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# SafePASS: A new chapter for passenger ship evacuation and marine emergency response

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**Abstract**

Despite the current high level of safety and the efforts to make passenger ships resilient to most fire and flooding scenarios, there are still gaps and challenges in the marine emergency response and ship evacuation processes. Those challenges arise from the fact that both processes are complex, multi-variable problems that rely on parameters involving not only people and technology but also procedural and managerial issues. SafePASS Project, funded under EU's Horizon 2020 Research and Innovation Programme, is set to radically redefine the evacuation processes by introducing new equipment, expanding the capabilities of legacy systems on-board, proposing new Life-Saving Appliances and ship layouts, and challenging the current international regulations, hence reducing the uncertainty, and increasing the efficiency in all the stages of ship evacuation and abandonment process.

*Keywords:* marine; AR; safety; evacuation; risk; passenger

## 1. Introduction

The work presented herein is an update on the SafePASS solutions and research developments within the various project ecosystems that were presented by Boulougouris et al, 2020 on the TRA2020 Conference. More specifically, the following pages constitute a brief report on the findings, technical developments and research outputs that have been produced within the context of the SafePASS project.

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**Nomenclature**

| | |
|---|---|
| AR | Augmented Reality |
| BLE | Bluetooth Low Energy |
| CBR | Case-Based Reasoning |
| CEP | Complex Event Processor |
| CE-SMS | Core Engine System Management Server |
| COP | Common Operational Picture |
| IMU | Inertial Measurement Unit |
| IPS | Indoor Positioning Systems |
| LDER | Location-based Dynamic Evacuation Route |
| LSAs | Life-Saving Appliances |
| PLL | Potential Loss of Life |
| PSE | Personal Survival Equipment |
| RCOs | Risk Control Options |
| RMT | Risk Modelling Tool |
| SafePASS | Next Generation of life saving appliances and systems for Safe and swift evacuation on high capacity PASSenger ships in extreme scenarios and conditions |
| UWB | Ultra-Wide Band |

### *1.1. Motivation: Maritime Accident Response*

The European Commission (European Commission, 2018) has taken a proactive approach in addressing the challenges of Maritime Accident Response by providing funding towards research and innovation initiatives that have the potential of not only minimizing the frequency of maritime accidents, but also mitigating the consequences through novel systems and updated emergency procedures. The SafePASS project lies well within this overarching strategy of reducing the risk by tackling, simultaneously, the various points of failure during an emergency and looking into solutions that improve the performance standards during the mustering and the abandonment phase of a passenger ship.

### *1.2. Approach: The SafePASS Strategy*

The SafePASS solutions, via the utilization of smart devices and Augmented Reality (AR) applications, improve crew training, offer personalized passenger evacuation route instructions, and enhance situational awareness of the decision makers through novel ‘real-time’ risk metrics and a Common Operational Picture (COP). The proposed approach aims to cover holistically and seamlessly all the critical stages of evacuation, from alarm to rescue. The SafePASS-proposed systems and procedures shall kick-start a new era for marine emergency response and ship evacuation, yielding tangible improvements on safety and efficiency during mustering and abandonment of large passenger vessels, regardless of the hazards (fire or flooding), weather conditions or passenger demographics. This paper is dedicated to a brief presentation of the SafePASS solutions in their current development status. Starting with the introduction of the SafePASS Core Engine, COP and Dynamic Signs, moving to the outline of the characteristics of the next generation of life-saving appliances (LSAs) and the proposed alternations in ship layouts before describing the use of indoor localization sensors and the overall integration of the various ‘smart’ SafePASS components. Finally, the scope and capabilities of each module of the SafePASS Risk Modelling Tool (RMT) are being explained.

## 2. SafePASS Core Platform

The Core Platform of SafePASS is a network of subsystems that altogether facilitate the management functionalities among the various SafePASS solutions and legacy systems on board the ship. The heart of the system is called Core Engine (see Figure 1a) and it comprises the System Management Server (CE-SMS), the Location-based

Dynamic Evacuation Route (LDER) and the Complex Event Processor (CEP). Among the most important functions of the Core Engine are: i) the generation of personalised evacuation routes through the LDER, ii) the handling of the Dynamic Exit Signs (see Figure 1b), iii) producing warnings and alerts, and sending them to the COP based on information received from sensors.

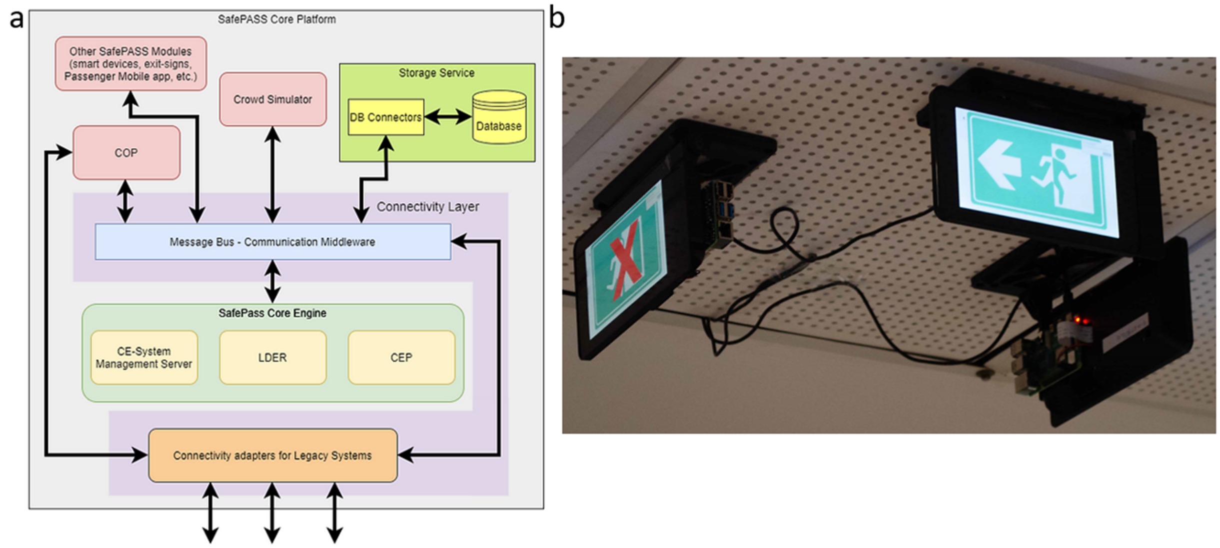


Fig. 1. SafePASS (a) Core Platform Architecture, (b) Dynamic Exit Signs

## *2.1. Common Operational Picture*

The COP was developed to enhance the situational awarness of both crew and passengers. It is essentially a 2D/3D application that allows the visualisation, in real time, of various information from both the legacy systems and the novel SafePASS using the digital twin of the ship as a picture to represent the situation and the ongoing operations. It is designed for two purposes; the first being the use in the vessel's Safety Centre using on one or several monitors (see Figure 2a), the second being to provide information and enable command and control anywhere in the ship without requiring a specific display due to the use of a mobile Mixed Reality headset delivering a holographic COP. For the latter, a crew member wears the HoloLens 2 glasses to display the COP in real time in the area of interest in order to get operational information (see Figure 2b), alerts and recommendations/orders and to provide live updates about the emergency situation to the Safety Centre.

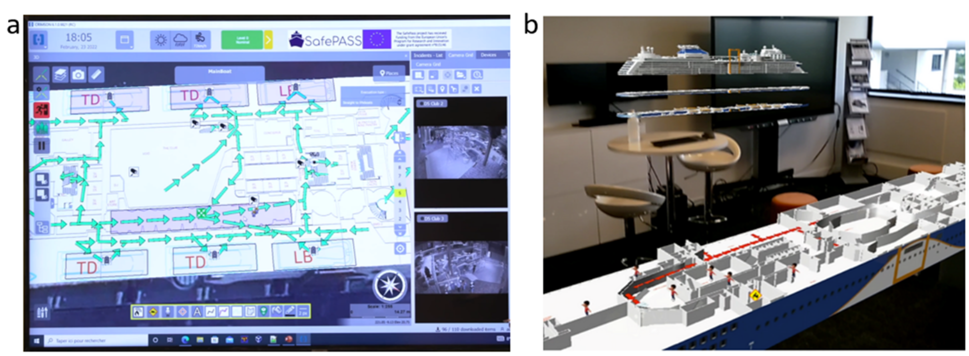


Fig. 2. SafePASS (a) 2D/3D Common Operational Picture, (b) Mobile Holographic COP

### 2.2. Location-based Dynamic Evacuation Route

In principle, the LDER is responsible for the calculation of dynamic routes allocated to passengers allowing them to follow the safest and fastest routes to evacuate the ship. The LDER is part of the SafePASS Core Engine, hence taking advantage of the various data around the ship such as indoor localization, counting-people devices, and damage sensors. In addition, it generates output such as crowd congestion and routes that can be displayed on the COP at the ship's bridge and communicated to passengers through exit signs, the mobile app, and the haptic actuators or chatbot application of the smart lifejackets.

## 3. Next Generation of Life-Saving Appliances

Tank experiments were conducted by the Maritime Research Institute Netherlands (MARIN) on behalf of the project's consortium and aimed in the evaluation of the current safety status of LSAs in severe weather by performing seakeeping experiments. The main aim of the tank tests was to assess and compare the LSA performance, passenger comfort and safety, linked with the ship's interreference and compare the standard LSAs to novel SafePASS LSA designs. More specifically, the experiments were focused on: i) Measurement of the motions of LSAs, ii) Verification of the mechanical resistance of system/interfaces, iii) Assessment of the passenger comfort, iv) Assessment of the passenger risk of injury, v) Description of the influence of sea state on embarkation and launch, vi) Description of the of ship condition on embarkation and launch, vii) Description of the influence of wind on LSA, viii) Determination of the influence of the embarkation duration.

Based on the analysis of the results from the tank tests and dedicated workshops on the design features of the next generation of LSAs, two designs were emerged and are presented in the following two subsections.

### 3.1. Sliding Lifeboats Solution

The Sliding Lifeboat design is based on the concept of integration of novel LSA lifeboats with novel ship architectural structures (Ventikos et al, 2021). In practice, this solution requires the LSA lifeboats being placed on rail platform (see Figure 3a) that is able to move longitudinally and approach an adjacent Vertical Fire Zone where the embarkation of passengers would be safe. In this way, it improves the availability and the accessibility of the Novel LSA Lifeboats in case of an emergency where the movement of passengers or crew members within the aft-most and fore-most Vertical Zones has been restricted (e.g. due to fire within those areas). More specifically, the Novel LSA container where the LSA lifeboats are enclosed, is secured on the rail platform with dedicated mechanisms. The platform, flat on top, will be moving on wheels, using an electric motor.

### 3.2. RESCUBE Hardshell Lifeboat Solution

With the standard ship layout, the lifeboat boarding procedures require a lot of time given that all passengers should travel to a specific deck level, where the lifeboat is located. Furthermore, distance traveling during an emergency situation is not an easy task for all passengers, especially for elderly or disabled passengers. In addition, mustering processes might also be impossible or at best more time-consuming in case emergency routes are blocked due to a fire or similar events. Additionally, maintaining control in a stressful evacuation procedure is very challenging for both passengers and crew. Having all the above in mind, the SafePASS project introduces the "RESCUBE" solution in order to improve the availability and the accessibility of the LSA from several decks.

The RESCUBE concept is able to reduce evacuation time significantly and the probability of not being able to reach a means of abandonment due to its vertical placement. In practice, the vertical placement of the RESCUBE concept, reduces or eliminates the need for passengers to walk long distances from deck to deck during an emergency. Besides, the ability of sea keeping and sail away resulting in sufficient forward motion is one of the main safety-critical focus-areas in all offshore safety studies related to evacuation safety cases.

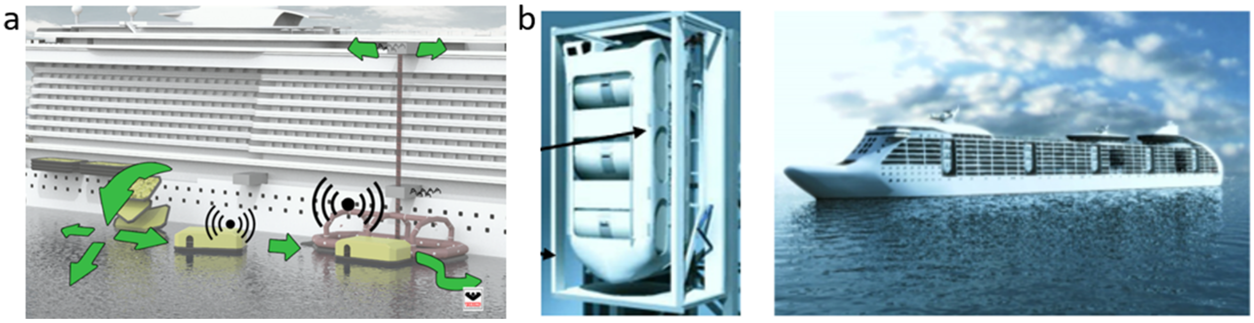


Fig. 3. SafePASS (a) Sliding Lifeboat Solution, (b) RESCUBE Hardshell Lifeboat Solution

## 4. Smart Environment

### *4.1. Indoor Localization*

Tracking passengers' and crew's position on board is vital for complex safety-related procedures. Even though satellite positioning signals are not available inside a vessel, there are several techniques developed alongside the cruise industry, using wearable devices to identify passengers' location.

In SafePASS, indoor localization for passengers and crew members has been achieved by using Bluetooth and Ultra-Wide Band (UWB) technology. To begin with the Bluetooth Low Energy (BLE), since all modern mobile smartphones have BLE transceivers, BLE-based IPS (Indoor Positioning System) has been implemented using smartphones which connect to the installed BLE beacon antennas throughout the cruise ship. Moving towards the UWB, the cruise ship's smart lifejackets have been equipped with a localization device which has an embedded UWB transceiver and can communicate with the UWB fixed anchors installed in different positions within the ship (Zafari, 2019). UWB and BLE technologies are enabled by the SafePASS Core Engine which supports all devices in order to accurately calculate each passenger's location in real-time, aiming to provide an integrated platform of indoor localization for passengers and crew members (Alarifi, 2016).

### *4.2. Passenger Mobile Application*

The Passenger Mobile Application can be installed on passengers' mobile devices (see Figure 4a). It provides monitoring of their real-time location, as well as visual navigation towards the designated evacuation exits. Furthermore, it gives the opportunity to passengers for easy and simple group chat communication via text messages with all the registered family members or companions. Moreover, passengers have the chance to quickly request for assistance from the ship crew. Finally, this component can communicate with the Core Engine to receive key passenger information, as well as the Biometric Monitoring Module to read the bio-signals measured by the Smart Wristband.

### *4.3. Smart Wristband*

The Smart wristband is responsible for enabling the physiological monitoring of passengers' vital signs (heartrate and oxygen saturation signals) by providing a near-real time, detection of potential stress upon ship evacuation, during an emergency. It will be given to passengers at ship embarkation which contains a unique identifier associated with the specific passenger. During distress conditions, the smart wristband will be able to associate the passenger with the Smart Lifejacket and monitor the biometrics per passenger. After all, the Wristband can be scanned by the Near Field Communication readers installed onboard the vessel.

*4.4. Passenger Chatbot*

The Passenger Chatbot is a hardware-software solution responsible for providing real-time audio instructions to passengers on board the vessel for navigation to the indicated exits during evacuation. In fact, being aware of the passenger's location within the ship, this component can playback audio files locally stored on the lifejacket-mounted board in order to assist the passenger navigate within the ship until they reach the confined area assigned to them according to the evacuation plan. Overall, the main features of the Passenger Chatbot are: i) voice-based user interface, ii) indoor localization, iii) language selection, iv) dynamic navigation through audio instructions.

*4.5. Smart Lifejacket*

The Smart Lifejacket (see Figure 4b) communicates with the Smart Wristband as described earlier. In addition, it provides haptic navigation. More specifically, in SafePASS, the haptic actuators are used as a route guidance system attached to the lifejackets. The actuators indicate to the passengers where they need to go during the navigation process. The Inertial Measurement Unit (IMU) provides orientation measurements in order to augment the localization module during the navigation process. In practice, in case the passenger becomes lost, and no crew members are present for assistance, tactile navigation is available to guide him to the confined areas. Lastly, the Smart Lifejacket is connected with the SafePASS Core Platform.

*4.6. Augmented Reality Toolkit Application*

The SafePASS AR toolkit is a set of AR applications being developed, in order to assist and enhance already existing training and emergency procedures and tools for large passenger ships (Bolierakis et al, 2020). The first part aims to help crew members and LSA manufacturers to train on handling LSAs such as lifeboats, liferafts, and MES in a plethora of different scenarios. The training is based on a virtual LSA in 3D allowing users to interact with it in order to complete successfully each step of the training. For each step of the training, images, text, animations or videos are available on the corresponding virtual parts of the LSA.

The second part of the AR training tool application targets to assist crew members or LSA manufacturers in the maintenance stage during the LSA maintenance procedure. It provides the necessary steps for the maintenance along with useful annotations on the actual equipment of the ship. In this way, the users will gain more experience and will be able to fix any unexpected malfunction during an emergency.

The third part consists of the AR Crew Rescue Assistant Application and the AR Passenger Assistant Application that enables crew to assist passengers and provides AR navigation features during an evacuation both for the crew and passengers.

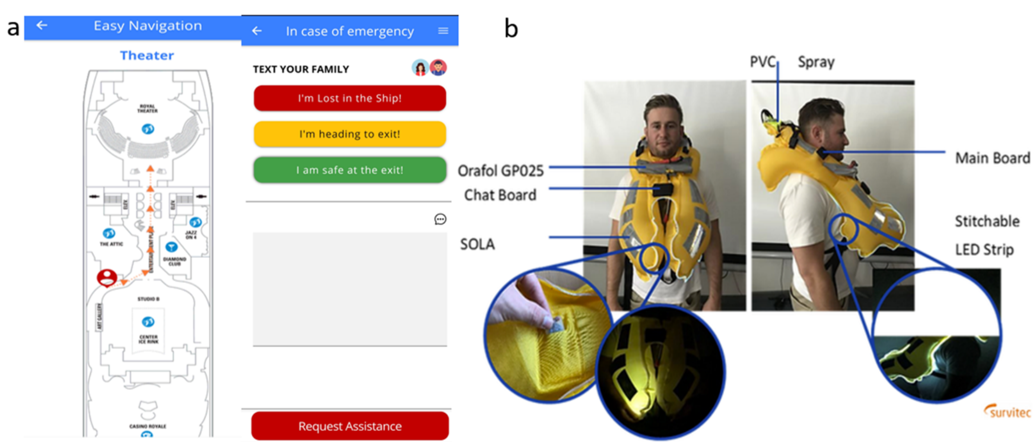


Fig. 4. SafePASS (a) Passenger  Mobile Application, (b) Smart Lifejacket

### *4.7. Dynamic Exit Signs*

The Dynamic Exit Signs are enhancing the evacuation procedure by providing dynamic instructions for the best evacuation route based on current conditions on the vessel. In fact, these smart signs show every time a safe path to the exit based on the conditions of an emergency situation where static exit signs may lead to a non-safe place of the ship. Besides, the dynamic exit signs send their own operational health status updates to the Core Engine, while displaying directions based on dynamic evacuation plans provided by the Core Engine.

## 5. Risk Modelling Tool (RMT)

The SafePASS RMT is dedicated in the quantification of the projected risk and the Potential Loss of Life (PLL).The proposed risk model framework constitutes a novel approach with the ability to assess the evacuation and abandonment risk dynamically, based on real-time data related to the passenger distribution, route and/ or LSA availability, procedural changes, and damage propagation. It is intended to work in collaboration with other SafePASS systems that will provide the necessary data input which will regulate the probability distribution on the SafePASS evacuation decision tree. The risk model aims to act as the backbone of a Decision Support Tool for the emergency response coordination teams (Stefanidis et al, 2020). The RMT is composed of the following four distinct modules.

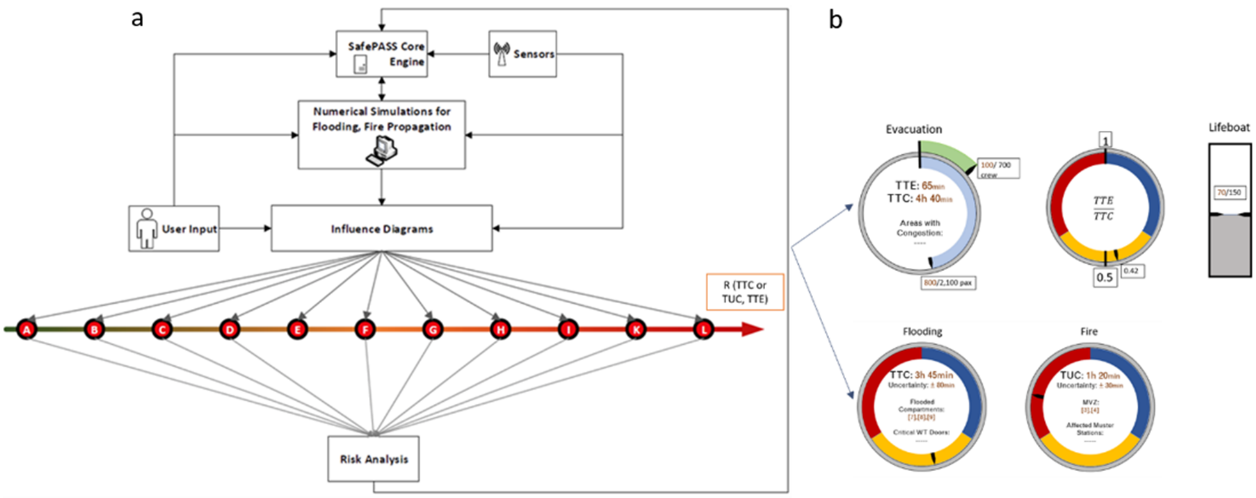


Fig. 5. SafePASS (a) RMT Flow of Information, (b) RMT Dashboard Concept

### *5.1. RMT Module 1: Numerical Simulations Database*

This module of the RMT contains data from numerical simulations of critical flooding and fire scenarios coupled with their corresponding advanced evacuation simulation data. The database is being used for prognostic purposes such as providing predictions on the potential ships motions, blocked areas, evacuation and abandonment time, number of potential fatalities.

### *5.2. RMT Module 2: Numerical Simulations Database*

The second module is responsible for the selection of the most probable/matching scenario from the database, based on live data received from the Core Engine. The CBR is a problem-solving approach that relies on relevant past cases to find solutions to emerging situation and is especially useful when it is impractical or impossible to do calculations in real time and past experience can be used instead (Kolonder, 1992 and Olcer et al, 2006). In order for CBR to be successful the following steps have to be completed: i) Indexing or classifying each case by features that are important, ii) Retrieval and Interpretation of the most appropriate case from the database, iii) Adaptation, where the useful information is inferred from the stored scenario so that it can be applied on the emergent case, iv) Evaluation and Repair, that together with the previous step, creates an iterative process which allows for an accurate prediction.

### *5.3. RMT Module 3: Dynamic Risk Analysis*

This module contains functions based on the influence diagrams for each node of the evacuation decision tree. The function determines, based on Module 1 and data from the Core Engine, the value of the top event of each influence diagram and leads to the calculation of the PLL.

### *5.4. RMT Module 4: Dashboard*

The Dashboard is responsible for the visualization of the results and a preliminary version of it can be seen in Figure 5b. This aspect of the RMT is comprised of different gauges and charts for indicating the risk indices, the progress of the evacuation and other safety critical information such as blocked areas and LSA availability.

## 6. Conclusions

SafePASS project has developed a series of novel systems and processes that have the potential of significantly changing the landscape of maritime safety and emergency response for large capacity passenger ships. Most of the SafePASS solutions can be used as standalone products but also work seamlessly together via the SafePASS Core Engine so as to ensure the maximum benefit in risk reduction in case of an emergency. The last months of the project will be focused on the cost-benefit analysis for each proposed Risk Control Option (RCO), thus allowing for the determination of feasibility for each RCO based on the techno-economical standards.

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