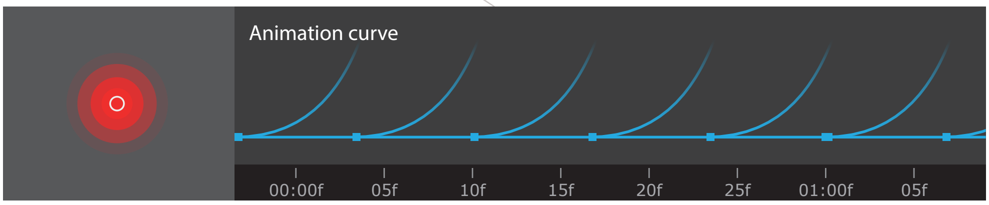


Figure 6.8
The non-acknowledged alarm symbol and its animation curve. Y direction on the curve corresponds to the circle radius, and the opacity of the curve corresponds to the opacity of the circles.

6.2 Edge marker

To fix the problem of not seeing alarms that is outside of the map bounds, an edge marker was designed. The edge marker is a signifier that lives on the edge of the screen and points towards an alarm that is outside of the map viewport. The idea is borrowed from video games, where you normally have a hit-indicator or quest marker to aid the player (Stephenson, 2018).

Figure 6.9
Edge marker sketches

Multiple edge marker designs were sketched and created (figure 6.9). In the end I settled on a simple bubble surrounding the alarm/warning map marker. When the alarm is outside the viewport, the alarm symbol will become an edge marker and stick to the closest viewport edge. When the alarm is moved into the viewport by scrolling the map, the edge marker disappears, and the alarm symbol snaps into place onto the map (fig. 6.10). The user can also press the edge marker to instantly go to the position of the alarm.

The edge marker also points at the specific floor if the alarm/prewarning is on another floor than what the operator is viewing. This is similar to how the pre-warning was prototyped in prototype 2.

Unfortunately, Figma does not have any option to do any custom programming of elements, so an accurate edge marker is not possible to prototype. A very crude implementation is, however, tested in prototype 3.

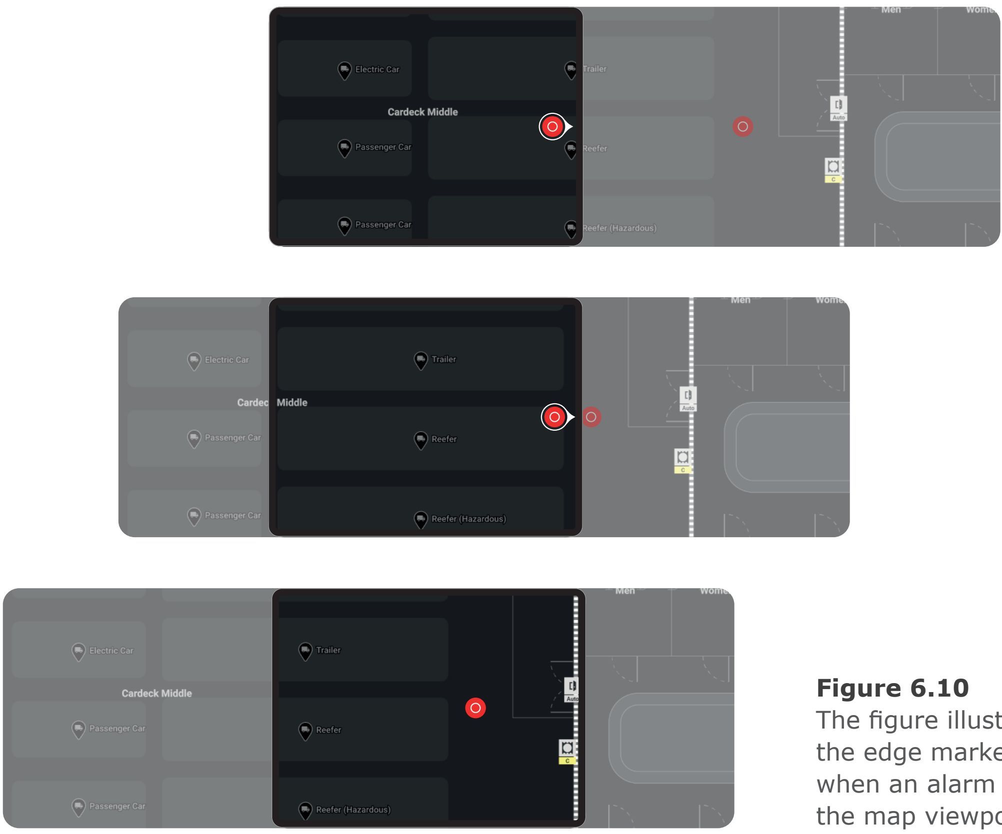


Figure 6.10
The figure illustrates how the edge marker works when an alarm is outside of the map viewport.

6.3 Acknowledge, mute, disconnect & silence

When testing prototype 2, it became very obvious that I had the wrong picture of what mute, disconnect and acknowledge meant for the users. It appears, acknowledge means to simply prevent the alarm from triggering the general alarm, mute means to stop the alarm from making any sound (but it can only be done after an alarm has triggered) and disconnect means to disconnect a detector from the system which stops all information flow from the detector to the system.

Through interviews and co-creation sessions, it seems that a function to mute all detectors in an area before they are triggered would be useful. This way, the operator does not have to deal with many alarm sounds and acknowledging new alarms during a large fire where many detectors gets triggered. In prototype 2, I called this disconnect, but it should actually have been called mute. However, it seems that many thinks that one can only mute a detector when it has already triggered an alarm, and not as a precursory action. The mute I want is to be used as a precursory action to minimize stress and disruptions for the operator. To work around the "mute-problem", I decided to use a completely different word that still explained the action well. After a quick synonym search on mute I decided to use "silence" as the action name.

Now, any detector can be disconnected, silenced or reset. When the operator wants to silence a detector, he navigates to the detector, selects which sensor he wants to silence (or both) and for how long (fig. 6.11). A silenced detector will not trigger general alarm or make any sound alarm, but it will show pre-warnings and alarms graphically. Similarly, the detector can be disconnected, but then the detector will not show any sensor information and it will not show pre-warnings or alarms graphically. Similarly, all detectors in a room can be silenced/disconnected/reset simultaneously through the room panel.

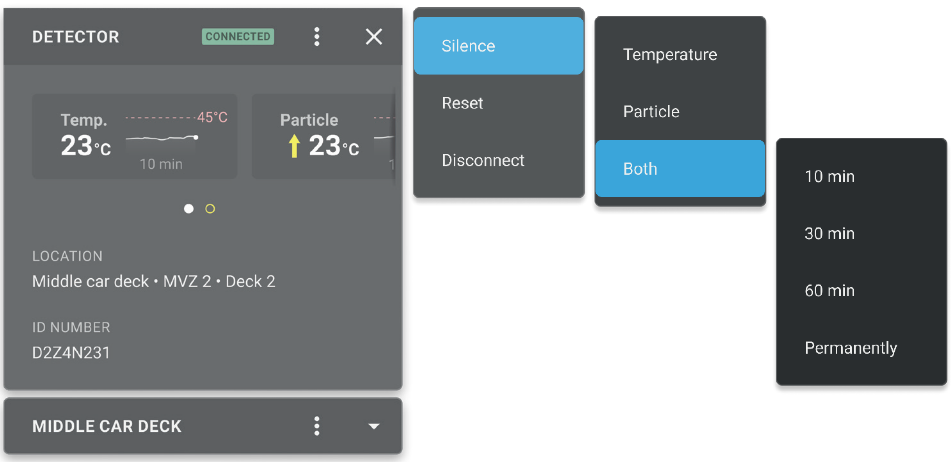


Figure 6.11
Through nested menus, the operator can silence or disconnect the detector for a given amount of time.

6.3.1 Silenced and disconnected detectors panel

For an operator, it is very important that the system clearly shows which detectors are silenced and disconnected. Since silenced detectors still show alarms graphically, it is maybe not as critical as showing disconnected alarms. Nevertheless, both silenced and disconnected detectors should be clearly visible.

In addition to indicating silenced and disconnected detectors on the map through an additional symbol on the map marker (fig. 6.12), silenced and disconnected detectors are also shown in a snack bar panel. The snack bar pops into existence only when there are silenced and disconnected detectors, and it shows a list of which detectors are silenced/disconnected, when the detectors will be unsilenced/reconnected and the option to unsilence/reconnect detectors (fig. 6.13).

In a bigger digital fire central terminal on the bridge, the silenced/disconnected panel should probably be shown permanently and have a dedicated spot in the UI. For a smaller portable terminal however, the screen real estate is too small to allow for a permanent panel that will be blank most of the time.

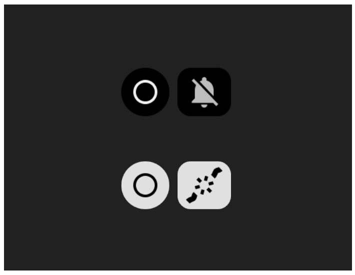


Figure 6.12
A silenced (top) and disconnected (bottom) detector without any ongoing alarms.

6.3.2 Acknowledge alarms

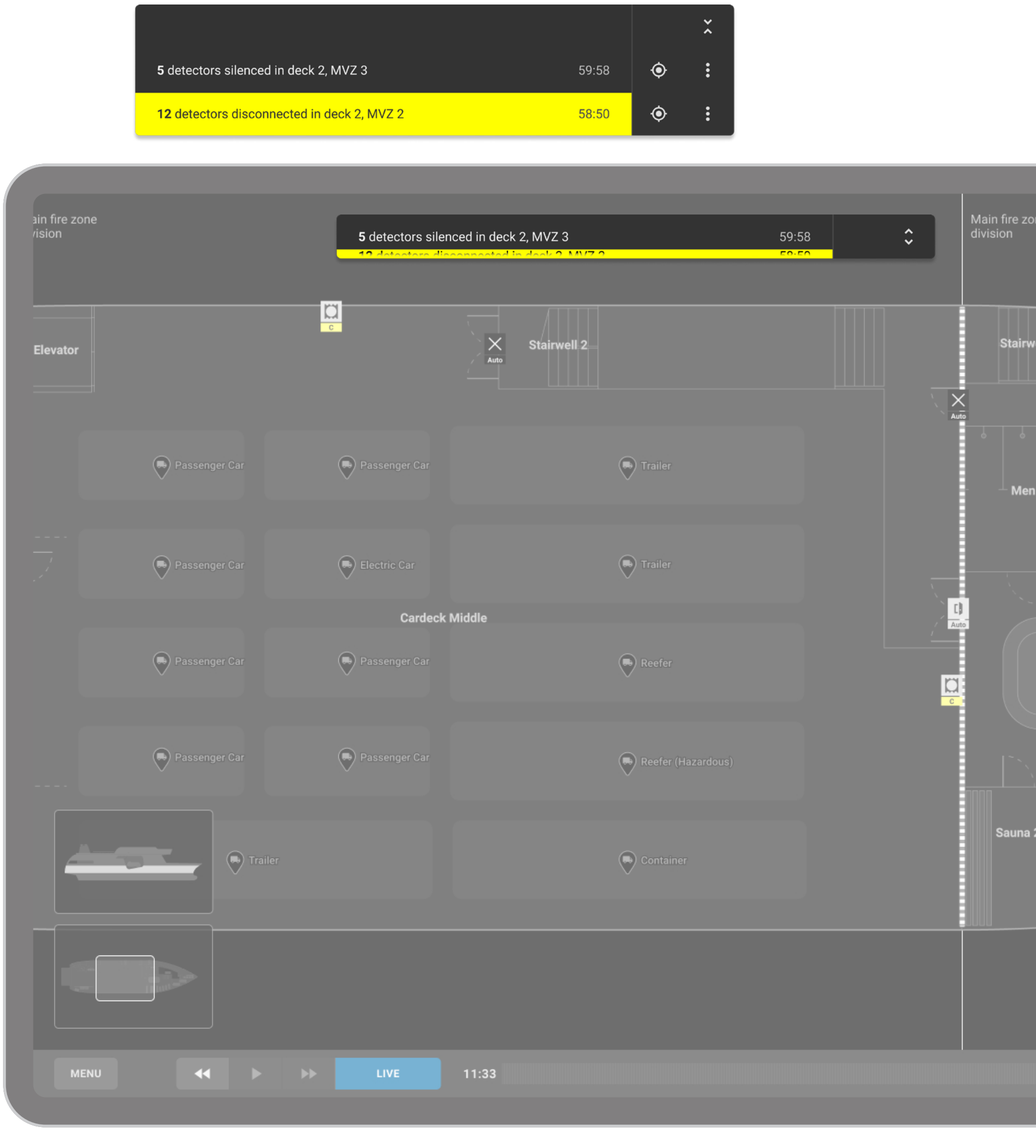


Figure 6.13
The silenced and disconnected overview snack bar (folded and unfolded). It has a prominent position at the top of the screen.

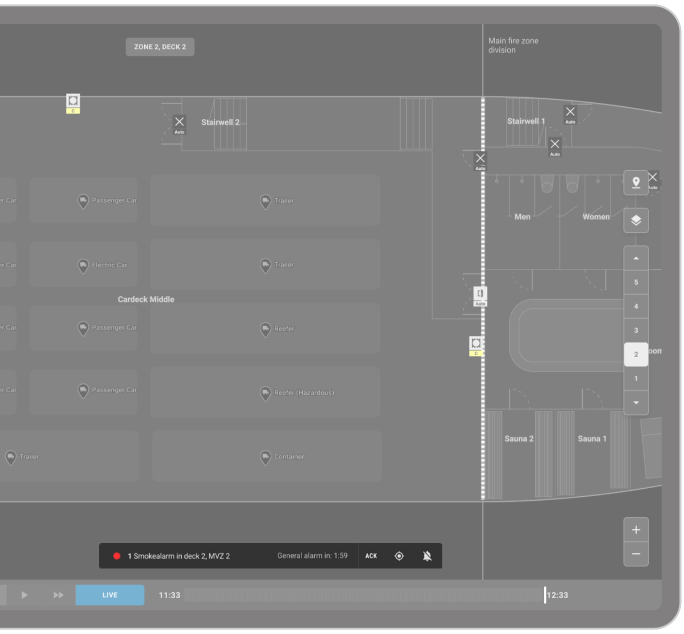


Figure 6.14
Alarm snack bar. It pops up when an alarm is triggered.

To acknowledge an alarm is to stop the ongoing alarm from triggering the general alarm, i.e. sounding the alarm on the entire ship. Acknowledge does, in some way, have the same effect as silencing a detector, expect it is only for a specific alarm trigger. That is, if you acknowledge a smoke alarm from a detector and the detector triggers a heat alarm two minutes later, then that heat alarm will have to be acknowledged again to prevent the general alarm from activating. Similarly, if a heat alarm is triggered, acknowledged and then triggered again a few minutes later, then the alarm will have to be acknowledged again.

As the acknowledge alarm UI on prototype 2 did not work very well, prototype 3 has a completely new one. Once an alarm is triggered, a bottom snack bar gives the operator information about which alarm is triggered and where it is (fig. 6.14). The snack bar has a small alarm animation to grab attention. In addition, the snack bar counts down to when the general alarm is triggered (which is something that many current systems do not show for some reason).

In the snack bar, the operator has the option to acknowledge the alarm, move the alarm into the map-viewport and silence the triggered detector or all detectors in a selected area.

When one or several alarms are acknowledged or silenced through the alarm snack bar, the bar informs that the general alarm has been cancelled before disappearing (fig. 6.15). This is simply to reassure the user that the general alarm actually has been cancelled.

Figure 6.15
The snack bar briefly reassures that the general alarm has been cancelled before it goes away.

6.4 New trigger symbols

As inevitable when changing alarm handling and animation, the trigger symbols have been refactored to better show alarms and pre-warnings. As mentioned earlier, the trigger markers have gotten new animations. In addition, the triggers have gotten a new indicator that shows info about the detector/alarm without needing the operator to click into the specific detector. The indicator shows what kind of alarm/pre-warning has been triggered, whether the alarm is acknowledged or silenced and if the detector is silenced, disconnected or missing. A missing detector is when the system does not reach a detector. This could be because of an electrical fault, malfunctioning hardware or that the detector has burned up or melted. Figure 6.16 shows an overview of the different states a trigger marker can have.

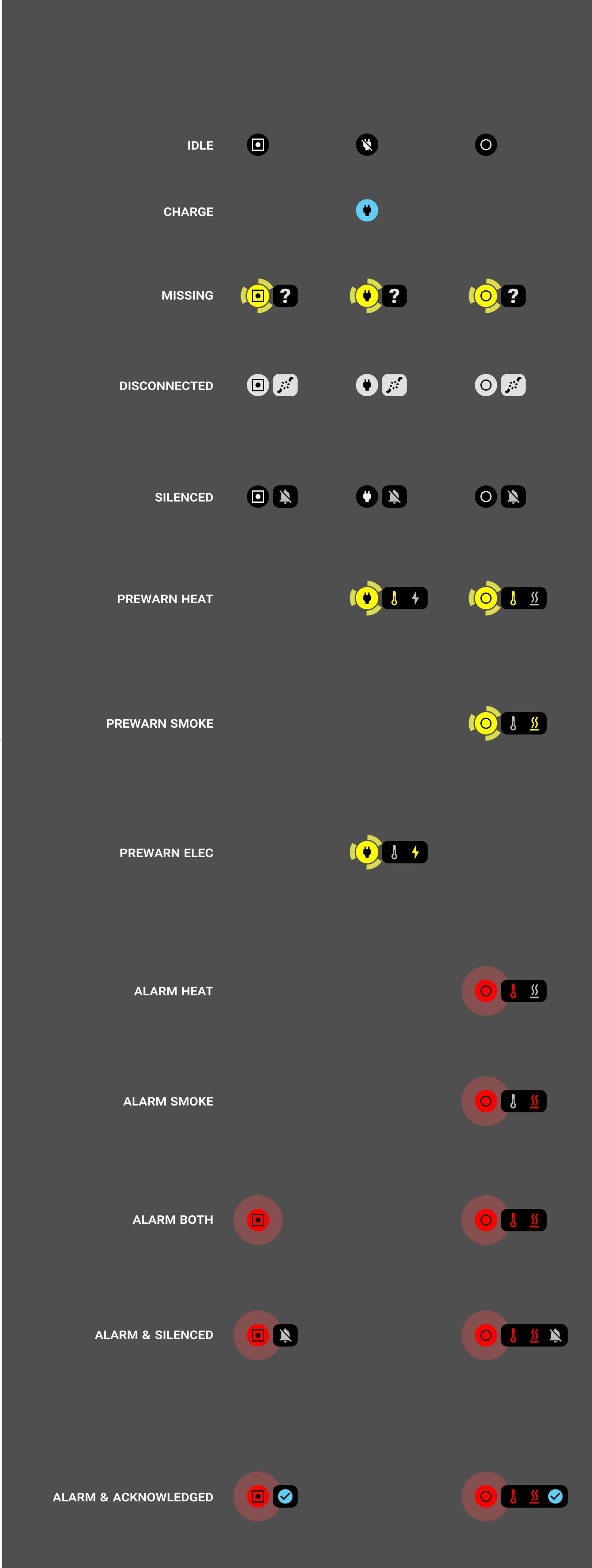


Figure 6.16
An overview of the refactored trigger symbols. A link to an animated version can be found in appendix O.

6.5 Search

Even though all of the users have found the map easy to navigate, I do realize that it will be difficult to find a specific systems installation or a specific detector by dragging around on the map. This is especially true if the operator does not know the exact spatial position of the thing he is searching for. To deal with this, prototype 3 incorporates a search function that makes it easy to quickly search for a system and go to it on the map (fig. 6.16).

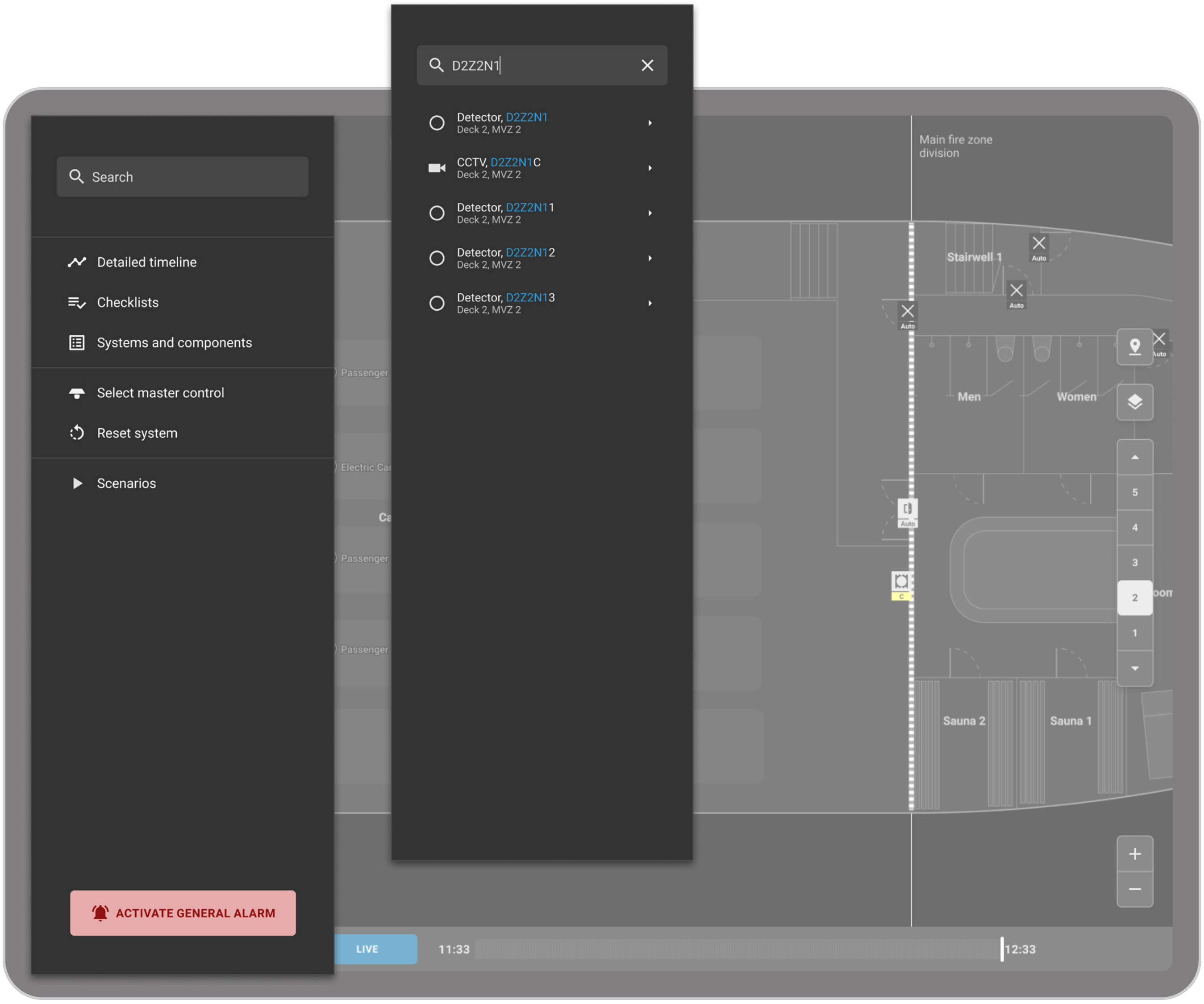


Figure 6.17
The search bar is accessible through the menu. From it, the operator can search for a specific component, much like how google maps search works.

6.6 Fixed extinguishing panel

As pointed out on prototype 2 and actually also on prototype 1, the users want to be able to press the fixed extinguisher zones and get more information about that extinguisher zone. Especially, information about pipeline pressure has been requested. Because of this, a simple panel has been added to prototype 3 that shows information about pipe pressure, nozzle number, nozzle type, ship location and last service of a selected extinguisher zone (fig. 6.18). The operator can also activate the extinguisher zone from the panel. Similarly to all map panels, the panel is an overlay to the map and can be opened by pressing on a specific fixed extinguishing zone.

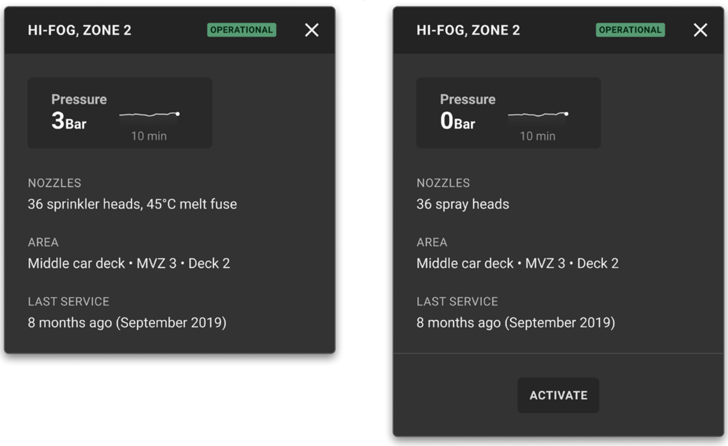


Figure 6.18
Two fixed extinguisher zone panel, one for sprinkler configuration and one for deluge systems.

6.7 Scroll indicator

To fix the problem of horizontal scroll, a simple signifier has been added to the horizontal scroll frames. The signifier shows how many information tiles the operator can scroll through, which one is currently shown and, in the case of an alarm or pre-warning, which information tile has caused the alarm/pre-warning.

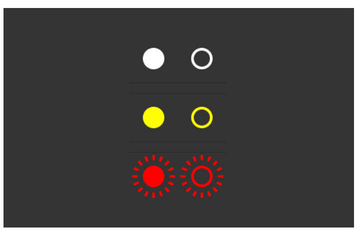


Figure 6.19
The scroll signifier consists of several small circles. They can have different design based on the scenario.

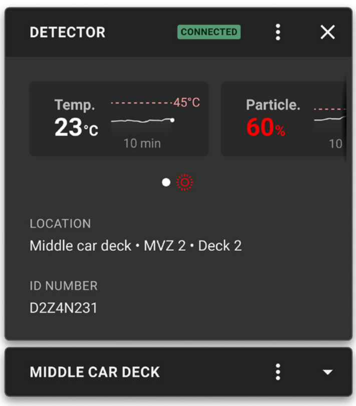


Figure 6.20
The scroll signifier added to a detector panel with an ongoing alarm

6.8 Dangerous cargo and extinguisher use

As requested in user tests of prototype 2, the system should show more information about dangerous cargo. It would be especially useful to show what extinguishing media it is ok to use (powder, water, CO_2) since some medias might actually make the fire worse. To accommodate this, the cargo panel shows how heavy the cargo is, what extinguisher it is ok to use, and it gives the possibility to open the safety datasheet of the cargo (fig. 6.21).

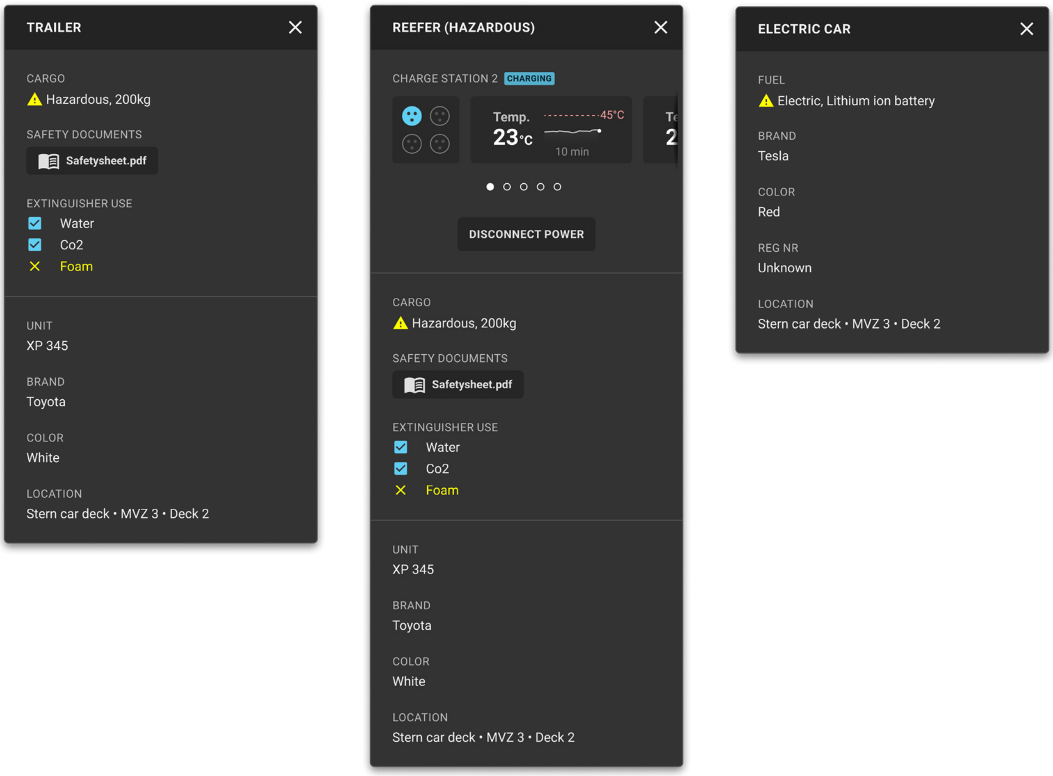


Figure 6.21
An example of cargo panels with relevant fire extinguishing info.
The information points have also gotten a symbol and color coding to make them easier to quickly go over and check if the cargo is dangerous and what kind of extinguisher to use.

6.9 User tests

The prototype was tested twice. Once on a chief engineer and once on a commander. Both of the test persons work at a major Nordic shipping company. The user testing was done in collaboration with the LASH FIRE team working on the FRMC and was split into two parts; first an interview of the user, then a user test. The interview was conducted by LASH FIRE while I conducted the user-test. Everything was done over Skype.

The user test was, similar to prototype 2, split into a free exploration part and a fire scenario part. In order to make the prototype less complex and easier to load, the pre-warning scenario in prototype 2 was omitted form prototype 3. The fire scenario part in prototype 3 is identical to that of prototype 2, only with more detail in how the system would react.

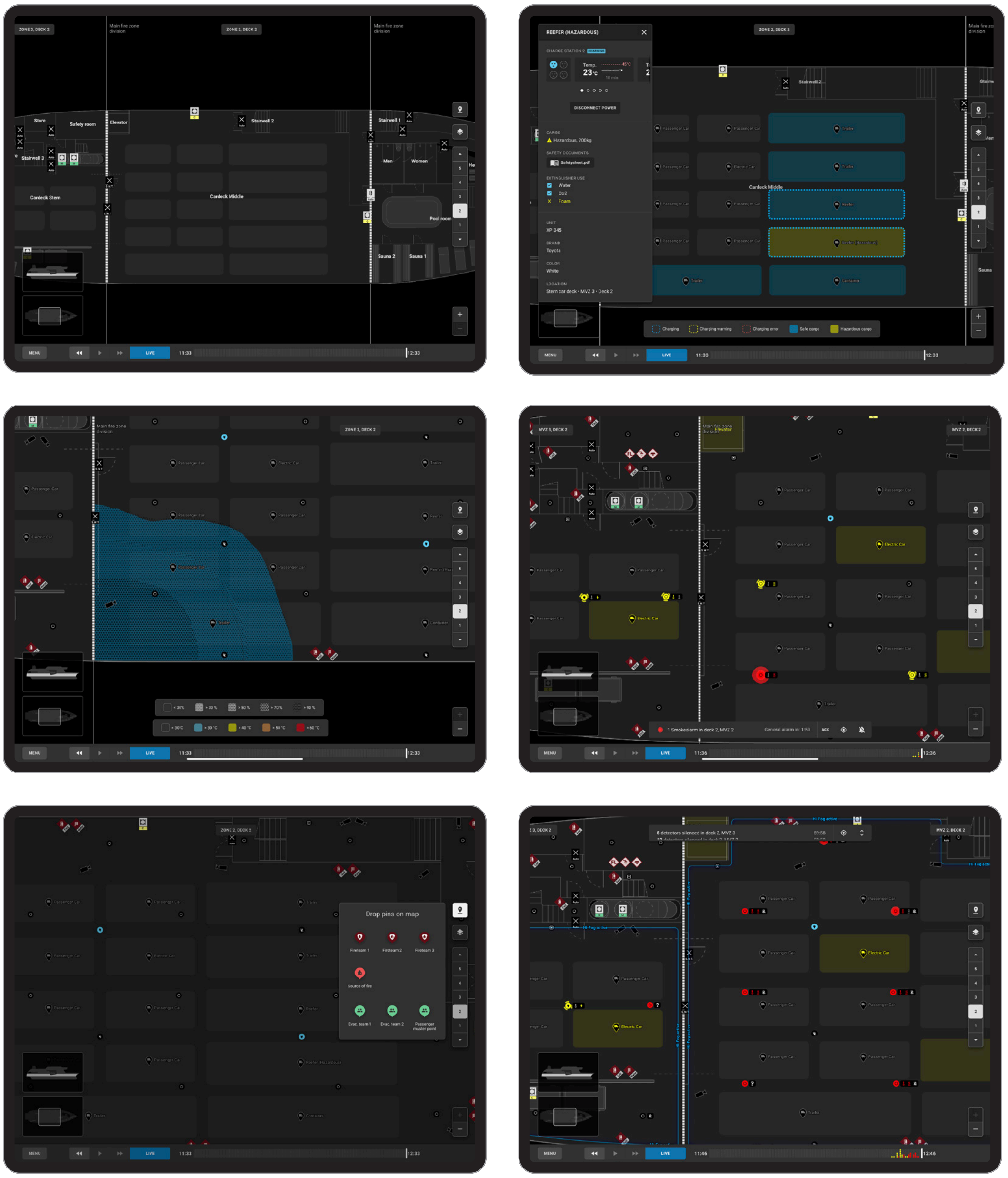


Figure 6.22
Some key UI screens from the user test

RESULTS

Generally, the interview conducted before the user tests confirmed that the digital fire central concept is something that the users want. There are many systems today that does have a digital fire central, but they are not as unified as the fire central concept here.

The feedback from the user tests were generally very good. The most exciting was how well the new wording and alarm handling system worked. However, the prototype was only tested twice, and it should be tested more to know if the good response was genuine or just out of luck.

The users did also have some technical and practical concerns regarding how some of the information is entered into the system. One of the concerns was how much extra work it would take to put cargo information and "last service" information into the system. This is a real concern and should be explored further. It could, however, result in less work for the crew as "last service" info and cargo info already exists aboard ships, it is just not properly digitized or integrated into a unified system.

In addition, the commander was concerned about how well the heatmap and smokemap will work in rooms with tall ceilings. This is also a very good concern and it has to be properly tested to know for sure. However, the heatmap and smokemap only functions as well as the detectors and if the heatmap/smokemap does not work, maybe the placement of detectors should be reconsidered. It is also a concern that the heatmap/smokemap will give a false sense of accuracy. To prevent this, the heatmap/smokemap should perhaps be deliberately decreased in resolution and be less smooth to signify a poor data resolution.

Figure 6.22 summarizes what was good with the prototype and what had improvement potentials.

Notes from the user test can be found in appendix L and M and link to the prototype in appendix N

🎉 **Good**

Alarm handling
Alarm type symbol on detectors
Animations as attention grabbers
Incorporation of fire control map
Choosing deck and deck layout (makes it easy to see what is directly over/under)
Possibility to toggle layers
Ability to control systemsaboard
Last service information
Silence entire rooms/zones
Cargo information
General system concept

🛠 **Improvement potentials**

Extinguisher not to use on dangerous cargo is not instantly understood
Maybe two screens or split screen to see two areas simultaneously
Escape routes in system. Can be used to show best route for fire teams as well
Alarm sequence animation not really noticed
Highlighting of dangerous areas/cargo when fire is not understood at once

Figure 6.22
A summary of the key findings from the user tests

7 From concept to FRMC

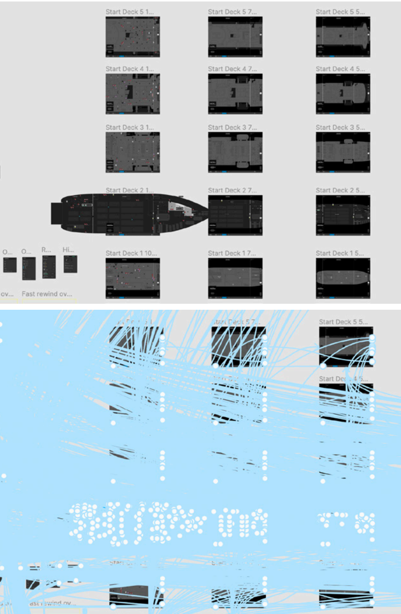


Figure 7.1
Screenshots from the Figma prototype.
Top: without prototype links
Bottom: with prototype links.

Prototype nr 3 is by far a perfect digital fire central and it will need more testing and prototyping to become something that can actually be used in a fire situation. That said, prototype 3 does showcase that a more unified digital fire central is something that ship crew finds useful and could help in fire extinguishing. The prototypes have also come a far way in figuring out what information is needed in a digital fire central and how it should be shown.

Also, the concept and prototype is not very linear in how the users interact with it, and it becomes increasingly difficult and complex to prototype the different functions for the fire central in traditional UI/ UX prototyping tools (fig. 7.1). Seeing as prototype 3 has come very far in verifying the concept and contents of a fire central, while also becoming unmanageable in Figma, I do not think it is feasible to iterate on prototype 3 further. That is, it will be very difficult to continue prototyping in Figma and it is probably easier to actually program the fire central in order to prototype further.

7.1 Recommendations for a FRMC

As mentioned in the beginning of this thesis, LASH FIRE is working on a firefighting resource management center (FRMC) that is supposed to make firefighting aboard ships easier and better. The concept and prototypes presented in this thesis is, in the end, a suggestion on how such a FRMC can look. Taking the accumulated learnings from the three prototypes, interviews and ship visits, I have formulated several recommendations for a FRMC. Some of these recommendations are ideas and concept that should be further explored.

STATIONARY TERMINAL

Although not talked much about here, the stationary terminal (e.g. bridge fire central) should be a large touch panel, but with keyboard and mouse as a backup input method. The screen size should not be over 55 inches and both a wall hung option and a touch table option should be adjustable to a slanted position.

All of the contents shown in the prototypes should be in the stationary terminal. Some of the content, e.g. the snack bar of silenced and disconnected alarms, should maybe have a permanent highly visible position on the stationary terminal.

Consider adding a split screen function to the UI so that two identical FRMCs can run simultaneously next to each other on the terminal. This way, the operator can keep an eye on two decks at once, or the terminal can be used by two persons at once.

PORTABLE TERMINAL

The portable terminal, although the prototypes have been designed for it, does not need all of the functions that the stationary terminal has. Consider focusing the portable terminal towards evacuation of passengers, routine maintenance and fire team briefing. This basically means that the portable terminal does not necessarily need the options to acknowledge and silence detectors, activate general alarm or control systems in other ways.

ADAPTIVE MAP

The map should hide and show info and map-markers dependent on the zoom level. When zoomed out, more overview info should be shown (e.g. room name), and when zooming in, more detailed info should be shown (e.g. individual fire detectors and CCTV). Alarms and pre-warnings should be shown no matter the zoom level, as well as fire doors and dampers.

MAP LAYERS

It should be able to toggle on and off information layers in the map. This way, the operator can toggle on the information he is interested in and hide the other layers. Alarms and pre-warnings are not a layer and cannot be hidden. The map layers I have found to be useful are:

- Fixed extinguishing systems
- Cargo information
- Fire equipment
- Evacuation equipment
- Heatmap
- Smokemap
- Fire walls
- Frame numbers

EVACUATION ROUTES

Consider adding evacuation routes as a map layer. The evacuation routes can not only be useful for evacuation, but it can also help the fireteams find the best place of entry when extinguishing a fire. It could also be useful to show routes to a specific point to further aid the fire teams in extinguishing planning (figure 7.2)

Figure 7.2
An example of how escape routes can be shown. Here, a primary and a secondary route to a marked point.

ALARM ANIMATION SUPPLEMENT

The alarm animations have worked perfectly in grabbing attention on small screens. On a bigger stationary terminal, the alarms might fall outside of the usable field of attention for animations. On the bigger stationary terminal, consider adding a supplement animation to unacknowledged alarms that swipes the entire screen once and brings the operators attention towards the new alarm (figure 7.3).

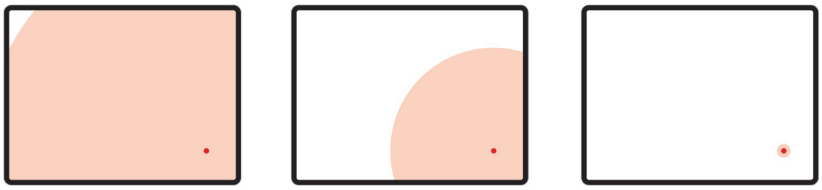


Figure 7.3
A large swiping circle shrinks in towards the alarm to grab the operators attention.

COMPONENT INFO

All of the map markers, systems and equipment marked on the map should be clickable. When clicked upon it should open an overlay with more info regarding that component. On a portable terminal, the panel should be fixed and it might be useful to limit the user to only one open panel at a time. On a larger stationary terminal, however, the user should be able to open as many panels as she wants and place them on the map where she finds it useful (fig. 7.4).

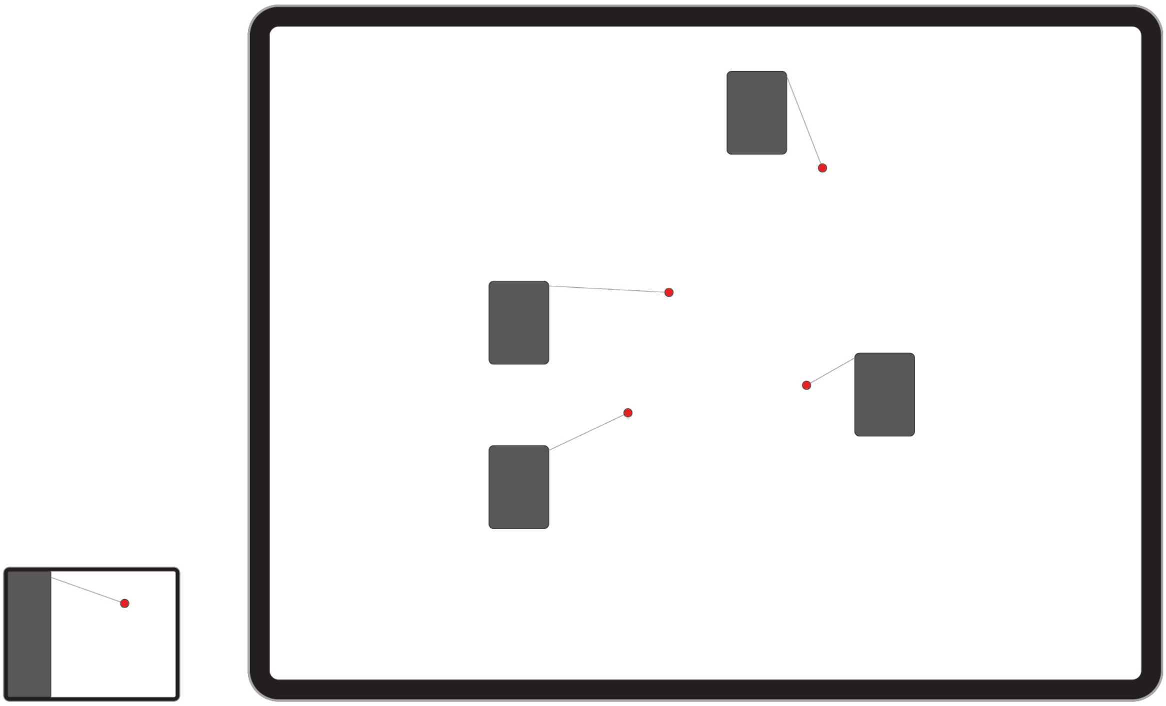


Figure 7.4
Large vs small screen and panel behavior. Larger screens give the user the option to place panels.

From insights and user testing, I have found several components that are useful to include as a map marker in the FRMC. Figure 7.5 lists all the components and what info and actions should be included for each component.

Figure 7.5 →
A list of components that I have found to be useful to include into the FRMC.
The list goes over two pages

	Info	Actions
Detector	Histogram over sensor data Alarm threshold Location of detector (Room name, MVZ and deck) ID number Connected, disconnected, silenced or missing	Silence Disconnect Reset
Manual call point	Location of detector (Room name, MVZ and deck) ID number Connected, disconnected, silenced or missing	Silence Disconnect Reset
CCTV	Camera feed Location (room name, MVZ and deck) Connected or missing Consider adding a graphical field of view cone	Scroll back in time Expand and zoom
Room	Location (MVZ and deck) Number and state of fire doors Number and state of dampers Number and state of scuppers (if applicable) Fixed extinguisher type, zone and state Ventilation zone and state	Silence, disable or reset all detectors in room Open/close fire doors Open/close dampers Open/close scuppers (if applicable) Activate/disable fixed extinguisher Turn on/off ventilation
Hose box	Length of hose (should also graphically show radius) Nozzle type Location (room, MVZ and deck) Last service date (both exact date and time since)	
Portable fire extinguisher	Extinguisher type (co2, powder, foam) Size Location (room, MVZ and deck) Last service/replaced (both exact date and time since)	

Continues on next page →

	Info	Actions
Fire door	Fire class Type (hinged, sliding) Location (room(s), MVZ and deck) Last service (both exact date and time since) State of door (open/closed) Connected or missing	Close door Open door (if possible)
Damper	To which room(s) Location (room, MVZ and deck) Last service (both exact date and time since) Connected or missing	Open/close
Charge station	Which connector is charging Data on charging connectors Connected, disconnected or missing Location (room, MVZ and deck)	Disconnect charge station from power Disconnect and reset
Cargo	Cargo/vehicle type Cargo hazardousness level Link to safety document What extinguisher to use Unit number Brand Color Fuel type Registration number Charge info (if known)	Disconnect charge station from power (if charge station is known) Open safety document (if available)
Fixed extinguisher zone	Histogram of pipe zone pressure Number of nozzles Nozzle type Location (Room(s), MVZ and deck) Last service (both exact date and time since) Active, operational or standby	Activate/deactivate extinguisher zone (if applicable)

PREVENTING OUT-OF-THE-LOOP SYNDROME

To prevent out-of-the-loop syndrome, the system should inform about automatic system responses that will happen in the future (or if no system response). An informative countdown snack bar was tested, but in hindsight this might just increase stress. Instead, I propose a snack bar or fixed panel that shows a graphical representation of what will happen in the future if, for example, one more alarm is triggered in main engine room (fig. 7.5). This will of course need more testing to see if it is intuitive and helpful to the users.

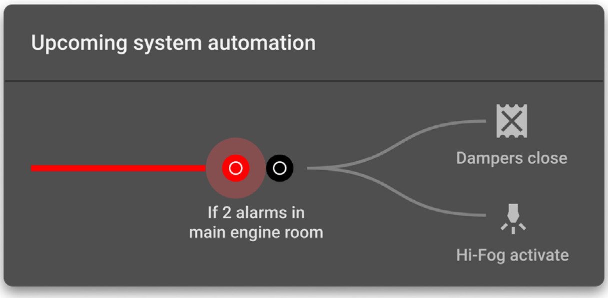


Figure 7.5
A concept for showing upcoming automation and preventing out-of-the-loop syndrome.

DECISION SUPPORT

The system should intelligently bring up actions based on the current scenario. E.g. two fire alarms in stern car deck will bring up buttons to activate fixed extinguisher system, close dampers and close fire doors (fig. 7.6).

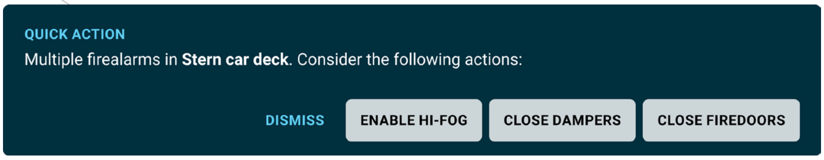


Figure 7.6
A pop-up snack bar with intelligently selected actions based on the scenario could help in quick activation of systems.

I would discourage to add any more complex decision support to the system, like giving the user several alternative actions and a percent indicator of how good the system thinks the actions are. This is because, as Endsley and Jones (2016) brings up, several studies have shown that presenting percentage or certainty numbers can have a negative effect on decision speed and accuracy.

SEARCH FUNCTION

The system should have a search function to easily search for a specific component on the ship. This can be useful for quickly finding a specific detector or equipment that the operator might not know the exact location of.

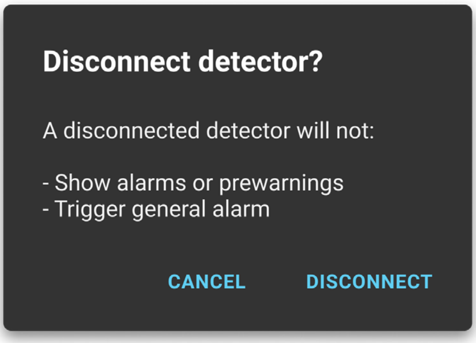


Figure 7.7
An example of a disconnect detector lock-in created for prototype 3.

LOCK-IN

To prevent accidental activation of systems, all systems control that has an external or severe effect should be confirmed through a lock-in. For example, disconnecting a detector, a popup should ask for confirmation of the action before the action is pushed out to the system (fig. 7.7).

TIMELINE

Even though a detailed timeline has, in many ways, been replaced by the scrollable timeline in the prototypes, I believe that a detailed timeline of system events should be available through the system menu. A detailed timeline might not be useful in most fire situations, as the scrollable timeline is quicker and more graphical, but it might be useful in some cases where you would want to know the exact time of alarm triggers.

EQUIPMENT LIST

To increase the usefulness of the FRMC, it might be a good idea to consider adding an equipment list/systems list where the operator gets a sortable list of all the equipment and systems aboard. The list should be sortable by equipment type, name, location and, most importantly, last service. This way the system can be used as a help in keeping track of routine services aboard.

OVERVIEW MAP

Although not requested or pointed out in any of the user tests, an overview map of the ship might be a helpful addition to the system. An overview map was omitted from the prototypes as it would take up much space on a small portable device. On a larger stationary station, the overview map will help in creating a broader global situational awareness. This overview map should show all the decks at once in either an isometric 3d fashion, or in a semitransparent 3d model of the ship to increase the operators spatial understanding. This will need a lot more testing to see if it actually have an effect on situational awareness, but from what Endsley and Jones (2016) writes, it seems promising.

SIDE MAP

A large side map has been requested from several of the user tests. It should be possible to switch between the side map and normal map by pressing the small overview maps in the lower left corner of the screen.

The reason for wanting a side map is to mostly get an overview and see if a fire is spreading up through the decks. Because of this, the side map might get redundant if a 3d/isometric overview map is added to the system, but more testing is needed on this subject.

DARK MODE

The systems UI should either have a negative contrast, i.e. white on black, to minimize brightness and eye strain during night sailing, or automatically change to a “dark mode” when the ambient brightness is low.

DRAG AND DROP MARKERS

The drag and drop markers should be easily accessible from the main screen of the FRMC. The markers function as a cognitive tool so the operator does not have to rely on her memory to remember where everyone is. The fire team's marker should also have a timer function, so that an operator can keep track of how long the fire teams have been smoke diving.

The drag and drop markers should also be shared between terminals. This way, a runner can, for example, mark where he has confirmed the fire with a portable terminal, and the location of the fire marker will be instantly available in the bridge terminal.

7.2 Closing thoughts

As my recommendations for a FMRC suggests, there are still much work to be done. I do believe, however, that the prototypes have come a long way in figuring out what an FRMC should contain and how it should work. The next steps will be to start programming a simple version of the FRMC, or at least move over to a more powerful prototyping tool that will allow for better prototyping and simulation of the system.
In addition, the prototypes will have to be redesigned for a larger stationary terminal, and this terminal will have to be user tested. There are also a lot of research to be done on overview maps and how to better present spatial information in a system such as a FRMC.

Another side of the FRMC that has been somewhat ignored in this thesis is how the evacuation crew will use and interact with the system. As mentioned several times earlier, both the portable terminal and the stationary terminal can be very helpful in organizing evacuation and helping in information flow between fire teams and evacuation teams. This side of the FRMC will have to be explored further.

7.2.1 Isolated FRMC

During prototyping, I have based the system upon a perfect scenario where all of the systems aboard the ship can be remotely controlled from the bridge and from the fire central. This is, however, not the case for most ships today. More often than not, ships will have several retrofitted systems or old systems that simply cannot be controlled or connected to a unified system. Also, the FRMC can become disconnected from systems aboard in the case of a complete ship blackout. In either of these cases, the FRMC is isolated and will not be able to control systems aboard or show any information from detectors.

By adding the static information found in fire control maps, evacuation control maps and information about system locations and zones into the FRMC, an isolated FRMC could still help the ship crew in dealing with fire situations faster and better, even if the FRMC cannot control the systems directly. In this isolated state, the crew can still use the FRMC as a cognitive aid and a helper tool to find equipment, fixed extinguishing zones, ventilation zones and escape routes aboard. By incorporating this, a FRMC can be valuable for basically any ship, no matter the level of system incorporation the FRMC has. Exactly how much value an isolated FRMC will give compared to a connected FRMC will need further testing.

7.2.2 Compared to traditional fire centrals

Since Covid-19 has made it difficult to test the prototypes aboard ships and in a realistic environment, it is hard to compare the FRMC concept to the systems ships use today. Nevertheless, the user tests show great potential and the users seems to be very positive to the idea. The users have also, at occasions, expressed that the concept is better than their existing system.

The prototypes only show the portable terminal, and in order to fully compare the FRMC concept to existing systems, the stationary terminal will have to be prototyped and tested as well. I will leave this for further work and hopefully, in the near future, there will be a functional 55” FRMC that can be tested in a proper simulated environment.

References

Accident Investigation Board Norway. (2013). REPORT ON THE INVESTIGATION OF A MARINE ACCIDENT NORDLYS LHCW - FIRE ON BOARD DURING APPROACH TO ÅLESUND 15 SEPTEMBER 2011 Retrieved from https://www.aibn.no/Marine/Reports/2013-02-eng

Autronica. (2020). MultiSensor BHH-320. In. produkt.autronicafire.com.

Brano Beliancin/Nytt i uka. (2011). Reparasjonen av det brannskadde hurtigruteskipet MS Nordlys i gang. In. nordlys.no: Nordlys.

Buchner, A., & Baumgartner, N. (2007). Text - background polarity affects performance irrespective of ambient illumination and colour contrast. Ergonomics, 50(7), 1036-1063. doi:10.1080/00140130701306413

Bureau Veritas, R., Stena,. (2018). FIRESAFE II Detection and Decision. Retrieved from http://www.emsa.europa.eu/firesafe/download/5485/2904/23.html

Danish Maritime Authority. (2011). Pearl of Scandinavia Fire 17 November 2010. Retrieved from https://dmaib.dk/media/9155/pearl-of-scandinavia-fire-on-17-november-2010.pdf

Dobres, J., Chahine, N., & Reimer, B. (2017). Effects of ambient illumination, contrast polarity, and letter size on text legibility under glance-like reading. Applied Ergonomics, 60, 68-73. doi:10.1016/j.apergo.2016.11.001

Endsley, M. R., & Jones, D. G. (2016). Designing for situation awareness: An approach to user-centered design: CRC press.

Forbrukerrådet. (2019). Den store brannslukkeguiden. In. forbrukerradet.no.

Forlines, C., Wigdor, D., Shen, C., & Balakrishnan, R. (2007). Direct-touch vs. mouse input for tabletop displays. In (pp. 647-656).

Grinschgl, S., Meyerhoff, H. S., & Papenmeier, F. (2020). Interface and interaction design: How mobile touch devices foster cognitive offloading. Computers in Human Behavior, 108. doi:10.1016/j.chb.2020.106317

IMO. (2020) Safety of ro-ro ferries. Retrieved from http://www.imo.org/en/OurWork/Safety/Regulations/Pages/RO-ROFerries.aspx

IMO. (2017). ESCAPE ROUTE SIGNS AND EQUIPMENT LOCATION MARKINGS. In.

Marioff. (2020). Water Mist Fire Protection in Brief. Retrieved from https://www.marioff.com/water-mist/water-mist-fire-protection-in-brief

Ministry of Infrastructure and Transport. (2018). Fire on board of the ro-ro pax NORMAN ATLANTIC 28 December 2014 Final Report. Retrieved from http://hbmci.gov.gr/js/investigation%20report/Final%20as%20Interested%20Authority/2014-NORMAN%20ATLANTIC.pdf

Nasatyas. (2019). Drencher Systems. In. nasatyas.com.

Noah, B., Li, J., & Rothrock, L. (2017). An evaluation of touchscreen versus keyboard/mouse interaction for large screen process control displays. Applied Ergonomics, 64, 1-13. doi:10.1016/j.apergo.2017.04.015

Petersen, H. E., & Dugas, D. J. (1972). The Relative Importance of Contrast and Motion in Visual Detection. Human Factors, 14(3), 207-216. doi:10.1177/001872087201400302

Piepenbrock, C., Mayr, S., & Buchner, A. (2014). Smaller pupil size and better proofreading performance with positive than with negative polarity displays. Ergonomics, 57(11), 1670-1677. doi:10.1080/00140139.2014.948496

Purpura, P. P. (2019). Security and Loss Prevention (Seventh Edition): Elsevier.

RISE. (2020). LASH FIRE. Retrieved from https://risefr.com/services/research-and-assessments/lash-fire

Shih, Y.-N., Huang, R.-H., Lu, S.-F., & Shih, Y.-N. (2013). The influence of computer screen polarity and color on the accuracy of workers' reading of graphics. Work (Reading, Mass.), 45(3), 335-342. doi:10.3233/WOR-131588

Stena line. Stena Estrid. In. stenaline.com: Stenaline.

Stephenson, J. (2018). A UX Analysis of First-Person Shooter Damage Indicators. Retrieved from https://medium.com/@jasper.stephenson/a-ux-analysis-of-first-person-shooter-damage-indicators-59ac9d41caf8

Theeuwes, J., & Kooi, F. L. (1994). Parallel search for a conjunction of contrast polarity and shape. Vision Research, 34(22), 3013-3016.

Vanguard. (2019). How Often Should Fire Sprinkler Systems Be Tested? In. vanguard-fire.com.

van Dokkum, K. (2016). Ship Knowledge (9th edition ed.): Dokkmar Maritime Publishers B.V.

Ware, C. (2013). Information visualization : perception for design (3rd ed. ed.). Amsterdam: Elsevier/Morgan Kaufmann.

8 Appendix

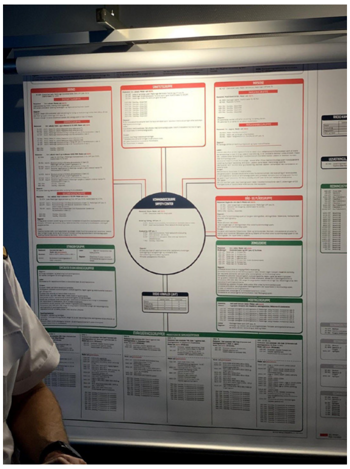
Appendix **A**

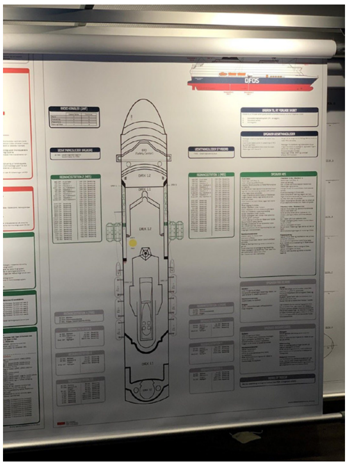
Visit at ro-ro-ship and fire drill, MS Large RoPax

We arrived at the departure-terminal around 10. From there, we were escorted to a meeting room on 11th deck on the ship, where we could store our things. From there, we divided the group into two groups. One group observed the firefighting drill from the car-deck, where the firefighting were actually taking place, and the other group observed the drill from the bridge, where the overarching decision making and planning happened. As a FRMC would be placed on the bridge, and used by the officers there, I observed the drill from the bridge.

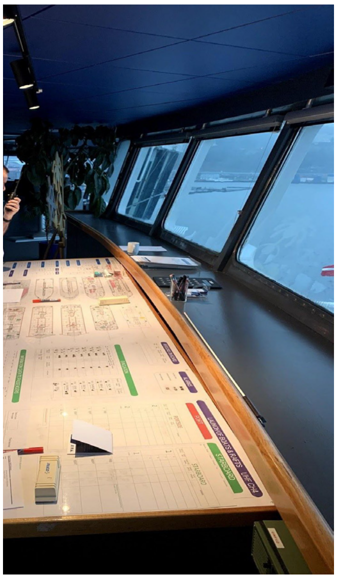
The bridge at MS Large RoPax. Observe that the bridge is quite roomy. This, however, varies very from ship to ship.

The fire drill started at 10:30 with the captain announcing the fire drill over the PA-system and briefing the crew (see third image above). At 10:31 the brief was done, and the crew went to their designated stations and tasks around the ship. On deck, only four crew members remained; the captain, and three officers. Each of the officers had their designated responsibilities and acted autonomously and communicated with the crew to lead the fire drill. Because of this, we could ask the captain a lot of questions during the fire drill.



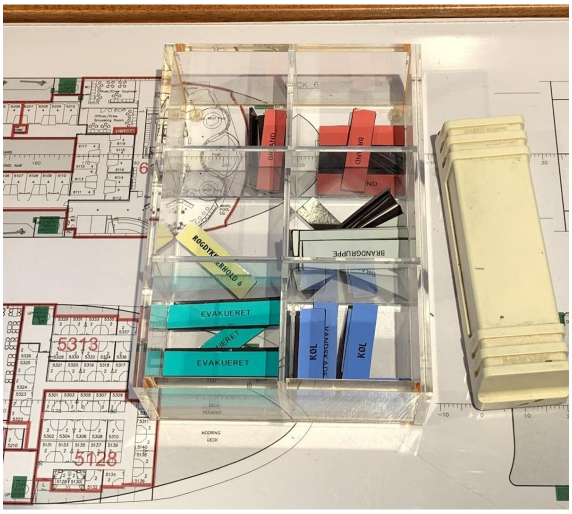


The images above show a poster that describes the different roles the officers have during a fire scenario (image 1) and during an evacuation scenario (image 2). Generally, the crew onboard the ship guides the passengers to “safe zones” on the ship if there is a fire scenario. Then the crew try and extinguish/get the fire under control (fire scenario, img. 1). If the crew fail in extinguishing the fire/getting the fire under control, the passengers are evacuated (evacuation scenario, img. 2).



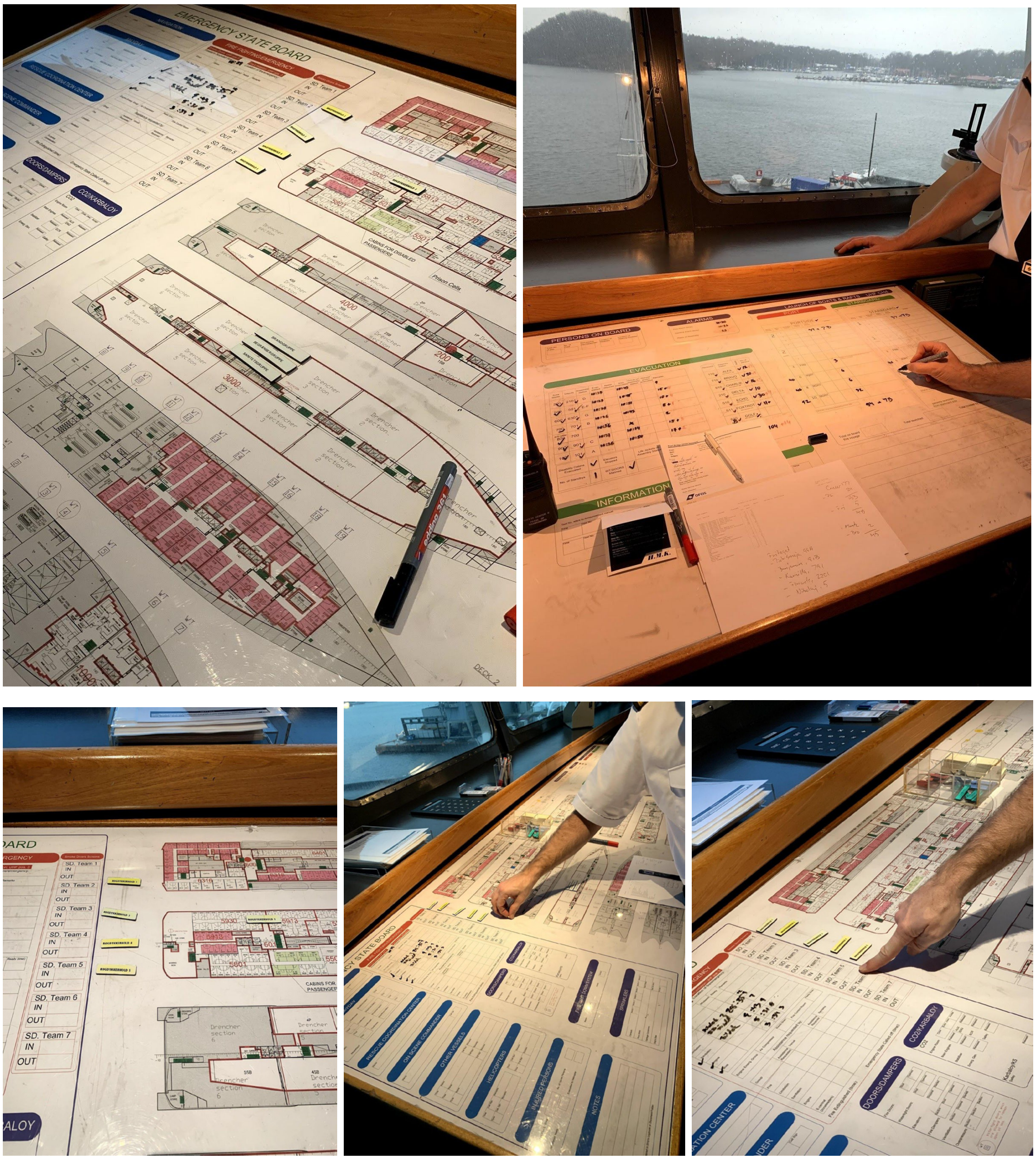
During the fire drill, the three officers used a table with a map of the ship and a few spaces to write notes. This table was used to write down what happened during the fire drill, e.g. where and when the smoke divers/crew entered to fight the fire, where the fire was and so on. Basically, the table was a tool that helped the crew to put knowledge in the world.

This table had a plastic cover on top and was written on during the fire drill with non-permanent markers. In case of an actual fire, the plastic cover would be removed and the paper underneath would be written on with pens. This paper would then be a log of what was done to fight the fire and how the evacuation went. In case of an evacuation, the paper is supposed to be rolled up and taken onboard the lifeboat.



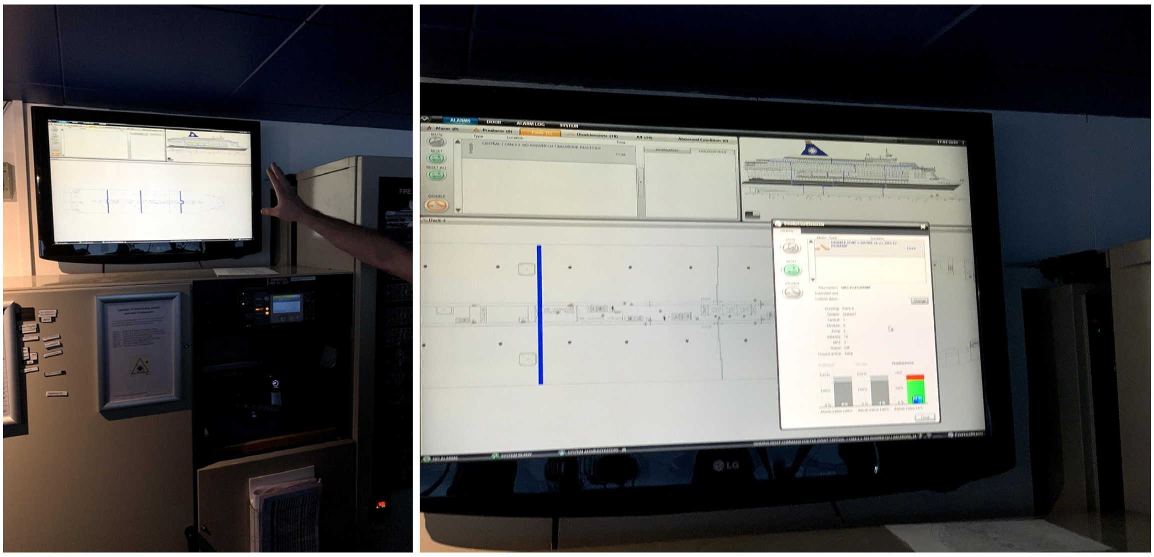
The officers used small labels/figures and placed them on the table to show where the different crews were and where the fire was. The labels were labeled smokediverteam1, firefighting team, evacuated, fire and so on.

The captain informed us that during an evacuation, some of the crew members had to go and evacuate the passenger-rooms. This was done by walking through and checking all of the passenger rooms. The crew would bring with them a set of yellow plastic-sheets that they could hang on the door when a room were checked and evacuated. The number of yellow plastic-sheets would match exactly the number of rooms in the section a crew-member would check. So if a crewmember finish with a section, but have a sheet left, he would know that something was wrong and had to check the section again.



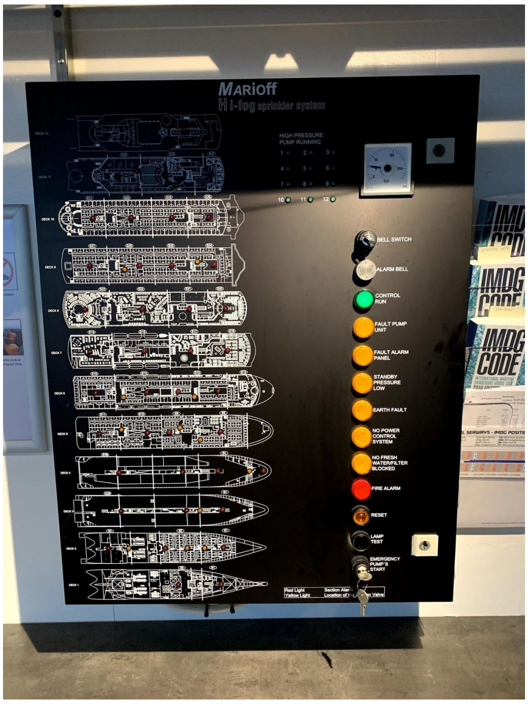
Images of the table in use. Notice how big the labels/figures are in comparison to the map of the ship. One of the officers showed us how the labels were used when a smoke-diver-team was used. Then, the officer would put the corresponding “smoke-diver-team-1” label on the map where the team would enter, then write down the time of entrance in a corresponding table (pointed at, last picture). Noticed, however, that the officer hesitated a bit when he put the label down because the label needed to be placed between two sections, thus making it unclear which section the smoke-diver-team entered.

When the officer has placed a smoke-diver-label and noted the time of entrance, he then has to keep track of how long the smoke-diver-team has been inside the section. This is to make sure that the smoke-divers don't run out of air. As a general rule, the officer will radio the smoke-diver-team after 10 minutes, and remind them to come back.



The above images show the fire alarm system. The screen is retrofitted to an older system. The old system only shows if a fire detector has been activated in a specific section by blinking a LED on a printed map of the ship. A single section might have several fire-detectors. The retrofitted system, however, shows every fire detector on the ship and allows the captain to zoom in on a deck to see what is going on. An interesting binote; although the system shows which fire alarm has been activated and allows the crew to see how the fire spreads, it isn't possible to see several decks at the same time. This might make it difficult to see if a fire spreads upwards or downwards across the decks.

In the second image (right), the captain has clicked on a specific fire-detector. Here, a small overlay window shows additional information about the fire-detector and options to mute, reset and disconnect it. It is worth mentioning that the fire-detectors onboard this ship had either three og two sensors in them. The fire-detectors in normal rooms had particle-, co2- and temperature sensors in them, while the fire-detectors in the car-deck had only particle- and temperature-detectors (and not co2 sensors for obvious reasons).



Above (left) is an image of a slate showing which drencher-zone (sprinkler system) is activated. The fire-detection system had a similar slate, but the retrofitted computer showed additional information. The drencher-slate was located on the bridge behind the table described over and next to the fire-detection system. The drencher-system could not, however, be activated from the bridge. In order to activate the drenchers, the bridge would radio down to the drencher room (right image) and a crew-member would manually activate it there. We were told that this was not the case with newer ships though. We were also told that it came down to personal preference whether ship-crews liked electronic activation from the bridge or manual activation in the drencher room best. The reason for liking manual activation was apparently that it was easier to “feel” the flow of water and be sure that the drencher-system actually had been activated.

Throughout the fire-drill, radio communication between the bridge and the crew were constantly maintained and essential. We asked if the ship had any “dead-zones” or if they have had any problems with radio communication (like interference). The captain told us that they might get some interference from other ships when docked in a harbour, but not when they were out to see. They had also experienced interference if external crew brought their own radios. In that case, they would give the external crew some spare radios to use. When it comes to “dead zones”, the ship has several repeater-stations spread around and virtually eliminating any dead-zones.

At 11:16, the fire-drill finished and the crew assembled on the bridge again.

Post-interviews

After the fire-drill, we had the opportunity to interview chief mechanic(?) and security officer(?). The “interview” were held with all of the people from LASH FIRE, so much of the insights gathered from them aren’t very applicable to WP7.

Underneath are some key takes from the interview that could be important going forward with WP7 and FRMC.

While the cables and communication to fire-detectors can be made fireproof, the sensors cannot. So a problem during fire is sensors burning up. This happened in 2011 when an electric car caught fire in the car-deck.

How can one improve alarm-stacking and alarm-prioritisation when several alarms goes off at once?

The crew hesitated to turn on the drenchers in 2011 and tried to extinguish/get an overview of the fire before they activated it. After the incident the crew seemed to agree that the drenchers should have been activated immediately.

An automatic activation of the drencher-systems cannot be done when only one sensor goes off, but the security officer (?) ment that it could be automatic of several sensors went off. It is unclear if the officer ment several sensors inside a single detector (e.g. particle and temperature) or several detectors (which all include several different sensors).

The captain seemed positive to an electronic system that gathered all the information needed for assessing a fire-situation and managing resources.

The cameras can be used to verify that there is an actual fire, but they would often be useless because of smoke in the room or if the camera has stopped working due to heat. They can, however, rewind the footage to see the severity of the fire before the camera went out. This is apparently easy to do in the camera surveillance terminal (Image underneath).

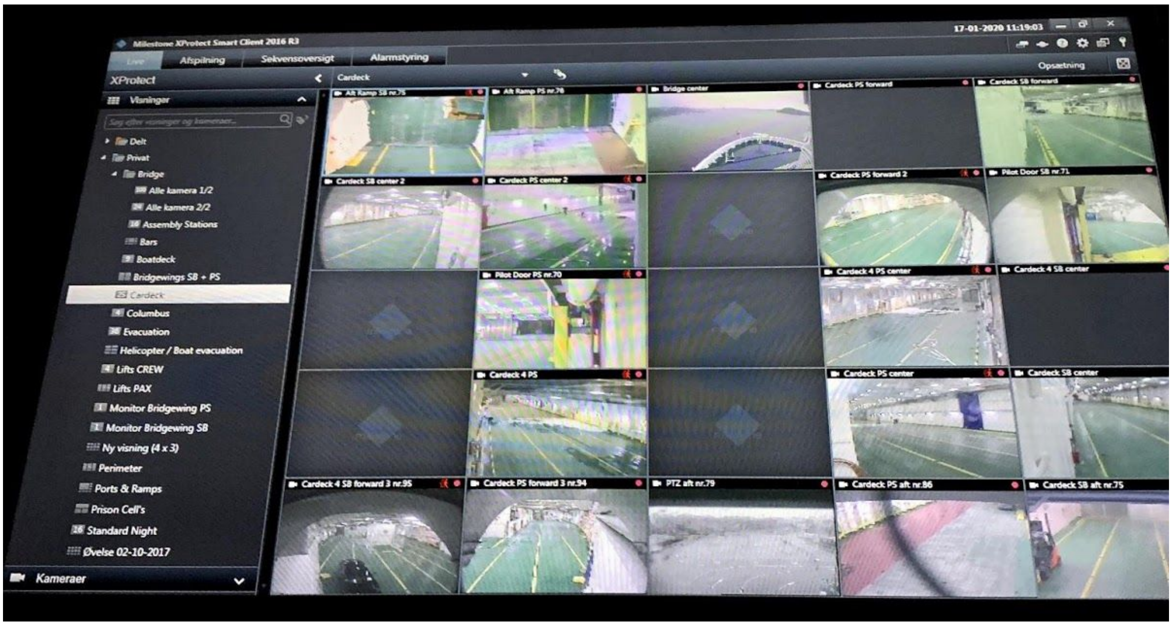


Image of the camera surveillance system onboard

Reference:

Date: 17-01-2020	Week: 03	Planned activity(is): Full Mission Fire & Evacuation Excercise
Place of fire:		Fire on cardeck.
Meeting place for fire corp:		Deck 3, mid port side without equipment
Meeting place for limitation group:		Deck 3, mid port side without equipment
Meeting place for sanitary group:		Deck 3, mid port side, bring a stretcher
Plan of action for Fire Exercise:		
Demonstration of foam equipment, extended fire fighting equipment, portable fire extinguishers, how to release the sprinkler system on cardeck and how to strap a person on to a stretcher.		
One fire person intoxicated by smoke. Treatment by sanitary group + strapping the person on to the stretcher..		
Use of smoke generator (area):		No
Closing of fire doors		Fire doors: Yes Watertight doors: Yes *(not to be opened at arrival).
Plan of action for Evacuation Exercise:		
All zoneleaders and zoneleadercrew must evacuate the persons in cabins. Teddy bears according to list		
Evacuation to (area):		Assembly stations
Plan of action for rescue exercise:		
Crew muster with life vests.		
Education on MES and boats.		
Launched lifeboat no.:		
With crew from:		
Safety instruction		☐ YES NO ☐
Team:		
Subject:		
Cabin inspection		Area 5: 2115-2120 &2125-2130
Various announcements/information		
Persons exempted:		Persons not shown:
Evaluation/debriefing of drill:		

The fire-drill performed

Visit at MS Medium Ferry

Images of exterior redacted

MS Medium Ferry is per definition a ro-pax ship, but the vehicle space is small and the ship doesn't normally carry many vehicles. A few years back, this ship had an accident where one of the engines caught fire due to fuel leakage. Because of this fire incident, most of the equipment on board is just a few years old

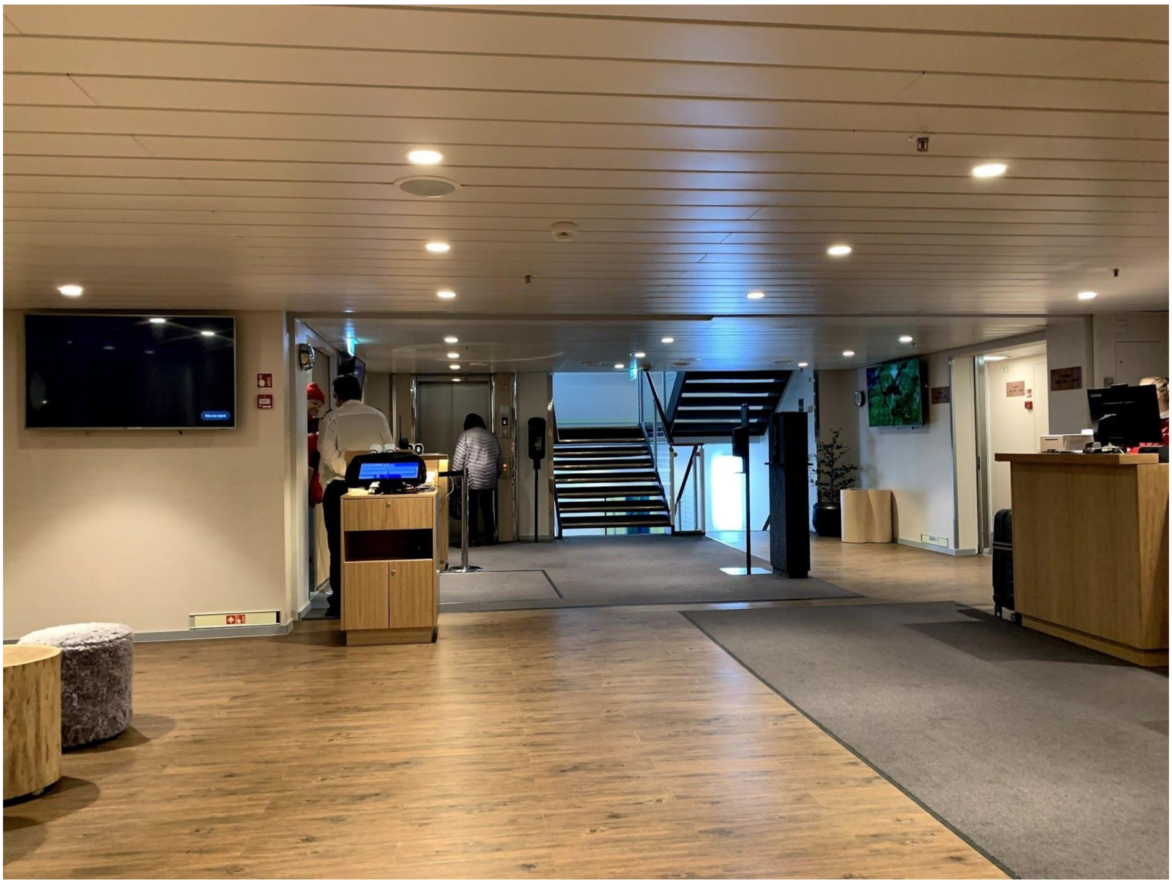
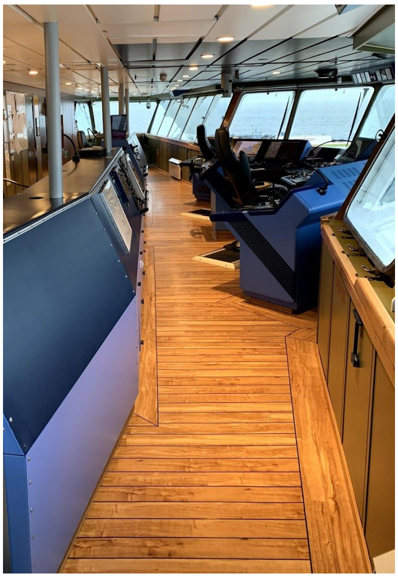
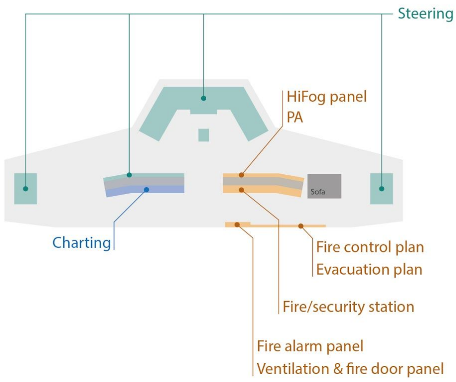


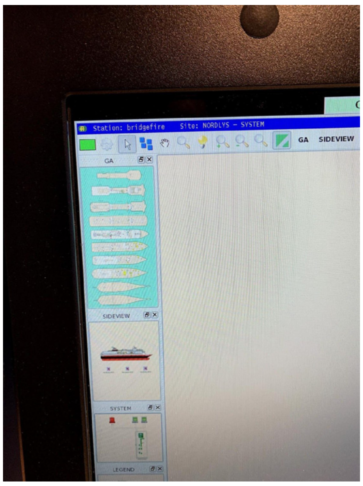
Image from the reception on the ship. During an evacuation, the cabins and ship are checked by crewmembers. The crewmembers report back to the reception and the reception report back to the bridge when an entire zone is checked.

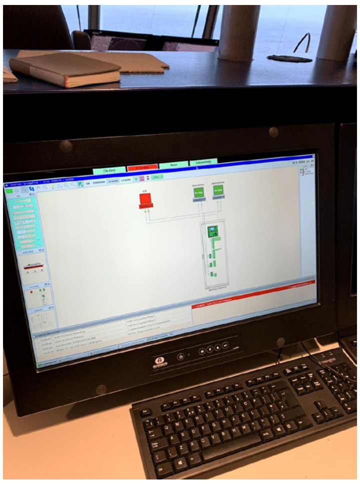




Left: Image of the bridge. It's not as spacious as other ships and retrofitted equipment is installed wherever there is enough space.

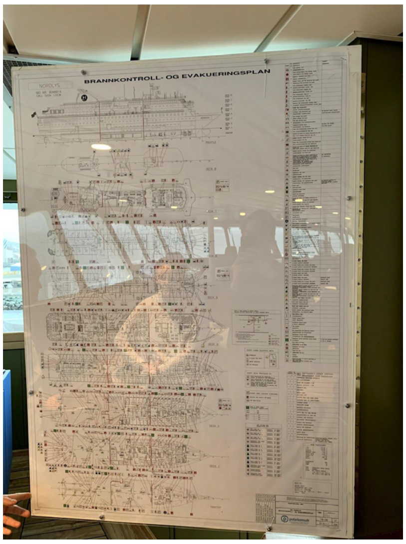
Right: Approximate layout of the bridge. Notice that the HiFog-panel and the PA are on the opposite side of the island that contains the fire/security station. Other than this, the equipment dealing with fire is quite gathered.





Left and middle: Image of the fire/security station. Here, all of the fire detectors are placed on an interactive graphical map of the ship.

Right: The fire detector control panel. This panel is behind you if you stand towards the fire/security station



Left: Image of the fire control and evacuation plan. It flips out from the wall and is normally stored with the fire control plan flipped inwards toward the wall. In the event of a fire, the security officer and chief engineer will use the board as a cognitive tool by writing notes on it.

Right: Image of a board with information about dampers and CO2 systems onboard.

Images of the ship’s alarm plan. In the event of a fire, 6 crewmembers muster on the bridge; the captain, chief officer, security officer, navigation officer, 2nd officer and the crew purser. Here, the captain has the overarching command, while the security officer deals with evacuation and the navigation officer deals with the preparation and launching of lifeboats. In addition, the chief engineer musters on the bridge and has the command of the firefighting.

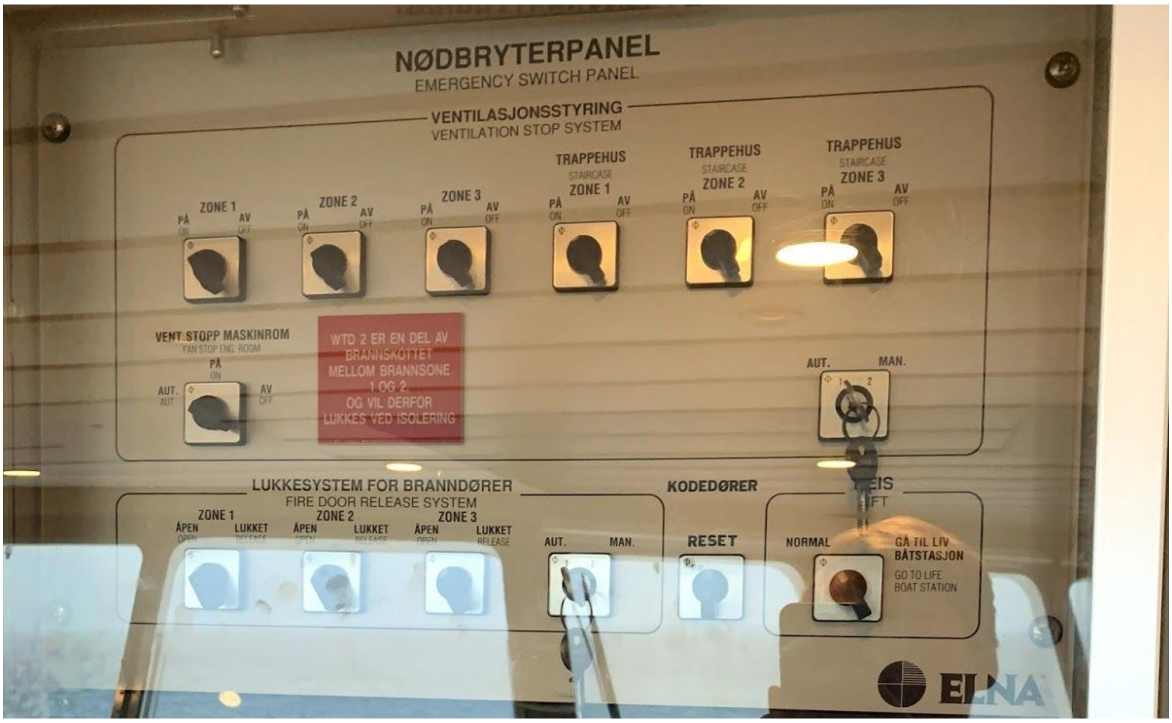


Image of the emergency switch panel. From here you can close fire doors, drive the elevators to the lifeboat station and turn on/off ventilation. In the event of a fire, the ventilation will be turned off and the fire doors will close automatically. The ventilation in the staircases will be kept on to maintain positive air pressure in the staircases. This will inhibit smoke from travelling into the staircases and will make evacuation safer and easier.

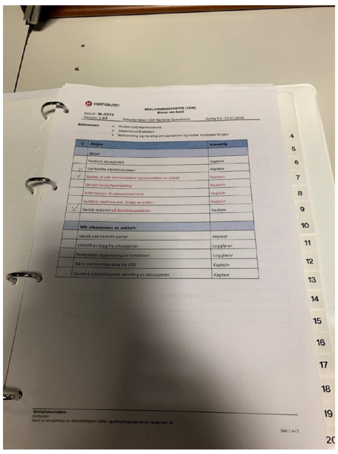
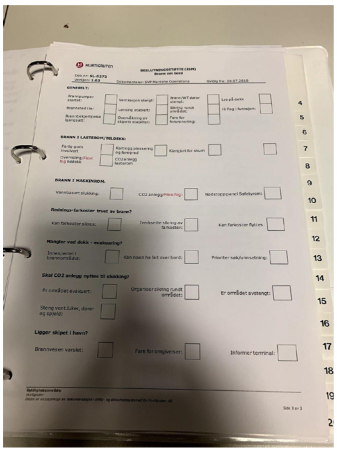
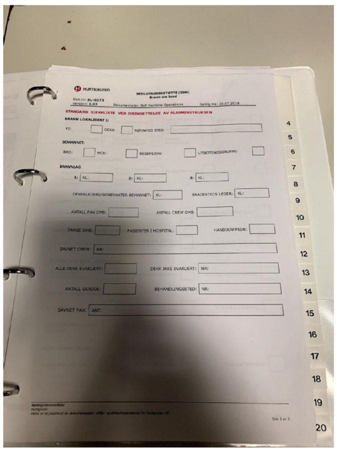
Visit at MS Sister

Exterior images redacted

MS Sister With is MS Medium Ferry's sister ship. They are not 100% identical, primarily because of the incident at MS Medium Ferry and the resulting repairs, but they share many similarities. As the ships are so similar, this report can in many ways be considered as a supplement to the report from MS Medium Ferry.

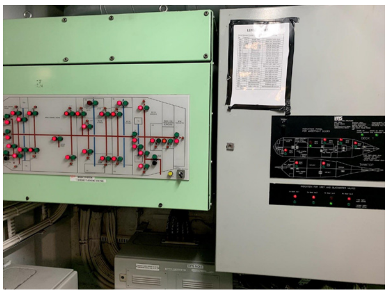
The bridge is similar to the bridge at Nordlys, with the exception of some chair placements and some panel placements. A crude illustration of the bridge can be seen on the left image.

Right: An image of the watertight door panel on the bridge. From here, the watertight doors can be controlled.

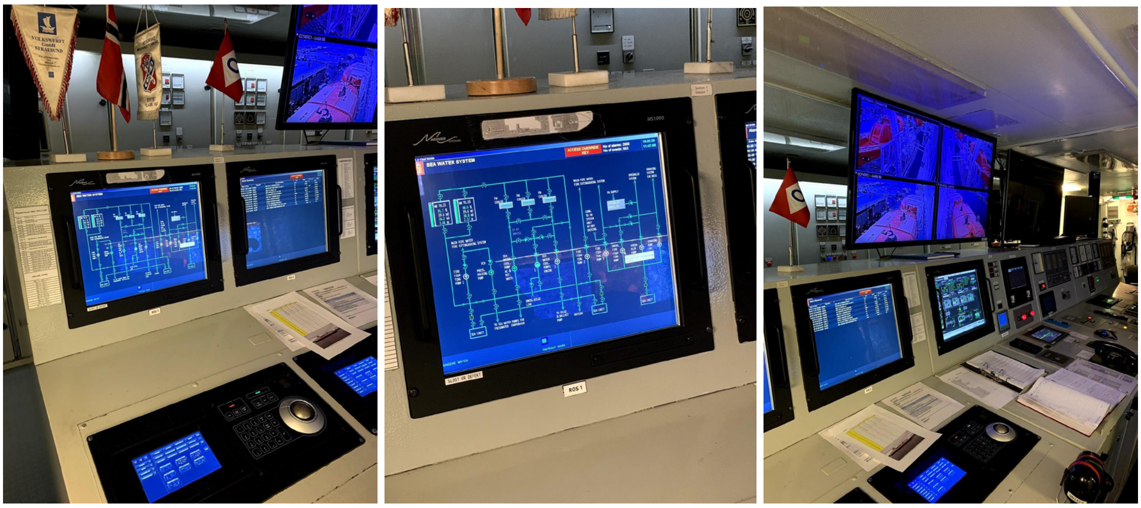




Next to the fire/security station is a binder with a decision support system in it. This binder contains several checklists about what one should do in the event of a fire.


The ship has three fire teams and three fire stations spread around the ship. These fire stations contain equipment used for firefighting, e.g. smoke diving equipment and fire-resistant clothing. There is one fire station in each of the three sections of the ship. In the images above, you can see one fire station with fire equipment for three persons (one fire team).



Images from the safety room. From the safety room, you can do an emergency shut down of the engines, close watertight doors, start fire pumps ++.



Images from the control room. The control room is situated lower in the ship next to the engine room. The control room is primarily for overseeing the engines, but it also contains a CCTV system and a fire/security station. This room is secured with a NOVEC gas system. The system is similar to a CO2 fire suppression system, but it uses a special gas (NOVEC) to essentially cool the fire. The advantage of using NOVEC instead of CO2 is that NOVEC is not fatal to humans. Other places on the ship there are CO2 systems. Exactly why they haven't changed all the CO2 systems to NOVEC systems is uncertain, but money is probably one of the reasons.

The engine room has both regular fire detectors and heat-detectors. These detectors are coupled into the fire/security station from Autronica.

Visit at MS Newbuilt Explorer

MS Newbuilt Explorer is a brand new ship. It's built-in the latest years and is a state of the art electric hybrid ship. The ship is built for arctic exploration and is therefore not a ro-ro-ship. Nevertheless, the fire detection system and management are similar to what they have in ro-ro-ships.

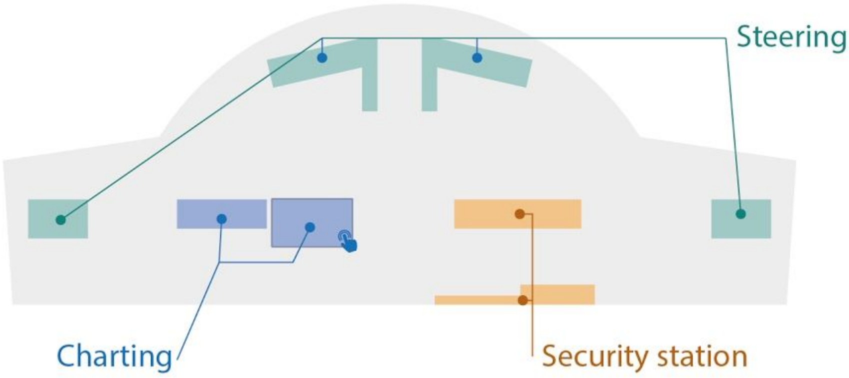
Images of ship outside redacted

The bridge on MS Newbuilt Explorer is very spacious and divided into three stations; the ship's controls and steering, navigation station and security station. In addition, the bridge had two steering stations on the far port- and starboard- side. The security station included comms for the ship, fire detection system and fire suppression system.



It's worth mentioning that the navigation station had a huge touch table for charting out routes and doing navigational tasks. This table was height adjustable and tiltable by pressing small buttons on its side. When I visited the ship, the table was in a low table-ish position, and there were some papers and equipment on top of it. When I asked the security officer about the station, he started to touch the screen, but the screen didn't respond because the things laying on top of the table interfered with the touch sensors. Because of this interference, the officer pulled out a small drawer underneath the table. Inside the drawer was a keyboard and a mouse…

When I asked the officer about touchscreens aboard, he didn't seem too keen on them. The reason seemed to be because of poor touch sensors and interference with possible objects on top of the screen. The officer did mention, however, that he would like a bigger screen for the fire station.



The figure above shows an approximate layout of the bridge.

The ship’s fire detection and suppression equipment panels are located at the security station on the bridge. Here they have an Autronica system for detecting and managing the fire. This system is split into two screens, where each screen runs a separate instance of the detection system on two separate computers. In addition, there is one screen for managing the ventilation and one screen for managing the CCTV-system on board. All of these screens run on separate computers with separate keyboards and mouses. There are also two separate computers on the lower right and left side. These are for personal use and don’t run any of the security/detection software.

An image of the station where the Autronica fire detection system, CCTV system, and ventilation controls are situated. Each running of a dedicated computer with a dedicated mouse and keyboard. It is easy to imagine how this can become frustrating in a high workload scenario.

The control panels for the drencher systems, watertight doors, lifts and fire doors are situated to the right of the computer screens in the image above. The Autronica fire detection system is connected to the drencher system, watertight doors, fire doors, and CCTV and shows their state. In addition, the fire doors and drencher systems are automatically activated in the case of a fire.

The Autronica system also shows the relevant CCTV camera when a fire detector goes off, and the ship is supposed to get a software upgrade from FIKE that allows the CCTV cameras to detect fire through some advanced image processing magic.

In addition to showing the state of fire detectors and fire doors and showing CCTV cameras, the Autronica system could be used to “place” fire teams and keep track of how long the teams had been inside an area of fire when e.g. smoke diving. The system also had checklists for different scenarios programmed in, e.g. in the event of a fire; do this and this and remember to check this. The system, however, seemed to be difficult to navigate and the alarms weren't graphically very distinct.

The digital map in the fire station system shows fire detectors, fire doors, watertight doors, CCTV cameras, and other digital equipment, but it didn’t show the location of fire extinguishers and other analogue extinguishing equipment. This was something that the officer wanted.

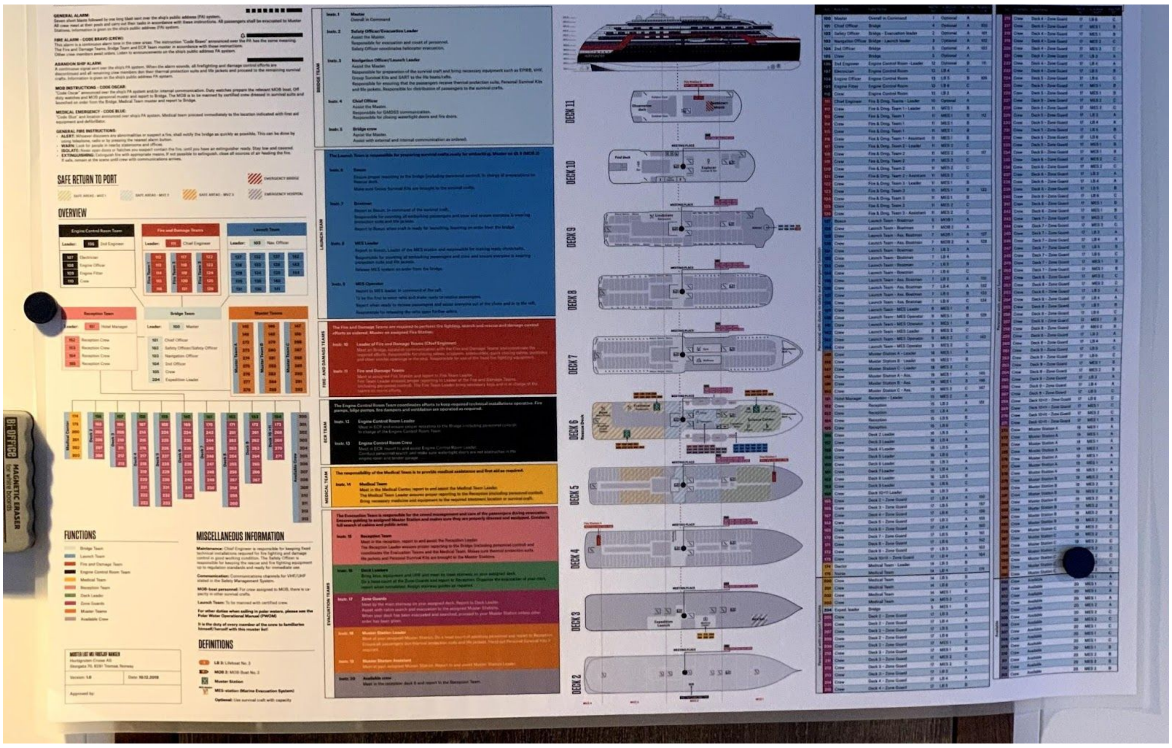
Two images of the alarm panel. One has an acknowledged alarm, while the other has both an acknowledged alarm and an ongoing alarm. Can you spot the difference?

An image of the checklist function on the system. The officer needed to dig a bit in the menus before he found it. It's worth mentioning that the ship is so new that the crew hasn’t trained on fire scenarios yet.

The drencher system onboard were exclusively HiFog systems. In normal rooms, this system has melting valves on each nozzle, while in engine rooms and rooms that can become warm, the system is activated through an automatic valve that opens if two or more fire detectors get activated. The officer mentioned that they even have HiFog-nozzles in the battery room, even though there is no chance for a HiFog-system to extinguish a battery fire. The officer said that during construction, the battery room was protected with a FirePro-system, a fire suppressant system that releases an aerosol that interrupts and halts the chemical reaction of a fire.

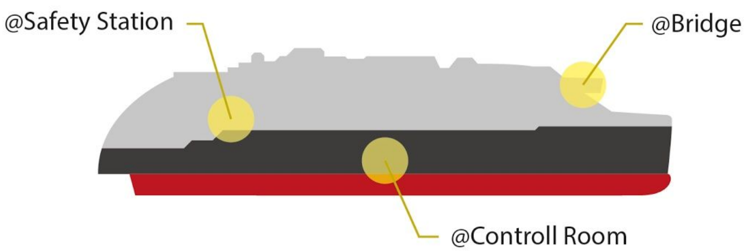
If the system detects a fire the fire doors, dampers and fire cloths are closed automatically.

During an evacuation, the crew checks every cabin and hangs on a yellow slip on the door to indicate that the cabin has been checked. The cabins are checked in zones, and the evacuation crew reports back to the reception, who then reports back to the bridge when a zone has been checked and evacuated. The “fire station system” (image above) has a checklist for evac, but the crew still uses a paper checklist.



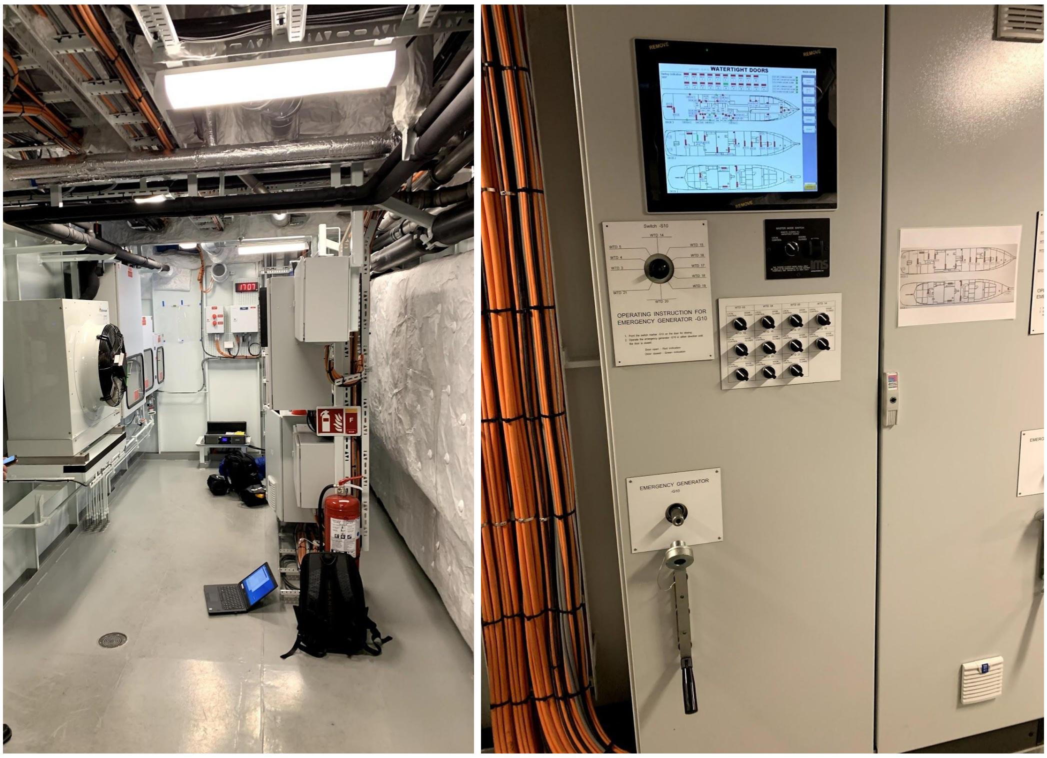
An image of MS Newbuilt Explorer's muster list. The fire plan (detailed map over the boat and fire doors and such) was located next to this muster list. Both of these maps were hung on the wall on the opposite side of the bridge than the fire station. The security officer wanted to have a laminated version of the fire plan, not only on the bridge but also for each fire team.

Location of fire stations:



Onboard MS Newbuilt Explorer there are three rooms that contain a fire station and controls to deal with a fire. These three rooms are the bridge, safety station and control room. The illustration above shows the approximate location of the different rooms on the ship.

In each of these rooms, there is a separate instance of the Autronica fire system. In total, there are four instances of the fire system; two on the bridge, one in the safety station and one in the control room. At any time one of the four fire systems is set as a master. This master will visually and audibly show alarms, and one can acknowledge, reset and mute alarms here. The remaining slave instances will only show the state of the ship's fire systems, but one cannot actually interact with it in any meaningful way. Each of the instances can be set as a master, but there can only be one master at any time.



Left: Image of the safety station. Inside is a fire/security station similar to what they have on the bridge.
Right: An image of a control panel for the watertight doors on the boat. From here they can also close the doors manually by generating power by a hand-crank, but this will not likely be used since each watertight door has a battery pack with enough charge to close and open the doors several times if the ship’s power is dead.

Image from the control room. This room is next to the engine room and contain control systems for the engines. In addition, a fire station is installed here, as well as CCTV access panel.

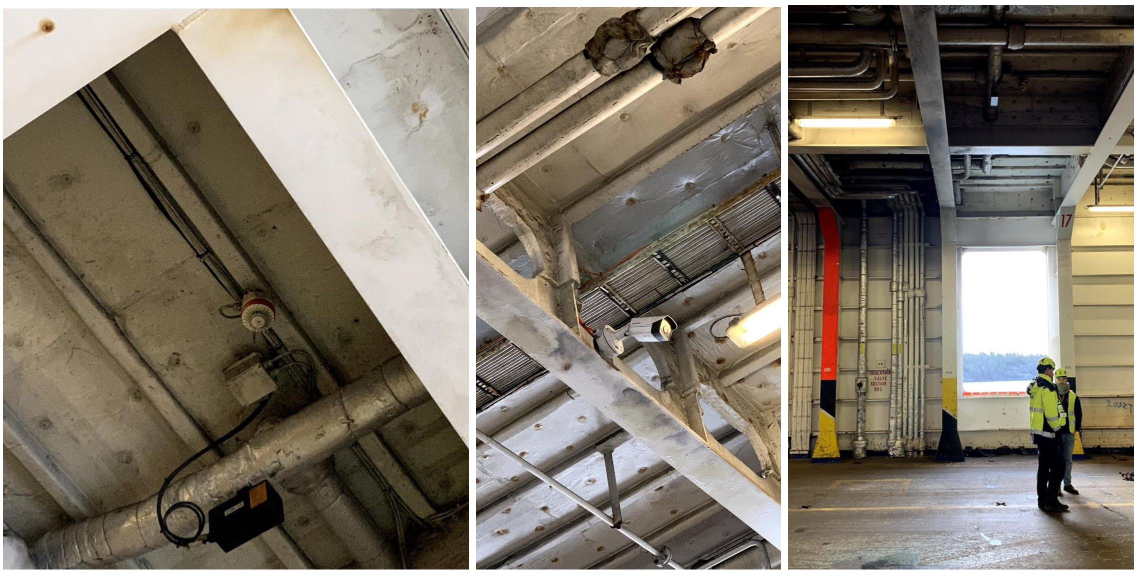
Bye-bye Newbuilt Explorer. Image of the boarding ramp.

Appendix E

Visit at MS Generic

MS Generic is a classic ro-pax-ship, meaning a ship that both takes vehicles and passengers. It has one vehicle ramp at the aft and the majority of its cargo seems to be commercial trailers, reefers and containers. In total, the ship has five vehicle decks, three closed(internal) and two open/semiopen decks. Three of these decks are primarily used for trailers and containers, while the uppermost open deck and a small internal deck is used for passenger cars. The MS Generic ship is a reference ship in the LASH FIRE project.

Image of the ramp to the semi-open ro-ro-space on deck 4 and a panorama of the ro-ro-space almost empty.



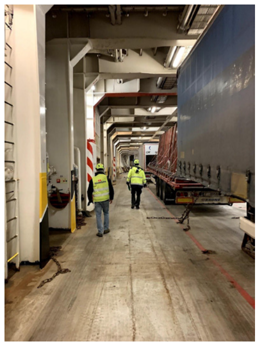
Left: Image of a smoke and temp detector inside a ro-ro-space. It was difficult to find the detectors in the ro-ro-spaces due to dirt and dust and it might be interesting to explore the possibility to add a larger led-indicator to indicate its state.

Middle: Image of a newly installed CCTV camera inside the same ro-ro-space. This is a "normal" (e.g. not IR) camera and is primarily used for surveillance, but can also be used to check if a fire detector actually detects a real fire.

Right: Image of the semi-open ro-ro-space. Notice the height of the roof and the large open windows. Most of these windows were welded shut, but a few remained open. The reason for welding them shut was to increase fire safety by reducing wind and oxygen supply in the event of a fire. Notice also the red beam in the picture. This red line indicates the border of a drencher zone, drencher zone 17 in this case.

Image of a drain opening inside a ro-ro-space. The drain opening is normally open at all times but can be plugged with a plug (left image) if needed. A scenario where the drain would be plugged is in the event of oil leakage.

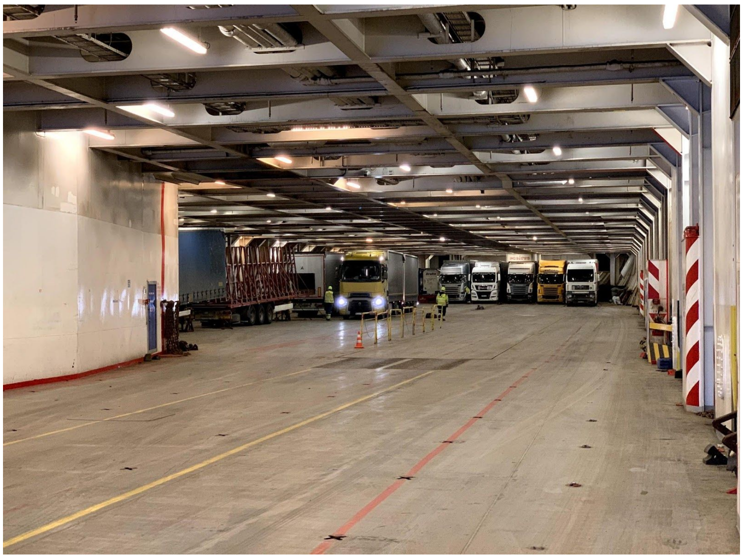
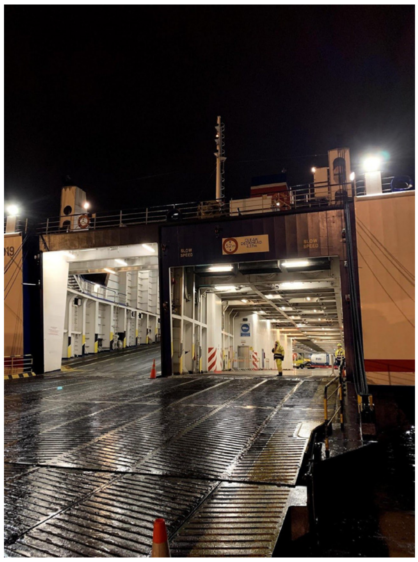


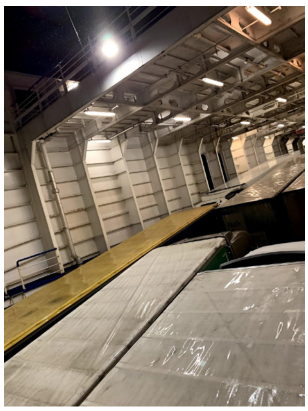


Left: Image of the closed/internal ro-ro-space for passenger cars.

Middle: Image of the first closed/internal ro-ro-space and a ramp down to the passenger car ro-ro-space and the lowermost ro-ro-space.

Right: Image of the first closed ro-ro-space. This space was mostly used for trucks and containers.

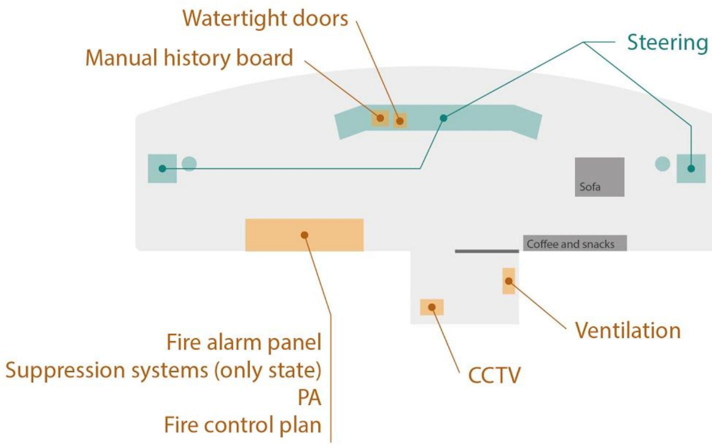


Images of the loading procedure in Ventspils. Notice how tight the trailers are packed.

Image of the topmost car deck. The ship had newly installed water cannons on this deck. The water cannons are connected to the drencher pipe system and can cover 100% of the deck with their water spray. Since the water cannons are connected to the drencher system, the drencher pump and zone have to be manually started and opened to use the cannons.

Images of a connected reefer. A reefer is a refrigerated or heated container. The pictured container is an electric reefer, a common source of fire aboard ro-ro-ships.

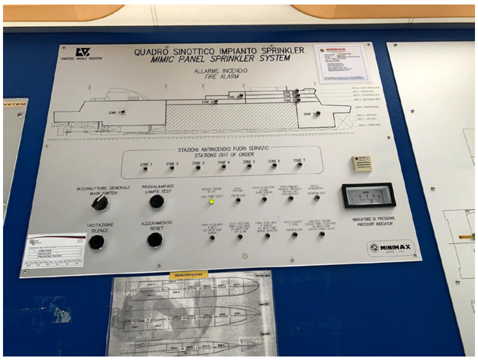

A picture of the bridge. It is quite spacious.



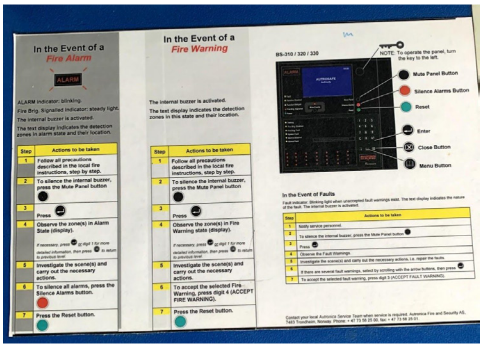
An illustration of the bridge layout. Controls and panels related to fire detection and handling is coloured orange. Notice how scattered they are. The ventilation control and CCTV is located in a semi-separate room. The CCTV is primarily used for surveillance, but they also use the CCTV system to verify a fire alarm. In this case, a crew member would find the nearest camera to the detector and zoom in to check if there is any smoke or fire. The CCTV system has a digital zoom function where you can zoom in as much as you want. Finding where the activated detector is and the correct camera seems like a hassle though. Which detector is activated is shown with a code on a separate system in the fire alarm panel, and the cameras are selected through a tree menu where each camera/tree has a semantic name that corresponds to its location.

Images of the main "fire station" on the bridge. The fire detection system, sprinkler panel, HiFog panel, fire doors control and the PA system is located here. The drencher system is purely manual and the bridge cannot see if a drencher is activated or not.

The fire doors could be controlled from the bridge, but the only control option was to close all of them. So if you wanted to close a single door, then you would have to do it locally. Also, the panel showed the state of each door (open or closed). When a door is closed the corresponding led to that door is turned off, and if the door is open the corresponding led is turned on. The officers on the bridge explained that this makes it hard to see which door is closed at night, simply because the led is turned off. The panel is pictured on the far right on the top picture.



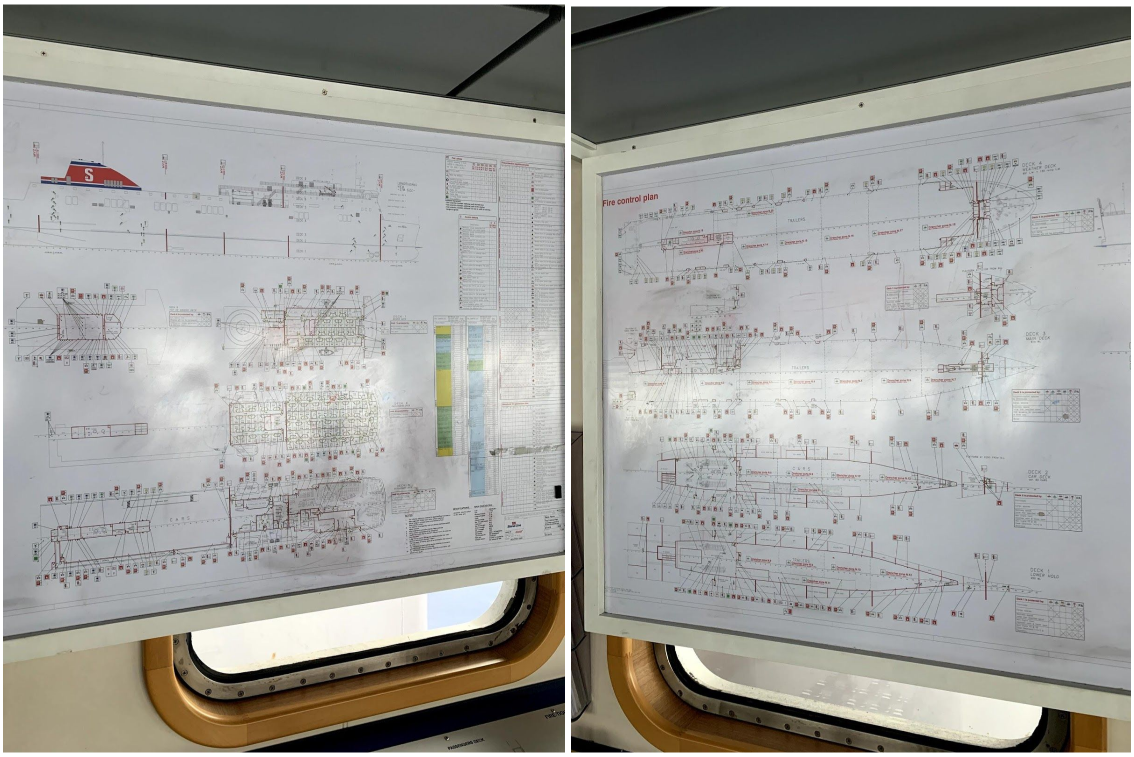
The other suppression systems can not be controlled from the bridge, but the panels show if a HiFog or sprinkler zone is activated. The activation is done locally; either manually, by sensors or through melting nozzles. The two pictures above show the HiFog panel and the sprinkler panel.



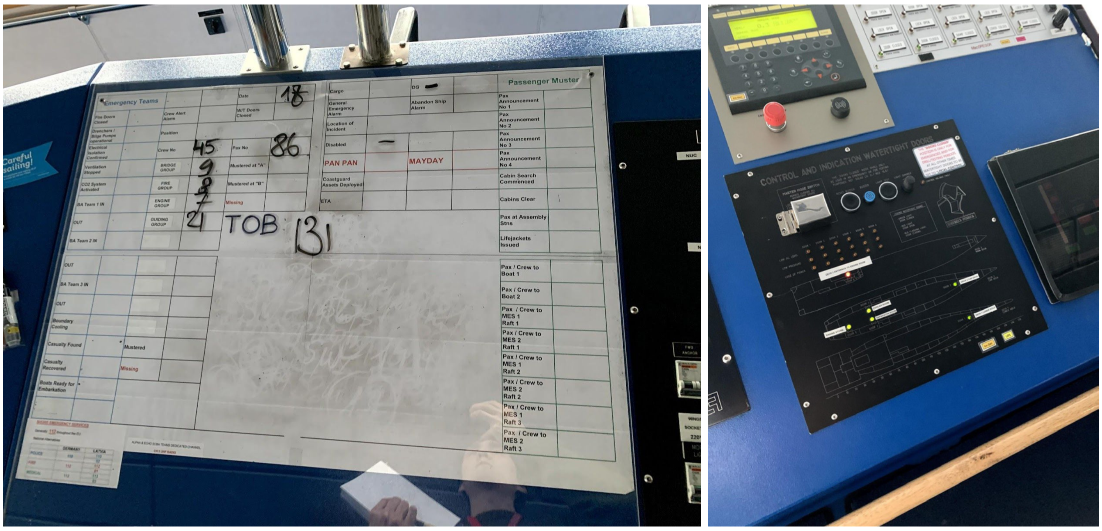
The pictures show the fire detection system. Notice the laminated guide describing how to operate the panel. The crew also explicitly said that almost no-one knows how to operate this panel.

In the case of a fire, the panel will display a code that corresponds to the activated sensor/detector. Apparently, this code contains wich deck and zone the detector is located, but to find the exact position you have to look up the code in a paper folder next to the alarm panel. When a fire alarm sounds, the system gives the crew two minutes to acknowledge the alarm before the general alarms sounds. When the alarm is acknowledged, the alarm is silenced and the crew can go and check whether the alarm is legit. Manual alarms do not have the two minutes of prewarning and activate the general alarm directly; to the crew's great disappear.

It's worth mentioning that this panel can be expanded with a digital screen that shows the detector states and alarms on a graphical map of the boat. Many of the other boats I have visited have installed this expansion.



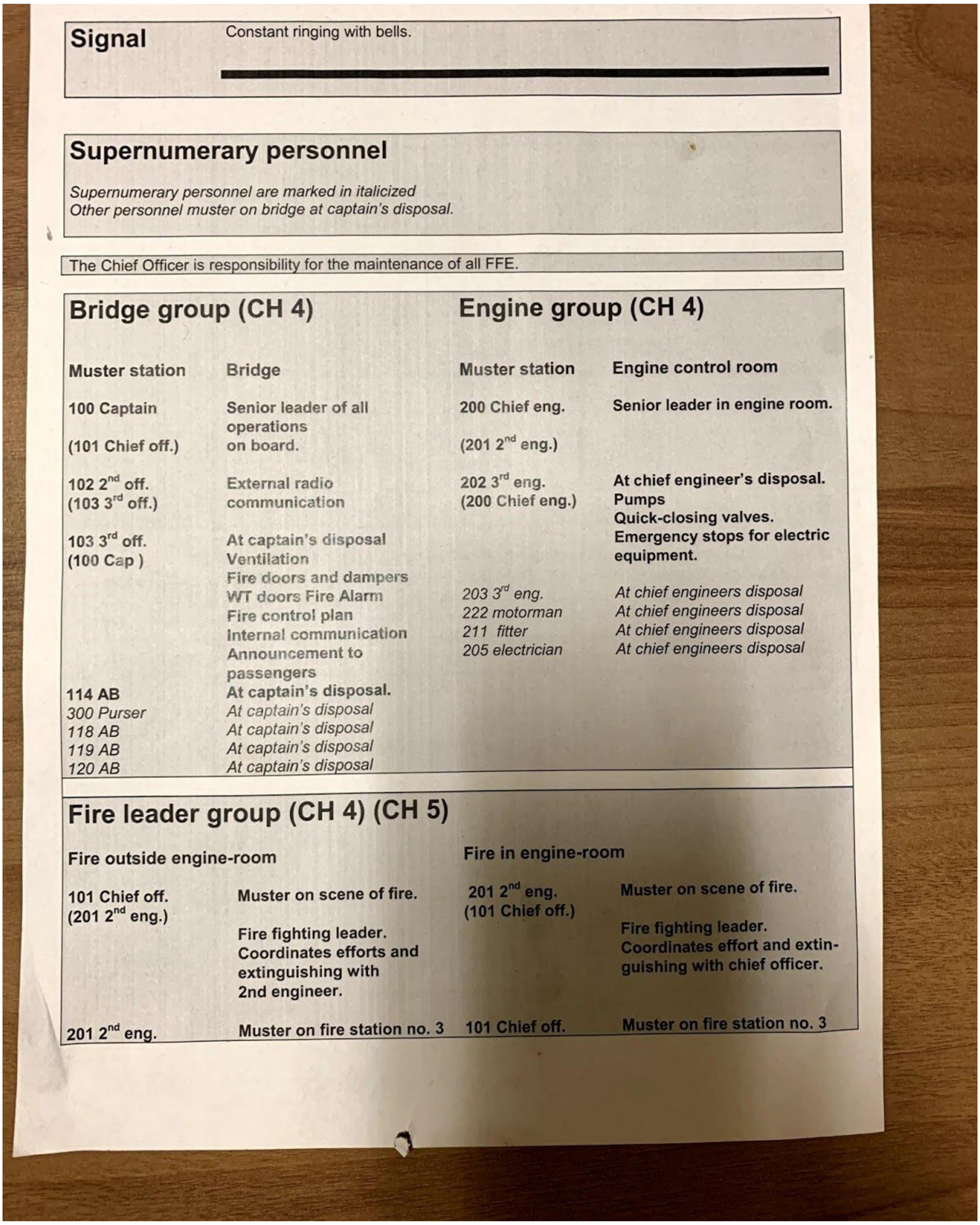
Over the “fire station” a flip-down fire control plan is located. This is used as a cognitive tool by drawing notes, location of the fire, location of fire teams and other information on the plan with markers. This is similar to most other boats I have visited.



Left: A manual history board where the crew can note down information about passengers, crew and events during a fire or evacuation.

Right; The control panel for the watertight doors. Similarly to the fire doors, the only control option is to close all of the doors. The panel also shows the state of the door (open or closed) and mechanical alarms (e.g. low on oil).

Both of these panels are located behind the “fire station”.



Signal Constant ringing with bells.

Supernumerary personnel

Supernumerary personnel are marked in italicized
Other personnel muster on bridge at captain's disposal.

The Chief Officer is responsibility for the maintenance of all FFE.

Bridge group (CH 4)

Muster station	Bridge
100 Captain (101 Chief off.)	Senior leader of all operations on board.
102 2nd off. (103 3rd off.)	External radio communication
103 3rd off. (100 Cap)	At captain's disposal Ventilation Fire doors and dampers WT doors Fire Alarm Fire control plan Internal communication Announcement to passengers
114 AB	At captain's disposal.
300 Purser	*At captain's disposal*
118 AB	*At captain's disposal*
119 AB	*At captain's disposal*
120 AB	*At captain's disposal*

Engine group (CH 4)

Muster station	Engine control room
200 Chief eng. (201 2nd eng.)	Senior leader in engine room.
202 3rd eng. (200 Chief eng.)	At chief engineer's disposal. Pumps Quick-closing valves. Emergency stops for electric equipment.
203 3rd eng.	*At chief engineers disposal*
222 motorman	*At chief engineers disposal*
211 fitter	*At chief engineers disposal*
205 electrician	*At chief engineers disposal*

Fire leader group (CH 4) (CH 5)

Fire outside engine-room

101 Chief off. (201 2nd eng.)	Muster on scene of fire. Fire fighting leader. Coordinates efforts and extinguishing with 2nd engineer.
201 2nd eng.	Muster on fire station no. 3

Fire in engine-room

201 2nd eng. (101 Chief off.)	Muster on scene of fire. Fire fighting leader. Coordinates effort and extinguishing with chief officer.
101 Chief off.	Muster on fire station no. 3

Image of the fire muster list.

Images from the control room. A separate CCTV system and a fire detection panel are located here.

Two images from the safety station. This station also functioned as a fire station. Here you can activate the ventilation safety stop, close fire doors remotely and shut off the fuel supply to the engine.

The HiFog pump room. The different HiFog zones can be started manually from here, but they can also be started remotely from the bridge.

An image of the drencher room. Pictured is the manual valves that open the flow of water to a drencher section. Next to the valves is a phone that should be used to inform the bridge of which drencher section has been activated. The pipes are marked with drencher section numbers, which beam it includes and whether the section contains lifeboats.

Image of the CO2 room onboard. From here the engine room can be flooded with CO2. When the CO2 is activated, the flow of gas makes a siren shriek to indicate that the CO2 is activated. There is no pre-alarm before the CO2 is released and if you hear the siren you just have to draw a deep breath and get the hell out of there. The routines demand that you have checked the engine room and verified that there is no-one inside before you activate the CO2.

Images from fire station #3. This is where the chief engineer and fireteam muster in the case of a fire. The room contains fire equipment and smoke diver equipment.

Image of the bridge at night. I think OLED screens could be good here…

Participatory design interview notes

During the visit, we had a small interview where we shared our ideas around a central digital fire management centre and asked the crew what they need and would like.

Generally, the crew was positive to the idea. Their main complaint about their current system is that its too difficult to understand where the fire is. They wanted a more graphical interface on the fire detection panel. They would like a big digital map of the ship with info about the fire detectors, doors, drencher system and other fire suppressing systems on the ship. Basically unite all the info about a fire and the suppressing systems into one place.

The crew were positive towards a touchscreen as long as the screen is of high quality. They mentioned some equipment on the bridge that had touchscreens, and they were happy with them. They also mentioned that it could be nice to have some physical buttons as well, maybe for important functions. It also has to be easy to use at night and in very low light since the bridge is completely dark when sailing at night

Currently, the crew has a binder with different checklists for different fire scenarios. This checklist could become digital and show the correct checklist immediately after a fire is detected. The crew was a bit hesitant towards this idea, but they said that it could be useful given the right circumstances.
The crew did not want CCTV to automatically pop up when a fire alarm is activated. But their mind changed after some discussion back and forth between themselves and they landed on being positive to CCTV integration if the screen is big (i.e. 50 inches or bigger).

In order for the captain and crew to get a good understanding and awareness of a fire situation they need info about what kind of alarm is activated (smoke, heat, CO_2 and so on), the location of the alarm (graphically) and how the alarm/fire is spreading. They would also like to know about potential dangerous things around the fire and suggested that things could be colour-coded dependent on the danger. Maybe also info about fire doors and watertight doors.

In addition, the captain wanted info about what kind of fire suppressor system is in the section of the fire.

Prototype 1
Usertest/Co-creation
6. April 2020

Prior to the meeting, the test subject (alsias Espen) was sent the digital Figma prototype. The test subject clicked around the prototype before the meeting started. This was done to maximize the short time we had for the meeting and focus the meeting towards the concept, rather than the usability aspect of the prototype.

The meeting started with an introduction of me, the project and the concept. Here, I stressed that the prototype was just a sketch we could use as a pivot point for a conversation about the concept and what he would like to have in such a system

Espen is a chief engineer aboard a ship operated by a major nordic shipping company. During a fire scenario he is the leader of the fireteams and is situated at a “fire station” on the bridge. Espen has tested several new fire central systems, and has a lot of insight into what he thinks is missing from current systems.

When talking about the prototype, espen says: “I like what I see!”
He lies the way all opf the different information in the prototype is split into different layers that he can toggle on/off. Many problems of current systems or new systems is that they incorporate a lot of information, but it becomes information overload. Espen said that the layers prevented this, and he can customize the system to only show what he needs. HE also likes the google maps analogy, where the map will show less detail when zoomed out.

When clicking around on the map, Espen would like the opportunity to toggle a large side view of the ship. This side view can be used as a quick navigation, but, more importantly, it is good to see what is in the deck below or over.

Espen would like the system to show the pressure on the drencher line. This pressure tells him if the system is ok or not. He would also like to activate the drenchers from the system, and the system should tell him the state of scuppers. When talking a little bit about this, we found out that it should show if all scuppers are open, and which scuppers are closed if not all are open.

Espen would also like frame numbers as a layer. The frame numbers are useful when planning the fire fighting.

The fire wall types are important to incorporate in the system. As well as doors and their state

Espen is very positive towards the system highlighting risk objects, such as cars and cargo. HE says that it is also important to highlight elevator and trash chutes, as these can let smoke spread throughout the ship. Espen also explains that in some scenarios, he might for example activate the sprinklers in a trash chute to prevent heat and smoke from spreading.

The detailed timeline is good, but Espen would like the possibility to play the last few minutes in loop. So that he can see what has happened. We talked about the possibility to have a timeline scrubber, and Espen liked the idea. If this timeline scrubber is incorporated, the detailed timeline might not be as useful, as the timeline scrubber will take over for it.

Espen likes the alarm and pre warning popups. He also likes the histogram view of sensordata.

Espen says that in car decks, the detectors might need to be disconnected during loading and unloading to prevent any alarm from going off because of car engines running. Newer detectors however, do not have this problem for some reason. Anywho, a function to disconnect a detector for a given time is good to have.

Espen is very interested in the heatmap function. It allows him to see better how the fire and smoke is spreading. “Good! Very interesting!” - Espen

Espen informs that when they train on large fire scenarios, they often have 20-30 alarms going off in a short time. Espen is worried that this will create a pop-up overload with how the prototype shows alarm handling. He suggests that I simulate a large fire to see how the system will respond. In some systems it is possible to disconnect a zone/area to prevent this pop-up overload.

When talking about the portable terminal, Espen is a little bit skeptical. It might be useful, but it just has to work. It is difficult with wifi signal around in a boat because of the metal hull. He also says that the portable terminal might be better suited for evacuation, however, he also says that it might make the reporting easier between teams.

Espen really likes the drag and drop markers. Or at least the concept of it (they don’t really work in the prototype). The markers makes it easy to note where the fire is and what is being done.

Back to evacuation, espen is into the idea of sharing the system with evacuation, as both fire and evacuation teams can benefit from shared information. He do want to have a separate screen for the evacuation leader though. To two large screens on the bridge.

“I’m very satisfied” - Espen

Link to prototype 1

https://www.figma.com/proto/8NCmy1McakCpkn2JCVxedh/Concept-v1?node-id=76%3A292&scaling=min-zoom

Prototyp 2
User test and co-design
06. Mai 2020

The usertest was done with Espen from prototype 1. This time, however, it was an actual usertest where Espen clicked through prototype 2 and some scenarios while I noted down his thoughts. BEfore we started, it was stressed that the prototype is in the really early stages and that he should think aloud and tell what he thinks doesn work or is missing.

First of all, Espen does not understand what zone means in the map. Is it drencher zone? The firezone should be called MVZ or main vertical fire zone, not just zone.

Espen, as before, wants the framenumbers incorporated into the prototype. Or at least some important numbers. He suggests that it could be a layer that he can toggle on or off.

Espen tries to click on the Hi-Fog zones, and expects more information about the zone to pop up. This does not happen however.

Espen misinterprets the orange color choice for the fire equipment. Orange is used to mark dangerous gasses, so it is wrong. He would like to have red color coding instead. He also says, however, that this can vary from ship to ship, so he could be used to it.

The CCTV camera is good. And good that he can zoom in. He would want to have a scroll to zoom or pinch to zoom function, but he understands that this is not possible due to the prototyping tool.

The power connector is easily understood by Espen. He also likes the indicator of where the different connectors are and whether they are plugged in or not. He’s uncertain of where the temperature measurement is. Is it in the car or in the plug? He says that it is useful to have temp in the plug, as this can become warm during charging. He does not see that he can scroll horizontally to get more data. So there should be a scroll indicator. However, the prototype does not give an accurate image, as it is not on a touch device. Espen wants the possibility to disconnect the charge station from power.

The layers are easily understood, and he likes them now as well. Firewalls are good and color coding works well. The cargo layer is good, but on his ship, they only have two classifications; normal and dangerous cargo. Espen would also like tips on fire fighting on dangerous goods and more info about the cargo. F.ex. the cargo weight, the safety datasheet, what the cargo is and so forth. The smoke and heat map layers work very well and Espen likes that there is a minimum threshold so that everything isnt colorcodedd blue when he turn the layers on.

Pre-warning

The yellow indicator is instantly understood by Espen.. He clicks on it and finds the prewarning very quickly. The histogram is very good and espen can see what is causing the prewarning. Espen also instantly understands that it is a pre-warning, and not an alarm. He mutes the alarm easily, however, he would like to mute only the smoke detector and not the entire detector.

Fire scenario

When an alarm is triggered, Espen does not understand what acknowledge and cancel means. What does that do? The timer counting down to when the g.a. Is activated is very good though.

Espen does not understand mute and disconnect. They don't correspond to what he is used to. For him, mute is something he can do after an alarm has triggered. And disconnect is something he can do before an alarm is triggered. So any detector can be disconnected and muted, but only muted once the alarm has triggered. Disconnect will disconnect the entire detector from the system. For him, it also doesnt make any sense to "disconnect from general alarm". What does that mean? Is it disconnect? Is it mute? What?!. He would call it mute are or disconnect are or something like that.

When the system automation snackbar pops up, Espen uses a little while to read it, but he understands what it is and understands that he can cancel the system automation of he wants. He says, however, that he would rather want some decision support og options for actions pop up. He dont like the automatic response. In fact, it is not allowed in some spaces because of international rules.

Espen would want an activate gen. Alarm. Button

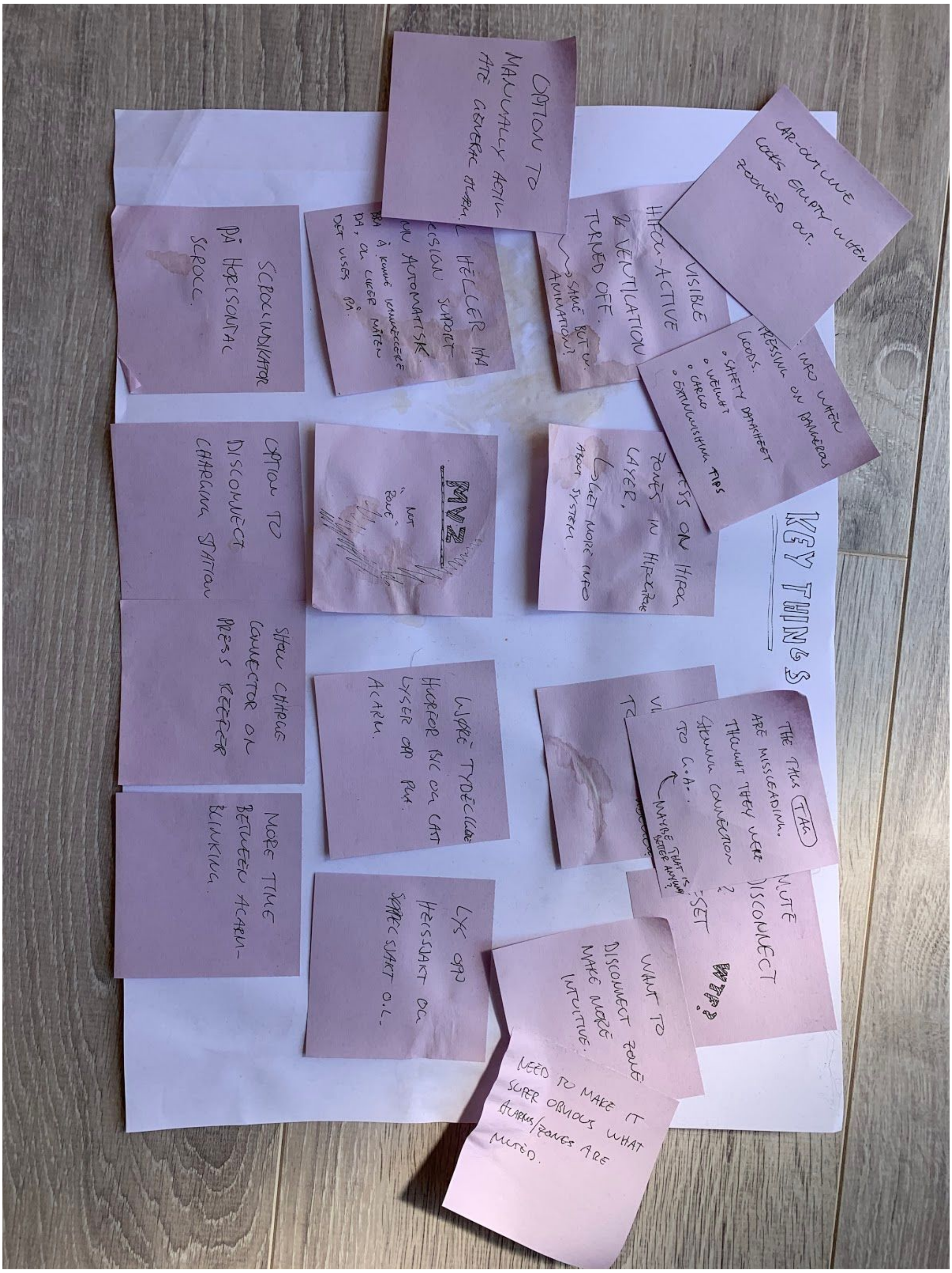
Again, Espen would like a side view. Yes, i forgot, sorry Espen
The activated hifog signifier works, but Espen does not see it at once. Espen says that this was just because he was not looking for it. Anyways, he also suggests that it might be nice to animate it, like a stapled line that moves in circles, to grab attention. Yes, i agree.

Espen does not understand at once why the electric car is highlighted red. He suggests that it might be better to highlight dangerous goods in another color. However, after some though, he says that red is probably good.

Espen understand the timeline instantly, and it works very well. At least in conveying the idea and how it works. It is not, for now, interactive.

The alarm blinking is lost on Espen. He does not see which alarms blinks first and he fails to point out the alarm that blinks first. So the alarm animation is a failure. But he also says that to know the few first alarms to get triggered is very good information.

Post-itting key takeaways. The coffee stains are an important part of the design process.



Prototype 2
Interview + user test
15. Mai 2020

Participants in the interview was a dutch captain and a chief engineer from a ship operated by a major nordic ship company. Present was also a few LASHFIRE team members. The interview was conducted by the LASHFIRE team members, and I conducted the user test.

From 13:05 - 13.18, technical troubles

Interview

Experience with fire?
No major ones the last 5 years. But had a fire in a cabin before that. It went well.

Procedures?
They perform a lot of drills with different scenarios.
Tries to learn something every time, and has a debrief where they ask: how can we improve?

Firepanels, do you get to decide which one to buy?
No. Everything is set before he joins the ship
They have a very basic model. Multiple alarms is a problem
Can print out papers to get a better overview of the alarm sequence
Was on another ship before, they had a very advanced system. The system here (on this ship) is like getting thrown back into the stone ages.

Wants a more incorporated system, not only for fire
    Yes, especially incorporated with cargo
    Cargo and where it is located

Ongoing fire → Other info regarding fire management?
    Could be nice. Maybe location of the teams

Drencher & ship stability
If everything is normal, then it should be no problem
But if there are a lot of debris from cargo or fire, then the scuppers might get clogged up.

Separate system for stability and cargo now?
Yes
Could be good to incorporate into FRMC, but unsure

Many alarms problem?
Yes. Alarms go off all the time! Annoying…

And it is not possible to isolate a detector before the alarm goes off...
So must mute alarm everytime when triggered…
Rarely false alarms, but plenty of fault alarms.

When dealing with fire situation
Chief engineer have to be everywhere. Has to run around to deal with systems. Wants to have everything in one screen. Gives a better overview.

Want info:
- Temp
- Start hifog
- Close firedampers
- Close firedoors
- Shut off electricity
- Drencher system matched with detector

Other persons that need info?
No, not really. The decisions are made on the bridge and the bridge has a separate radio line.

Touchscreen?
Naaah, dont like

Usertest

The users are situated on a teenytiny laptop… so this didnt go so well...

Free exploration
Nice with open/close damper
Detector, drencher-section and power connection looks good

Wants an overview of boat that they can click. (sideview that is)
Nice with hosebox
CCTV is very good

Now we are having extremely much technical problems with sound and video over skype….

Fire alarm works well. Sees that the alarm is at 40*C

They think they can get a lot of info in a short time with this system. Thats good!

Because of technical problems, the usertest was ended prematurely.

Links to prototype 2

Idle

https://www.figma.com/proto/7PlEP2mpmt1PnmeDeCepOG/Concept-V2?node-id=414%3A46118&viewport=-1056%2C377%2C0.05526823550462723&scaling=min-zoom

Pre warning

https://www.figma.com/proto/7PlEP2mpmt1PnmeDeCepOG/Concept-V2?node-id=495%3A0&viewport=-1056%2C377%2C0.05526823550462723&scaling=min-zoom

Fire

https://www.figma.com/proto/7PlEP2mpmt1PnmeDeCepOG/Concept-V2?node-id=495%3A53579&viewport=-1056%2C377%2C0.05526823550462723&scaling=min-zoom

INTERVJU ~~KAPTEIN(?)~~ BEFÅLHAVARE

ROLLE I BRANN-SITUASJON

↳ OVERALL COMMAND

↳ FRA BRYGGEN.

HAR SPESIELT BORD FOR BRANNSJEF.

LAMINERT G.A. OG SPRIT-TUSJER.

ALARM-PANEL

↳ CONSILIUM PANEL + DATA (GA og GRAFISK).

→ MANGE SKIP MÅ SLÅ OPP I BOK FOR Å FINNE ALARM-POSISJON.

HVOR OFTE ØVINGER?

↳ GANSKE REGELMESSIG.

ALARMLISTE

→ KAN SCROLLE OG SE ALARMHISTORIKK.

FORBEDRINGSMULIGHETER

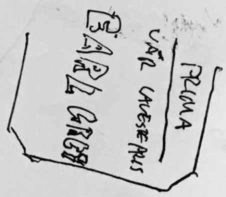
↳ GRAFISK → BRA

↳ BRA AT PANEL HOPPER TIL BRANN-DETECTOR.

↳ MEN OG HVIS GÅENDE BRANN!

↳ BÅDE JA OG NEI...

↳ VIL KUNNE STENGE AV FUNKSJONEN.



2

TRENDENE PÅ SENSOR KAN HJELPE MYE!

HVA GJØR DET VANSKELIG Å ORIENTERE SEG?

↳ VED FORLENGELSE

↳ KORRIDORER BLIR BRUTT

↳ HALVE DEKK OG HALVE ETASJER.

INTEGRERE INFO I NYTT ALARMSYSTEM

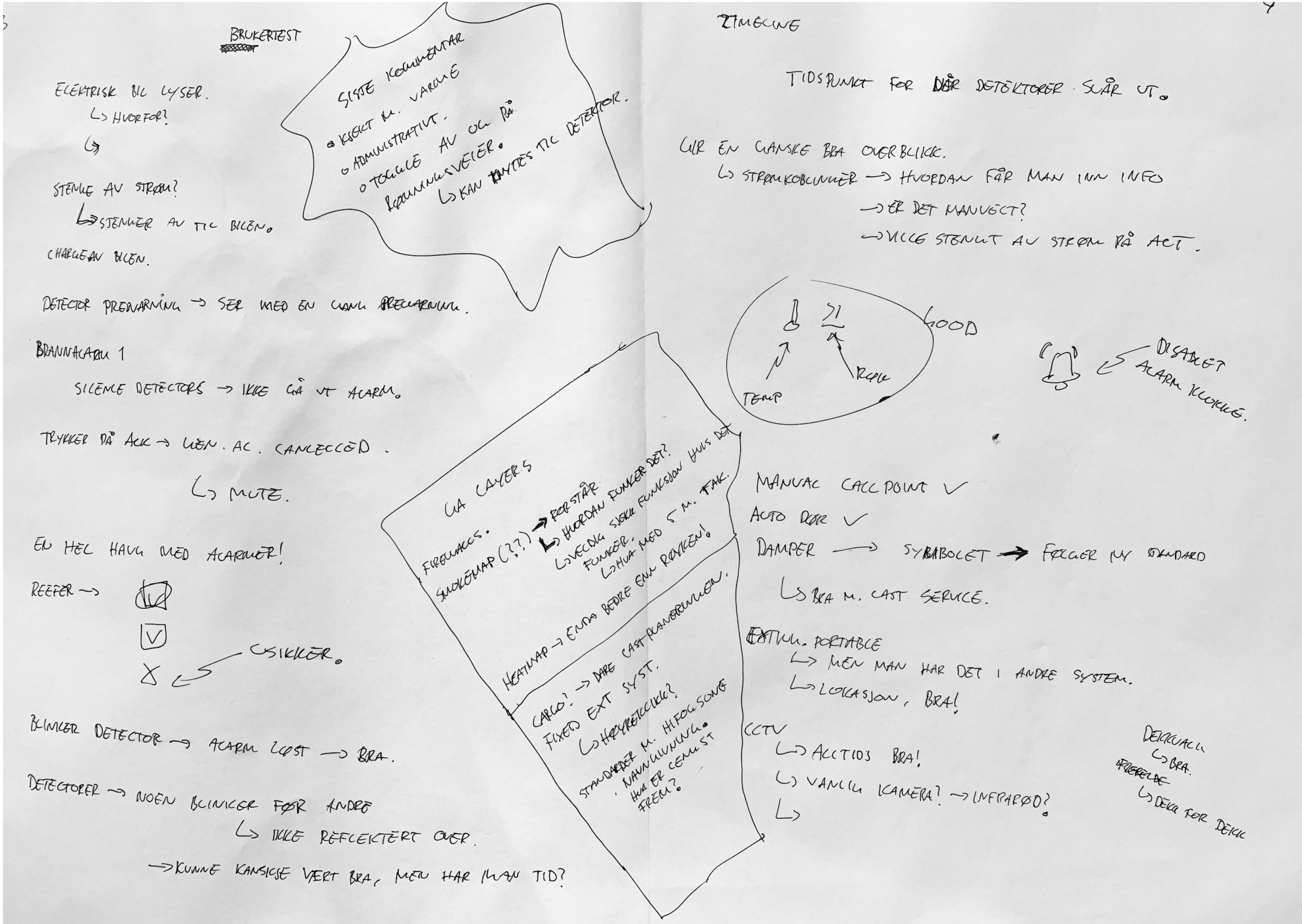
↳ PILER TIL RØMNINGSVEIER → KAN VISE ENKELT HVOR DET ER BEST Å GÅ INN.

↳ NÆRMESTE SLANGEKOBLING

HAR FOKUS PÅ INF. GIVING TIL PAX OG SKIPS-STABILITET UNDER BRANN.

- VIL HA EN KNAPP SOM STENGER AV LYDEN!

"HAR EN TID TIL Å SJEKKE LAST OG SÅNT?"



BRUKERTEST

ELEKTRISK BIL LYSER.
↳ HVORFOR?
↳

STENGE AV STRØM?
↳ STENGER AV TIL BILEN.

CHARGE AV BILEN.

DETECTOR PREVARSLING → SER MED EN GANG PREALARMEN.

BRANNALARM 1

SILENCE DETECTORS → IKKE GÅ UT ALARM.

TRYKKER PÅ ACK → MEN. AL. CANCELLED.

↳ MUTE.

EN HEL HAUG MED ALARMER!

REEFER →

USIKKER.

BLINKER DETECTOR → ALARM LOST → BRA.

DETECTORER → NOEN BLINKER FØR ANDRE
↳ IKKE REFLEKTERT OVER.
→ KUNNE KANSKJE VÆRT BRA, MEN HAR MAN TID?

SISTE KOMMENTAR
• KJEKT M. VARME
• ADMINISTRATIVT.
• TOGGLE AV OG PÅ RØMNINGSVEIER.
↳ KAN KOBLES TIL DETEKTOR.

GA LAYERS

FIREWALLS.

SMOKEMAP (???) → FORSTÅR
↳ HVORDAN FUNKER DET?
↳ VELDIG SKEIK FUNKSJON HVIS DET FUNKER.
↳ HVA MED 5 M. TAK.

HEATMAP → ENDA BEDRE ENN RØYKEN!

CARGO? → DÅRE LAST PLANLEGGINGEN.

FIXED EXT SYST.
↳ HØYREKLIKK?

STANDARDER M. HIFOLSONG, NAVNGIVNING.
HVA ER LETTEST FREM?

TIMELINE

TIDSPUNKT FOR NÅR DETEKTORER SLÅR UT.

GIR EN GANSKE BRA OVERBLIKK.
↳ STRØMKOBLINGER → HVORDAN FÅR MAN INN INFO
→ ER DET MANUELT?
→ VILLE STENGT AV STRØM PÅ ALT.

GOOD

TEMP

[illegible]

DISABLET ALARM KLOKKE.

MANUAL CALL POINT ✓

AUTO DØR ✓

DAMPER → SYMBOLET → FØLGER NY STANDARD

↳ BRA M. LAST SERVICE.

EXTING. PORTABLE
↳ MEN MAN HAR DET I ANDRE SYSTEM.
↳ LOKASJON, BRA!

CCTV
↳ ACTIONS BRA!
↳ VANLIG KAMERA? → INFRARØD?
↳

DEKKCALL
↳ BRA.
↳ DEKK FOR DEKK

1

MASKINSJEF INTERVJU!

FALSK ALARM STORT PROBLEM!

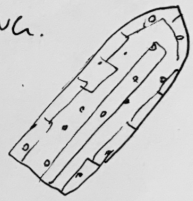
↳ DUSJING ER ET STORT PROBLEM.

PÅ SIEMENS-SYSTEMET FINNES DET ALGORITMER SOM HINDRER FALSK ALARM.

↳ GREIER Å ANALYSERE PÅ ET ELLER ANNET VIS.

HOVEDPANELET → LITE TEKSTPANEL, KUN ET PAR LINJER M. TEKST. ← MINSTE-KRAV

↳ KOBLET OPP MOT PC M. GA. OG GRAFISK ANVISNING.



IMO ← FOR MYE POLITIKK.

↳ LAGET AV FOLK SOM IKKE HAR PEILING...

CCTV VED SIDEN AV ALARMSYSTEM, MEN IKKE KOBLET SAMMEN

"VIL KOBLE SAMMEN KAMERASYSTEM OG BRANNALARMSYSTEM"

2

BRUKERTEST

TRYKKER PÅ KAMERA → VELDIG BRA.

SELVE BRANNUTSTYRET → BRA!

PASSENGER CAR

KRYSSET I MIDTEN:? → MEN BRA!

CHARGE – STATION ? → DISCONNECT POWER?
↳ STENGER AV STRØM? –
↳ SELVE BRANNSENSOR?
↳ ÅJA! JA FORSTÅR!

TRAILER
↳ OKAY, SÅ MAN FÅR INFORMASJON OM LASTEN!
↳ ABSOLUTT NYTTIG!
↳ TESTET NOE LIGNENDE I 1988!
↳ FOLK VIL IKKE ALLTID OPPGI HVA LASTEN ER...

⁝ SILENCE → EEEHM... ALARMEN GÅR IKKE UT, MEN VISER!
DISCONNECT
RESET

⁝ "STENGE LOOPEN" → JA, DET ER BRA.
DET ER EN LAYOUT SAK. CONSEILIUMS LAYOUT ER VANT TIL.

KNAPPENE PÅ SIDEN...

↳ OPP OG NED → BRA.

↳ JA, BRA M KAMERA UTFOR "HYTTENE"

→ SE BRANN-MATERIALET → BRA!

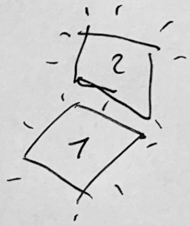
GA-LAYERS

↳ KAN SORTERE INFO!

→ JA DET ER BRA SYSTEM

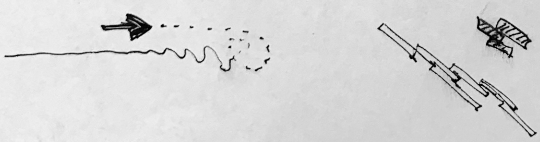
↳ KAN ANVENDE SOM FIREPLAN.

↳ PROBLEMET ER PAPIR-KARTENE.



→ BURDE NESTEN HATT TO SKJERMER HER! → SPLIT-SCREEN?

" RISKEN ER AT MAN HAR
FINE SYSTEMER, MEN FUNKER IKKE
I STRESSINFORMASJONEN. "



Appendix N

Links to prototype 3

Idle

https://www.figma.com/proto/jLyNO3rHrYgNhIh3eR62PL/Concept?node-id=446%3A8&viewport=-544%2C739%2C0.023780975490808487&scaling=contain

Fire scenario

https://www.figma.com/proto/jLyNO3rHrYgNhIh3eR62PL/Concept?node-id=558%3A322&viewport=-544%2C739%2C0.023780975490808487&scaling=contain

Appendix O

Links to animations

Animations sequence

https://www.figma.com/proto/
zlBdHpqdaJBdJ9s33Ywayq/Components?node-id=112
%3A9&viewport=135%2C1018%2C0.3051935732364
6545&scaling=min-zoom

Animations v2 tests

https://www.figma.com/proto/
zlBdHpqdaJBdJ9s33Ywayq/Components?node-id=205
%3A4209&viewport=135%2C1018%2C0.3051935732
3646545&scaling=min-zoom

Animations sequence v2

https://www.figma.com/proto/
zlBdHpqdaJBdJ9s33Ywayq/Components?node-id=216
%3A143&viewport=135%2C1018%2C0.30519357323
646545&scaling=min-zoom

Many alarms sequence test

https://www.figma.com/proto/
zlBdHpqdaJBdJ9s33Ywayq/Components?node-id=216
%3A16&viewport=135%2C1018%2C0.305193573236
46545&scaling=min-zoom

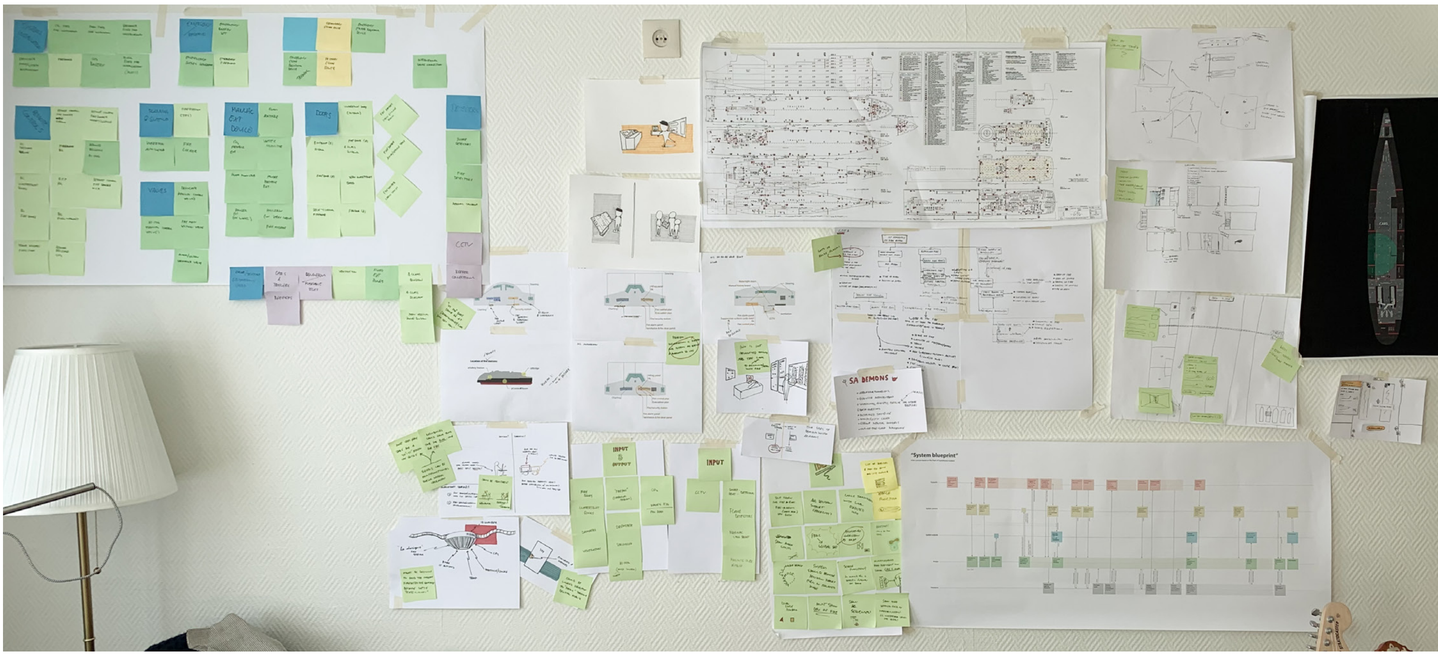
Edge marker sketches

https://www.figma.com/proto/zlBdHpqdaJBdJ9s33Ywayq/Components?node-id=222%3A31&viewport=135%2C1018%2C0.30519357323646545&scaling=min-zoom

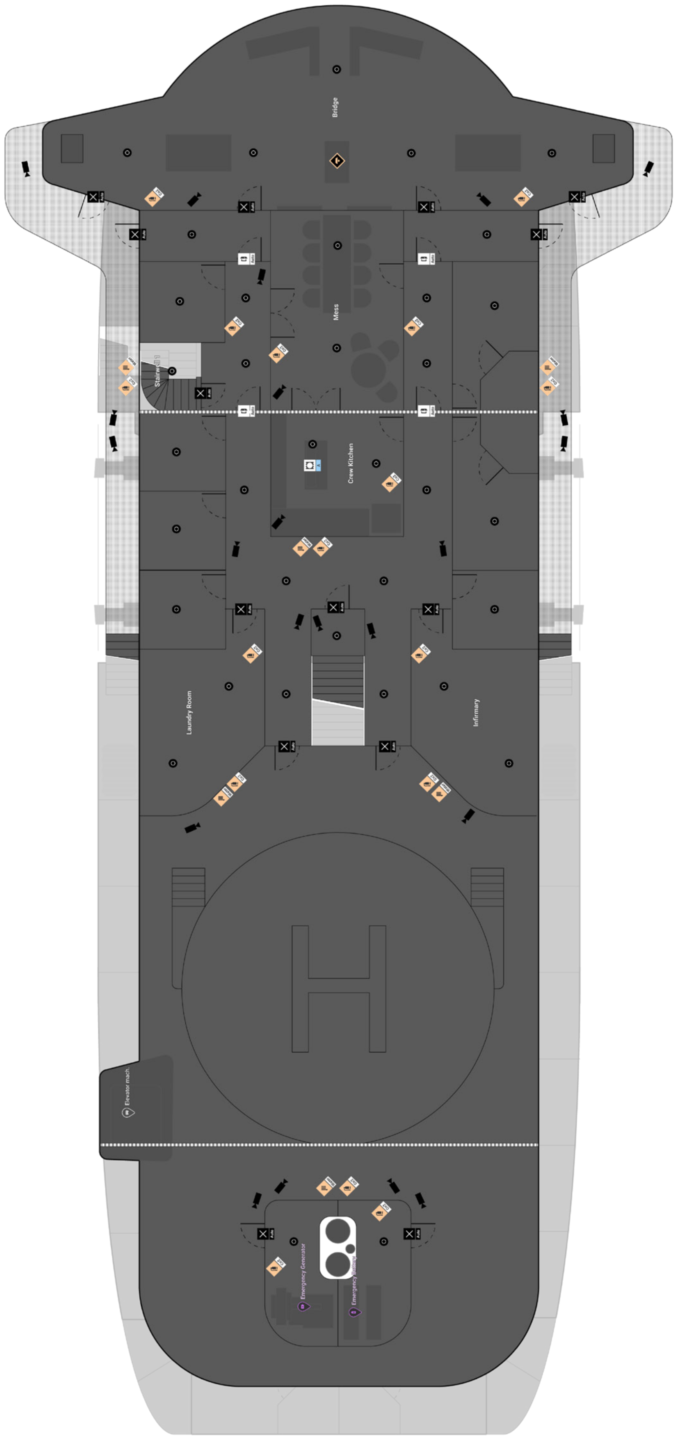
Trigger overview

https://www.figma.com/proto/zlBdHpqdaJBdJ9s33Ywayq/Components?node-id=369%3A7159&viewport=135%2C1018%2C0.30519357323646545&scaling=min-zoom

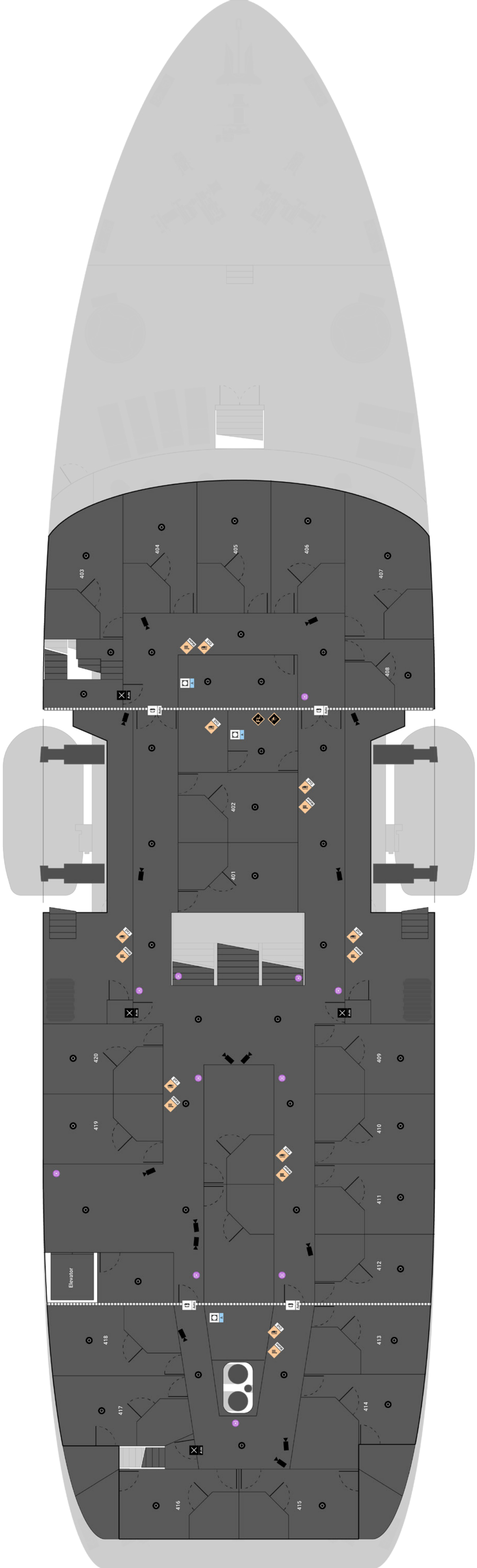
My “home office” because of Covid-19



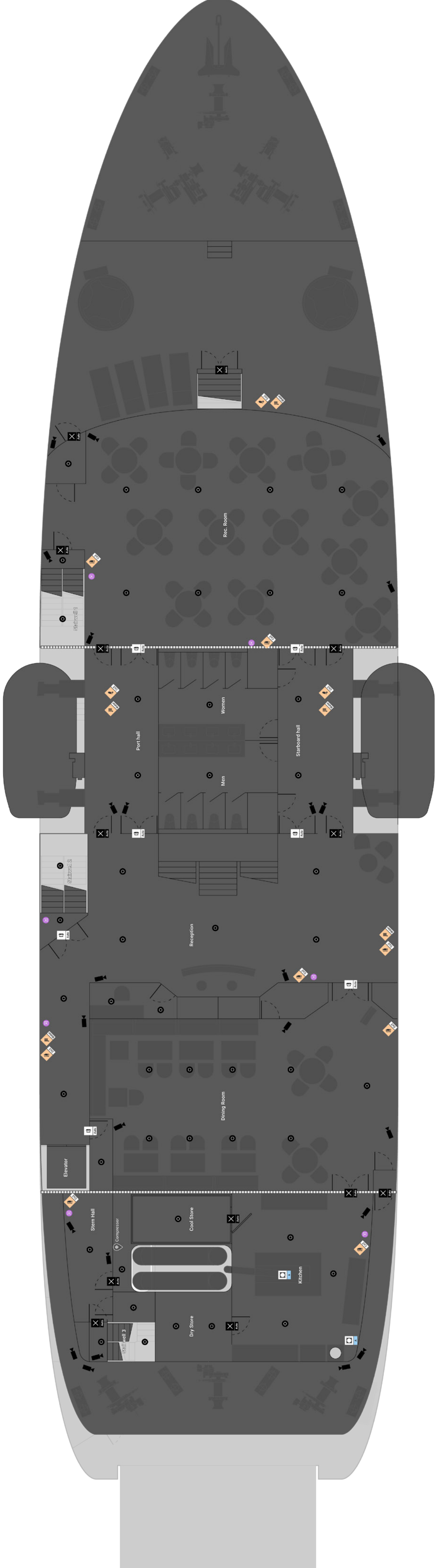
Deck 5


Bridge
Mess
Crew Kitchen
Laundry Room
Infirmary
Elevator mach.
Emergency Generator

Deck 4

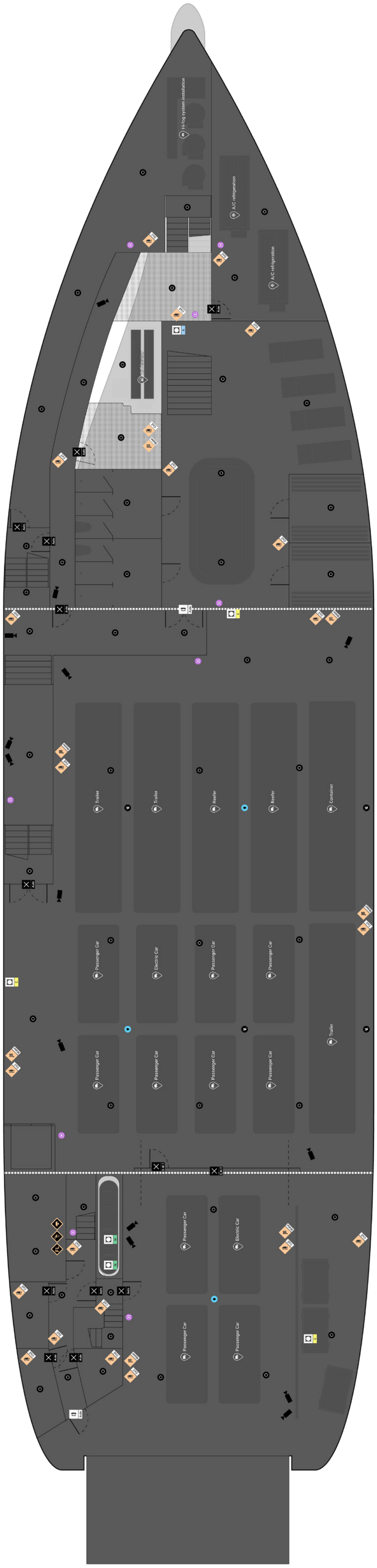


Deck 3

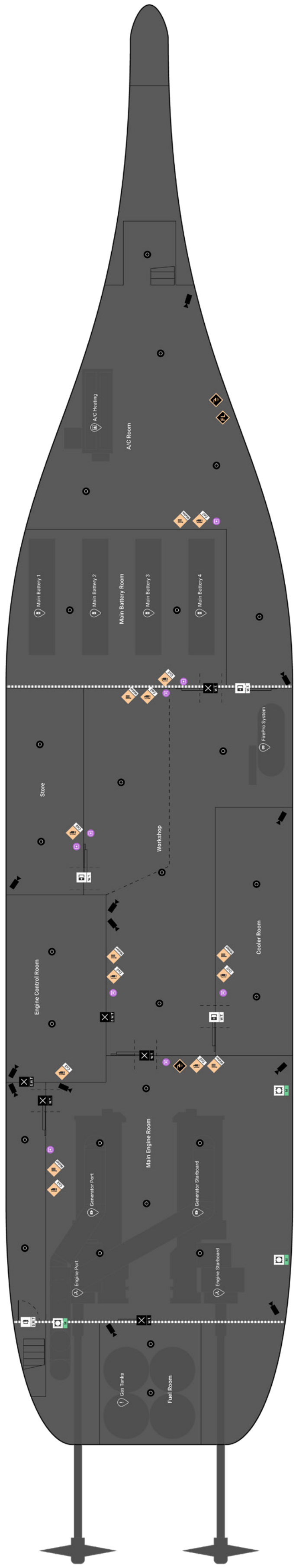


Rec. Room
Women
Port hall
Starboard hall
Men
Reception
Dining Room
Elevator
Stern Hall
Compressor
Cool Store
Kitchen
Dry Store

Deck 2


Hi-fog system installation
A/C refrigeration
A/C refrigeration
Trailer
Trailer
Reefer
Reefer
Container
Passenger Car
Electric Car
Passenger Car
Passenger Car
Trailer
Passenger Car
Passenger Car
Passenger Car
Passenger Car
Passenger Car
Electric Car
Passenger Car
Passenger Car

Deck 1


A/C Room
Main Battery Room
Store
Workshop
Cooler Room
Engine Control Room
Main Engine Room
Fuel Room

Thomas Colin Guo Kaland

Design of a firefighting resource management center for critical situations aboard RoRo-ships.

NTNU

Kunnskap for en bedre verden