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Alarm system interface prototype development and testing

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Abstract

The current standard of analogue fire plans and alarm systems on ro-ro ships is a relic of its time. It works as intended, but it also has a lot of potential for problems. Other, preceding works within LASH FIRE have analysed the potential bottlenecks, high cognitive load, and out-of-date interface design of current standards. Next to these analyses, earlier work has also lined out design guidelines for a digital alarm interface for fire centrals on board. This report presents the design and demonstration of the Digital Fire Central (DFC) developed within the LASH FIRE project. The main objectives were to present information about the situation on the digital fire plan by visualising sensor data, enable the user to access the historical data of the development of the fire, and a centralisation of the controls of extinguishing equipment. The user will be able to oversee and coordinate the entire attack on the fire from one interface. The demonstration of the prototype was performed with fire leaders who are active on ro-ro vessels in which they had to coordinate an attack on a fire on a car deck. The results of the DFC demonstration support the original idea of integration of information based on the principles of user centred design and ecological display design. Departing in user needs and the physical properties of the problem to be addressed – ro-ro deck fire – by the first analysis the DFC demonstrator provides a level of effectiveness, efficiency, satisfaction and intuitiveness that appears to surpass present-day installations and -systems. In short, this means that a DFC, or a DFC-like system, is likely to improve of firefighting capability on ro-ro ships, and thus that this is a valid risk control option from a functional perspective.

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1 Executive Summary

1.1 Problem definition

Current standards for fire centrals and fire plans on board are a long way behind the options provided by current technological developments. Often using paper-based products, every deck must be shown in its entirety, with all possibly useful information being displayed, creating a cluttered overview of the ship. In addition, its static nature means that all information about the fire and the crew has to be drawn and updated manually. This creates a significant workload for the operator and thus invites potential mistakes. Even the process of locating the fire can be tedious and time consuming, which means that valuable time for the attack on the fire is lost.

On vessels with digital systems, decentralization is a big issue. More often than not, systems are decoupled, meaning one single system for alarm positions, one for CCTV, one for fire doors, etc., all with their own screen and input devices, as well as their own interaction paradigms and styles. Apart from providing operational inconsistency, this creates a lot of clutter in control rooms and makes it difficult to gather the necessary information for the correct conclusions for an effective attack on the fire.

Digital systems are under rapid developments, also in the shipping industry, but experientially, simply converting existing practices into digital solutions are not necessarily providing the full benefits; indeed, such solutions may exhibit poor usability. The work on LASH FIRE task T07.5 *Demonstration and validation of alarm system interface prototype* is set to explore whether the application of Human Centred Design, as well as Ecological Interface Design, can mitigate such potential shortcomings, and bring about an improvement in the usability of digital firefighting.

1.2 Method

This report is fundamentally based on the work reported in D07.10 *Deployment and validation of firefighting resource management simulator prototype* , D07.4 *Development of firefighting resource management centre design,* and D07.2. *Field study report of alarm panel insufficiencies and improvement identification*. The goal was to develop a prototype of a holistic alarm interface of a digital fire central (DFC). The aim is to use the potential of an integrated digital interface for fire plans and alarm displays by combining various already existing interfaces as well as new concepts in one. This approach delivers a demonstration of an interface which shows live information about the fire and the firefighting effort directly on the fire plan while also enabling the fire commander to exclude irrelevant information. In addition, a centralised, digital interface integrates all the information necessary in one place. This has been achieved by prototyping in four iterations and user testing of the DFC with active crewmembers.

The DFC features a digital fire plan with visualisations of the spread of heat and smoke. In addition, the historical data about triggered alarms and emergency-related events are plotted on a timeline on the display to provide historical data about the emergency, as well as predictions of near future developments. The DFC also includes controls for all fixed emergency equipment necessary for attacking a fire.

The experimental sessions were conducted in a laboratory environment at a shipowner's headquarters with active fire leaders. They entered their position at the DFC to manage the firefighting effort on a car deck of a ro-ro vessel.

This report includes detailed descriptions of the different elements of the interface of the DFC, the physical design of the operator’s station, and the testing of the DFC. As a part of Action 7-A, the work presented in this report is also intertwined with the rest of WP07.

1.3 Results and achievements

The results of the DFC demonstration show a lot of potential for such an integrated system. Participants especially liked how easy it was to gain full understanding of the location, spread, and intensity of the fire, in addition to an understanding of what happened before they took their position at the fire control centre. Further tracking of the development of the fire, as well as the effectivity of used countermeasures was also perceived as very easy. Seen to save time, increase situational awareness, and present high usability, a graphical visualisation of the fire on the fire plan, together with a visualisation of the historical development, was seen to be effective and is recommended to be implemented in future systems.

The integration of safety-relevant information about loaded goods (lorries, electric cars etc.) was also very valuable. Being able to interact with the cargo on the fire plan to access information about dangerous goods was significantly more user friendly than looking up the information in a separate cargo manifest. It allowed for less errors and gave the operator immediate access to the wanted information in its context on the deck. Furthermore, the holistic integration of the different emergency controls in one system shortened response times to the fire and eliminated misunderstandings between the operator and crewmembers who otherwise would have to engage those systems on different locations.

The work presented in this report achieved its goal of demonstrating a prototype of a digital alarm panel in the form of the DFC. Going forward, the design solutions used in this prototype show significant potential to improve fire safety on board and present possible guidance for new requirements in a digital age.

1.4 Contribution to LASH FIRE objectives

The present work has achieved its goal of developing and prototype of a digital alarm panel and demonstrating it as a part of WP07 *Inherently Safe Design*, specifically Action 7-A. It works towards the overarching goal of Action 7-A to re-design and develop guidelines for improved fire detection systems design, promoting intuitive operations and quick decision-making. Additionally, it was built using the previous foundational work within WP07 and the data gathered will further contribute to Action 7-C.

1.5 Exploitation and implementation

The vast amount of data gathered during the work for this deliverable is also useful for further deliverables under Action 7-C and will be used for further research on the fire resource management centre as a whole, especially in D07.3 *Design guidelines for bridge alarm panels*.

2 List of symbols and abbreviations

AGV	Automated Guided Vehicle
DFC	Digital fire central
ECR	Engine control room
GA	General Arrangement
OOW	Officer on the watch
RORO	Roll-on/roll-off ferry with focus on carriage of cargo
RO-pax	Roll-on/roll-off ferry with combined focus on passengers and cargo

UI	User interface
VHF	Very High Frequency two-way radio transceivers

3 Introduction

Main author of the chapter: Julian Steinke, NTNU

Results from studies of weaknesses with current firefighting systems on passenger and cargo ferries found that existing systems were often deficient in terms of the information and how it was presented, which can negatively impact decision-making, and cause delays during which a fire can expand, creating a more difficult operative situation (EMSA, 2018). The report identified cost effective options for improving fire safety by supporting fire detection and supporting quicker decisions to activate the fire-extinguishing system This is central background to the decision to develop the digital fire central.

3.1 Goals of the interface

The main objective of the Digital Fire Central (DFC) is to provide the human operators with the information they need to fight the fire effectively, as pointed out in D07.2 *Field study report of alarm panel insufficiencies and improvement identification*. The digital fire central aims to integrate multiple information sources, from elements of current fire centrals, in one user interface, with the aim to enhance the ability of the crew to engage the fire. As such, it is not intended as a replacement for existing firefighting information and communication technologies, but as a useful additional tool in the firefighting effort. In order to design new solutions for fire management interfaces, it is important to first define the goals of a digital system for the management of the extinguishing situation.

The D07.2 report identified that the perceptual and cognitive processes involved in identifying and processing information for firefighting, i.e., the mental workload, was high. A suggestion for supporting the management of firefighting was therefore to find a way to present available data in a more easily comprehended fashion, thus lowering the mental workload. The aim of the digital fire centre is to provide immediate, precise and accessible information that supports the localisation and monitoring of a fire, and that provides the information necessary to support firefighting, especially activation of drenchers, which are a highly effective firefighting tool.

For that, it is necessary to indicate the spread of the fire and the smoke on an accurate plan of the entire ship. To fight the fire with firefighters on the scene, it must also be possible to monitor the position of firefighters and their status, the temperature in a specific section, as well as the O_2 levels in the ship. It is also important to indicate the storage of personnel firefighting equipment to direct the crew to the best positions. The cargo of the ship must also be represented accurately. By achieving this, the operators would know which routes on the car decks are accessible and where dangerous or flammable goods are located. This information can then be used to plan the extinguishing effort and to predict the spread of the fire.

The DFC also has to meet demands from the context of use, for example the crew's skills, time and efficiency pressures, as well as IMO guidelines, and company guidelines.

The skills of the crew include learned emergency procedures, but also general skills, including cognitive abilities, as well as seamanship and experience with actual fires on board. The interview material gathered through the LASH FIRE project clearly shows, that the crew involved is very capable. Fire drills are regularly conducted, and many of the interviewed personnel have experienced actual fire incidents on the job. This again underlines the benefits and necessity to align design solutions with existing procedures as far as possible.

Time as a demand is very straight forward. Firefighting must be completed as effectively and efficiently as possible. The interface has to support the efficiency of the firefighting effort. This should be one of the benchmarks the performance of the DFC would be assessed with.

The interface has been chosen to comply to the IMO regulations regarding fire plans (IMO IA847E) in the use of its symbols and general designs. This provides a baseline which all SOLAS ships need to comply with, yet certain company design or work process guidelines can vary. Hence there may be a need to be able to customize certain features. However, this is not taken into consideration in the design of the prototype presented in this report.

3.2 Design solutions

The design solutions that are to be implemented are divided into three categories. The first is how the DFC will support detection, localisation, and monitoring of fire on board. The second category includes elements working towards a faster activation of the fixed emergency systems and therefore a faster active response to the fire. Thirdly, this section will discuss design elements that are intended to aid the communication between the operator of the DFC and the firefighting crew.

3.2.1 Detection, localisation, monitoring

The design solutions presented in this section regard the presentation of information, thus only elements which do not require actions by the user are presented. The first group of design solutions are visualizations of data that support assessment of the fire's location, characteristics, environment, and its spread. This includes a visual representation of the fire plan itself. A combination of information about the spread of heat and smoke detection has to be implemented to rapidly detect the onset of fire and aid situational awareness.

Access to the CCTV system of the ship from the fire plan would also be beneficial for fire identification and monitoring. The user should not have to switch through the cameras on a different system, but choose them on the fire plan. By doing this, there is less chance for disorientation.

Alarm handling has to be improved. The locations of triggered sensors have to be clearly identifiable and their status has to be identifiable without error. It also has to be possible to view the alarm history and the most recent alarms in order to get awareness of where the fire originated and how fast other sensors were triggered. There also have to be means to suppress alarms while making sure that alarms with ongoing trigger conditions are still clearly visible. This way, a large number of alarms does not have to be muted one by one continuously.

3.2.2 Emergency response

The controls for emergency systems used in firefighting should not be spread over different locations. It should be possible to operate ventilation, fire doors, fire pumps, and drenchers from one system. The DFC has to integrate those controls.

In addition, drencher activation has to be accelerated, if possible. Clearer marking of drencher zones on the fire plan in combination with a drencher release panel on the same interface should aid to shorten the response time. Easily accessible information about cargo that must not come into contact with water would further aid this process.

3.2.3 Communication between operator and crew

The way in which information is presented to the user also has to aid the user in the coordination of fire fighters on the ground. The DFC has to create awareness of the location of the fire to the user and aid in communicating the location to the firefighters. It also has to present information about temperatures and visibility. Another important factor is quickly accessible information about dangerous goods. With this information, the firefighters can be made aware of potential hazards before entering the deck.

3.3 Previous iterations

Following the canons of Human Centred Design, the development of the DFC has been developed iteratively. This section will summarize these iterations to provide context for the demonstration presented in this document. All earlier iterations were developed in Figma and were presented to the participants without running a full scenario.

3.3.1 Prototype 1

The first iteration includes one car deck on a fictive ferry. The interface shows the layout of the deck with parked cars and the fixed elements of the fire plan, like piping, firewalls, hoses, detectors, drenchers, and extinguishers. The interface also features layers that can be added to show temperatures, smoke and the range of extinguishing equipment. The fire is visualised by showing the concentration of smoke with density of dots, variation of temperature is indicated with a colour scheme reaching from blue (cold) to red (hot). It also featured limited interactivity, for example temperature- and smoke levels when clicking on a detector or range of motion when clicking on a firehose. For general orientation, there was a mini-map showing all decks.

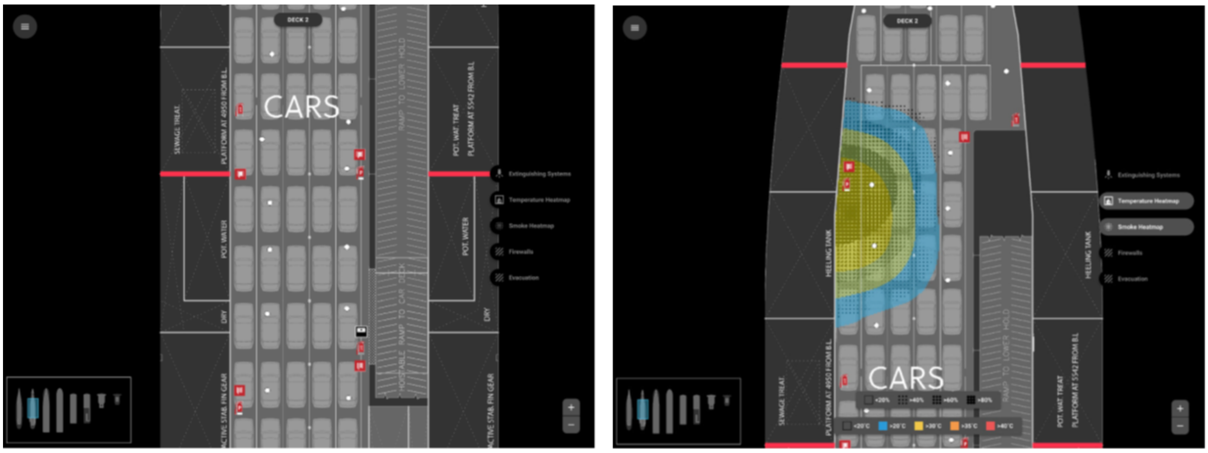

Figure 1. Figure visualisation of heat and smoke in the first prototype (right) compared to the idle state (right).

The concept was well received by the participants. Layers for the spread of smoke and higher temperatures were very beneficial, as well as the pre-alarm. In general, the visualisation of the basic information of heat, smoke, and position was very useful for the operator. Implementing a side view of the decks in relation to each other would enhance the understanding of the position of the fire even more, so it should be implemented in future iterations. It was to be expected that customisable markers and pop-ups for sensor data would be seen as beneficial as those are digital pendants to the analogue use of current fire centrals. Access to looping or rewinding the situation should be implemented in future iterations. It enables the operator to receive important information about the spread of the fire and by that an immediate understanding of the severity of the situation. Structural equipment had to be implemented as well, so that the operator gets a complete overview of the equipment in place. The suggestion of mute functions for alarms had to be implemented as well. This step supports the usual fire procedure on ships, as the alarm has to be confirmed first.

3.3.2 Prototype 2

Based on the feedback, the second iteration focused on salience of alarms, inclusion of more firefighting equipment, different viewing angles, and a muting function for alarms.

The salience of alarms was increased with animations. A pulsing around the triggered sensor was expected to have the added benefit of an animation going through the deck, which would indicate the spread of the fire. The detectors also showed a muted state and a pre-alarm-state. Portable, fixed, and structural firefighting equipment was also included. It was also possible to view more information about vehicles and cargo loaded by clicking on it.

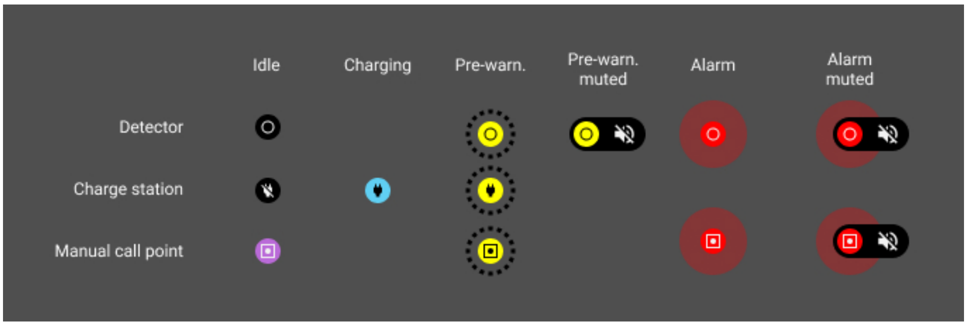

Figure 2. Different states of the icons used on the fire plan.

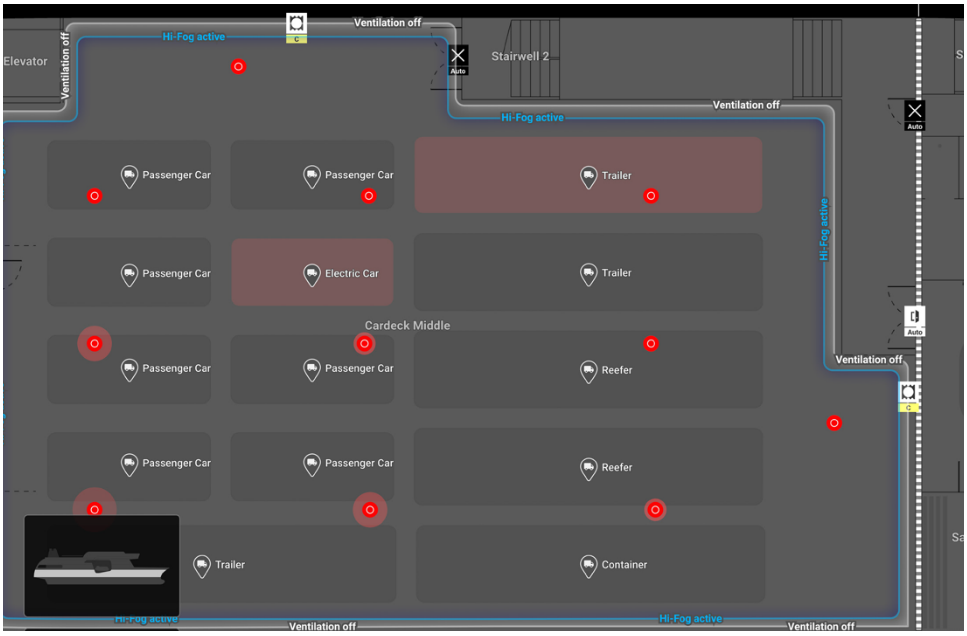

Figure 3. Indication of cars loaded and area of effect for fixed extinguishing equipment.

Many of the new features were well received by the participants and should be included in future iterations of the prototype. However, some negative remarks have to be addressed. First, cargo has to be presented in a lighter colour than the deck. Participants were confused whether cargo was actually there, or if it was an empty space. When the operator interacts with the vehicle, possible information about hazardous cargo has to be accessible in detail, as well as usable extinguishing material. Regarding animations, deployed firefighting equipment could benefit from an animation, for example highlighting engaged drenchers. The animation of the alarms had to be changed in a way that makes the wave-pattern, and therefore the spread of the fire, more recognizable. In this version, the pulse was too even, so participants could not identify the first alarm. A detailed side-view of the ship had to be included. This would offer a better indication of the position of the fire in relation to the entire ship. As fire tends to spread upwards, this is a very understandable request. Lastly, the problems with automated responses by the fire central were highlighted. This is clearly due to the current procedures on a ship. The fire commander gives the command to engage a fire with any equipment and this iteration of the prototype took that action over in part. It was decided to step back on automated processes and keep the decision making fully in the hands of the operator.

3.3.3 Prototype 3

Prototype 3 was based on the results from the previous iteration. This new version had to include more salient animations, more interaction options with alarms, clear overview over disconnected sensors, and revised sub-menus.

The pulse of an activated alarm worked in attracting attention, but the intended effect of being able to track a wave of alarms to the first sensor triggered was not achieved by participants in the user evaluations. The animation was changed from an even, sinusoidal rise and fall to a more rapid rise, therefore increasing the salience of the start of the animation. The interface for acknowledging alarms also had to be redesigned. Participants sometimes missed the window of time to respond to an alarm. The new interface would be a pop-up on screen with the type of alarm, the location, and the options to acknowledge, locate, and silence the alarm.

To resolve the confusion in an alarm being muted or disconnected, a new menu and set of icons had to be introduced. The pop-up menu of a detector now included the options silence, reset, and disconnect.

Lastly, dangerous goods and electric cars were highlighted on the map with icons and a different colour. If they were interacted with, a pop up with detailed information would be shown.

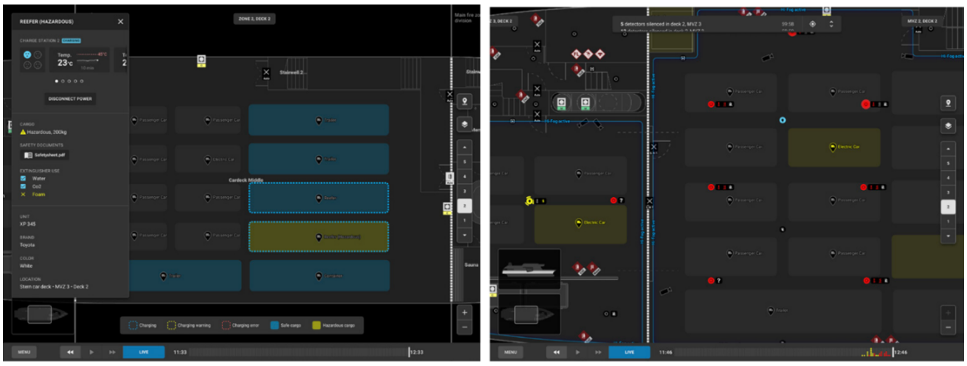

Figure 4. Left: Information about hazardous cargo. Right: Multiple alarms on the car deck. The bar at the top shows currently silenced alarms.

Although animations are a great advantage of digital systems, the idea was scrapped. The animation of alarms was too confusing and therefore did not add value. Instead, a replay function was proposed to give the user awareness about the development of the fire. Highlighting dangerous cargo was well received. The participants could immediately see potential hazards on the fire plan and adjust their attack accordingly. The colour scheme of the entire fire plan, however, would have to be reworked to a light theme. Also, a lot of the icons used would have to be replaced as well, to fit IMO regulations.

3.3.4 Recommendations future iterations

After the three first iterations, the following recommendations for the full demonstrator have been made based on the work presented above. First, it was recommended to introduce features that would enable the user to take a look back in time. Ideally, this would be done with a timeline logging events and a scrubbing function to look in the past in order to compare to the current situation. In addition, the user should have the opportunity to take notes. This should be possible on a digital notepad, which would also be integrated with the time keeping tool. By the time this specific recommendation was formulated, the need for a better way of keeping track of events during the attack was also identified in the field work presented in D7.2. This stresses the urgency of the recommendation.

Second, the earlier prototypes had too many drop-down menus. This is not ideal for an emergency system, as there is a possibility of missing important information. If pop-ups are necessary, they should never cover the map, or any other information. Therefore, the controls for emergency equipment should be detached from the individual icons on the map and centralised in one location. Also, the sensor data should not be attached to a sensor point directly, but next to the map with a clear indication to which sensor it belongs.

Third, there should be a 3D view of the decks in relation to each other. This would enable the user to get more situational awareness, as the spread of the fire would be clearly visualised in a 3D model of the entire ship. A zoom function, however, is not necessary. The actual physical prototype will be a full-sized table, so there is plenty of space for all necessary details.

Fourth, the colour scheme and iconography have to be reworked. All symbols that are normed by the IMO have to use those approved symbols. The fire plan itself should not be a dark design. Cargo indications on the fire plan are received very well, but dangerous goods have to be more salient.

Oxygen levels also have to be included. Oxygen supply is one of the three elements a fire needs, so an indication of oxygen in the area would be beneficial for the attack on the fire.

4 Prototype 4

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This final planned prototype would be implemented on table-top touchscreen. Its position, thus height and tilt, would also be adjustable. This would give the operator the opportunity to work to their liking. The main part of the interface would be the fire plan, giving an overview of one deck at a time. It would display all emergency equipment, as well as indicate the position of alarms, spread of smoke, temperatures, and oxygen values. The second element would be the control panel. This is the operational area of the operator. All operations required to attack the fire with fixed equipment will be accessed here. The third element would be an overview of historical data. This would log actions taken, alarms triggered, and communications made. Additionally, a physical solution for the 55-inch touchscreen, henceforth referred to as ‘the table’, had to be developed. The following sections will describe the design processes and design solutions for these elements.

4.1 Development of the table

In this section the development and building process of the LASH FIRE DFC table will be described.

Alongside the development of the DFC prototype, which was conceptualized for a 55-inch touchscreen, there was a need for a physical solution that would hold the screen during the test sessions. In the conceptualization of the DFC an idea was to be able to lift and tilt the screen, so that the operator could adjust the table to the optimal working condition, and the table to be used in different modes (Kaland T. C. G., 2020). The three modes proposed were (1) an idle mode where the screen would be in an upright but somewhat tilted position, (2) a table mode using it as a flat table for several operators to monitor and interact, and finally (3) a vertical mode for a briefing situation. Another idea that emerged from the master thesis by T. C. G. Kaland, was to have handrails around the screen for the crew to hold on to during rough sea. An additional small table for a backup keyboard and mouse, should also be integrated.

4.1.1 Shaping the requirements

As a starting point the endpoints and the movability of lift and tilt was figured out. This was guided by G*uidance Notes on the Application of Ergonomics to Marine Systems* (American Bureau of Shipping, 1998), and a preferable minimum height of 85 cm and a maximum height for the top of the screen of 180 cm was chosen. An additional tilt function from 0 to 90 degrees would give the necessary flexibility to adjust the screen to the operator's ideal position. As the digital prototype was to be tested with seafarers, emphasis was put on both actual and perceived rigidity of the table. It should give a sturdy impression, and both look and feel like something that could be mounted on a ship bridge. As the test were to be conducted at the Shore Control Lab in Trondheim, and possible dissemination use at other locations, easy movability of the prototype was also applicable. The touchscreen for the digital prototype had already been decided to be the size of 55-inch (Dell C5522QT).

Early in the process it was decided that the physical prototyping would be done at the workshop of the department of design NTNU, but the final physical prototype would be manufactured by a professional workshop, for more precision and professional finish.

The requirements for the projects can be summarized in the table below:

Table 1. Requirements for the development process.

Must-have	Optional
Min. height flat: 90 cm	Backup-table for keyboard and mouse
Max height vertical: 180 cm	Easy to assemble and disassemble
Tilt: 0-90 degrees	Compatible to other 55-inch screens
Handrails	
Easy to move	
Rigid construction	

4.1.2 Existing products

A look into existing marine consoles was also conducted. Adjustable consoles are already becoming standard on modern ship bridges. A common construction is a liftable table were the front is used for physical control devices such as keyboard, mouse and joysticks. On top of these consoles there is a screen of typically 20 inches which in some cases are tiltable. Prominent suppliers of these consoles are e.g., Wärtsilä, Kongsberg and MTU (left picture in fig 5). Then there are entire screen arrays, usually used for navigation, which can be height adjusted vertically, but to the authors knowledge there are no solutions for the adjustability described above, tailored to the screen size of 55-inches. Screen sizes of those dimensions are mostly used as digital chart tables in a horizontal position as shown on the right in fig 5.

Figure 5. Typical consoles on modern ship bridges. (Wärtsilä) (CSN)

In the domain of office supply there are several lift and tilt solutions for 55-inch touchscreens already. An interesting solution comes from the manufacturer Volanti who produces lightweight solutions for design studios. These do have the same lift and tilt functions as given by the requirements and do in most cases feature a table for keyboard and mouse.

The reason for not going with existing solutions from the office supply was because of actual and perceived rigidity. As the DFC was to be tested with seafarers an early guideline was to create a physical solution that in theory could withstand possibly huge forces during bad weather and rough sea ashore while crewmembers hold on to it. Available solutions from the office supply market were not seen to meet these requirements.

4.1.3 Translating requirements into mechanical components

Translating the preferred dimensions into mechanical components was the natural next step. Linear actuators for movability were chosen because of static rigidity, seamless operation, and market availably of ready-made high-quality components. Several sketches and cardboard models were made to explore the basic movability and possibilities within the requirements above.

A little further into the process, the first CAD model was established alongside sketching and cardboard prototyping. Through meetings with the project group, it was decided that the table should have two legs for better stability, and the possibility to create an enclosure to hide necessary equipment between the columns.

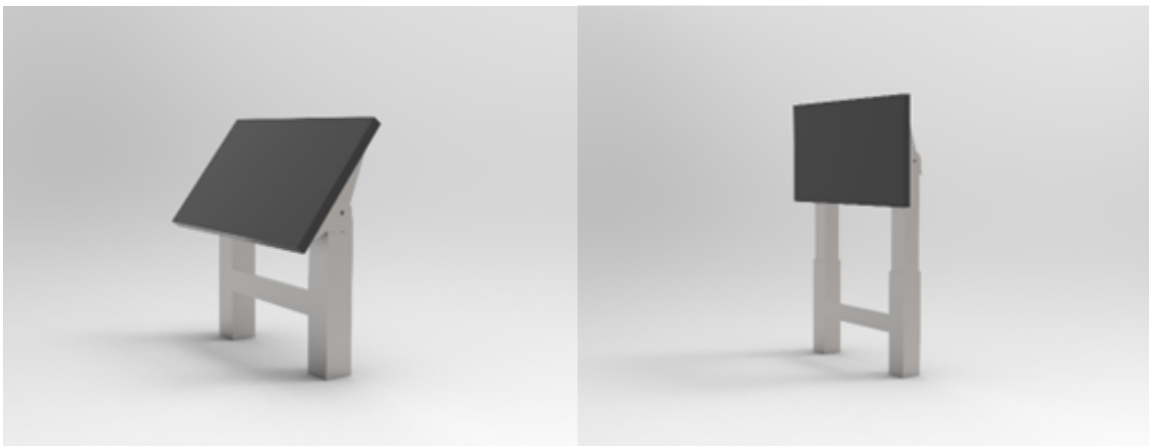

Figure 6. First CAD model of the table concept.

The constructional outline was divided into three main functional parts that had to be developed: (1) a frame with handrails for the screen, (2) a “bridge part” that would connect the screen frame to the columns, and (3) wagon that would serve as a solid stand, and make it mobile. Lastly an enclosure would cover up the lifting columns and create a space for a PC and other equipment.

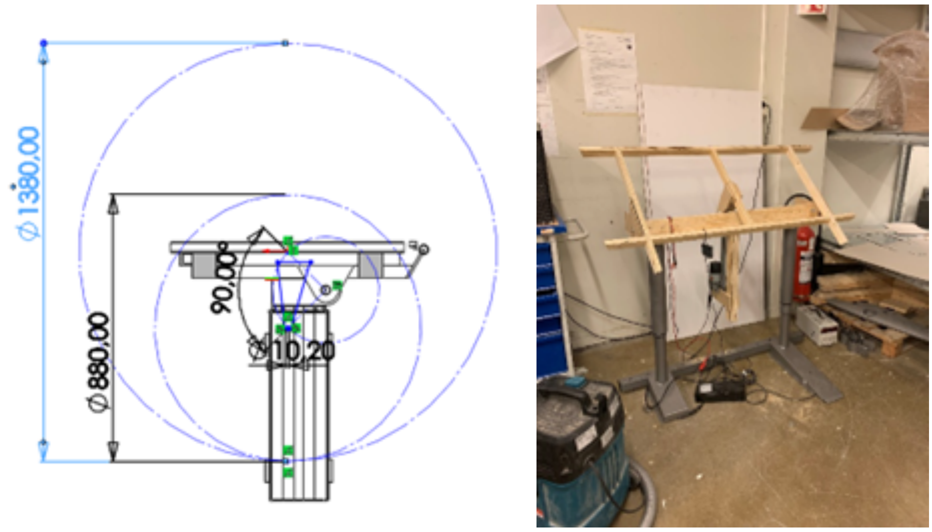

Figure 7. Development process. Stroke length calculation to the left, and first full-size mock-up on the right.

The process of finding suitable lifting columns according to the screen size and positional requirements served as a starting point for the detailed design. The DL2 actuator from LINAK were chosen for lifting the table vertically. These are rigid columns that can withstand a high momentum even in the fully elongated position. Together with the high lifting capacity and compatibility to run in parallel with other actuators, made these columns suitable for the application. Provided CAD models from LINAK were used for further development of the other components. A real size mock-up was realized by using calculations done on the computer (Figure 7).

4.1.4 Final table design

After several iterations of the different constructive elements a first full concept was presented 21-11-2021 (Figure 8). Further development of an optimised position and stroke-length of the tilt-actuator (Linak LA31) led to the final version that was being realized (Figure 8). The table mode and briefing mode are shown in Figure 9. The back-up table for keyboard and mouse was not realised at the end.

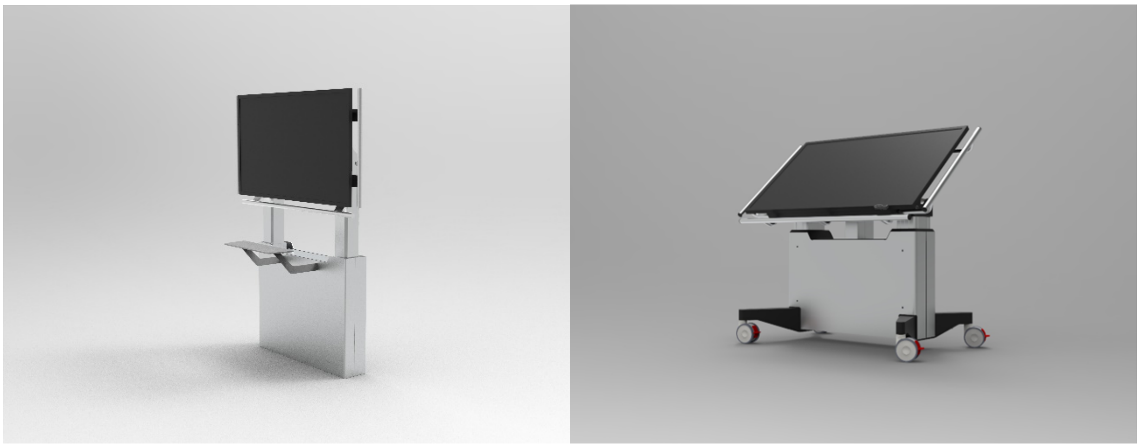

Figure 8. First full concept on the left-hand side. Realised concept on the right.

In line with the constructive outline mentioned above, the prototype is comprised of a screen frame carrying the touchscreen and featuring handrails, the T frame that connects the screen frame to the lifting columns and is the pivoting point for the tilt, and a wagon carrying the whole construction. A control box attached to the top of the T-frame, and a control panel sitting at the handrails in front allows the user to adjust the table.

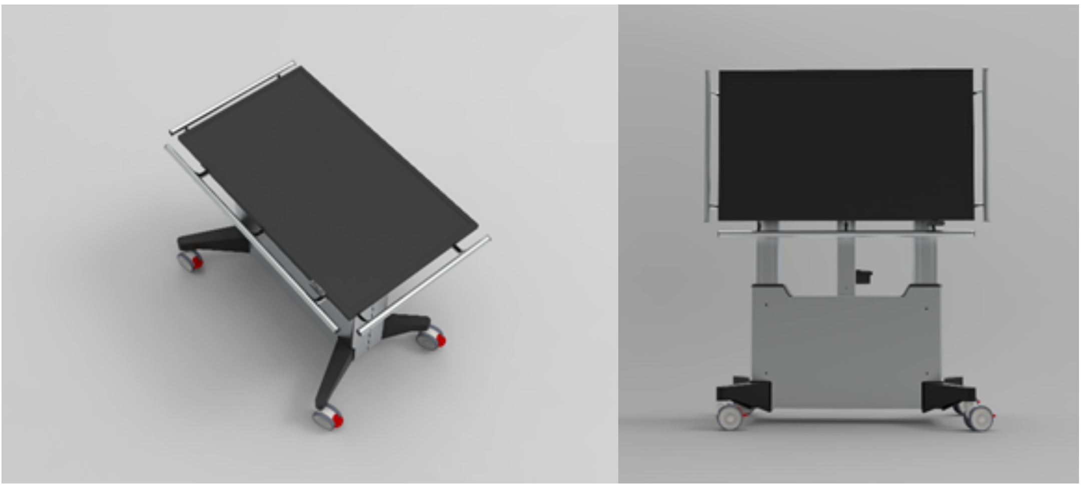

Figure 9. Table mode and briefing mode of the table.

4.1.4.1 The screen frame

The screen frame is constructed like a protective crib for the 55-inch touchscreen. The parts for the frame are cut from 4 mm steel plate, bent and welded together. The handrails with a diameter of 32mm are also welded to the frame. These give a sturdy support for the operator and protect the screen from the sides. Additional accessories can also be attached to the handrails.

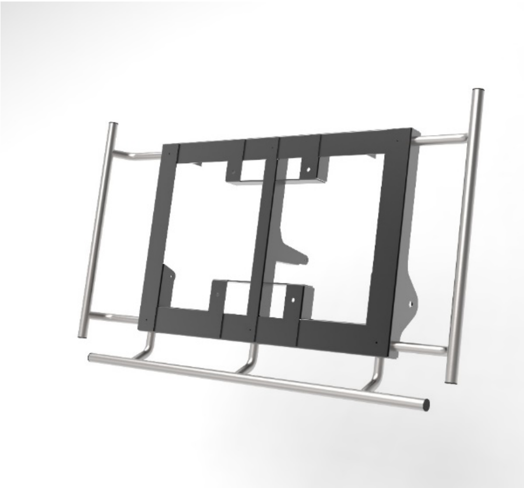

Figure 10. The screen frame of the table.

4.1.4.2 The T-frame

The final shape of the T frame (Figure 11) emerged from the pivoting point for the tilt function and the chosen stroke length of the electric actuator. The downward elongated part of the T-frame supports the actuator that has a stroke length of 250mm. The actuator for tilt was positioned to maximise the normal arm to the pivot point.

The top of the frame was shaped in such a way that the control box for the actuator and lifting column can be placed there along with the respective cables. Gas-springs for stabilisation of the screen against slack and vibrations are fastened to the smaller arms stretching out on the backside (Figure 11).

The core part of the frame is welded together as a cross by 60X30mm steel profiles. The shoulder parts are cut out of 4mm steel sheets, bent, and welded. The sides of the T-frame behind the pivot point are lowered to avoid danger of crushing when the table is in table mode.

Figure 11. The T-frame on the left-hand side. On the right: Assembly of the tilt function involving the screen frame and the T-frame driven by an electric actuator and stabilised by two gas-springs.

4.1.4.3 The wagon

To make the assembly both stable and mobile, a wagon made of 4 mm sheet metal was designed (Figure 12). The length of the wheel arms in the front are to compensate for the overhang of the screen when in briefing mode. The wheel arms stretch out sideways to give room for the feet of the operator in front of the screen, and for additional stability. The width is approximately 80 cm which is compliant within the standard door width of 90 cm.

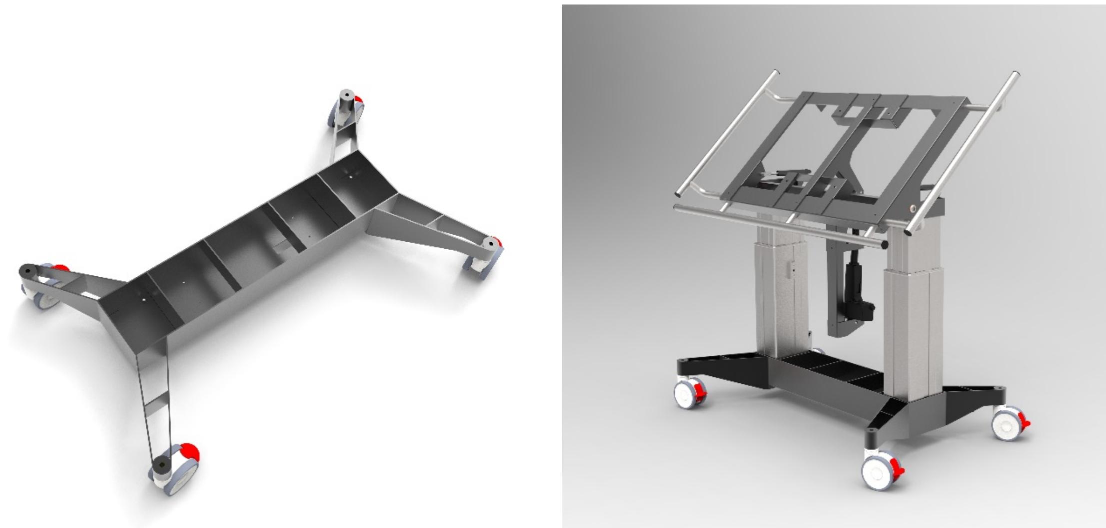

Figure 12. The wagon on the left-hand side. On the right: Assembly of the key functional parts.

4.1.4.4 The enclosure

The enclosure is made of 3mm aluminium which are cut, bent, and fastened to the lifting columns by brackets. Inside the enclosure there is space for power connections and a computer to run the software. On the back of the enclosure there is hatch which makes the inner space accessible. The downward elongated part of the T-frame, which is covered in Figure 13, acts as tunnel for cables between the monitor and the enclosure.

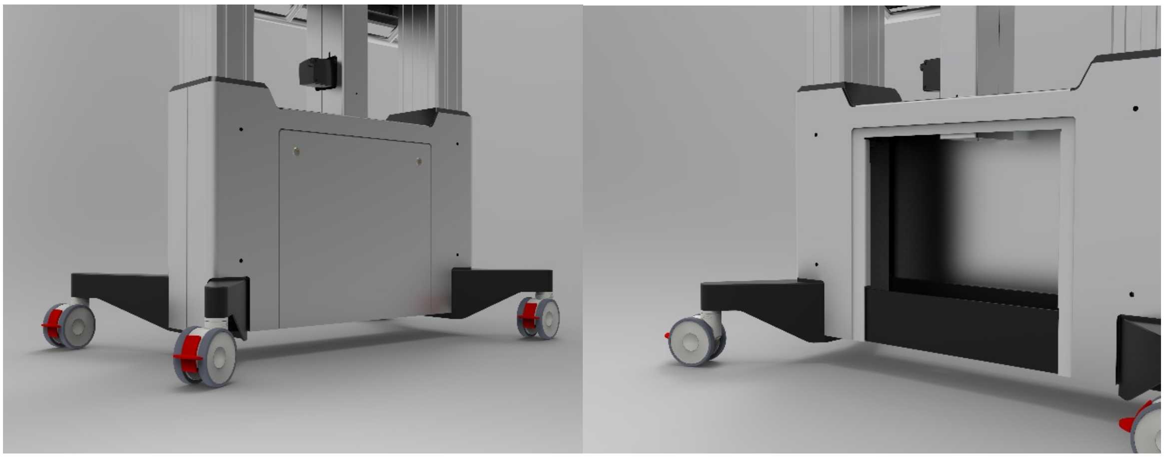

Figure 13. Closed and opened enclosure.

4.2 Interface prototype

The UI consists of four main areas: General Arrangement (GA), timeline, emergency controls and map details as shown in Figure 14. All of these areas had several interactive elements. During a fire, dynamic information would show the development of the fire, utilizing several of the interactive elements. A description of the interface will follow in this section.

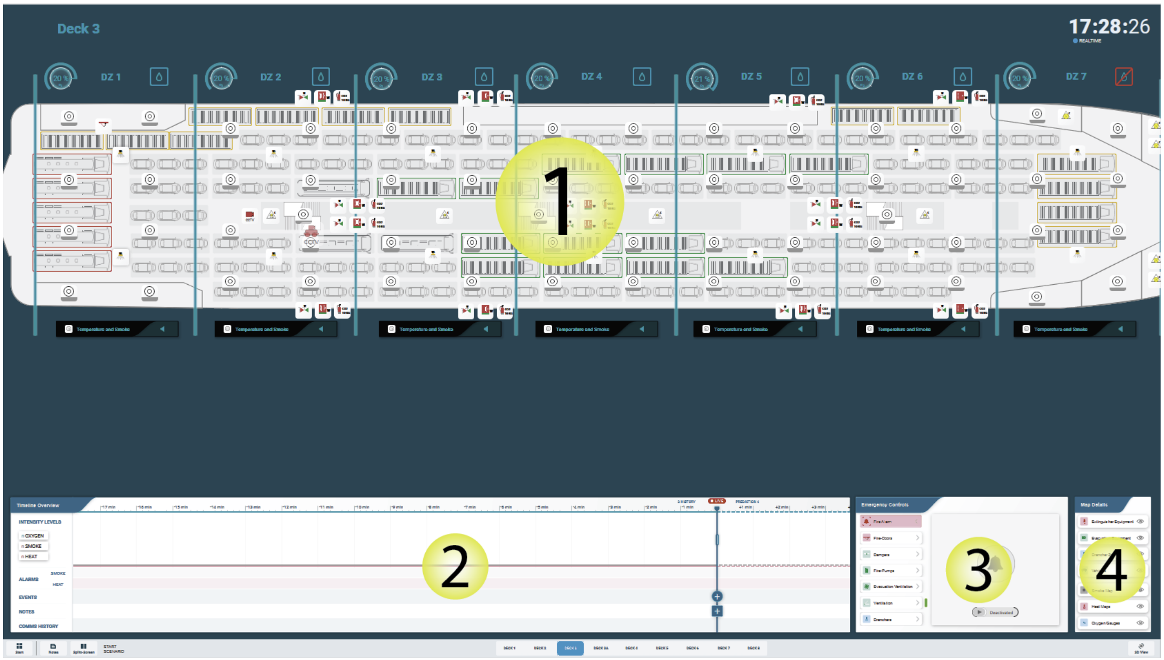

Figure 14. Overview of the UI, highlighting the four main areas: General Arrangement (1), timeline (2), emergency controls (3) and map details (4).

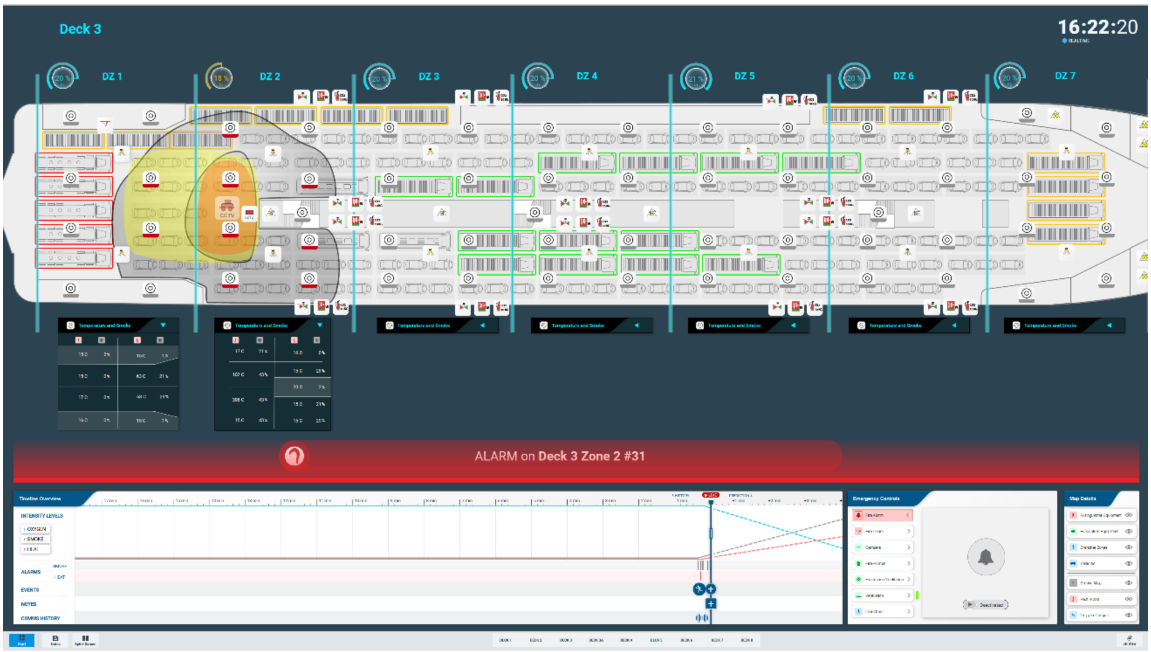

Figure 15. Overview of the UI in an alarm state.

4.2.1 General arrangement and layout

The general arrangement (Figure 16) was based on the emergency plans of the MS Dunkerque Seaways. All the three car decks were modelled, where deck 3 is used for the actual scenario and contains most of the interactive elements.

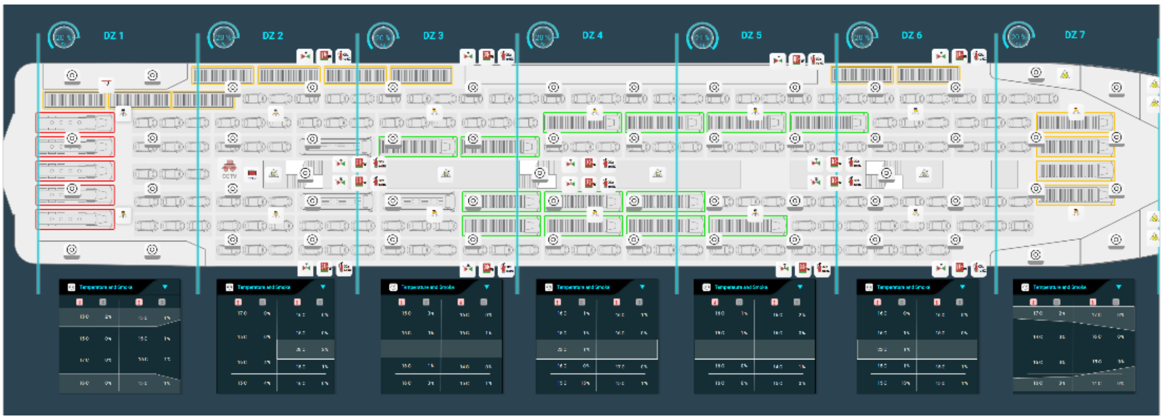

Figure 16. Overview of the general arrangement with drencher zones, oxygen gauges, and opened tabs for temperature and smoke readings.

On the very top of the UI a deck indicator is shown on the left-hand side, together with a Realtime clock in the upper right-hand corner. In the upper middle part of the screen a general arrangement of the present deck gives an overview over the stowage, emergency equipment, drencher zones, detectors, and the general structure of the deck.

4.2.1.1 Heat and smoke map

Heat- and smoke maps showing density and temperature respectively, will evolve over the deck layout as a fire would spread. The smoke map consists of a grey tone overlay with three different opacities to indicate three different densities of smoke. A solid black line marks the outline of the different densities. The temperature map is a coloured overlay that also has three stages. Yellow is used for the lowest temperature range, orange for the middle range, and red for the highest temperatures. The ranges for the different smoke and temperature stages are shown in table 2. Randomised values within the respective ranges would be indicated in the temperature and smoke tab described above (Figure 16). When a detector is triggered, a red bar will appear on the detector icon (Figure 17).

	Stage 1	Stage 2	Stage 3
Smoke values	10-39 %	40-79 %	> 80%
Heat values	43-99 Celsius	100 – 499 Celsius	> 500 Celsius

Table 2. Three different stages of smoke and heat.

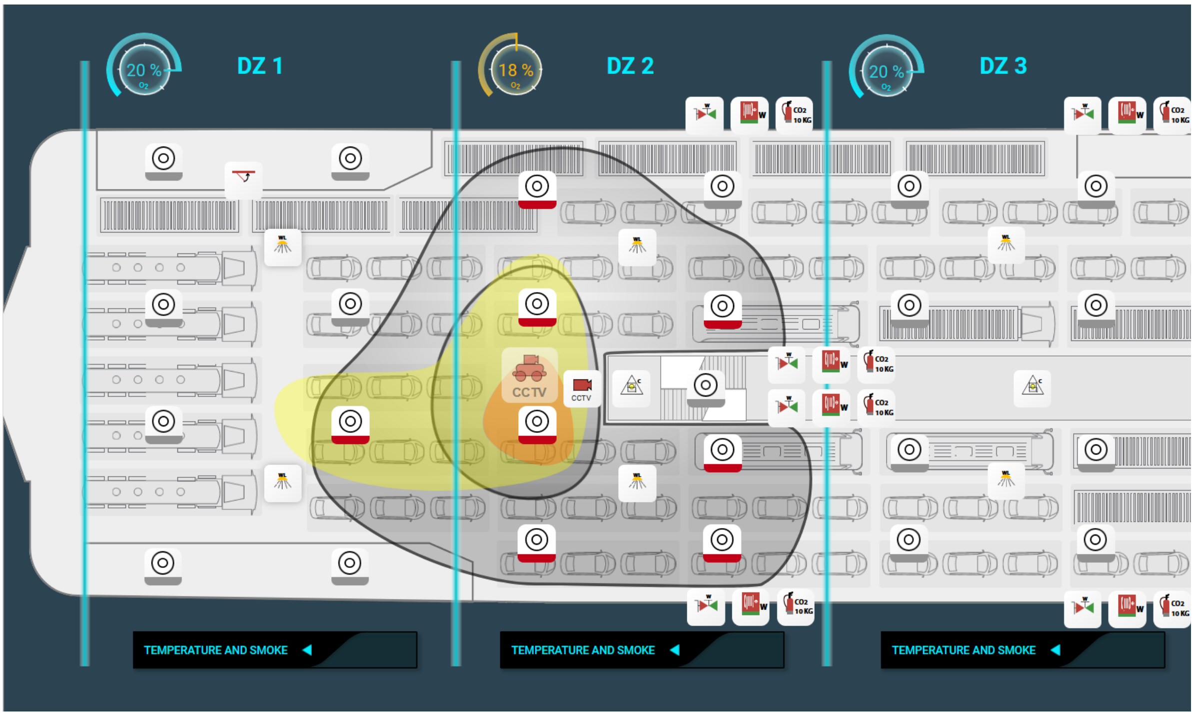

Figure 17. Development of a fire visualised by smoke and temperature maps.

4.2.1.2 Oxygen gauges

An oxygen gauge is placed in each drencher zone that shows the respective level of oxygen (Figure 18). The range indicated by the gauges stretches from 15% to 21%. The gauge would change colour to either red, yellow, or turquoise to indicate three different stages. In idle the gauge is turquoise and measuring 20-21%.

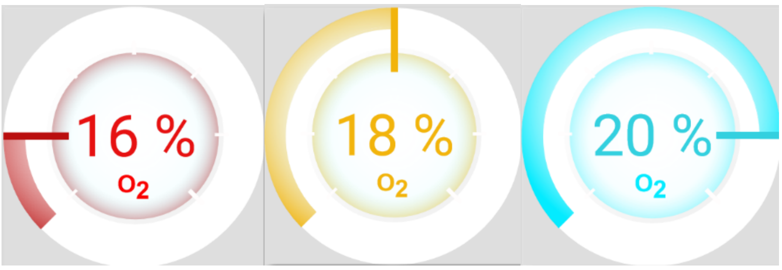

Figure 18. Oxygen gauges showing different levels of oxygen.

The development of heat and smoke maps in the test scenario is pre-defined. This is aligned with the events appearing on the timeline. The full development of the fire in the scenario can be seen in figure 19. Approximately 4 min after the final stage of the temperature is reached, the temperature would start to reverse. The smoke map will be in the fully developed stage until the ventilation is re-activated in the emergency controls.

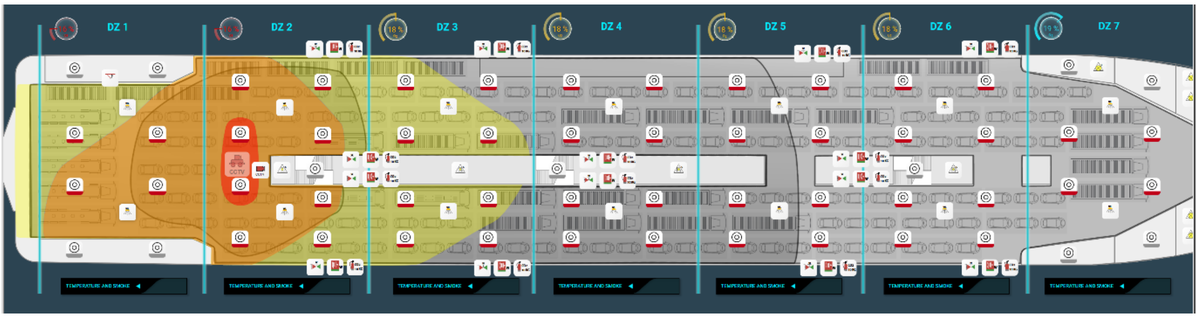

Figure 19. Full development of the fire in the scenario.

4.2.2 General arrangement of the user interface

The general arrangement shows an overview of the current deck together with emergency equipment and general installations by using standardized IMO symbols. This includes hydrants, fire hoses and fire extinguishers spread around the deck, as well as dampers and ventilation in the front and middle section. The car deck on deck three is divided into seven drencher zones indicated by turquoise lines which are labelled DZ1 to DZ7. Each drencher zone has two drencher nozzles. Furthermore, a number of smoke and heat detectors are assigned to each drencher zone. These have their own symbol indicating a general detector for smoke and heat to unclutter the GA (Figure 20). Stretching from DZ2 to DZ6, horizontally, an enclosed middle section divides the car deck in an upper and lower part. Three staircases can be found in the middle section (in the zones DZ 2, DZ 4 and DZ 6 respectively). Each of the staircases do also contain a combined smoke and heat detector, as indicated in fig xx. In the front and aft section (DZ1 and DZ7) there are also enclosed areas on the sides containing smoke and heat detectors.

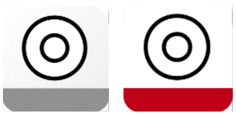

Figure 20. Detector icons developed by the research team.

Under each drencher zone a tab called "Temperature and Smoke" can be opened for the detected values on smoke and heat (Figure 21). Temperature is indicated in Celsius, whereas smoke is indicated in percentage according to the Ringelmann smoke chart (Kundlich, 1936). The idle value for temperature is between 15-17 degrees Celsius, and 0-2% for smoke. The arrangements of the information in the opened tab, mimics the placement of the detectors in the GA. The enclosed areas, as in the aft and front section along with the middle section of the ship, are highlighted on the respective tabs for detector readings.

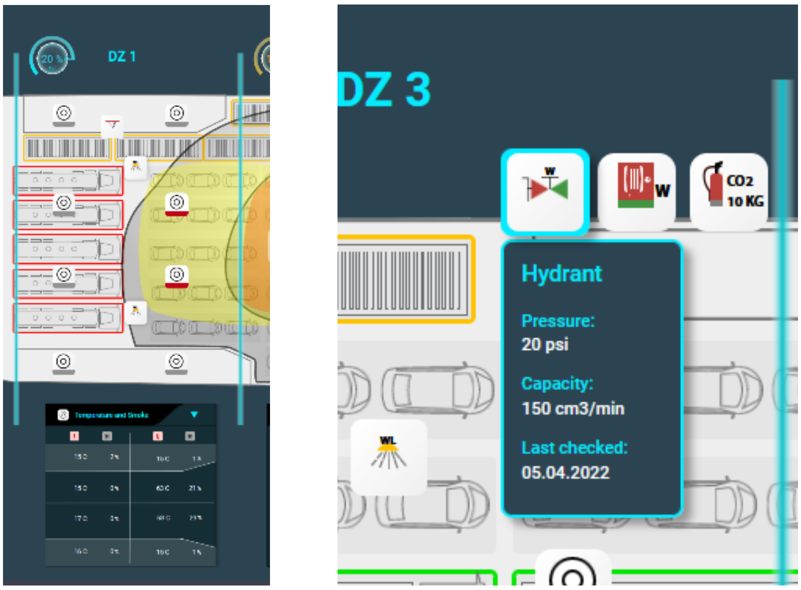

Figure 21. Left: Temperature and smoke tab with detector values. Right: Clickable emergency equipment showing detailed information. The figure shows information for a hydrant.

Hydrants, fire hoses and fire extinguishers are indicated using their respective IMO symbols. This equipment which appears all around the deck is clickable for detailed information (Figure 21). Dampers, ventilation, detectors and drenchers were not clickable by their symbols on the GA.

Additionally, a 3D view with an indication of the location of the first fire detection, is shown (Figure 22). This acts as an overlay over the GA. The 3D view can be activated by touching the 3D-button in the lower left-hand corner.

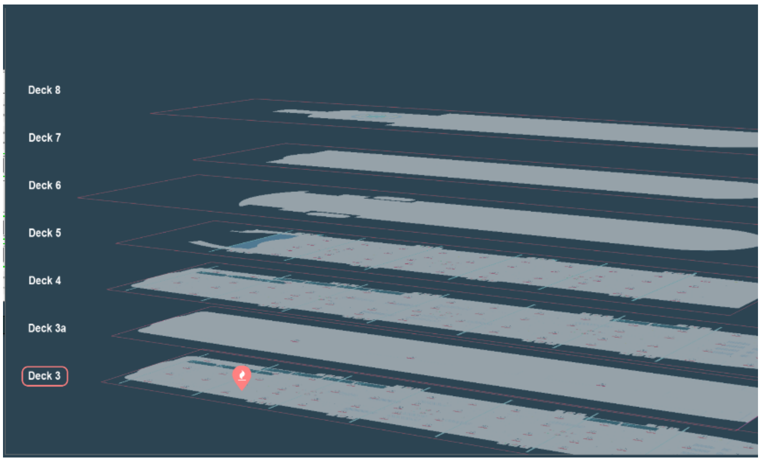

Figure 22. 3D-view of the decks indicating the first fire detection on deck 3.

4.2.2.1 Cargo Cards

The cargo cards indicate each vehicle (except cars) on deck of a ro-ro vessel. Each vehicle is put on deck in its actual location. It should assist the fire chef in understanding where cargo and cars are positioned. The vehicle may be shown as a trailer with a truck (A), a trailer or container (B), or a tanker lorry (C) (Figure 23). According to the fire hazard classification, the cargo frame may be coloured green (low fire hazard), yellow (medium fire hazard), or red (high fire hazard), depending on how combustible the cargo is.

If the system operator clicks on a cargo unit, it will flip and display more detailed information about the cargo, such as the cargo and booking number to identify the vehicle and make it possible to match the cargo documents with other systems, a summary of the containing cargo and tonnage, and UN or ADR pictograms if applicable to have a quick overview of what hazardous cargo is loaded. An extension of the cargo card might be accessed later through the arrow on the right side of the cargo card to see more extensive information, such as scans of cargo documents or FLIR imagery from the rover which serves as an early warning system that crawls over the decks.

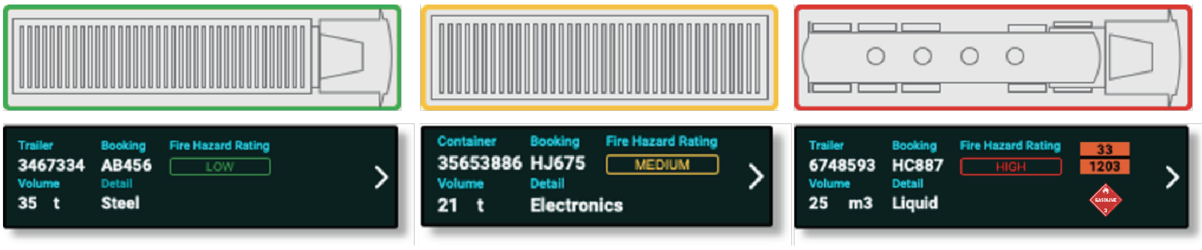

Figure 23. Representation of cargo on deck categorised in three fire hazard ratings (A) low, (B) medium, (C) High

4.2.2.2 Drone Deck

This component of the user interface (UI) was conceptualised and built around the drone idea introduced in Action 7-C. The operator of the DFC should be able to activate the drone and choose the angle from which he wants to examine the outside of the ship. This user interface idea provides the operator with a choice between five different predetermined locations, which makes accessibility much simpler than indicating precise locations on the touch interface (Figure 24). After selecting one of the rings, the drone will hover to that location, and the images from the associated CCTV/FLIR cameras will be shown on a separate screen. The functionality of this element was intentionally kept to a bare minimum since it was decided that the drone idea should be included in order to get some input from the people who were actually using the system.

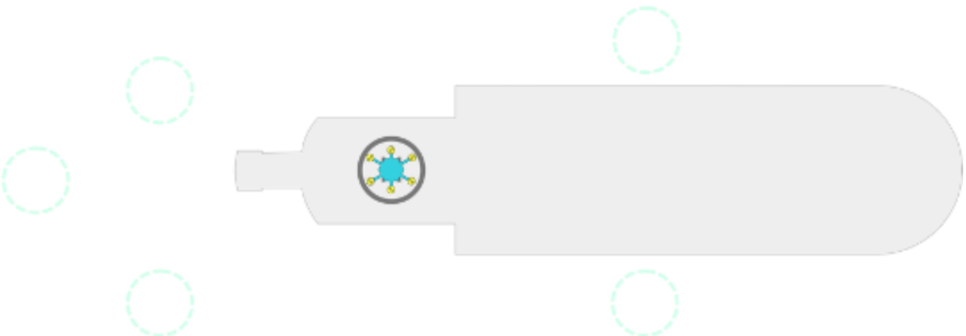

Figure 24. Deck 8 with drone controls to get video / IR feed from outside the vessel.

4.2.3 Emergency controls

The emergency control panel must provide users easy access to a variety of different firefighting measures, as seen in Figure 25. This control incorporates a variety of subcomponents, each of which ordinarily calls for the participation of a separate actor within the system, such as the officers-on-watch on the bridge, the fire chef and their crew, or the engineers working in the engine room. The control should function as a check list and provide the operator with direction on the activities that they should be thinking about. If the operator has turned on a particular safety feature, the status LED on the interface will light up in green to indicate this action as done or active. On the left side of Figure 25 is a list of all the available functionality, and on the right is the interface, which gives the operator control over whether or not the fire bells are ringing. The use of a slider allowed for the activation and deactivation of all safety features. The slider had the purpose of preventing any of the emergency controls from being accidentally activated or deactivated.

Figure 25. Emergency control with fire bells deactivated.

The operator is required to initiate the procedure with the slider in order to successfully shut the fire door located on the deck. In the future, a miniature map might be shown in the vacated area to show the operational state of each fire door on its corresponding position (Figure 26)

Figure 26. Emergency control to operate the Fire doors

The emergency control shown in figure 27 provides information on the location of all ventilations on the deck as well as their operational state at the moment. In the event that there is a malfunction, it has the capability of displaying the status as either active, inactive, or out of order. The user is able to activate and deactivate the ventilation by using the slider, and they will instantly get feedback on the tiny map representation as a validation of their action. Within the scope of the ventilation system, it might be necessary to open and shut the fire dampers located on the various decks. By using the slider, it is possible to open or shut any or all of the dampers simultaneously (Figure 28).

Figure 27. Emergency control to activate and deactivate the ventilation on deck.

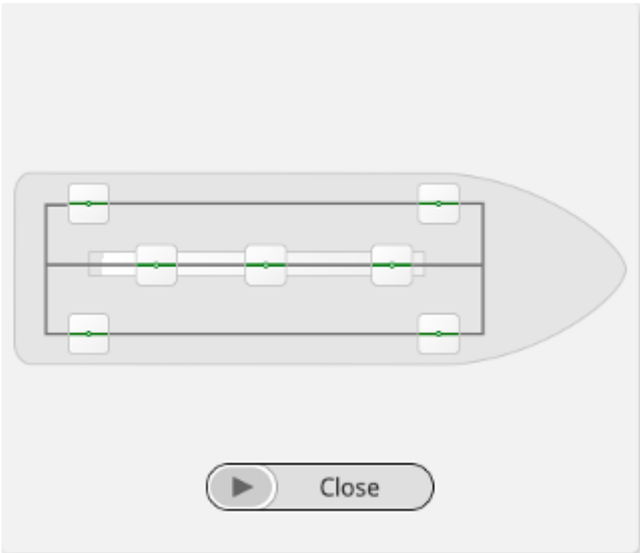

Figure 28. Emergency control to close and open the fire dampers.

The operator is able to activate an evacuation ventilation system, such as the one located in the stairwell. The graphic shows where the vents are located as well as their current state (Figure 29)

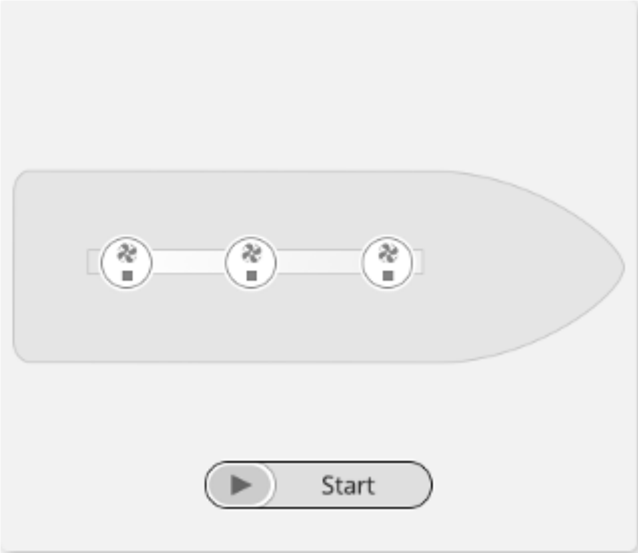

Figure 29. Emergency control to activate and deactivate the evacuation ventilation in the staircases.

A diagram of the fire pumps, pipelines, and valves is shown in figure 30, which is the control panel for the fire pumps. The user is able to see the status of each pump, including whether it is active, inactive, or experiencing some kind of failure. The same idea applies to every single one of the valves that are part of the system. In order to maintain the consistency of the interaction with the other emergency controls, this one may also be triggered using the slider.

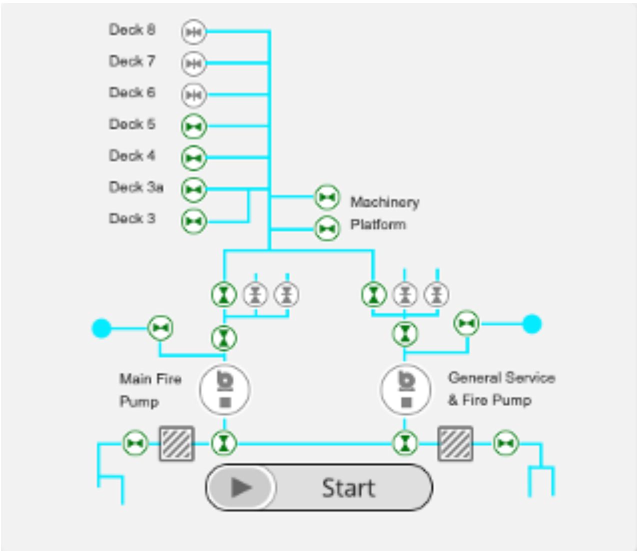

Figure 30. Emergency control to activate the fire pumps.

The user may choose which drencher zones they wish to activate as the last option in the emergency control panel. Following that, the active regions are marked in blue. If a zone should not be drenched with water, for example, if a drencher zone includes cargo that is sensitive to water or might react with water, the zone will be marked in red to indicate this. The user is only able to select a maximum of three drencher zones at once due to drencher system capacity. Following the user's selection of drenchers and subsequent activation of those drenchers through the slider interaction, a process will commence prior to the actual drencher delivering water, and the user will be kept apprised of the process's progress as well as each step along the way (Figure 31).

Figure 31. Emergency control to activate and deactivate the drencher system in different drencher zones.

4.2.4 Timeline & notepad

The timeline (Figure 32) is intended to give the user an overview of what has already happened, but also to provide a prediction of the development of the heat, smoke and oxygen level.

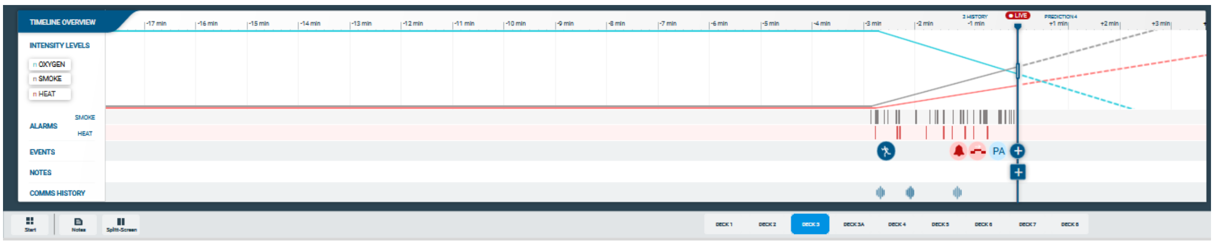

Figure 32. Timeline.

The first row contains the intensity levels that tells if the heat, smoke and oxygen levels are increasing, decreasing or constant. On the right side of the blue vertical line, the current time marker, are predictions of how the levels are expected to develop. The curves are increasing as long as there are new detections, flattens out when there are no new detections and decreases as heat, smoke and oxygen levels returns to normal.

Under the curves are two rows for detections; one for smoke and one for heat. When heat or smoke is detected by one of the detectors, a bar will appear on the timeline.

Below the detection rows is the event logging row. Here, the system will automatically log events such as fire alarm, drencher activation, PA and closing fire doors. In addition to this, the user can manually log events by pressing the round plus sign button (Figure 33). Similarly, the user can also press the rectangular plus sign button and add free text notes to the timeline.

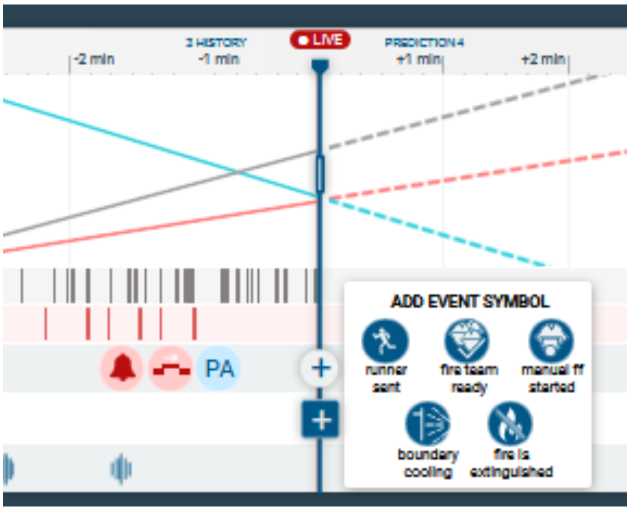

Figure 33. Adding event symbols.

The last row on the timeline contains communication history, where it should be possible to replay recorded radio communication. This was however not possible in the prototype. The communication symbols on the timeline had to be added manually by a researcher via a Bluetooth keyboard.

By grabbing, sliding and releasing the current time marker, the user can see what the ship layout with heat and smoke maps looked like at any time. This was a heavy operation for a prototype built in Axure and it caused occasional glitches.

4.2.5 Snack Bar

A “snack bar” with information on the first detector triggered flashes up above the timeline, when the alarm goes off. (Figure 34).

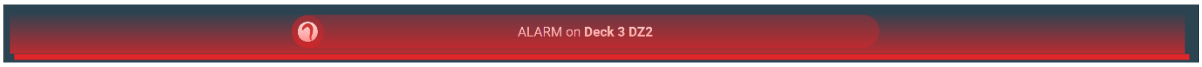

Figure 34. Snack bar with detector information.

5 Demonstration

Authors: Julian Steinke NTNU, Hedvig Aminoff NTNU, Julia Burgén RISE, Felix M. Petermann NTNU, Leander Spyridon Pantelatos NTNU

The demonstration was an opportunity to investigate the extent to which the DFC supports users’ performance, and how it meets their needs and expectations. It also presented an opportunity to investigate how using the DFC might contrast to current procedures, as well as to learn more about managing firefighting on ro-ro ships in general. The demonstration could also provide input and feedback which can be useful for Action 7-C.

5.1 Objectives

The digital fire centre was designed with the intention to make information that is important during firefighting activities, such as the localisation and monitoring of a fire, more accessible by integrating available data in easily understood representations. In addition, the design was intended to support effective firefighting measures, such as the activation of drenchers, through information which is relevant for key decisions and by enabling control of key functions from one single panel.

A user-centred testing approach was chosen in order to investigate the key question 'does the DFC improve firefighting capability in ro-ro ships', as well as to uncover limitations and suggestions that can inform further design and redesign.

5.1.1 Usability

Usability is an outcome of the *use* of a system, and assessing usability requires consideration of the context of use, which includes users, the goals and tasks, as well as the resources and environment (ISO 9241-11:2018).

Usability is a central concept within Human-centred design (HCD), which is defined in ISO 9241- 210 and provides methods to achieve high usability and user experience, and to minimize the risk of failing to meet user/stakeholder needs and expectations. The ISO/IEC standard 9241 defines usability from the user's view of performance and satisfaction, which contrasts slightly to the usability definition in the software quality standard ISO/IEC 9126 which defines usability as an attribute of a product. The ISO-9241-210 definitions of usability also contrast to commonly used but more vague terms such as user friendliness or ease-of-use. ISO-9241-11 provides detailed definitions and a conceptual framework for uncovering information about users, the context of use, and for defining usability criteria for evaluation purposes. In this international standard, usability is defined as

"The extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO9241-11:2018)

Effectiveness, efficiency and satisfaction are defined as:

- 'accuracy and completeness with which users achieve specified goals'
- 'resources used in relation to the results achieved', and
- 'extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations'

Hence, assessing the usability of the DFC required understanding the extent to which it helps the user achieve intended outcomes– where the overarching goals is putting out a fire. That assessment can be built on details about the time and effort required to achieve goals and subgoals, whether use errors or difficulties were encountered, if important functions are missing, whether the operator's mental workload is reasonable, and whether the user's response from using the system meets their needs and expectations (satisfaction).

The concept of usability supports the design and evaluation of human-centred qualities- how 'good' a product is from a user perspective. Appropriate usability makes a system easier to understand and to learn how to use. In this report we have called this *intuitiveness of use*, a characteristic which is hypothesized to for example lead to fewer mistakes being made by a user under pressure.

5.2 Participants

Four participants, all from the same major ferry operator, took part in the demonstration: one in the pilot session, and three at the session conducted at the company's headquarters. All participants were Danish and work as Chief Engineer and with the role Fire Commander in the fire organization, and are therefore considered to represent the users for which the DFC is intended.

	Pilot participant	Participant A	Participant B	Participant C
Works at ship type	Ro-pax	Ro-pax	Ro-ro	Cargo ship, previous Ro-Pax pax experience
Male/female	M	M	F	M

Table 3. Description of the participants.

5.2.1 Ethics

Ethical considerations were made in alignment with Lash Fire guidelines for ethics in research methods (LASH FIRE D12.1). Participants were informed about the purpose of the study, how data will be collected, processed and stored, that participation is voluntary, and that confidentiality is ensured. The consent form and consent details are included in Appendix 1.

5.3 Test tasks

The test task in the demonstration was provided through a fire scenario. The DFC was programmed to provide alarms and sensor readings to represent a fire, and this was combined with role-play between the test participants and the research team. The fire scenario was intended to provide a context of use during testing which would bear likeness with a real-life situation. The participant was instructed to act as they would during a real fire, using the DFC and communicating with other “crew members” through VHF.

The scenario was modelled based on a real drill undertaken on Ship A in the study presented in D07.2, which was recorded using Go-pro cameras worn by key crew members and staff supporting the drill. Footage from this drill had been transcribed, and this was the basis for the timeline of events in the scenario, how animated effects on the DFC were modelled, as well as the plan for interaction between the fire commander and crew members. More details about the scenario and how it was implemented in the DFC are provided in section 5.5.3 Scenario design.

5.4 Test facility

The pilot test was conducted in the facilities of the shore control lab of NTNU. The prototype was set up in a lab room, and the researchers acting as crewmembers of the fire teams and the engine control room were located in an observation room. Those researchers observed and recorded the session with a ceiling-mounted camera and communicated with the participant over an intercom system. The debriefing was conducted in a meeting room next to the laboratory.

The demonstration was conducted at a major ferry operator’s headquarters. Two meeting rooms were used; one for the test session with the DFC and all recording devices and the other for researchers acting as crewmembers. The second room was also used for pre-test information talk and post-test interview.

During the tests, the participant was accompanied by a person working for the same shipowner, who was familiar with the project and the DFC. This person observed the familiarization session, and also played the role as captain during the scenario. One researcher facilitated the familiarization session. Another researcher was also present to observe both sessions.

5.5 Materials and apparatus

This section describes the physical apparatus, as the well as the configuration of the UI and the fire scenario, which combined events that would be triggered by the test participant’s interaction with the DFC, as well as pre-programmed animations. This section also includes a description of how the demonstration was recorded.

5.5.1 Table

Together with the 55-inch touchscreen, which the prototype was conceptualised for, the table allowed the participant to use the system in different positions. The screen could be tilted between 0 and 90 degrees, and the lifting columns enabled the participants to lower the screen to about 90 cm in a flat position, and to 180 cm to the upper edge in an upright position. During the test sessions the table was put in idle mode (see section 4.2). Mounted on the handrail in the front, a controller allowed the participant to adjust the table by controlling the actuators.

5.5.2 User Interface

The UI that the participant was asked to interact with was a prototype built in Axure RP 10. The emergency plan from real a ship served as a model for the ship in the prototype. The prototype had two modes; an 'idle mode' and a 'scenario mode'.

The 'idle mode' was used for the training session. In this mode heat and oxygen were set to normal values and the smoke concentration was set to 0. All functions were available to the participant in this mode, but fire related information such as heatmaps and intensity curves was not. The 'scenario mode' was used for the experimental session. In this mode, the heat, smoke and oxygen developed and regressed according to the script. For both the idle mode and the scenario mode, the functions were primarily developed for use on deck 3 (location of the fire).

5.5.3 Scenario design (simulation?)

The fire scenario was initiated with the first alarm at a sensor in the aft section of deck 3. Fire bells sounded via speakers and the test participant took his or her position at the DFC table. At this point, the facilitator, playing the role of officer on watch explained that, a runner was sent to investigate. In addition, the CCTV footage showing smoke on the deck was started (image). The fire was confirmed by the runner and the OOW activated the fire alarm.

Figure 35. Screenshot of the CCTV footage shown to the participant on a separate screen.

Pre-programmed temperature and smoke detections and values served to indicate the spread of the fire and smoke. Specific information on temperature and smoke levels at each triggered sensor could be accessed by clicking on the drop-down menu under the map for each drencher zone.

The timeline also presented the alarms and development of the fire, through a graphical representation of changes in temperature and spread of smoke. After five minutes, the CCTV feed was no longer accessible, simulating damage to the camera. Throughout the scenario, the participant could talk to facilitators acting as engine control room operators, as well as two fire teams via VHF. The information they provided was tied to the progression of the scenario in the original fire drill, and was summarised in role cards (Appendix 3).

The procedure for fighting the fire included the following possible steps available to the operator of the DFC:

1. Shut down ventilation via the control panel
2. Close the dampers via the control panel
3. Start the fire pumps via the control panel
4. Start drenchers in zones 1-3 via the control panel
5. Muster fire teams via VHF
6. Stop the drenchers when the heat alarms stop
7. Send in a fire team via VHF
8. Open dampers via the control panel when ventilation is needed
9. Restart ventilation via the control panel

However, the scenario was not intended to dictate a certain order of actions. In a real-world scenario these activities would be taken at the discretion of the operator, at the time and in the order deemed correct under the circumstances.

The effect of fighting the fire with the drenchers was represented visually with the colours of the heat layer fading and gradual deactivation of the temperature-alarms. After the fire had been extinguished, the graphical smoke layer would gradually reduce as ventilation was re-activated.

At the endpoint, no alarms would be active on the UI, and the timeline would indicate a nominal status.

5.5.4 Data capture

Multiple sources were recorded for each usability assessment. The configuration is depicted in figure (XX). All contacts with the real test subject were captured by three GoPro 10 cameras, one connected to the chest of the fire commander, one filming the scenario from the top front, and one recording from the rear. This should first assist in observing the user's interaction from many angles, but it should also serve as a backup in case one of the cameras fails throughout the experiment. A screen recording of the UI was captured independently. In addition to the previously described cameras, the researcher playing the role of OOW, was equipped with a GoPro 10 chest-mounted camera. In addition to the audio source from the cameras, the fire commander and the OOW were equipped with a wireless microphone (Sennheiser SK 100 G4) for a clear capture of each individual statement. Using a streaming device, the aforementioned sources have been immediately recorded to an SSD (Black Magic ATEM Mini Extreme ISO). This device's Multiview output was wirelessly transmitted to a conference room in close proximity to the actual test setup (figure XX). Observers and recorders were able to view all ongoing operations from a separate room without interfering with the experiment. Two of the present researchers in the observation room used VHF (very high frequency) radios to impersonate the engine room's team and two fire teams.

Additionally, the fire commander was outfitted with a Pupil Labs *"PupilCore"* eye tracker. Using the world camera, the eye tracker captured the surroundings of the test subject, while two other cameras recorded eye movement and pupil dilation. This data indicates what the subject was seeing during the experiment.

The debriefing session was recorded with a camera as well. The debriefing during the pilot test was done via Teams as some researchers could not be present on location.

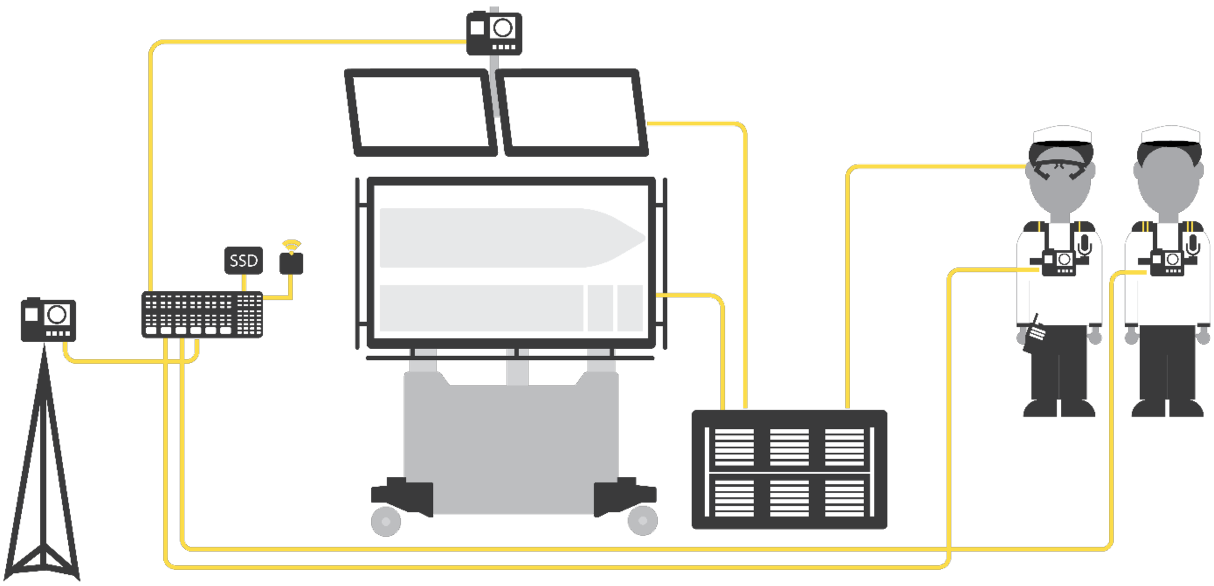

Figure 36. Overview of the test setup showing the used devices and data connections.

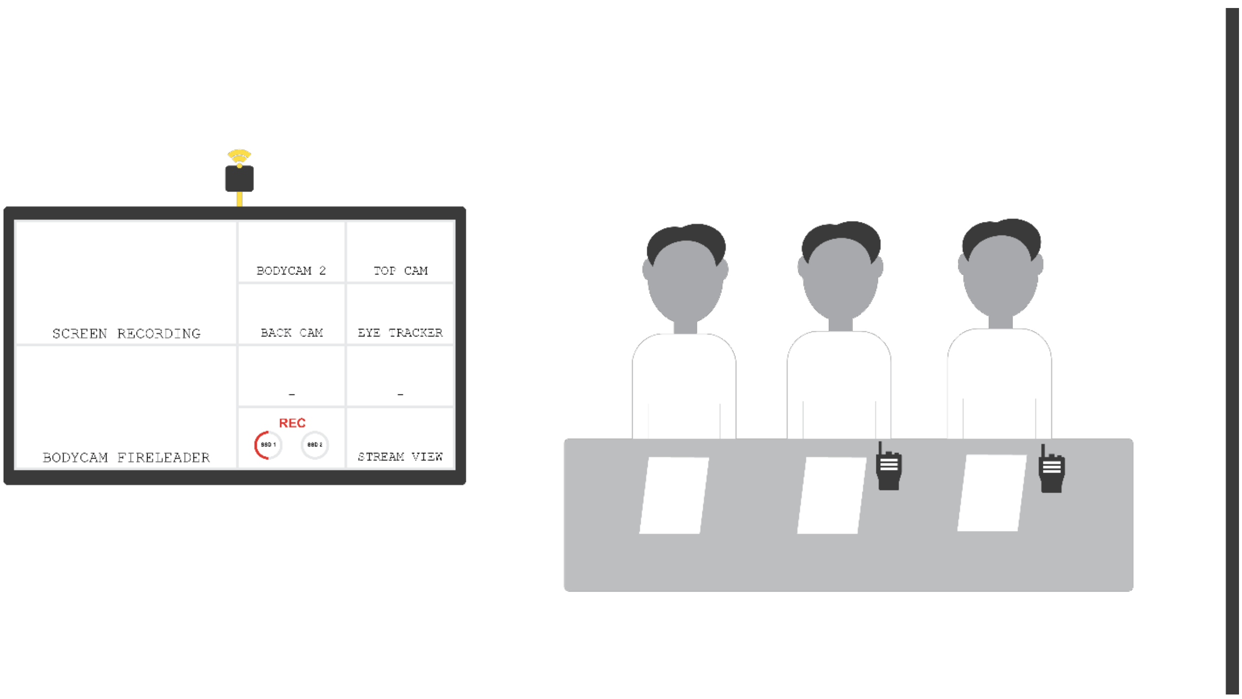

Figure 37. Overview of setup in the observation room, the screen displays the multi view of all cameras.

5.6 Demonstration Procedure

The demonstration session included the following steps: introduction, familiarization, fire scenario, and debriefing. The participants completed an online questionnaire after the session.

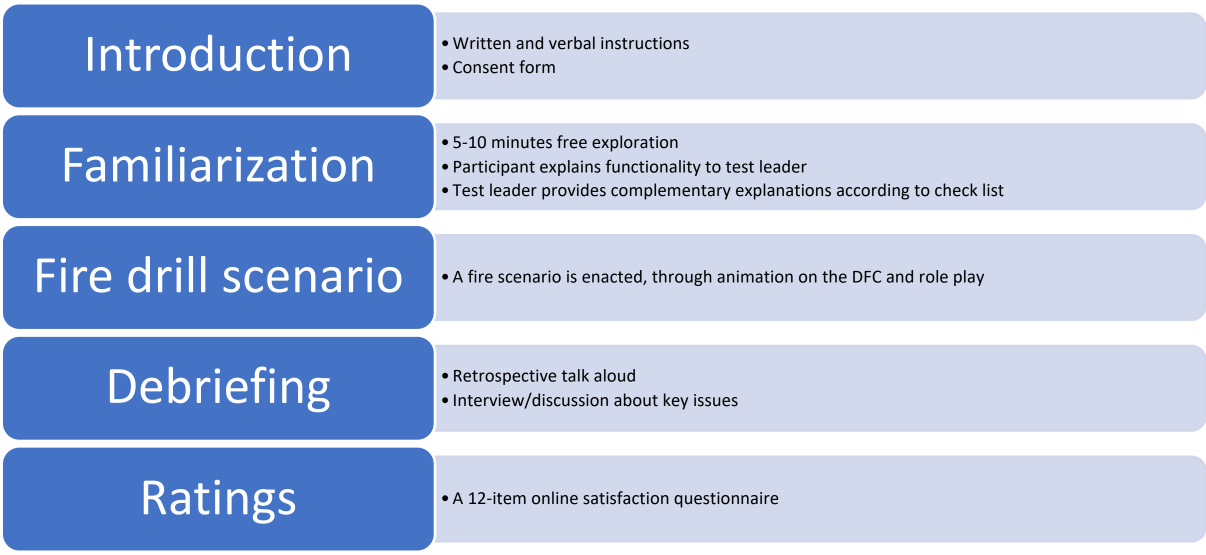

Figure 38. Steps of the experimental session.

5.6.1 Introduction

Upon arrival at the facilities for the demonstration, participants were welcomed and given a verbal and written description of the background, design, and purpose of the study, as well as the implications of participation, to ensure that they felt comfortable and to secure informed consent (appendix 1).

5.6.2 Familiarization

Each participant was given 10 minutes to freely explore and interact with the prototype while reporting with a think aloud method, where they verbalize their ideas, expectations, concerns etc as the interact with the system. The aim of this session was to have the participants understand all features of the interface as well as gathering initial feedback on the demonstrator intuitiveness as well as possible usability problems relating to the user interface. After the free exploration, the features the participants missed, and especially, the features which the user had misunderstood to any extent, were explained, to ensure that the user at the end of the session was able to use the DFC confidently.

In the context of the latter, it should be noted that the research team is well aware that the introduction of a novel, safety-critical system in a real-world context would entail a much more in-depth introduction and training session(s). Moreover, once installed on the target ship, the users onboard would become increasingly used to the DFC during recurring drills, increasing the familiarity of use, and the detailed usage of particular features.

5.6.3 Fire scenario

The test participant was provided with verbal instructions according to a protocol (see appendix 2).

Inspired by the real scenario on which the fire scenario was modelled, the test participant and the DFC were situated in a fictive Safety Control Center, a location which in real life would be in direct vicinity to the ship's bridge. Simulated CCTV from the ship was available on an external screen, showing footage of a cargo deck with smoke development. VHF radios were available for communication with the firefighting teams, engine control room etc. A physical note bloc and a pen was also available for notetaking. No other equipment was available.

Crewmember roles were played by facilitating members of the research team, located in an adjoining room. The crew member roles included:

- Bridge officer on the watch (OOW)
- Watch-keeper in the ECR (on watch when the scenario starts)
- Fire team 1, which will muster responding to the fire bells and announcement from the bridge. This team will not undertake any actions unless directed by the Fire Commander.
- Fire team 2 – same as fire team one.

The information provided and requested by the facilitators was based on the timeline of real interaction between crew members in the filmed drill. Interactions with the participant was supported by ‘role-cards’, which outline the information available during the unfolding events.

The first event of the scenario was a fire alert in the Safety Control Center. The OOW took initial steps according to fire alarm protocol, namely to send a runner so as to confirm the fire. The test participant “arrives at the bridge” after 2.5 minutes, upon which the OOW explained that so far, the fire was confirmed but nothing else was done. The participant was then expected to deactivate the fire alarm, and the OOW would make made a public announcement that there was a fire on the ship and that the fire teams needed to assemble at the fire stations. The participant was instructed to lead the fire management from that point, using the information and controls on the DFC, as well as the VHF radio to communicate with relevant crew members.

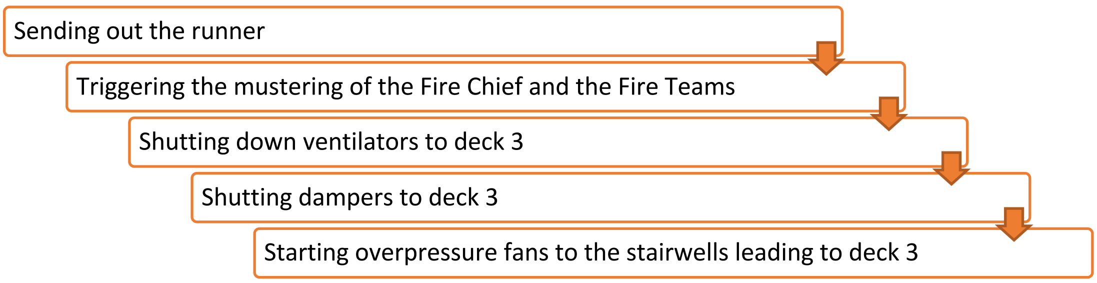

Figure 39. Simulated actions taken by the OOW.

After the camera feed from the deck was cut, the DFC did not provide means for remote visual confirmation that the fire had been extinguished. The participant therefore had to give directions via VHF to the fire team to investigate whether the fire had been extinguished or not. The scenario was concluded once the tester was satisfied that the fire has been managed.

5.6.4 Debriefing

Each participant was debriefed and had the opportunity to give feedback on the system in a semi structured interview. The debriefing session took approximately one hour and included a retrospective think aloud method, during which the test participant watched and commented the recorded test session. The participants were also asked questions about specific events during the drill as well as questions about the conceptual design of the DFC; possible benefits, it's possible role in the fire organization and risks, among other things (interview guide in Appendix 4).

5.6.5 Ratings

Once the debriefing was concluded the participants were given a link to online questionnaire which they could fill in once they had had time to reflect on the demonstration experience. The questionnaire included 8 usability ratings, on a 7-point Likert scale, and 4 text response questions about usefulness and potential barriers to using the DFC (Appendix 5).

Usability ratings	Text response questions
1. The DFC is easy to use 2. The features meet my needs 3. The DFC provided a clear overview of the location of the fire 4. The DFC provided a clear overview of the firefighting activities 5. The DFC provided a clear overview of the how the fire was developing 6. Using the DFC could support my job performance 7. Using the DFC could make it easier to do my job 8. The DFC could be useful in my job	1. What would be the most important differences between using the DFC, compared to how you work today? 2. What do you see as the main benefit of the Digital Fire Central? 3. Do you see any possible barriers to the Digital Fire Central concept? (Technical, organizational, work processes, risks etc). 4. Was there anything missing: features/information which you would expect, or wish for?

Table 4. Items of the questionnaire.

6 Results

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Overall, the participants described the DFC favourably. Many of the DFC features and controls were intuitively understood by users, however a few required an explanation. The participants also described some features which they expected but which were not available in the DFC.

The familiarization phase provided insight into the participant's first understandings and impressions of the design.

The programmed scenario took 23 minutes to complete. Regarding the overall task outcome, all participants activated the fire pumps and drenchers in a way that would successfully extinguish the fire. However, the participants applied different approaches to fire extinguishment. The first participant activated the drenchers immediately in the three drencher zones with heat indications, and sent in smoke divers once the sensor data showed that the fire was extinguished. At this point the participant attempted to turn off one drencher zone to keep fire team from getting wet, but this was not possible due to the limited functionality in the prototype. The drenchers were finally turned off after all heat and smoke was gone.

The second participant activated the drenchers quite late, which created a mismatch with the animated heat and smoke maps, which were programmed to follow a certain timeline, rather than the participants interaction with the prototype. As a consequence, the representation showed heat reduction, even though the firefighting had not yet commenced. The third participant made a quick decision to activate drenchers, but only in one zone, and with the aim of cooling dangerous cargo placed close to the fire, rather than extinguishing the source of fire which was in another zone.

The debriefing sessions provided opportunity for feedback about specific features as well as discussions about how the scenario and DFC current contrasted with current work practices.

All in all, the documentation of the exercises undertaken, in terms of recordings and other evidence, came to around a staggering 500 Gb of data. The analysis involved viewing the recordings of the familiarization session and the debriefing, to identify themes related to usability and to describe these with illustrative examples. Considering the short timespan between the demonstration and the preparation of this deliverable, it should be emphasized that results reflect an initial assessment, rather than a deep qualitative analysis. Future work, discussed in section 7, may provide more dimensions and nuances to the results, and could, finesse the results which are presented here.

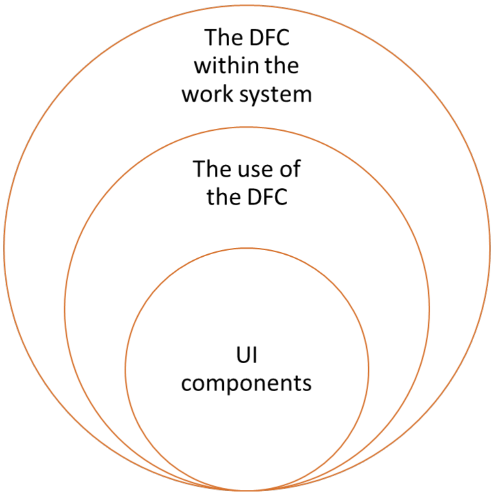

Figure 40. The results are structured along three levels of specificity: individual elements of the UI; the use of the DFC, and the DFC as part of a larger sociotechnical work system, where its use comes to interact with existing work practices.

The structure of this section is as follows:

- 6.1 UI components: zooming in on individual UI elements.
- 6.2 The use of the DFC: new insights about users and the tasks that the DFC is intended to support
- 6.3 The DFC in the work system: zooming out, to look at how DFC may fit within the wider sociotechnical context of use on board ro-ro ferries.
- 6.4 Questionnaire results
- 6.5 Effectiveness, efficiency and satisfaction. Here the results are framed within the usability concepts.

6.1 Individual UI components

The familiarization phase of the exercises helped provide insights about how specific design features were immediately interpreted, and the scenario provided opportunity to uncover more details about how the participants perceived interactive elements and if they could accurately predict the results of their interactions.

This section goes deeper into these results, looking at interaction design aspects of individual elements of the UI:

- The emergency controls panel 6.1.1
- The timeline 6.1.2
- Dynamic information & oxygen, including layers 6.1.3
- GA elements and layout (including cargo cards, deck navigation) 6.1.4

6.1.1 Emergency controls panel

The design of the emergency controls panel itself was perceived as very user-friendly and intuitive. Every participant knew how to navigate through the different controls immediately. The location was chosen adequately, as all participants found the panel instantly. But while operating the panel, one participant would have liked the panel more in the middle. In addition, all participants would have liked feedback on initial actions, thus closing of fire doors, deactivation of the ventilation, and activation of the fire pumps, to be indicated on the map as well.

That the activation switch is a slider was not immediately understood. All participants tried to press the slider at first, but immediately switched to a sliding motion afterwards. At no point during the training session or the actual scenario did any participant try to use it as a button again.

One participant misunderstood the "Fire alarm" panel. They interpreted it in a way that the action would activate/deactivate the alarm panel, i.e., mute the entire alarm system instead of the fire alarm itself.

All participants activated the fire pumps and drenchers successfully. They understood that activating the fire pumps would put pressure on the system but missed pressure indications at the pumps and/or the drenchers. One participant indicated that they used the drenchers in only one zone because of the dangerous cargo in the area and to at least minimize the spread of the fire to the dangerous cargo. They were aware that they did not use the drencher zone over the fire and said that this was because they had no idea what it looked like down there, i.e., if it was a small fire burning something that creates lots of smoke. But it has to be said, that all participants operated the drenchers without user errors and were aware of what the effects of their operations were.

The indication of a drencher zone that should not be used (DZ7) was understood easily. The participants indicated, that the red colour shows that it cannot be used. However, the reason, the cargo in that area, was not clear.

Both evacuation ventilation and deck ventilation were understood immediately. The participants pointed out what these represented during the familiarization phase and all activated and deactivated them correctly.

User satisfaction with the emergency controls was mostly high, the participants had direct access to the necessary controls and could easily use them. But it was also indicated that the concentration of tasks created a lack of checks: "Usually, you just say things on the radio and it is started by the bridge team for instance (i.e., pumps), but here I have to do it myself. 'Did I actually do it?' It is an additional burden."

In addition, the green indicator LEDs on the control panel are understood, but pointed out as being not enough of an indication. All participants expected more indications on the map. It was also pointed out, that there is a conflict between status and action taken with the green status indicator. It displays whether an action has been taken and not the status of the system, which was confusing to some participants.

The panel for emergency controls turned out to be highly intuitive and easy to comprehend. An example was when a participant was looking for a way to control the fire doors and ventilation, and found the control panel with one glance. The organization was understood immediately and they started to interact with the panel correctly.

6.1.2 Timeline and note pad

The timeline was immediately seen as a valuable system feature. One participant noted that the history was useful and thought that '*I can see when it started and I guess the alarm will show up here [points at alarm plot]. If I come in and I am new to the situation, I would see, that there was an alarm 11 minutes ago*'.

The historical plot was perceived as very useful and easy to understand. All participants reported that it was very helpful to arrive to the situation and being able to see how many alarms had gone off and how the situation had developed so far in terms of heat, smoke, and oxygen on the deck. The graphs were also reported to be very helpful to assess whether the attack worked.

The event markers were seen as a very useful tool, to mark important events. In combination with the historical overview, all participants pointed out their usefulness, as they provide a good overview of actions taken. The logging was also intuitive, as participants indicated that they would expect taken actions to show up on the history even before activating an emergency operation. However, only one participant manually put in an event marker. During the interviews, all participants stated that they forgot about the menu. All would have preferred the icons being present at all times, seeing the importance of the events. Additionally, the plus-symbol used on the slider to open the menu was perceived as unlabelled as it was not in proximity to the label 'events' used for the entire row.

The participants were unsure about the predictions. The element was understood correctly, but two participants would rather rely on the reports of smoke divers than the automation, as they did not know how the prediction was calculated. They would not want to rely on a graph to decide whether to send people on the deck. One participant used the predictions a lot to assess if the taken measures had an effect.

The slider was perceived as a good addition. Scrubbing back offered a visual comparison of the development of the fire. However, no participant used the feature during the scenario.

The note-function was not used during the scenario. Participants understood how it works but did not see the necessity for it. They indicated, that quickly taking notes on paper would be easier and more natural. In addition, one participant indicated that they would also not use the notepad, because it covers a large part of the screen.

However, in spite of immediately comprehending and appreciating the timeline, two participants expected the notepad to include a drawing function.

6.1.3 Dynamic information and layers

The dynamic elements of the ship's fireplan were seen as very useful. What was pointed out as its largest benefit was the ability to locate the fire and understand the situation in one glance, compared to being told by the captain where the fire alarm was located together with a static fire plan. This ability was well liked and sped up the response time a significantly, according to the participants. It was also pointed out, that assessing the temperature with a colour scale during high cognitive load is less demanding than a table full of values. But participants were missing a legend to know what temperature was indicated by which colour. This also caused one participant to not recognizing that the temperatures had returned to normal without looking at the specific sensor data. The participants also pointed out that it was very easy for them to understand the effect of the drenchers and the ventilation on heat and smoke.

The oxygen gauges were pointed out as important information by all participants and the indication was understood by everyone. However, it was mostly used to decide whether the air was breathable for fire fighters and not to see if the fire would be suffocated. One participant specifically pointed out that they would not use the oxygen gauges during a fire, as all firefighters on the deck would be wearing breathing apparatuses. They said that they would not wait for the fire to suffocate, because they would want to extinguish it at fast as possible.

The toggle buttons for the different layers were not used by any participant. All participants understood what the function was and how to use them without error in the familiarization phase, but removing information was not wanted during the scenario. It is however possible, that removing layers would be necessary during more complex scenarios.

6.1.4 GA elements and layout

The users easily and correctly understood the ship arrangement and the overall layout of the display into functional areas. Similarly, the information provided by the heat and smoke sensors – including the drop-down information boxes, was readily understood by the participants. They correctly identified the spatial mapping of sensors in the drop-downs to the overall ship arrangement, but also correctly interpreted the numeric information provided.

6.1.4.1 Fire plan, iconography, navigation

In general, the layout of icons, choice of symbols, and the fire plan were very well received. All participants understood the ships' layout, the emergency equipment on board, and the positioning of the cargo without problems. No participant lost awareness of which deck they were on, or were the fire was. They also appreciated the integration of multiple plans in the system, which are on separate sheets in real life. However, there was information missing from the plans in the prototype. The absence of frame numbers, manual call buttons, and emergency doors made it difficult for the participants to give the fire fighters specific instructions. In addition to that, there was no way for the user to keep track of the position of the fire teams, like with a marker in real life.

One participant found it inefficient to have to switch between different decks in order to get an overview. They would have liked a small picture of the deck with the deck number that they could press to access it. That way, it would not be necessary to switch between different decks to assess the spread of the fire on other decks. The 3D map was not adequate for that, in their opinion.

6.1.4.2 Sensor data

The positional relationship between the sensor locations and the data in the drop-down menu was understood by all participants, as well as the values themselves. However, the participants would rather have had the values next to each sensor symbol, instead of in a drop-down menu next to it. One participant elaborated on this idea, by stating that they would have liked to toggle a temperature indication for every sensor. Another participant indicated that they wanted to see one thing at once on the map and not read detector values, pointing at the usefulness of the heat-layer.

6.1.4.3 Icons

The iconography was based on IMO symbols used in fire plans and was generally understood without an explanation. The only new symbol were the sensors, which were understood as well. However, each participant expected the icons to be buttons, trying to click on them multiple times. This was a clear inconsistency, as it was not apparent which icons could be interacted with, and which ones not.

Furthermore, the information about emergency equipment was not entirely relevant for fire fighting. Information about the pressure on a fire hose or hydrant would have been relevant, instead of the date the system was last serviced.

6.1.4.4 Cargo cards

All participants found the cargo information very valuable. The colour coding of the dangerous goods was not intuitively understood but pointed out as very useful after an explanation. All participants were used to having the IMDG code on dangerous cargo, instead of what was used on the cargo cards. Whether or not the cargo should get wet should also be indicated on the cargo itself, and not only the drencher zone. In current procedures, the 1st officer would check dangerous cargo. The fire commander would be with the smoke divers and call the bridge and ask where dangerous cargo is. It was indicated, that this presentation of the cargo would make this process much more efficient and effective.

6.1.5 Physical table

The table was positioned in idle mode during the tests. All the three participants including the one in the pilot test made plenty use of the handles. During the familiarization all participant were made aware of the lift and tilt function of the table, but no one felt the need to adjust it. The table mode and briefing mode were only highlighted during the pilot test, where the participant thought the table mode would be useful for tabletop exercises, and the briefing mode would serve well during debriefing on the bridge.

6.2 The use of the DFC

This section describes deepened insights about user needs during the work that the DFC is intended to support, and is organized around recurring themes which emerged from the results of the demonstration sessions.

6.2.1 Situation overview

The participants all said that they believe that the DFC can provide a good overview of a fire situation. The users easily and correctly understood the ship arrangement and the visual representations of the heat and smoke overlaid on this 'map'. One participant described the experience of using the DFC by saying *'It's a very clear tool for creating yourself an overview of the situation'*, a viewpoint which was supported by another participant, who similarly found that '*the system is good at providing you with an overview of what is going on*'.

Another participant emphasized that the most important contribution of the DFC was how the heat and smoke maps, along with the trend curves on the timeline control provided a clear image of the development of the situation.

One participant described how it normally can be challenging to understand how a fire is developing. They may know that there is a fire on deck three, aft, port side, but they will not know if the smoke has developed midship or to the forward section of the ship.

Currently, a large number of smoke detectors going off only will only provide information that the smoke is spreading. In contrast, the DFC shows the pattern in which the smoke is spreading, and also an indication about the direction in which the fire is moving. One participant explained that this would give the captain a good overview of the situation, for example when determining the access points to the fire, even if an overwhelming number of detectors were going off.

6.2.2 Saliency of important information and feedback on actions

Users expected more salient representations of important structures such as fire doors, dampers, emergency exits, stairways, and also to be provided with further information when these types of icons were clicked. A considerable deficiency was that frame numbers and detector numbers were missing. Especially frame numbers are used for specific orientation on the ship, as they are easily identified and unique to their locations.

There were additional details which were expected but not provided. For example, while the emergency controls panel provided a visual indication that fire pumps were activated, there was no pressure indication.

Users also expected clear confirmation/feedback for certain actions, such as closing fire doors and dampers, and that this also would be represented on the deck maps, in addition to the signals provided on the emergency controls panel.

6.2.3 Orientation and localisation

Participants repeatedly expressed a need to track the location of the fire team, as well as means to provide adequate guidance to specific locations. This emphasized the need to include important points of reference, as well as a way of representing the location of fire teams, such as a drag-and-drop marker.

To further ease manual firefighting, one of the participants said that the cargo load layout could also include where to find passages between vehicles so that you can better direct fire fighter in how to gain access to the fire.

One participant stated "You can pinpoint very precisely what is happening and where it is happening, which was very nice."

6.3 The DFC within the wider context of use

This section presents results that are related to how the DFC might interact with firefighting as it is currently organized and conducted, and possible consequences of introducing this type of tool into the sociotechnical system.

6.3.1 Differences in how firefighting is organized

The design of the DFC made it most suitable for the bridge as a tool for the captain and the assisting officer, according to the participants. All participants in the study are normally the fire leader onboard their ships, which in their organization means that they lead the fire teams near the location of the fire. The test scenario was based on a drill on a ship (internal WP7 reference "Ship A"), which belonged to another ferry operator. As we found out during the demonstration, there were differences in how the two ferry operators organize firefighting. On ship A, the fire commander mainly resided on the bridge. The participants deemed it unlikely that the fire organization would change to the extent that they could leave this operative function to take on the fire management role implied by the DFC.

There are many differences between being close to the fire site rather than being on the bridge. One of these involves making decisions based on sensory perceptions in close vicinity to a fire, or only based on information shared over the radio. In the debriefing, one participant said:

In this situation I have data, but I'm used to having a sensation. In my daily life I can see that there is a fire. I can see that there is smoke. I can feel that it is warm, or that it's getting warmer. I have an idea of the general environment; how is the wind? Is the ventilation turned off? Are dampers open or closed? All this is impressions that I see down there, but now everything is on screen.

Another participant said, *'I normally have three ears, I have the communication with safety centre on one radio, the fire teams on another radio and then the ones who are near me without a radio'.*

However, there was agreement that the DFC would be a useful tool for directing firefighting from the bridge. A LASH FIRE team member asked, *'So the captain could be the strategist in a way, and you could do the tactical work?'. 'Yes, that's a good way'.*

6.3.2 Possible impacts on the organization of firefighting work

One participant said that the DFC could provide benefits for the fire commander, thus the bridge would be able to answer requests for information more efficiently: not having to first seek the specific information that could be spread across various systems or team members, and then get back to them. It was also said by one person that how they work today is that one person would be in charge of communication, and another would be responsible for activating the drencher. The participant asked themselves how the DFC would allow two persons working individually with different things.

One participant said that currently, the fire commander would not keep track of elapsed time and that this is something that the assisting officer on bridge would do. They also said that this is primarily for investigations after an incident. Participants were still interested in the possibility (for bridge officer) to log events on the timeline, but exactly how that could benefit an on-scene fire commander was not discussed.

It was mentioned by one participant that the DFC seemed very focused on activating the drencher. In the remote ethnography study (D7.2) the drencher activation was carried out as soon as possible, but in the DFC tests 2 of the 3 participants were more reluctant to do so. One of them explained that they were still concerned with people possibly being missing and that drenchers should not be activated until you know the ro-ro space is empty, otherwise you can make things difficult for the people still in the ro-ro space. The other participant toggled with the drencher zones a bit back and forth and eventually only activated the drencher zone over the dangerous cargo. The participant later explained that they decided to do so to keep the fire from spreading to the dangerous cargo, but that they did not want to activate more zones because they did not know the full picture until the smoke divers had gone in and the temperature seemed to remain stable. The participant also explained that normally, the on-scene fire commander would tell the bridge that they want drenchers, who in turn would ask the ECR to activate them. This would serve to take several opinions into account, opinions that according to the participant could be both good and bad. The same participant also expressed in the post-interview that they actually could have done everything from the DFC and almost tell the fire team to suit up and be stand-by while the fire was extinguished with only drencher, but that this is a new way of thinking and something that was a bit confusing.

6.3.3 Barriers and risks

In the debriefing, the participants were asked if they saw any risks related to the DFC. These primarily related to technology dependency, but it was also mentioned how it would be to use the touch screen in heavy seas. Given the above, however, participants were touching upon a lack of joint decision-making potentially introduced by integrated systems like the DFC. In a way, this was brought about by the ease of action provided by the DFC, which means that the operator can act, without discussion and consultation, on her – or his – own line of thinking, or indeed impulse. Providing cause for careful consideration with relation to procedures and manning of the fire muster lists, it could arguably be so that the optimum usage of the DFC would be for a two-man team, discussing decisions in front of the system – or, alternatively, a discussion between several locations, all sharing DFC displays. Future research could reasonably look into such organizational changes:

> '… *It's a one-man doing everything on the screen. It's a one-man screen and it works if the screen is working and all the sensors are working'*

Certain features of the DFC were appreciated as concepts but the participants said that they would not rely on the information if they did not understand how it was derived. One example is the timeline, where there were questions about whether the lines showed the development of temperature and smoke for a specific zone only, or if it was an average of the whole deck. Similarly, the predictions were considered valuable, but it would not be possible to base important assessments or decisions on the information since it was unclear exactly what they showed and how they were calculated.

One participant stated '*Can I rely on the measurements? What is it like 10 meters away from the detector? … Can I enter based on just these measurements?'*

Another participant said *'The more parameters I have that works independently, the more trust I have in the system. But I would never give myself into trusting the system. That is how we are taught. In the end it is what you see.'*

6.4 Questionnaire results

The questionnaire was the last step of the demonstration, and these results reflected the findings that have been elaborated in the previous sections.

The usability ratings capture aspects of "The use of the DFC", while the text responses elicited answers about "the DFC within the work system".

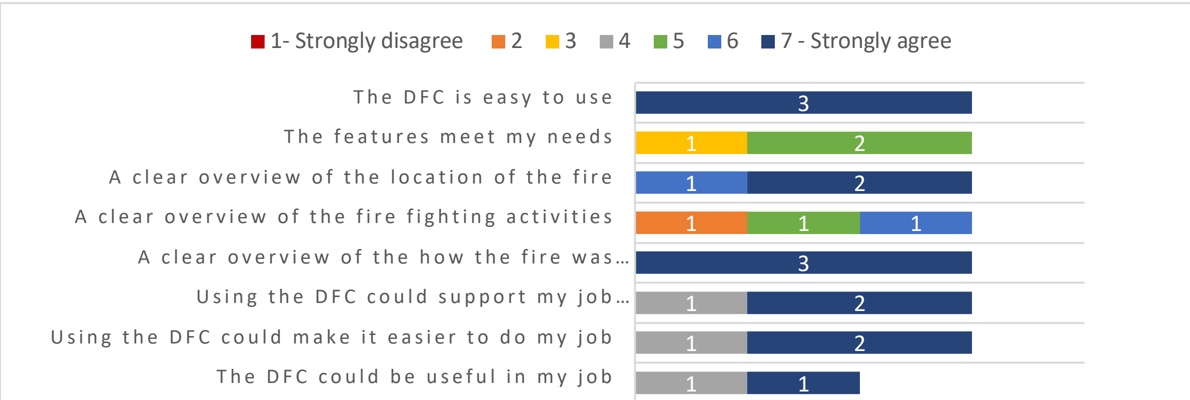

Figure 41. usability ratings gathered with the questionnaire.

The participants all strongly agreed that the DFC was easy to use, and that it gave a clear overview of how the fire was developing. There was less agreement on the statement "The features meet my needs", which we interpreted as an effect of the participants' regular roles as fire leader, where they would be leading the fire teams close to the fire location, rather than being on the bridge as their role was defined in the test scenario.

Similarly, there was less agreement with the statement "The DFC provided a clear overview of the firefighting activities", which reflects comments during the debriefing where participants expressed a need for more salient feedback, and to be able to track and communicate the location of firefighters. Two participants strongly agreed that the DFC could support their job performance and also make it easier to do the job, while one participant was neutral, which we also believe derives from the discrepancy between their regular work activities and the work situation in the scenario.

The responses about the DFC's most important contribution stated that it provided a useful visualization of the location and development of the fire, and that data/information as well as controls which are currently distributed across different tools are provided in one place through the DFC.

Possible barriers to using the DFC were related to the fire commanders' need to be on site during the fire, and that a fire commander using a DFC would change the configuration of their regular roles and tasks. There were also concerns about how a large touch screen would function on hard seas, and that the work system becomes vulnerable if users rely on a single system.

The full questionnaire results are included in Appendix 5.2.

6.5 Effectiveness, efficiency and satisfaction

6.5.1 Effectiveness

Effectiveness is defined as the accuracy and completeness with which users achieve specified goals, i.e., that there is a reasonable level of match between actual outcomes and intended outcomes. An example of how the use of the DFC can contribute to effectiveness is how the visual representation of the fire on DFC can help a user direct the fire team to the correct location.

Use errors or difficulties can have an impact on effectiveness. While there were some issues with consistency and ambiguity in the design, for example how slider buttons should be activated, or that some icons were clickable and others not, our overall conclusion is that users were able to conduct the tasks and actions that they intended to.

6.5.2 Efficiency

The results indicate that the use of the DFC can be expected to contribute to the efficiency of firefighting, as its use can have a positive contribution to the time and effort required for certain activities.

One participant said that the DFC would provide important efficiency benefits for the fire commander, who would not having to search for and integrate information that could be spread across various systems or team members. This would in turn would allow the bridge to answer requests for information more efficiently.

This also illustrates how the DFC may reduce the effort for certain tasks. The effort required for integrating data into useful information, for example matching sensor numbers to a specific location, contributes to mental workload. This data is already integrated into useful information within the DFC maps. Similarly, the data from multiple types of sensors is integrated, which can be expected to contribute to lower mental workload for understanding the location and spread of a fire.

Being asked about how the DFC might affect mental workload, one participant stated that the primary concern was 'where do I have my people', which in turn validates the need for the 'drag-and-drop' marker for the fireteams mentioned under section 6.2.3.

Efficiency was only subjectively assessed but analysis of the eye-tracking data can potentially contribute to these insights.

As a conclusion, one participant stated that 'for a captain…I think it would be less work'.

6.5.3 Satisfaction

The participants' satisfaction of working with the DFC was overall very positive, potentially indicating that they would embrace the tool in real-world installations, thus increasing their motivation and capabilities as fire commanders:

"[It is] also a very easy tool to use when it comes to the execution of the firefighting. I think it is a very, very good system. "

“I think the system was very nice, the concept, to have it on a screen, I’m from the younger generation so….”

The first impressions relating to intuitiveness gained during the familiarization sessions were supported during the debriefings. Participants found the DFC to be easy to use, to support their understanding of the situation, and they quickly felt comfortable with the DFC:

“It’s very, very intuitive. I’m used to using my own gadgets, and it’s more or less same intuition that I bring into this. It’s like whatever you use in your daily life. “

“As I mentioned earlier, I like gadgets and it is not like you have to wrap your head around this one. It’s like picking up a very large iPhone. The icons beg for you to push them, so it is very intuitive.”

In the debriefing, one participant mentioned that they experienced time pressure from wanting to put out the fire, but also said ‘I don’t think it [DFC] was demanding, I think it was easy to use’. However, it should be expected that there is a threshold to fully grasping a new system for highly specialized work, and another participant stated ‘If I knew the system better it would be easy and it would be a help’.

7 Discussion

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7.1 The DFC system

The fire plan element of the DFC worked well. It offers high efficiency and effectiveness, as the participants were able to understand the plan and its elements, and were able to navigate through different decks. The only unfamiliar static elements were also understood after an explanation. The fire plan itself was incomplete, but given the ratings by the participants, this can be viewed as less relevant.

The visualisation of heat and smoke directly on the fire plan is a strong recommendation for all future digital mimic panels. It enables an immediate understanding of the situation and supports the attack on the fire immensely. This understanding is even further developed in combination with visualisation of historical data, for example with the timeline of the DFC. It was difficult for some participants to understand the timeline element on it’s own, but as soon as it was put into context, this feature was used and apprechiated by every participant. One of the main objectives of the DFC was achieved with this combination; enabling the user to activate counter measures fast and in the correct way. However, one participant pointed out that the DFC focused on the drencher system as the primary means of putting out a fire, and that it provided less support for the information and actions required during manual firefighting. This is an important insight that shows that further consideration has to be given to a wider variety of goals and tasks during firefighting.

Additional prediction of the near future is a useful tool to assess whether the attack is working. Although the visualisation of this prediction was a good approach, it is a prediction with very high stakes. In order for users to trust such a prediction, the computing of it must be transparent. Otherwise, it should not be included, because it may cause doubt in the entire system.

A centralized emergency control panel on the bridge has to be explored more. This report shows the advantages of such an integrated system, but this includes only the interface for the final user. The technical challenges of getting all information and control integrated into one system are significant, depending on the technological maturity of the underlying information sources, but have a large potential to improve fire safety.

Displaying cargo on a digital fire plan has shown to be effective in planning the attack on a fire. The time and cognitive load saved by clicking directly on the cargo instead of looking up a booking number in the cargo manifest is significant. An indication whether cargo could come in contact with water is necessary also, but a different design solution has to be found than the one used in the DFC presented in this report.

The greatest shortcoming in terms of usability was that the DFC in its current state offers no possibility of tracking fire teams on the map. This is a deviation from current work practice on board, where physical markers are moved on a paper map, thus a digital pendant would be very beneficial. In the version presented here, the user has to track the positions of fire teams off the interface, either mentally or on paper, which will be very demanding in a more complex and/or longer emergency. Given the digital nature of the DFC, one could also think of an automated marker of the fire team on the map. Drag-and-drop markers or automatic trackers for fire teams are options that should be investigated for digital fire plan solutions.

The table used for the DFC itself is a good prototype for digital workstations in a marine environment. Users should be able to adjust the position of the screen to their liking while using handles around the surface to hold on and to prevent accidental touches. One additional factor pointed out by a participant that was not thought of before was the possibility to operate the interface with dirty or greasy hands. This was not considered before, but relevant, given the environment of a commercial vessel. As the specific screen of the DFC was pressure based, it can be operated with any object; skin conductance is not required. This was an unexpected, but very beneficial feature of the DFC and should be a feature of all touch interfaces on board a vessel. It is also worth investigating if the table should be able to be set completely horizontal and consequently have objects placed on it, or if it should stop at an angle where objects would fall off.

7.2 Features not evaluated

Not all DFC functions and features were used in the scenarios and are not yet properly evaluated. These are the following features that remains to be evaluated:

Manual logging of events on the timeline was only used occasionally and note-taking not at all. Participants said that logging events is not something that they would normally do and that they forgot this functionality. But it was also expressed that this is something someone else is normally responsible for and that this person may find this function useful. As for note-taking, the efficiency of an on-screen keyboard should be further researched, especially in a high-pressure situation such as a fire and during heavy seas.

The scrolling back in time on the timeline was not fully functional in the DFC prototype, but it was neither attempted to be used by the participants. It was not explored in the familiarization sessions, only mentioned as a possible interaction, which may be a reason to why the participants did not attempt to use it during the tests. It is possible that the intensity graphs serve the need for keeping track of history and that the function is unnecessary.

Participants did not make use of the 3D map during the scenario itself, although they liked the idea. Given that the decks are visualised on top of each other, it could be the case that the 3D map was redundant. One could also argue, that this is an artifact of actual fire plans, where all decks are visualised in 2D next to each other. A comparative usability study between a 2D and a 3D map with the same degree of detail would have to be performed to answer this question.

The communication recording and playback was not functional. It was said that all communication on board is recorded, but this does not include the possibility to play specific recordings back instantly. In the scenario the participants did not seem to desire the possibility to playback recordings and it is yet to be researched if it can be useful in a complex situation.

The scenario was not covering a case where the participants would turn to the drone for more information about the fire. The AGV on the car deck could have been useful, but it was not necessary in the scenario presented here. By the time the participant entered, the fire was already confirmed. The controls for the drone however, were perceived as intuitive.

Heat and smoke development on other decks was not included in the scenario, so dealing with information on several decks at once was not evaluated. One participant expressed that a better overview of all decks (i.e., miniatures of other decks) is necessary, which is something that should be included in future iterations.

The DFC should also be tested while responding to false alarms, as they are common on vessels. It has to be investigated if and how the DFC would make it easier to identify false alarms.

The diverse use options of the table were not explored in entirety. In the present demonstration, it was used by a single user to fight the fire, and the aspects of several persons collaborating to fight the fire, with the DFC providing shared situational awareness, as well as the situation of debriefing, where several persons would be involved in front of the display, using its features to evaluate past performance, were not included in the assessment.

7.3 DFC and the fire organization

The participants of this study all agreed that the fire commander should stay by the fire scene and that the DFC should rather be used by the captain and assisting officer on the bridge. In other organizations, on the other hand, the fire commander is not at the scene and would likely be the person using the DFC. Regardless of where the fire commander is located, the information provided by the DFC must be easy to share orally, and the DFC is currently lacking some location references to truly facilitate that. Participants mentioned frames and door numbers as missing references, but also some indications of door openings. It could be further researched as well what types of references that are useful in dark or smoke-filled environments.

This study indicates that there may be several users of the screen and that it should possibly be accessible from different locations. Further tests of how the DFC facilitates this and can benefit from this if necessary. This may also uncover other possible challenges that the ship environment may bring.

In addition, there were also concerns by participants that the centralisation of information in such a way like the DFC does might lower communication and therefore information spread about important aspects, because the operator would already have all the information at hand. This in turn could potentially have a negative impact on shared situation awareness. Such a potential negative effect of a centralised emergency system should be investigated in the future.

7.4 Limitations

Usability measures of effectiveness and efficiency can be considered with regards to observable outcomes and/or the user's perception of the outcome. However, in this study both participants' performance as well as their perceptions were influenced by the exercise situation as well as a lack of sufficient practice with the DFC. The scenario was designed to simulate a realistic context of use in a controlled setting, but the complex nature of the firefighting task makes it difficult to use typical usability measures of effectiveness, such as task success rates or completion times. For example, the participants used very different strategies. One participant activated the drenchers rather late, compared to the imagined scenario timeline. Due to the hard-coded scenario in the prototype, this only served to prolong the time it took to actually put out the fire, whereas in a real-life situation, the fire would have developed rapidly and potentially have gotten out of control. Another participant used the drenchers in a different way than expected, using them to cool the dangerous cargo units, rather than extinguishing the fire at its source, the rationale being 'not to cook' the fireteams when they enter the vehicle deck. This limited drencher action had no effect on the fire development in the prototype, but again, in a real-life situation, the fire could have developed quickly and become unmanageable. We argue that in a real situation, the heat and smoke maps on the DFC would have alerted the operator that their firefighting strategy was not successful.

Usability testing on a system like the DFC is to an extend contradictory. It requires first-time impressions and users of a safety critical system that would require extensive training up front. It can be argued that some systems were not utilised simply because the participants were not used to them.

All participants were from one organisation. It is possible that the invited participants were not the ideal participants as they all said that they would rather give the DFC to the captain or bridge officers. The DFC has to be tested with other companies as well, to investigate how it would perform in other organisational structures.

Participants pointed out, that being in a laboratory setting had an influence on their performance. To achieve a more realistic setting, the DFC should be tested on board. This means of course placing it on a bridge and not installing it in a ship's system.

The interface was limited in its complexity due to the software it was built with. Although very powerful, Axure is not made for building such a complex system as intended. Icons and systems that would be present on a real-life fire plan, but were not scenario-critical, were excluded from the interface.

8 Conclusion

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From a LASH FIRE perspective, and at this stage of development of the Digital Fire Central, the overall question to be answered is 'does the DFC have the potential to improve firefighting capability in ro-ro ships?'. And our conclusion is that it has. This conclusion is derived from the demonstration, our choice of evaluation metrics and our interpretation of the results from the exercise.

The DFC in its entirety was well received and presents an interface with good usability for the tasks it was tested for. A digitalised fire plan on a tabletop touch screen offers a lot of opportunities for user friendly design solutions. The presented centralisation of visualised sensor data, control interfaces, and event logging has a large potential to improve the coordination of firefighting on board of vessels. In particular, a visualisation of the spread of heat and smoke in combination with the historical data, here presented with the timeline, enhances situational awareness greatly. Additionally, an integration of cargo data into the fire plan shortens response time significantly, as the operator does not have to look up specific booking numbers in a cargo manifest.

Some features that were included were not tested with the limited number of participants and the specific scenario used for the assessments. These will have to be evaluated further.

This report provides a first indication of how the DFC would improve the fire safety onboard ships. It has succeeded in presenting concepts that are delivering towards that goal. The results of this first assessment of the DFC show how these concepts could be included for comparable interfaces in the real world. In addition, the work presented in this report also gives valuable insights for the work around the entire FRMC and will deliver input for future work in WP07.

All-in-all, we find that the DFC demonstrations/tests support the original idea of integration of information based on the principles of user centred design and ecological display design. Departing in user needs and the physical properties of the problem to be addressed – ro-ro deck fire – by the first analysis the DFC demonstrator provides a level of effectiveness, efficiency, satisfaction and intuitiveness that appears to surpass present-day installations and -systems.

In short, this means that a DFC, or a DFC-like system, is likely to improve of firefighting capability on ro-ro ships, and thus that this is a valid RCO from a functional perspective.

As is discussed both above and in the chapter about future work – see section 7.2 – there is however still a need for additional analysis to cement the initial results described in the foregoing. Also, there should preferably be more sessions with more, and more diverse, demonstration/test participants to provide additional validity to the results, and to finesse the design of the DFC. Already now, it is clear that some additional functions will provide immediate benefits, like the add-on of drop-and-drag fire team markers, but also rectifying the design where the design language indicates functions which however are unavailable should become a part of a next iteration.

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10 Appendices

10.1 Informed consent

Consent form

Within the LASH FIRE* project, NTNU and RISE have developed a “Digital Fire Cental” prototype, which integrates firefighting information that is usually spread across different systems and tools.

You were contacted by your employer on behalf of NTNU and RISE, to take part in the demonstration of the Digital Fire Central. The main purpose of this session today is to demonstrate how the prototype integrates information from various sources to a new type of user interface, and to investigate how this answers to users’ needs and expectations.

The session is expected to take approximately 2,5 hours.

1) You will be given time to familiarize yourself with the system.
2) You will be asked to manage the response to a fictive fire alarm on board a ship, using the DFC and a pre-programmed fire scenario. This is **NOT a test of your skills** but a way to learn about how the prototype suits your needs in this type of situation.
3) Afterwards you will be asked questions about your experiences, and there will be an opportunity for a discussion about the proposed design.

We now want to ask for your consent to record the session and for processing and storing the data.

Informed consent

The main purpose of this demonstration session today is to learn more about how the Digital Fire Central prototype answers to potential users' needs and expectations. The results will be used for project reports within the EU LASH FIRE project, as well as for design research purposes.

Voluntary participation: We want to stress that your participation in the Digital Fire Center demonstration is entirely voluntary. You have the right to withdraw from its activities at any time without stating a reason, and without any consequences.

Privacy and integrity: We take steps to ensure that neither data nor published reports expose you in an unwanted way or have any negative consequences. You will not be recognizable through images or statements in project or research reports.

We will avoid storage of any unnecessary information, and all personal information (name, workplace, organization, contact information) will be treated confidentially.

We will anonymize the data as soon as possible.

So long as you can be identified in the collected data, you have the right to:
access the personal data that is being processed about you
request that your personal data is deleted
request that incorrect personal data about you is corrected/rectified
receive a copy of your personal data (data portability), and

- send a complaint to the Norwegian Data Protection Authority regarding the processing of your personal data
- Only project researchers with legitimate reasons will have access to the data

- Stored data, such as quotations or observations will not be linked to any personal information as we will use participant codes (a pseudonymization approach).

NTNU in Norway and RISE in Sweden are LASH FIRE partners, and share the same strict procedures for data protection. RISE are responsible for the project and are the main data controller.

The planned end of the project is August 2023. At this time, video recordings where participants can be recognized, and all personal data will be deleted from RISE. Anonymized material, such as transcribed interviews will be archived with the project material, in accordance with the formal data management plan established in the EU Horizon 2020 project.

Results from our research will be shared within the project group, on our project website www.lashfire.eu, on conferences and in scientific journals.

We again want to thank you for taking the time to participate in this demonstration. If you have any further questions afterwards, please do not hesitate to contact us.

Consent

- ❑ I have been fully informed about the purpose of this demonstration, how information is gathered and treated
- ❑ I have been given opportunity to ask questions about the demonstration before it begins and know who to contact with further questions
- ❑ I have been informed that my participation is voluntary and anonymous and that I, whenever I feel the need, may cancel my participation without stating a reason
- ❑ I hereby consent to participating in this demonstration which is part of the LASH FIRE project.

Place/Date/Year

____

Signature of the participant

____

Printed name

____

10.2 Instructions

Written instructions to be presented to participant before starting

“Welcome! Thank you for agreeing to test the “Digital Fire Center”. This is a part of the LASH FIRE project, where an effort has been made to integrate information and functions needed for managing fires on board. The test today builds upon a scenario from a real drill undertaken at the Stena Jutlantica by her regular crew.

We want to emphasize that this is NOT a test of your skills in any way, but a way for us to understand if the design matches the work it is meant to support. We are interested in your reactions to the prototype, and your opinion about the design and functions.

This test will take up to two hours during which we will take a few short breaks. We will also record the whole session, as this is important for our analysis. A closer description of issues such as confidentiality and data management are included in the consent form, which you are asked to read and sign before the test commences.

You will first be given 5 minutes to freely explore the prototype. You can click anywhere you like. During this part we ask you to describe what you see and what you expect to happen if you click on anything. Please also mention if there for example is anything that you expect to see and cannot find. During this time we will not provide explanations or answer questions.

After the 5 minutes of exploration we will answer any of your questions, and we will also show features you may have missed.

The next phase of the test is a fire scenario.
This is a programmed sequence of events, based on a fire drill. During the scenario we ask you to act as the fire chief on the bridge, and manage the fire as you would have if there was a real fire taking place.
You will have the prototype to your disposal, and will also be able to communicate with the “crew” through the VHF.

Then we will together look at the recording of the events during the scenario, asking you to describe the steps you took and also to comment the prototype.
After that there will be a short interview, and as a final step we will ask you to fill in a short questionnaire.“

Verbal instructions - familiarization

“Please explore the prototype.

You can click on anything you like. Please describe out loud – what you are thinking, what you see, and what you expect to happen if you click on something.

You can also mention if things do not work as you expect them to, or if there is something you are looking for and cannot find, etc.

We will avoid giving instructions or answering questions during this time, unless there are any technical issues.

After 5 minutes, we will answer questions, and we will also show you if there is anything you have missed.

Are the instructions clear? You now have 5 minutes to freely explore the prototype. If you remain silent for some time I will remind you to keep talking!”

After 10 minutes
Time for questions/answers. Try not to explain too much, reply to specific questions.
Nudge them towards things they have missed.
After X minutes, ask them to point out and demonstrate/describe the following elements

- ☐ Timeline
- ☐ Sensors (also drones)
- ☐ Cargo Information
- ☐ Layers
- ☐ Decks

- ☐ Emergency controls
- ☐ Drenchers
- ☐ Ventilation
- ☐ …
- ☐ Communication
- ☐ More?

Instruction script

Idle mode of the prototype
The interface has three segments, the map, the timeline, and the control panel.
Map
This is the map of the ship with fixed and portable fire-fighting equipment. More information about portable equipment can be accessed by just clicking on it. The drencher zones are shown with the blue lines and the zone number on top. Next to the drencher zone number, you can see the current oxygen level in that drencher zone.
Underneath every drencher zone is a banner for the temperature and amount of smoke measured by each sensor. That information can be folded out by clicking on the bar.
The map also shows the loaded vehicles. Electric cars are indicated as well. The cargo manifest of a loaded trailer can also be accessed, just click on the trailer to view it.
You are currently on deck 3. You can access other decks at the bottom of the screen.
Timeline
This chart is the timeline. Right now, it does not show information, because there is no emergency. As you can see on the left, the timeline will show the intensity of heat and smoke, as well as the amount of oxygen over time.
Under that, the timeline will also show when an alarm was triggered. Under that, events like for example drencher activation or public announcements will show up when they have happened.
The next element is the note function. Taken notes are shown here, so that they are also logged with the time. As you can see, the notepad, can also be accessed in the bottom left corner of the interface.
The last rom of the timeline, comms history, shows any communication by the operator of this interface to other crew.
At the present time of the timeline, you can see a slider. This slider shows the present time, but it can also be used to look back in time by sliding it around on the timeline. You can also use the two buttons to add events or notes to the timeline.
The dashed lines on the right of the slider will show the expected intensities of smoke, heat, and oxygen.
Control panel
The control panel lets you access all emergency controls as well as different layers of the map. Via this interface, you will be able to activate and deactivate the fire alarm, close the fire doors, control dampers, start fire pumps, control the ventilation, the drenchers, and over-pressure ventilation in the staircases. All of these actions can be activated with a slider.
Bottom right corner, you can see a button for a 3D view. This map will show you the different decks of the ship above each other and will show you the location of the first alarm.

Instructions scenario part

Background

The scenario is built on a real drill undertaken at the Stena Jutlantica by her regular crew.
That drill was recorded using Go-pro cameras warn by the key crew members and staff supporting the drill. Footage has been transcribed, the timeline established and the interaction between crew members noted in 'role-cards'; for the present test, these roles are played by members of the NTNU research team. The roles include

- Bridge OOW
- Watch-keeper in the ECR (on watch when the scenario starts)
- Fire team 1, which will muster responding to the fire bells and announcement from the bridge. This team will not undertake any actions unless directed by the Fire Chief.
- Fire team 2 – as fire team one.

The development of the test scenario on the demonstrator/prototype has been modelled to follow the timeline; in other words, it is as inflexible as a real fire would be – the test participants can only intervene, and react to the way the fire develops and/or is managed.
Test objective

The test objective is to evaluate the usability of the demonstrator, i.e. how 'well' it works in supporting the Fire Chief in his work to manage the fire. The performance of the DFC will be derived from analysis of the recorded data as well as the debriefing session that will follow the scenario itself.
Test setting

All relevant details of the ship fire and safety plan are included in the demonstrator. The vehicles on the deck being on display are not symbolic, but represents the real cargo for the voyage.
Fire fighting is directed from the Safety Control Center, lying immediately aft of the bridge, and in direct connection to the bridge. In this room, the DFC is available, as is VHF radios to communicate with the other rooms. CCTV from the ship is also available, as is CCTV from the airborne, external drone. No other relevant equipment is available.
Procedure

The test is triggered by receiving a fire alert in the Safety Control Center. At the starting point, the OOW is dealing with the initial actions:

- Sending out the runner to get confirmation of the fire being real
- Starting the fire bells, to trigger mustering of the Fire Chief and the Fire Teams
- Using the PA, send out the following message: 'OOW speaking. This is not a drill. We have a confirmed fire in deck 3, aft. All crew to muster according to the rooster. I repeat, this is not a drill. All crew to muster station according to the fire rooster.
- Shutting down ventilators in deck 3
- Shutting dampers to deck 3
- Starting overpressure fans to the stairwells leading to deck 3

After 2.5 minutes, the tester 'enters' the room, and will start to perform the actions deemed necessary.
Teams (i.e. NTNU staff) will respond accordingly, being aware of the fixed timeline of the demonstrator, and the need to stick to the scenario.
The testing is concluded once the tester is satisfied that the fire has been managed.

Role cards

OOW/Captain (in the lab with participant)

- Briefs participant on the situation so far

We have had fire alarms on deck 4 in the aft section. There are a lot of alarms, both smoke and heat. We can see the smoke on CCTV. The fire has also been confirmed by crew, one peeked inside and there was a lot smoke in the space. The ventilation on the deck has not been stopped.

- Speed of the vessel: Standstill at the moment
- After drencher activation: Coast guard has been notified, they are on stand-by if needed
- If the participant does not give regular updates, ask for a report on the situation

Engine control room

- climbing temperatures until 4:37
- after drencher activation: stable temperatures, no further rising temperatures
- after TIME: temperatures are decreasing
- after ventilation activation: smoke is decreasing, oxygen levels are normalising
- after completed ventilation: all sensors nominal

- Full knowledge of sensors triggered
- Smoke on CCTV
- Temperature measurements
- High pressure fans activated
- No problems with the engines or pumps
- Has the same information about alarms and temperatures as the fire commander
- After activation of any counter-measure: ECR has full information about it

Fireteam 1

Will be called to assemble by the fire commander. Will report ready at 10:00 and waits in the aft staircase for orders.

- Deploys on deck 3 when the drenchers are stopped.
- 15s after deployment: Find some flames at a vehicle and will start to extinguish it with a hose.
- Flames are put out 90s later
- after ventilation activated: Will keep supressing the hotspot to prevent the fire from flaring up
- after ventilation completion: Reporting extinguishing to be successful
- Stay in position at prevent fire from flaring up again until told to retreat

Fireteam 2 (optional)

- Deployed on deck 5 to monitor temperatures above the fire
- Cooling the floor, if necessary
- Two minutes after drencher activation: Report decreasing temperatures of the floor

- No FLIR, but they will feel the deck floor. Slightly warm, will monitor further.

10.3 Debriefing

The debriefing was conducted as a semi-structured interview. The recorded scenario was watched by the participant who was asked to use a retrospective think aloud method.

How do you work today:

Can you describe your role during a similar type of event as the scenario today -

- Main tasks and activities
- detection system tools etc.
- What is most difficult or challenging (recurring problems, frustrations)
- What generally works very well?...
- Beyond drills, do you have any experience of fires onboard?

Instructions for retrospective think aloud

"I'd like you to look at this recording of the test and to describe what you were doing and thinking. Start by describing the situation as if to a fellow officer. We will then watch the recording, and stop at a few points during the scenario to ask some questions"

Probes:

1) What can you see?
2) What information do you have at this point? Would you have wanted/needed any additional information?
3) Now in retrospect can you think of
    a. anything that you would have done differently?
    b. information, features that could be modified, added?

10.4 Questionnaire

10.4.1 Form

1. Please rate the digital fire center prototype! Indicate how strongly you agree with each statement, where 1= Strongly disagree and 7 = Strongly agree

	1- Strongly disagree	2	3	4	5	6	7 - Strongly agree
The DFC is easy to use	○	○	○	○	○	○	○
The features meet my needs	○	○	○	○	○	○	○
The DFC provided a clear overview of the location of the fire	○	○	○	○	○	○	○
The DFC provided a clear overview of the fire fighting activities	○	○	○	○	○	○	○
The DFC provided a clear overview of the how the fire was developing	○	○	○	○	○	○	○
Using the DFC could support my job performance	○	○	○	○	○	○	○
Using the DFC could make it easier to do my job	○	○	○	○	○	○	○
The DFC could be useful in my job	○	○	○	○	○	○	○

2. What would be the most important differences between using the DFC, compared to how you work today?

3. What do you see as the main benefit of the Digital Fire Central?

4. Do you see any possible barriers to the Digital Fire Central concept? (Technical, organizational, work processes, risks etc).

5. Was there anything missing: features/information which you would expect, or wish for?

10.4.2 Results

	Strongly disagree						Strongly agree
Rating items	**1**	**2**	**3**	**4**	**5**	**6**	**7**
The DFC is easy to use							3
The features meet my needs			1		2		
The DFC provided a clear overview of…							
the location of the fire						1	2
the firefighting activities		1			1	1	
how the fire was developing							3
Using the DFC could support my job performance				1			2
Using the DFC could make it easier to do my job				1			2
The DFC could be useful in my job				1			1

Text responses

What would be the most important differences between using the DFC, compared to how you work today?

I. Much better overview of the situations and much easier to do a proper evaluation of a drill or an actual fire
II. Creating an overview of the location and development of the fire.
III. It's a digital overview of what is used now. All information in one place instead of different places

What do you see as the main benefit of the Digital Fire Central?

I. The good overview and that you have an easy access to all the different firefighting system and can control everything from one screen
II. Creating an overview of the location and development of the fire.
III. The development of the fire

Do you see any possible barriers to the Digital Fire Central concept? (Technical, organizational, work processes, risks etc).

I. If you as a fire leader are not down close to your firefighting teams then it can be difficult to control the smoke divers and do a proper briefing.
II. "Yes, there are a few concerns: How stable is the OS? How is it to use, when the ship is rolling and vibrating? The fire commander is usually “on-scene”, so duties and muster lists have to be reconfigured. "
III. Redundancy. We need more than one in case that we cannot access one.

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