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Consolidated guidelines on screening systems [including ignition prevention sensors], appropriateness and placement indications.

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Abstract

This report is based on several reports delivered from the LASH FIRE project, both from work package 8 “Ignition Prevention” and others. It focuses on three solutions. One is a sophisticated Stowage Planning Tool (SPT) presented in D08.4 Stowage planning optimization and visualization aid [13] The tool uses not only the IMDG [10] for stowage and segregation, it has a new type of risk assessment model, that allows for the usage of historical data regarding incidents with any type of cargo or vehicle to be used to plan a better loading, stowage and segregation of goods and vehicles. The other two solutions are based on automation for screening, a Vehicle Hotspot Detection (VHD) system of cargo and vehicles prior to loading, during loading or during the voyage. One is a stationary system for automatic screening of the objects cargo units, that are to be loaded. The third is an Automatic Guided Vehicle (AGV) that can patrol the cargo deck and position vehicles and cargo as well as monitor the objects using different sensors like thermographic infrared sensors. They have been designed to look for a specific task, monitoring of a battery electric vehicle (BEV) during charging, and the VHD system for overheated refrigeration units.
They could also be equipped for more generic overview e.g. monitor a specific type of volatile gas like hydro carbons or a more generic, heat signature from a specific part/section of an object that is obstructed for other detection systems.
The systems can either give a snapshot of the status or continuous monitoring. Some systems could provide both, such as drone systems that patrol the deck and can be appointed to specific target/areas of interest.

All three solutions have performed well in simulations and the Vehicle Hotspot Detection system (VHD) with the new functions developed for LASH FIRE has been active since June 2022 at the Stena Line terminal at Majnabbe.

The SPT-software has been successfully tested when it comes to the implementation of the scoring feature. The new subsequent cargo distribution reduces the overall risk in terms of the initial score value. This way, the solution helps to increase the fire protection of ro-ro ships at the ignition prevention stage, which represents a contribution to the #1 global objective for the project. The VHD-system showed the capability to detect refrigeration units, automatic temperature scanning and trigger alarms to the operator on predefined thresholds. The automated guided vehicle (AGV) demonstrated that even with a low vertical clearance of 130mm, an AGV equipped with LWIR sensor could detect heat signatures from the under carriage of a BEV.

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Content

1 Executive summary

This generic Guideline is a short description of three different Risk Control Measures (RCM) prototyped in the LASH FIRE project from work package 8 – “Ignition Prevention” and their proposed three solutions for the action 8A “Automatic Screening and management of cargo fire hazards”. The goal is preventive actions and early detection of risks. Preventive in this context means better stowage and segregation of vehicles and goods, not allowing vehicles with temperature anomalies onboard, and continuous monitoring of cargo decks with the capabilities to survey the undercarriage of vehicles and rolling cargo. The developed concepts and solutions are:

Stowage Planning Tool (SPT) - A novel approach to include inherent risk from vehicles and cargo. The concept is to not just comply with rules about ADR/IMDG goods as of today, but to apply a new type of risk assessment model using historical data regarding the type of cargo/vehicle to achieve better planning of stowage and segregation onboard ships.

Vehicle Hotspot Detection (VHD) - As cargo and vehicles enter the terminal or ship, they are automatically screened from sides and above for heat anomalies. The demonstration focused on detection of refrigeration units.

Automatic Guided Vehicle (AGV) – Usage of a ground-based drones to patrol the cargo decks after loading; positioning cargo and vehicles using license plate reading software scanning and detecting heat anomalies using long wave infrared (LWIR) sensors.

These three tools developed in Action 8-A focus on prevention and addresses the increasing complexity that different types of power sources for vehicles, Alternative Powered Vehicles (APV) including Battery Electric Vehicles (BEV) and identified risks with refrigeration units (Reefers) possess, and the aim is to lower the risks with vehicles and cargo onboard a RoRo-ship’s cargo decks. This deliverable is meant as an introduction to these concepts and more detailed information can be found in their corresponding public deliveries.

1.1 Problem definition

Today, ro-ro cargo units other than dangerous goods are loaded without consideration to the hazards they involve, leaving room for improving the stowage process from a fire prevention perspective. In other words, current cargo placement in ro-ro spaces is not optimal against fire hazards. The screening of the cargo and vehicles are done manually.
Statistics reveal that around 90% of fires are initiated in the carried cargo onboard RoRo and RoPax ships. From WP8, improvements focus on more effective management of vehicles and units based on available information coming from previous incidents. These resources contribute with valuable feedback that can be used to distribute the cargo trying to minimize the overall fire risk before departing and during the voyage.

This generic Guideline is a short description of three different Risk Control Measures and their proposed solutions, in work package 8 'Ignition', action 8-A. They focus on prevention and addresses the increasing complexity stemming from the new types of power sources for vehicles, as well as identified risks with refrigeration units. The goal is to lower the risks associated with vehicles and cargo onboard a ro- ro ship cargo deck through improved planning capabilities. This guideline is meant as an introduction to these concepts as more thorough information can be found in the public deliveries listed as references in section 7 References or found on LASH FIRE web page https://lashfire.eu/deliverables/

1.2 Method

This report is fundamentally based on the work reported in D08.1 'Definition and parametrization of critical fire hazards, classification of cargoes, transport units, engines, fuels and vessels and identification methodologies' [11] and D8.10 'Demonstration of prototype for detection of potential ignition sources' [3] and D08.4 Stowage planning optimization and visualization aid [13].

Stowage planning tool (SPT)

The SPT is built up as a combination of different applications that work in concert to recommend and create guidelines for how cargo should be placed to minimize risks. The main algorithm evaluates the synergies of placing cargo with respect to other cargo to find out whether it is a suitable placement or not. A graphical user interface was created to allow the users easy access to the information and an ability to quickly try out different combinations of planning possibilities.

Automated guided vehicle (AGV)

The AGV was constructed with the expressed ability to navigate in a loaded cargo space and travel underneath vehicles. The goal is to screen the cargo for anomalous heat signatures and catch potential ignition sources at an early stage. To achieve this a navigation system based on LiDAR data and Simultaneous Localisation And Mapping (SLAM) has been developed. It uses a combination of a path planning system that operates based on a set of global key points, creating a local path based on the object information in between the key points. A thermal camera is used to detect the temperatures. The camera is angled slightly upwards to cover the entirety of the undercarriages of vehicles passed underneath.

Vehicle hotspot detection (VHD)

Built as a gate system where vehicles can pass through, the VHD system works as a stationary means of scanning transports on shore before they are boarded. By utilizing a high precision LiDAR, the VHD system is capable of measuring and profiling vehicles that pass through. In order to find the heat anomalies of the transports Long Wave Infrared sensors are used. Additionally, two Automatic

Number Plate Readers find the license plates of the vehicles, which allows for a more automated logging system.

1.3 Results and achievements

The systems have been tested in different simulations, testbeds, and demonstrations. They have delivered not only proof of concepts solving the tasks listed in section 1.4 below. The now proven functionality for detection of heat signature on refrigeration units is ready to be implemented as a risk control option. The Stowage Planning Tool and AGV have high technology readiness and could be developed for the market relatively quickly. The SPT is designed to be a plug-in to existing systems, as a standalone system or it could be incorporated into the original planning system. An AGV system has challenges such as how to operate in an explosive atmosphere, but since the start of the project similar systems have been developed for the oil and gas, petrochemical domain.

The solution can either be looked upon as a standalone system or integrated to a more capable system of systems sharing data via a common communication bus. Such solutions can be expanded to include fire resource management control systems (FRMC) [12].

1.4 Contribution to LASH FIRE objectives

The development of the LASH FIRE Stowage Planning Tool directly addresses the potential fire safety gains associated with a managed stowage process, where fire risk is mitigated by a safety-optimized usage of deck space, and where the consequences of an eventual fire are reduced by an optimum cargo distribution. The SPT is the developed solution for the task: **T08.5: Fire hazard matching and mapping (Integration software development).**

The modifications of the VHD system aim to improve the understanding of reefer unit's heat signatures and the possibility for early warning of anomalies if detected heat signature is more than accepted maximum temperature threshold.

The AGV system minimizes fire risk by allowing for data gathering in a way not possible for personnel on a ship. By navigating under vehicles that are packed tightly in the ship's hold the AGV system supports allows for early warning and prevention

Both the VHD and AGV share technologies, hardware and software, to solve the different tasks:
Task T08.7: Demonstration of vehicle identification tool, where automated number plate reading is implemented and demonstrated as an important tool to identify, report and to keep track of individual units and vehicles, from the moment a unit/vehicle passing a VHD system to its stowed/parked position onboard.

T08.8 Demonstration of detection of potential ignition sources, both the VHD and AGV uses LWIR sensors for measuring temperature and a user-friendly thermographic presentation for the operators.

T08.10 Appropriate placement of monitoring systems based on hazard map and screening methodologies, this is solved with a system of systems approach, the SPT system will have adequate information from the booking system on cargo and vehicles to be loaded. This information is validated and screened with stationary systems, VHD as cargo/vehicles is passing, and after loading where portable sensors can be placed to monitor units/vehicles that is of special interest and mobile systems such as the AGV that can patrol areas or monitor specific cargo/vehicles on demand.

1.5 Exploitation

The main usage of this report is as a guideline on how the systems operate and how they can lower the risks for ignition and/or consequences of an ignition. The VHD system would provide vital information to ship operators about vehicles and cargo as they pass the system at the gate to the terminal/port or as the vehicles are to be loaded. The AGV will allow ship operators to scan underneath vehicles on ro-ro decks to detect and prevent fires from erupting. The SPT provides the shipping companies with valuable information on how to load the cargo and vehicles in the ships, it could also be used as a method of communicating information to a digital fire centre-system and to and from an AGV system, providing information for route planning. The AGV can also provide information on how vehicles and goods are finally parked, as final confirmation of a stowage plan.

2 List of symbols and abbreviations

2D	Two Dimensional
3D	Three Dimensional
ADR	A Accord européen relatif au transport international des marchandises Dangereuses par Route
AGV	Automated Guided Vehicle
ATEX	Equipment intended for use in explosive atmospheres
BEV	Battery Electric Vehicle
DFC	Digital Fire Central
EX	Explossive Environnement
FRMC	Fire Resource Management Centre
IMDG	International Maritime Dangerous Goods Code
LiDAR	Light Detection and Radar sensor
LWIR	Longwave Infrared
RCM	Risk Control Measure, a means of controlling a single element of risk
RCO	Risk Control Options, a combination of risk control measures
Reefer	Refrigeration Unit e.g. air conditioning unit on a trailer or container
SLAM	Simultaneous Localization And Mapping
SPT	Stowage Planning Tool
VDG	Vehicle Dangerous Goods detection system
VHD	Vehicle Hotspot Detection system
TOS	Terminal Operation System

3 Introduction

Main author of the chapter: Robert Rylander, RISE

To be able to lower the risks of ignition, a system of systems approach has been investigated in WP 8A. Three Risk Control Measures (RCM) or solutions were proposed in this work package, to help preventing fire ignition through usage of digitalisation and usage of automation in conjunction with human operators. The automatic screening and management of cargo fire hazards – the Vehicle Hotspot Detection system and Automatic Guided Vehicle; as two of the risk control measures. Together with the stowage planning tool they make a strong Risk Control Option (RCO) as illustrated in Figure 1.

Figure 1 System of systems approach in WP8-A

The three proposed solutions or RCMs could also be implemented as standalone solutions, fulfilling their individual tasks and contributing to lower risk and/or early detection of possible sources of ignition.

The following chapters describe each of the three systems on a general level, how they are constructed, their purpose, and how they performed in the evaluations. For details on each system there are several reports that describe the components and functions;

Stowage Planning Tool

D08.4 Stowage planning optimization and visualization aid [13]

D8.8 Stowage plan visualization aid [4]

Vehicle Hot Spot detection system and AGV

D08.10 Demonstration of prototype for detection of potential ignition sources [3]

D08.11 Description of prototypes and demonstration for identification of vehicles and ignition sources [7]

4 Risk Control Measures

Main author of the chapter: Robert Rylander, RISE

4.1 Stowage Planning Tool

The SPT supports the loading process by means of guidelines and recommendations, suggesting appropriate placement of the cargo based on historical data from the database and, optionally, additional constraints. For further information about SBT the report D08.4 Stowage planning optimization and visualization aid [13].

This tool is a set of applications that work together, aiming to identify and detect the potential risks associated to a loading plan, given a certain ship deck configuration:

- The core component is an algorithm that searches for the combination of cargo placements that avoid high risk and minimizes the risk overall. This will include, for example, not only finding places where certain types of cargo should be placed (i.e., because of the need to be under surveillance) but also where it should not (i.e, preventing proximity to other cargo that may drive to potential hazards).
- End users interact with the previous component using a visual interface that manages external events and user actions as needed. Definition of requirements associated to this visual interface can be found in the delivery D08.8 Stowage plan visualization aid [4].

Figure 2 Overview of the interaction of the Stowage Planning Tool with external software.

As illustrated in Figure 2 above, the SPT tool was designed to work in iterations with external software in the process of loading the ships. The stowage plan evolves as the bookings are being made and then later the arrival of cargo and vehicles to the terminal. And finally during the loading of the ship and is completed with the cargo manifest after the loading operation is finished and the ship is ready to sail.

4.1.1 Information concerning the cargo

The STP system has to take many aspects of the cargo units that are expected to be stowed on a given ship into consideration: physical characteristics, their type with specific focus in case of Dangerous Goods (DG) and, optionally, the location in function of the deck, lane and frame_start/frame_end (attributes are considered. frame relates to the frames between aft to front in the structure of the hull, and they are numbered the same on all decks of the ship see ANNEX A 9.1).

Physical characteristics of a cargo unit include height, length and weight. The first two are used to manage on which decks a cargo may fit. Once a deck is selected, height and length is relevant for calculating the remaining space in a given lane after placement. Finally, weight is not used during the cargo distribution process but since it is basic information that can be retrieved from external booking system, it has been included to support future features concerning risk assessment in function of this parameter or stability calculation, embedded or through external components. Also, for those units not labelled as dangerous goods, type of the cargo is used to retrieve information compiled in the database in order to calculate frequencies and probability of certain risks.

In order to properly assess whether fire incidents in each cargo unit are relevant, we must know how many units of each type of cargo that are transported, in order to evaluate their impact.
For this purpose, information on the cargo transported during one year was requested from the operators and a pattern was obtained showing the average of each type of cargo transported on a typical ship.
The incidents were ranked as illustrated in Figure 3, colours also used in the SPT- human machine interface (HMI).

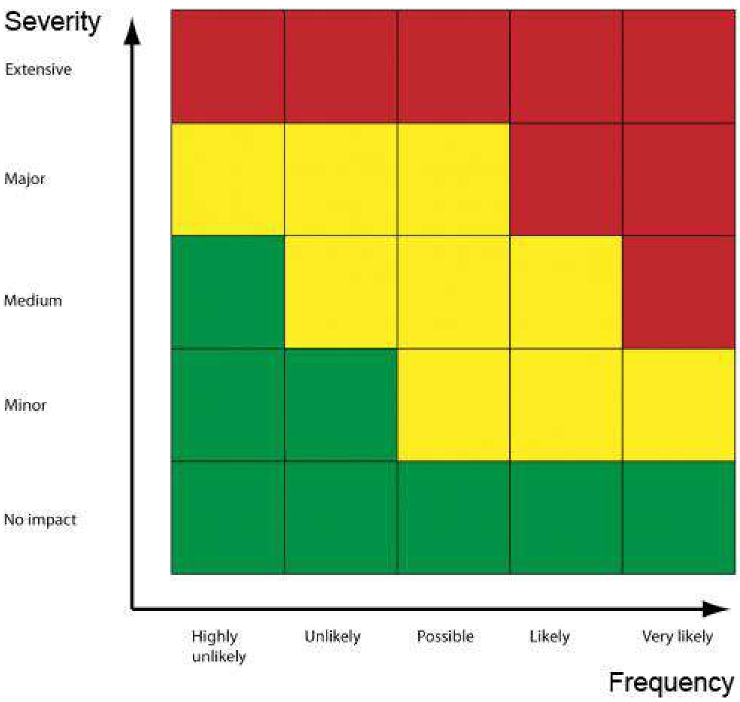

Figure 3 Severity - Frequency from D08.3

For each type of load, the causes that have produced the fire in the load have been analysed, classifying them in causes of origin:

- Electrical
- Overheating
- Leakage of liquids

- Mechanical
- Other

In addition to each type of failure, the severity of the accidents has been analysed, within each category. The severity scale is based on IMO definitions [5].

Accidents may be classified (in order of severity) as follows:

- Very serious marine casualties
- Serious marine casualties
- Less serious casualties
- Marine incidents

4.1.2 Stowage and segregation

Depending on rules, such as IMDG, cargo with a known risk should be separated or segregated from other cargo with a risk in both horizontal and vertical dimensions. Depending on type of cargo and its risk, the distance and separation on different cargo deck can vary. All these considerations are incorporated in the SPT.

Below is an example of horizontal separation in Figure 4 and vertical separation in Figure 5

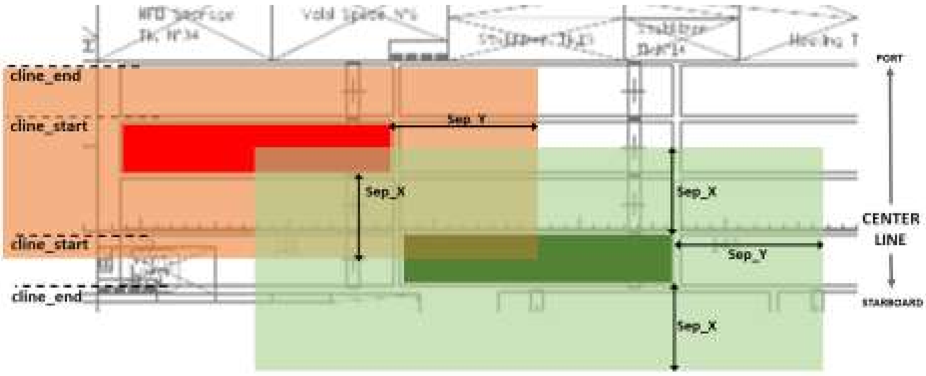

Figure 4 Horizontal segregation, from D08.4

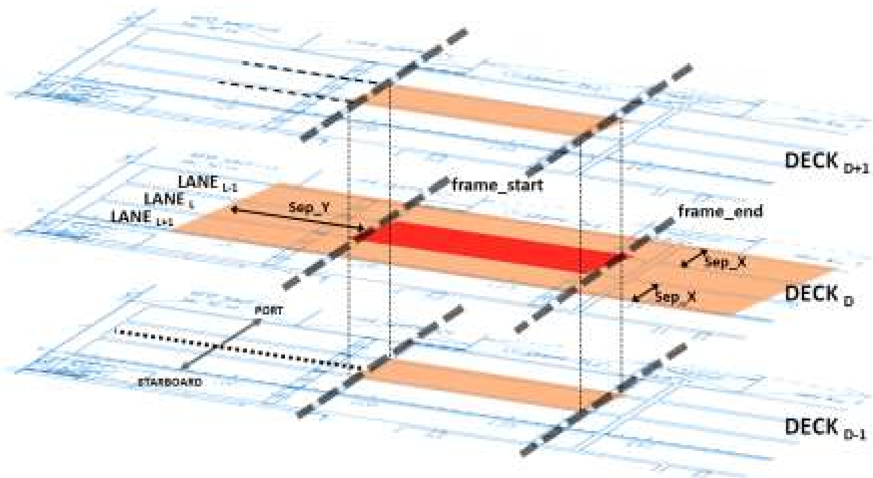

Figure 5 Vertical segregation, from D08.4

4.1.3 Optimization principle

Table one shows he planned stowage of cargo and vehicles in Table 1,. An objects ego Risk Score is RS0. RS is the risk score of the unit at its current location e.g. planned position on deck. Then the SPT is run, with results shown in Table 2.

In the tables, the first column represents each deck with a summary of the objects RS0 and current RS value for the planned location. The same principle applies for each object in the next column. For example, for Deck 4, RS0 values are summed up to 13. However, with regard to the plan for loading the RS goes up to 16. When the SPT optimization is run, objects are shifted around, on all decks and location that are available. Table 2 shows how this achieves an overall lower risk on all cargo decks.

Table 1 Planned stowage of cargo and vehicles.

Deck	**Id Unit** **RS0** **RS**		
	4001 1 1	4002 2 3	4003 1 1
4 **13** **16**	4004 2 3	4005 3 4	4006 1 1
	4007 1 1	4008 1 1	4009 1 1
	3001 1 1	3004 1 1	3005 2 3
3 **13** **16**	3002 1 1	3006 3 4	3007 2 3
	3003 1 1	3008 1 1	3009 1 1
	2001 1 1	2002 1 1	2003 1 1
2 **12** **14**	2004 1 1	2005 1 1	2006 1 1
	2007 1 1	2008 2 3	2009 3 4

→

Table 2 Result after SPT optimization.

Deck	**Id Unit** **RS0** **RS**		
	4001 1 1	4007 1 1	4009 1 1
4 **13** **13**	4006 1 1	4003 1 1	4004 2 2
	4005 3 3	4008 1 1	4002 2 2
	3006 3 3	3004 1 1	3005 2 2
3 **13** **13.5**	3002 1 1	3009 1 1	3001 1 1
	3003 1 1	3008 1 1	3007 2 2.5
	2004 1 1	2002 1 1	2003 1 1
2 **12** **12.25**	2007 1 1	2005 1 1	2006 1 1
	2008 2 2	2001 1 1	2009 3 3.25

4.2 SPT User interface

In order to achieve high usability. The user interface was developed according to Human cantered design principles the interface has been developed together with WP7. Illustrated below in Figure 6 is the initial planned loading plan uploaded into the SPT stowage and an initial risk is analysed, and the score is calculated and presented.

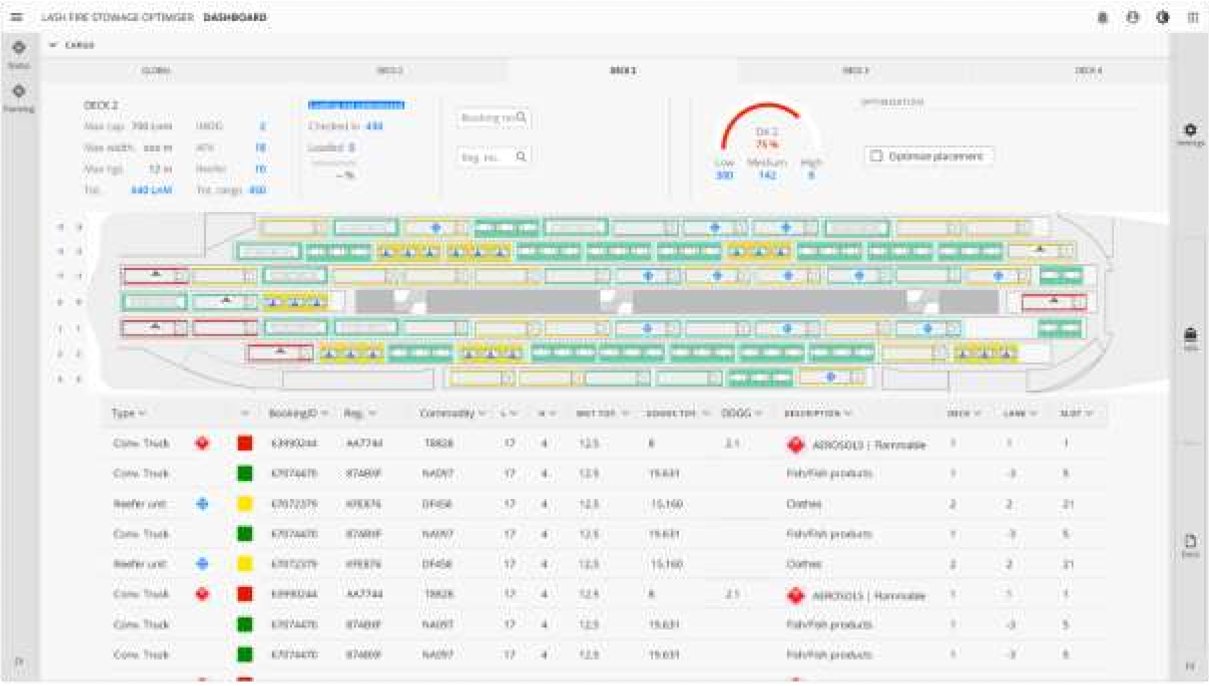

Figure 6 SPT Front end, planned loading prior optimization.

The upper part shows the current deck layout and ship specific data.

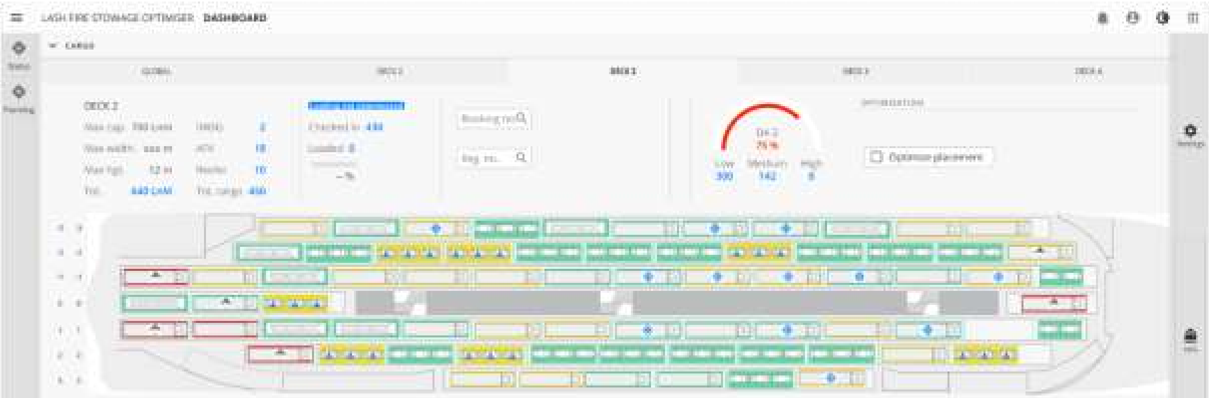

Figure 7 Upper pane of SPT user client.

The left section shown in Figure 8, the upper left pane shows information about lane meters used, units (vehicle and goods) loaded. The function to search for specific unit is located here too.

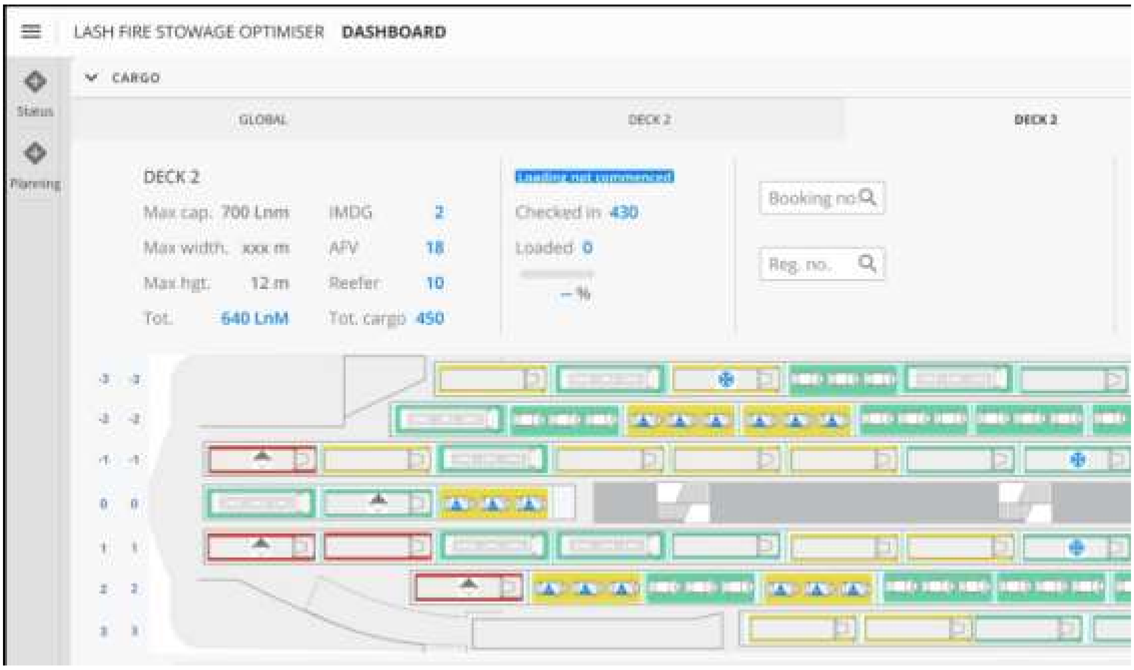

Figure 8 Upper left pane with ship and deck specific data.

The right section shown in Figure 9 show the current risk score for the deck and the optimisation function can be triggered from here.

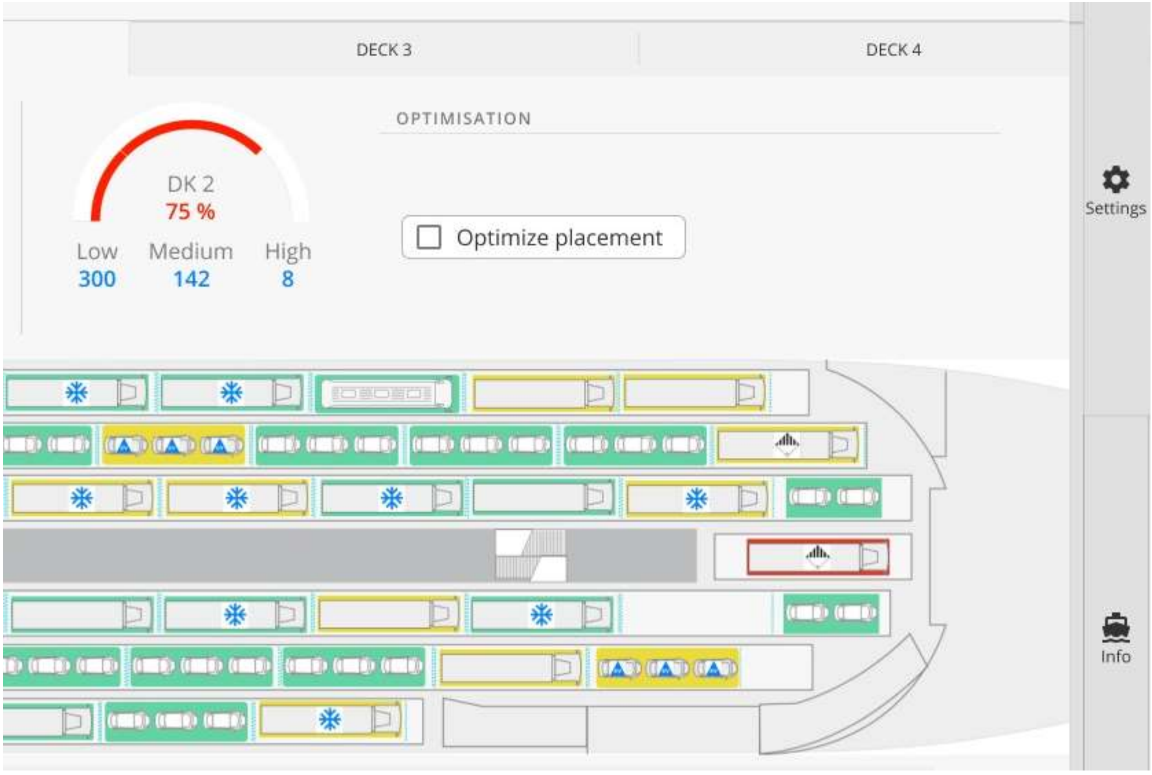

Figure 9 Right part of upper pane showing current risk score.

The lower pane Figure 10, shows information about each unit. Refrigeration units, IMDG units and additional information such as booking number.

Figure 10 SPT lower pane with information about the units.

After optimisation

After the SPT optimisation algorithm has been run, the Deck 2 Risk Score has dropped from 75% to 25% as shown in Figure 11.

Figure 11 SPT optimisation for deck 2 completed.

In Figure 12, the number of units with low risk increased to 350 from 300, medium decreased from 142 to 98 and the number of units with high-risk score from 8 units to 2.

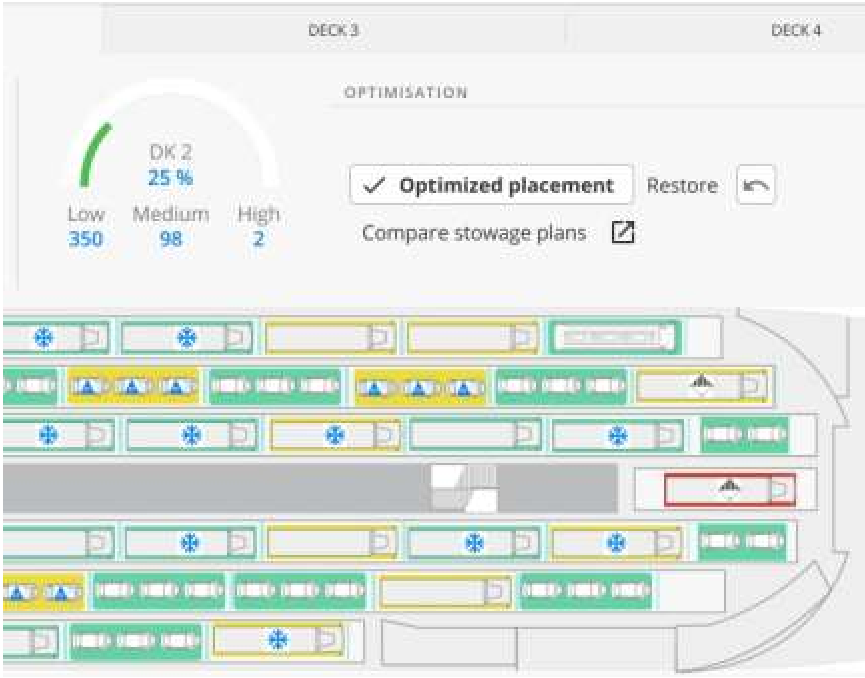

Figure 12 SPT optimisation led to RSO lowered to 25%.

4.3 Data sharing

From the SPT system, the proposed stowage plan can be exported or exchanged with other systems. Below is the information which can be shared with the FRMC (via the DFC) or AGV in order to create fire patrol reports or path plans, respectively.

- Cargo unit identifier: Unique identifier of the unit itself.
- Type: Value for the cargo type as defined in MT_FIREORIGIN2 table.
- DG class: Optional. In case of a DG, it contains the IMDG classification.
- Deck, lane, frame_start/frame_end: Accurate location of the unit (placement slot).
- Score values: Two values defining the initial risk score (type dependent) and the final risk score (location dependent) as per the risk assessment based on historical data.
- List of nearby units: According to *Sep_X* and *Sep_Y*, the list includes the nearby units in the same deck.

5 Automatic screening of goods and vehicles

This section describes the proposed usage of sensors for automatic solution in a system of systems thinking with layers of sensors and software that collaborate in a mesh style to get as good understanding of the situation as possible. This is to emulate what humans do when screening an object using human senses and knowledge.

The drawback of non-intrusive scanning is the lower accuracy of the screening/sensor reading and the benefit is the possibility to screen large number of objects with a minimum of intrusions on the flow of units or business model.
But to maximize the benefits of these types of sensors and systems, changes to the physical layout of terminals and ships might be necessary. And retro fit these types of systems to ships and terminals will cost more than if they are implemented at the design stage of new ships and terminals.

Typical sensors used

Common for these types of screening system is the usage of infrared wavelength detection (IR) sensors, cameras colour/monochrome/night vision and often sensors for measuring distance or location of objects. For flammable gases, different types of sensors must be used since gasses can be either heavier or lighter than air. Also, linear sensors such as a fibre optic technology, where a large area can be covered by a loop or line of sensing technology, could be used and place above or beneath the vehicle or cargo.

5.1.1 Stationary systems

Fixed sensors on infrastructure at terminals or ships doors/ramps provides an opportunity to monitor an object as it passes by or is parked. This can be used to detect objects of interest in a flow of units, or a live feed of sensor information from a specific area. In D8.10 [3] and D8.11 [7]
Fixed sensors can be mounted above, from the sides, and even below the objects. Side and top side scanning is the less complicated approach, since vehicles/cargo is often rolled onboard, and the wheels and undercarriage it will often be dirty, which can contaminate sensors. This can be solved with specific systems to keep the sensors clean, but this types of solutions are complex and costly. Floor mounted systems are more exposed to damage from the loading operations and the cargo itself, due to the types of cargo/vehicles being transported.

5.1.2 Mobile systems

Portable

These systems are larger than a hand-held device and are used to monitor specific objects or specific areas of interest. The idea is to have local presence at a point/area of interest over a longer time. These could be single sensor units or multisensory units that are placed strategically near the object of interest. Another option is to use them to fill gaps where other sensors are obstructed, or not suited for the identified risk. Handheld IR-sensor devices use the same technology and are covered by WP6 and demonstrated in D06.2 Guidelines-for-manual-screening-of-cargo-fire-hazards-and-effective-fire-patrols [6].

Self-propelled or motorized

Automatic systems can patrol larger areas or reach places that humans have problems to access. An automatic system could be in the form of drones, airborne or driven on the cargo deck. Automatic Guided Vehicles (AGV) can be so small that they can run underneath the majority of vehicles and use upward facing sensors to scan the undercarriage of vehicles. An AGV can also be equipped with sensors for detecting gases that are heavier than air, or use cameras to search for puddles of liquid.

5.2 Vehicle Hotspot Detection system

The Vehicle hotspot detection system is stationary and is used to scan as much as possible of a truck, trailer, or other cargo unit for heat anomalies. The benefit with VHD is that it does this with a minimum intrusion on the object and the flow of units. A portal with fixed sensors is used as illustrated below in Figure 13, the set-up is described of a LASH FIRE VHD system [7], with the modifications needed for the project goals: downward LWIR accompanied with a LiDAR for profiling of the top side, and one extra LiDAR for high precision longitudinal tracking of the object as it passes the VHD portal. The added sensors and development in software made it possible to locate refrigeration units on truck and trailers, segment out refrigeration units and measure their temperature.
The system is stationary, and the cargo and vehicles pass through with little or no obstruction to the flow. During the LASH FIRE project, the system has been demonstrated at the Stena Line Majnabbe terminal in Gothenburg, Sweden.

Figure 13 Concept illustration of the LASHFIRE VHD portal.

Below in Figure 14, the side and downward facing LiDAR that profiles the truck and trailer for the 2D and 3D models is illustrated with light blue and the LWIR sensor is illustrated with light red.

Figure 14 LASH FIRE VHD illustration from LASH FIRE final video.

The profiling and thermographic scanning is processed by the Traffic Enhanced Monitoring Software (TEMS) and the results are visualised by as images that are easy to interpret, showing segmentation of the vehicle into parts/section of the vehicle that is of concern. To each of these segments a temperature alarm threshold can be set. Below in the following four images Figure 15, Figure 16, Figure 17 and Figure 18, a truck and trailer has been scanned and processed in TEMS v. 3.1.1 software and presented to the operator in the VHD Analyzer software.

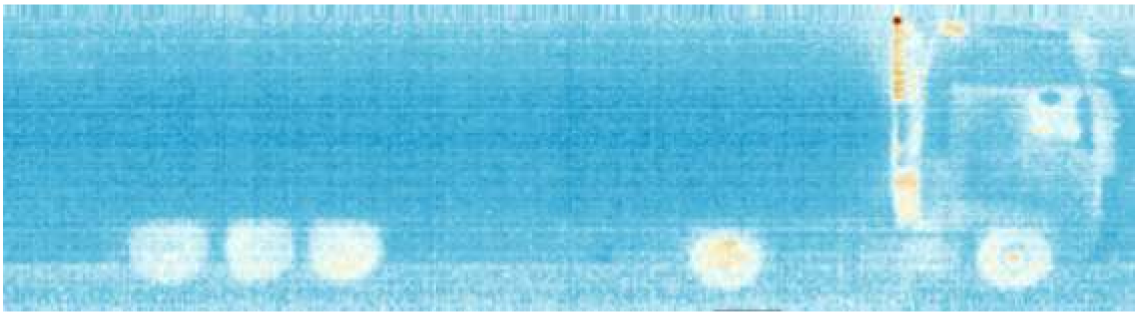

Figure 15 Thermographic image of the right side of a truck and trailer.

Above is the right side of the vehicle, the artificial adjustable temperature range is 0-50°C. The red dot behind the cabin in the upper right part is the top of the refrigeration unit.

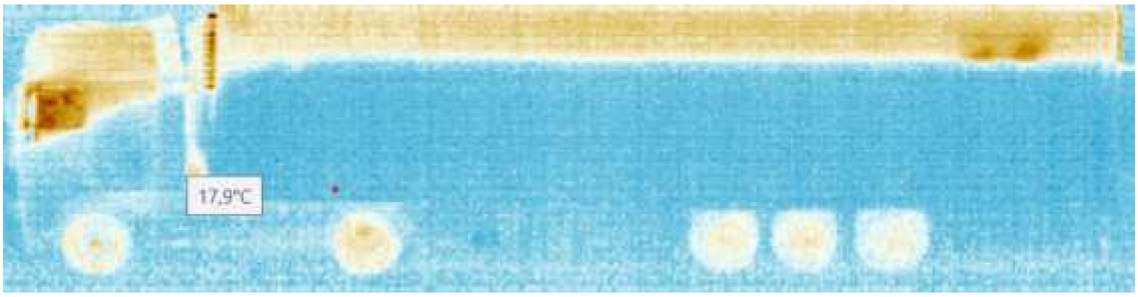

Figure 16 Left side of truck and trailer, the driver is visible since the window is down.

In the image above the right side is visible. The sun has heated the upper part of the truck and trailer.

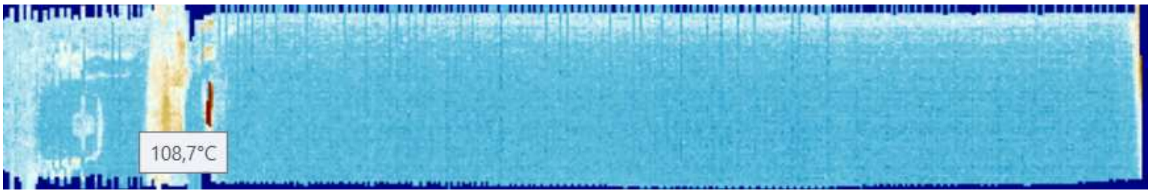

Figure 17 Thermographic image of the vehicle top side with spot temperature reading.

In the image above, the vertical dark stripe is the top of the refrigeration unit, the yellow patches on the left is the void between the truck’s cabin and the refrigeration unit. On many trucks this section between the front and rear wheel contains the engine with gearbox and exhaust system.

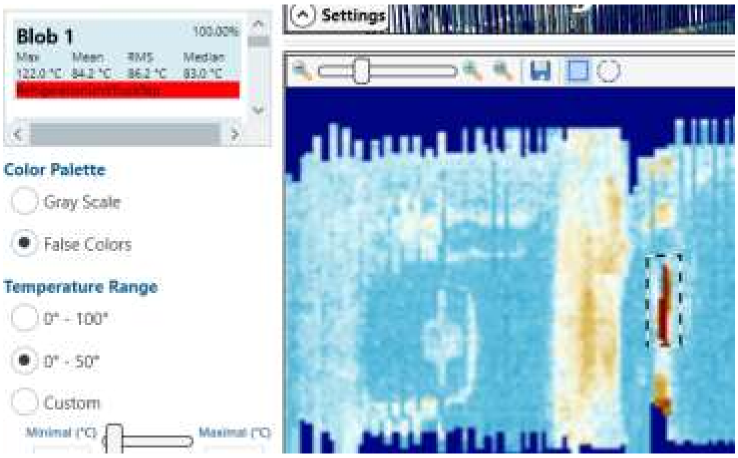

Figure 18 Automatic segmented and temperature reading.

In the image above the operator has selected a box in the TEMS Analyzer, the same function is present in the VHD Client, and a temperature reading is presented: 122°C is the hottest pixel in the selected box.

3D model

Figure 19 3D model of truck and trailer.

In the above picture, a 3D model of the truck and trailer is presented. The model is made up from the three profiling LiDARs used and put together by the TEMS software. On top of the 3D model, the 2D thermographic images are presented in the Figure 20.

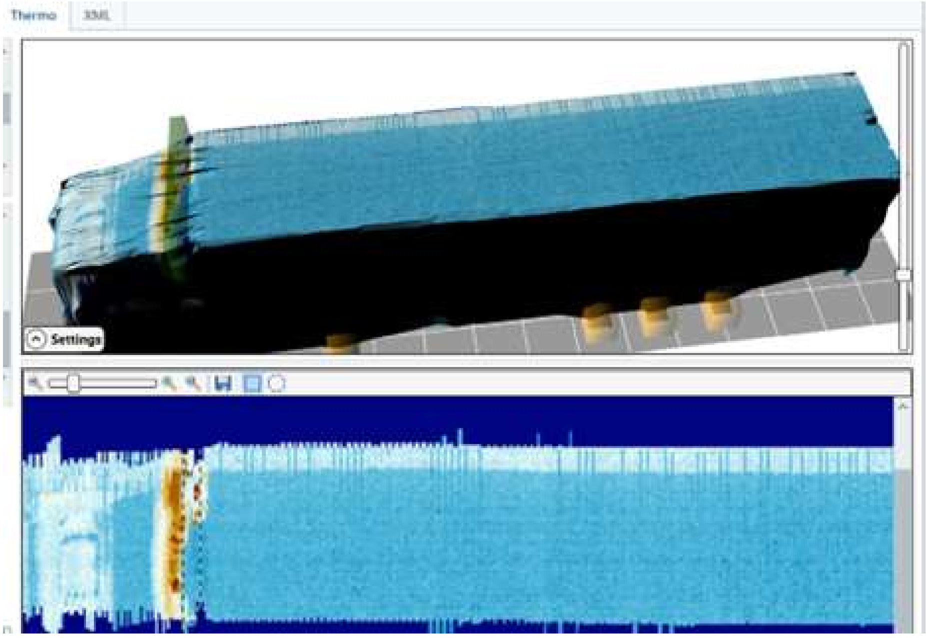

Figure 20 3D-model and thermographic image.

In the image above, the top pane is a user rotational image and the bottom pane a 2D thermographic image. In both panes the user can zoom in and out.

Machine learning

Usage of machine learning to locate and segment the refrigeration unit on the trailer, to the operator it is illustrated with a box in the upper pane and dashed lines in the lower pane.

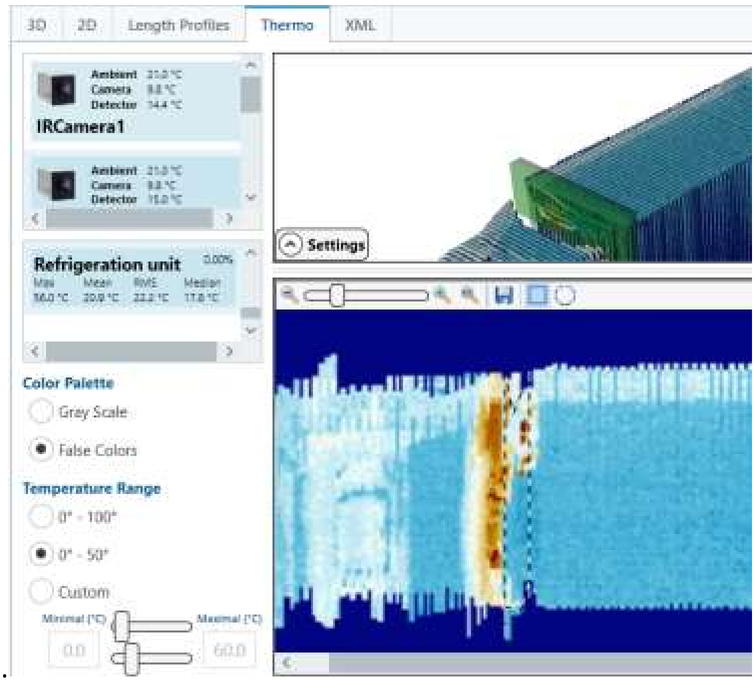

Figure 21 Refrigeration unit detected, segmented and temperature read using machine learning.

5.2.1 License plate and ADR/IMDG placard reading

The principle for reading license plates and ADR/IMD placards are the same in the VHD system and similar to the system used in the AGV.

In the VHD system, monochrome cameras are coupled with software. They are in general called Automatic Numeric Plate Reader (ANPR) or License Plate Reader (LPR). They were located inside the gate house at Majnabbe and mounted in tandem, two plus two cameras, so they could read both the license plates and ADR/IMDG placard on the front and rear of the vehicle. This is a new function developed in LASH FIRE which allows the VHD system to capture and present two license plates. The ability to read both the truck and trailers license plates allows the operator to track accompanied and unaccompanied trailers.

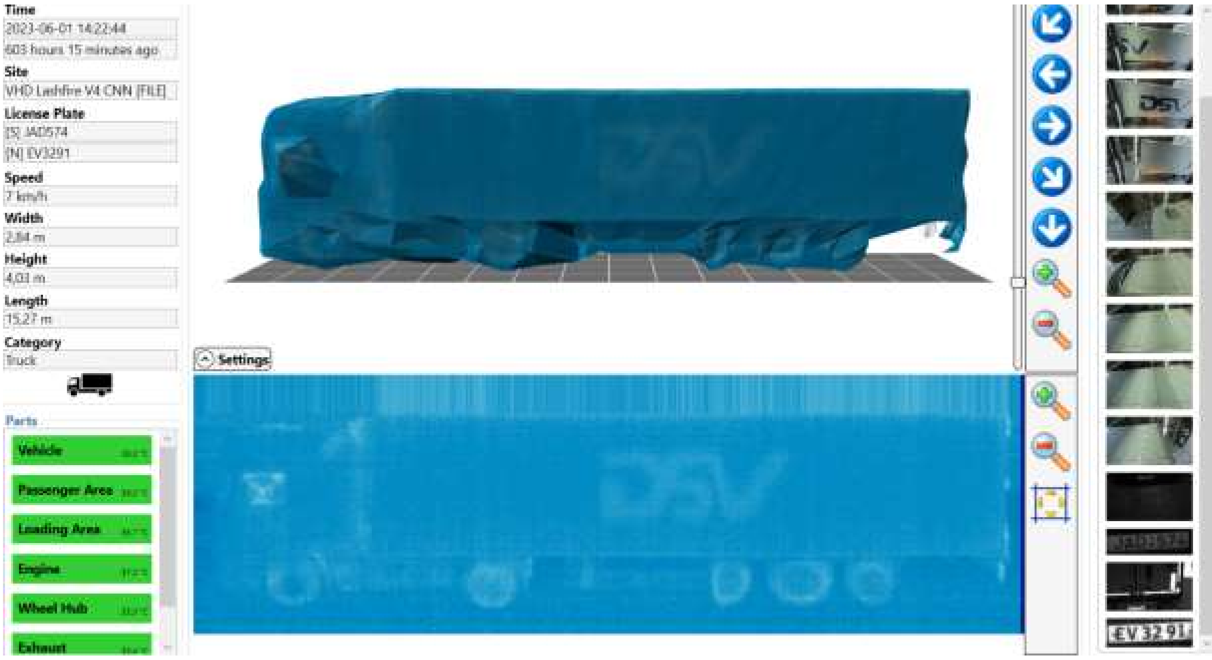

Figure 22 NPR from both truck and trailer in the VHD Client.

In Figure 22 above, the license plate that is read out is presented in the left column, and the actual sensor images are visible in the right column with CCTV images of the unit.

ADR/IMDG placard reading

The VHD system uses the ANPR sensors to read the numbers on the placards from the illustration below. The VHD system can extract the IMDG numbers, the lower part of the placard.

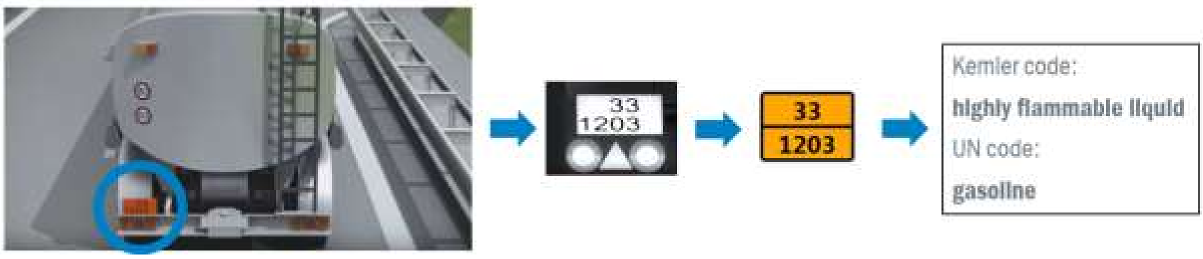

Figure 23 ADR/IMDG placard reading principle in VHD.

In the illustration in Figure 23, the 1203 number will be presented for the user and other software if there is a connection. In Figure 24 below, an ADR/IMDG placard is captured and the monochrome image used by the software and is also presented to the operator.

Figure 24 ADT/IMDG goods placard captured in VHD.

In the Figure 25 below the software has segmented the IMDG part of the placard and cropped the image.

Figure 25 The IMDG numbers segmented out.

5.3 Automatic Guided Vehicle

Automatic drones can patrol the cargo decks after loading is completed and monitor specific object/rows/locations on the deck. The drones can be flying/airborne or AGVs.

Figure 26 Test of AGV running under two BEVs.

There are a number of challenges with regard to cluttered decks and limited space, however the benefit is that they can provide a flexible remote presence in the case of an emergency.
AGVs can carry an array of sensors and if flat enough, pass under the most types of vehicles and scan the undercarriage for issues. The drone systems might need EX/ATEX classification to operate in all areas and on all types of cargo decks.

5.3.1 Navigation

The AGV prototype developed in the project performs navigation and locomotion, i.e., automated driving based on a list of target waypoints. It senses its environment using a 2D LiDAR scanner that detects nearby obstacles in a range of up to 16 meters away. Based on the LiDAR scanner's output, a map of the environment is created and the AGV's position in it is tracked.

5.3.2 Global map

The AGV system has the deck layout of the ship: Figure 27 below is a global map from the practical demonstration, red is the physical limits or no-go areas (the thin red lines).

Figure 27 Global map from AGV demonstration.

5.3.3 Simultaneous Localization And Mapping

The image Figure 28 below, shows the rotation-aligned overlay of the SLAM map (blue) and corresponding static environment map (brown). Alignment was carried out with the use of the (combined) global map. Referencing to the physical deck layout allows for faster localisation and positioning of both the AGV and the objects on the deck.

Figure 28 LiDAR used for SLAM on global map.

And also, the outlines of the vehicle is clearly visible as blue shadows in the image above.

5.3.4 Pathfinding algorithm

A pathfinding algorithm then uses this map to generate a path to the next waypoint, and a motor control system drives the two motors of the AGV such that the vehicle follows the path.

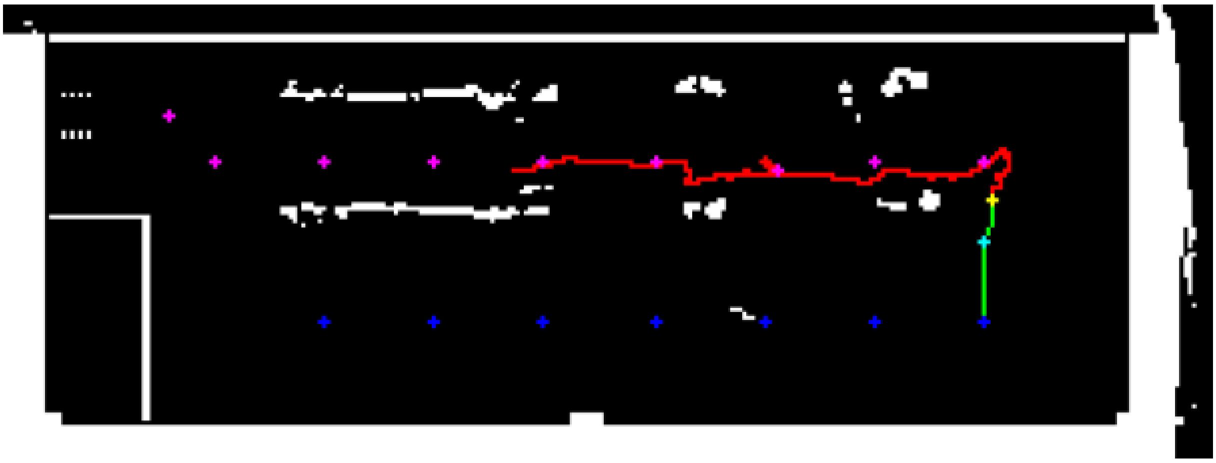

Figure 29 Downscaled global map with AGVs current location as a yellow cross, planned way points, trail and planned path in green.

Figure 29 shows the global map saved by the AGV after around 50% of the run has been completed. For reasons of computational demand, it is downscaled in resolution by a factor of 5 compared to the static and SLAM maps and therefore more pixelated.

- White: Solid obstacles, either detected by the AGV's SLAM system or provided in the static

environment map.
- Yellow: The AGV's current position.
- Red: The AGV's most recent trajectory.
- Green: The currently planned path.
- Turquoise: The current target waypoint.
- Blue: Future waypoints.
- Pink: Past (reached) waypoints
- Red cross-markers: Skipped waypoints, these were unreachable due to obstacle proximity and were therefore progressively shifted to the nearest reachable location.

Once a waypoint is reached, the next waypoint is selected, until there are no more waypoints in the list. The concept for navigation and perception can be found in ANNEX B 9.2.

A [video] has been uploaded that illustrates the potential of an AGV for surveillance and monitoring of cargo and vehicles in a realistic environment and also in a lab environment [video recording].

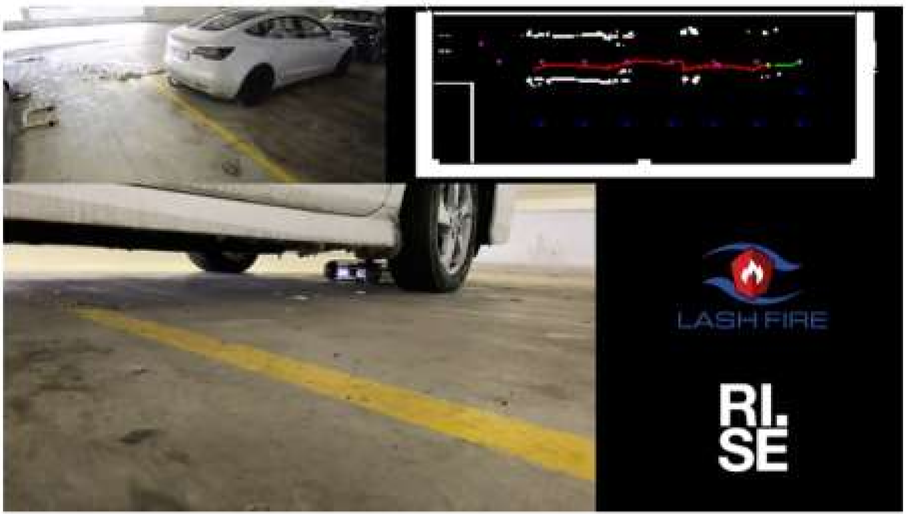

Figure 30 From AGV test underneath BEVs

In this way, the AGV can navigate the changing stowage situation on the deck from voyage to voyage, it can replan if there is an obstacle e.g. lashing equipment, cable for refrigeration units or BEVs.
In a system of systems perspective, the AGV could receive prioritised targets or areas to patrol. The AGV could also report back to a system the location of specific cargo/vehicle as it patrols a cargo deck.

5.3.5 Hotspot detection

The AGV was equipped with a LWIR sensor, it was placed as low as possible to allow as much vertical clearance to a low undercarriage of a BEV. As illustrated in Figure 31 and Figure 32, the plate is 1600mm wide illustrating the undercarriage of a vehicle, and in this case approximately the width of a battery bank.

Figure 31 Illustration of the field of view for a LWIR on the AGV.

The vertical clearance in this simulation was set to 150mm as illustrated in Figure 32 below, not only covering the undercarriage but the sensor can be used to detect objects in front of the AGV e.g. cables that are warm due to usage.

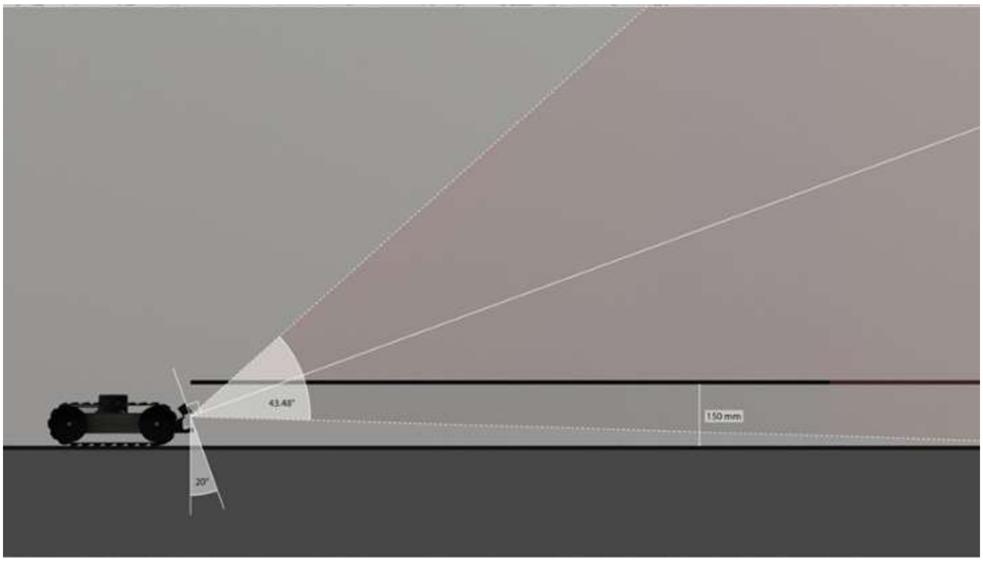

Figure 32 Illustration of the mounting point for the forward looking LWIR sensor.

With one LWIR sensor the whole undercarrige can be covered, and with two or more sensors, redunancy and resolution could be increased..

5.3.6 License plate reading

The AGV used OpenALPR [8] software and a RGB camera, Logitech Webcam C930e. The environment is similar to a ship's cargo deck and practical for testing was a parking garage at Lindholmen, Gothenburg. A small section of the garage was used as the test site, with two passenger EVs parked in a row. This test was conducted with the drone statically placed behind the vehicles and inside the calibration rig as seen in Figure 33.

Figure 33 License plate reading test.

The readout and logging procedure for license plates were activated. The log file outputs show repeated readouts such as the following:

detection: RKW36G

In this example, the license plate was read out correctly, and the license plate readout system was thus determined functional. However, some inconsistency in the readout was detected; In a significant fraction of repeated reads, it was recognized as “RKW6G”, thus missing the “3”, despite the favourable viewing angle and occlusion-free line of sight. While relatively simple post-processing (e.g., closest match in database, majority vote over time, etc.) could be applied to achieve a more stable readout of license plates, we rate this test as only partially successful. In particular, readouts in less favourable conditions are likely to be less accurate than what was observed in this test.

6 Conclusion

Main author of the chapter: Robert Rylander, RISE

The Stowage Planning Tool is a software component entirely developed during the LASH FIRE project that supports load planning while including fire hazard management, by the means of a risk assessment of the units that is based on historical data. The software has been successfully tested when it comes to the implementation of the scoring feature and the subsequent cargo distribution in order to reduce the overall risk in terms of that score value. This way, the solution helps to increase the fire protection of ro-ro ships at the ignition prevention stage, which represents a contribution to the global objective #1 of the project. The SW is supported by a risk assessment based on historical data; in order to effectively address actual risks, it is strongly recommended to foster standardization of incident reporting and to allow public access to that information so that automatisms can be used to keep the tool updated continuously.

The usage of remote sensing can give ship and terminal operators a new types of information about the vehicle and cargo that they currently do not capture today during loading operations. Automatic systems can operate in parallel with the crew and personnel to increase safety. If the types of cargo would be standardized and homogenic, it could replace manually screening, but that is not the goal for LASHFIRE they are designed as a compliment.

The hotspot detection has proven to be a good strategy for early detection of ignition, as small areas of temperature change can easily be detected. The automatic types of systems tested can also monitor an object over time and thereby provide accurate history of the development on induvial objects. The solutions show that it is possible to screen vehicles and cargo with minimal impact on the flow and thereby not hinder operations or slow down the turnaround time in ports. The solutions also show how it is possible to still gain a lot of knowledge about the vehicles and cargo prior to loading and during the sea voyage, which can give the crew and personnel ample time to take actions that will mitigate risks and reduce the risks of ignition from vehicles and cargo. In addition, the solutions describe provide the possibility to get access to the undercarriage of cargo and vehicles, providing a new dimension to early indication of hazards and preventive actions.

Systems installed on a ship can increase crew situational awareness by their presence inside the cargo hold in the event of an emergency. The challenge is to get as good cover as possible. Most systems will work well if the vehicles or cargo are parked in specific spots/rows were good coverage, where line of sight or access for sensors is good. Onboard many ships CCTV cameras cover the decks, but as the decks get loaded the field of view gets obscured.

UK Maritime and Coast Guard Agency MGN 653 (M) Electric vehicles onboard passenger roll-on/roll-off (ro-ro) ferries [9], stresses the importance to know more about the vehicles onboard the ship and to have continuous monitoring during the voyage. The three systems developed and prototyped from 8A - Ignition are tools that can assist not only with the handling of AFVs but also anomaly detection on other types of cargo and vehicles, as standalone, or part of a system of systems concept.

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8 Indexes

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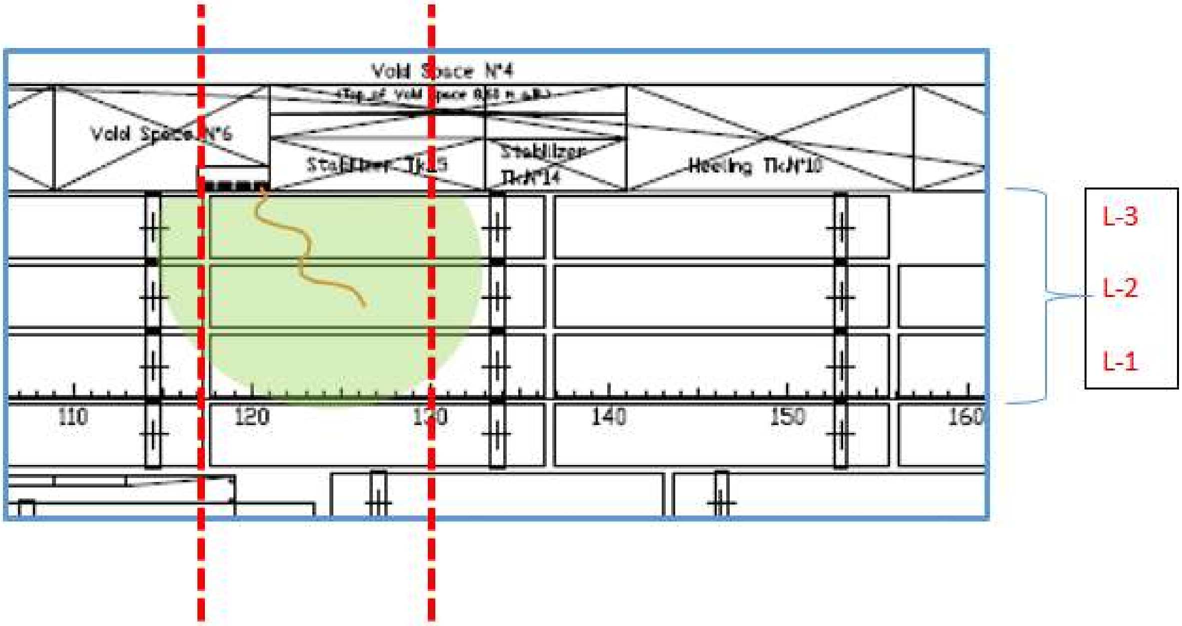
9 ANNEXES

9.1 ANNEX A Illustration of frames



Red lines are frame from aft 118 and 130 to the front of the ship.

9.2 ANNEX B AGV Sense-plan-act control architecture

Conceptual sketch of processing flow (sense-plan-act control architecture in the left half, license plate detection and thermal imaging in the top right corner)