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SafePASS – Transforming Marine Accident Response

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Abstract

The evacuation of a ship is the last line of defence against human loses in case of emergencies in extreme fire and flooding casualties. Since the establishment of the International Maritime Organisation (IMO), Maritime Safety is its cornerstone with the Safety of Life at Sea Convention (SOLAS) spearheading its relentless efforts to reduce risks to human life at sea. However, the times are changing. On one hand, we have the new opportunities created with the vast technological advances of today. On the other, we are facing new challenges, with the ever-increasing size of the passenger ships and the societal pressure for a continuous improvement of maritime safety. In this respect, the EU-funded Horizon 2020 Research and Innovation Programme project SafePASS, presented herein, aims to radically redefine the evacuation processes, the involved systems and equipment and challenge the international regulations for large passenger ships, in all environments, hazards and weather conditions, independently of the demographic factors. The project consortium, which brings together 15 European partners from industry, academia and classification societies. The SafePASS vision and plan for a safer, faster and smarter ship evacuation involves: i) a holistic and seamless approach to evacuation, addressing all states from alarm to rescue, including the design of the next generation of life-saving appliances and; ii) the integration of 'smart' technology and Augmented Reality (AR) applications to provide individual guidance to passengers, regardless of their demographic characteristics or hazard (flooding or fire), towards the optimal route of escape.

Keywords: marine accident response; ship evacuation; lifesaving appliances; pedestrian dynamics; dynamic route finding; risk modelling; passenger ships;

1.1.1. Nomenclature

SafePASS	Next generation of life SAving appliances and systems for saFE and swift evacuation on high capacity PASSenger ships in extreme scenarios and conditions
IMO	International Maritime Organisation
SOLAS	Safety of Life at Sea convention
AR	Augmented Reality
LSAs	Life-Saving Appliances
RCCL	Royal Caribbean Cruises Ltd

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RCOs	Risk Control Options
PSE	Personal Survival Equipment
COP	Common Operational Picture
HEP	Human Error Probability
UWB	Ultra-Wideband
LDER	Location-based Dynamic Evacuation Route
CEP	Complex Event Processing
PLL	Potential Loss of Life
SCOPE	System Change and Operations Evaluation
SLO	Social License to Operate

1. Introduction

1.1 The challenge: Marine Accident Response

Recent accidents such as the grounding of Costa Concordia, the fire on MS Norman Atlantic and the Viking Sky incident, indicate gaps in addressing maritime safety and, in particular, emergency response, gaps that give rise to societal 'ultimatum' for legislators to take action. Furthermore, the magnitude and consequences of a marine accident, both in terms of loss of life and environmental impact, are greatly dependant on the actions taken immediately after and throughout the emergency state. The issue of evacuation and emergency response is crucial for large capacity passenger vessels for which even the assumptions behind the conventional evacuation procedures and life-saving appliances (LSAs) in place are challenging.

The EU, appreciating the need to address the existing gaps and challenges in the subject and capitalising on the opportunities presented by the recent technological developments, decided to fund, under the Horizon 2020 Research and Innovation programme, proposals for international cooperation for radical transformation of the existing evacuation systems (European Commission, 2017).

1.2. The solution: SafePASS Project

The ability to provide the decision-makers with accurate and real-time information regarding the passenger distribution on-board, the availability of LSAs and the extent/ propagation of emergency state (fire, flooding, security threat), will have a significant effect on their ability to properly assess the situation and consider appropriate actions (Vassalos et al., 2004; Stefanidis et al., 2019). The SafePASS consortium consists of researchers, manufacturers and professionals in the fields of IoT, maritime safety, LSA design and cruise ship operations (RCCL) that can provide the know-how for a revolutionised marine accident response by addressing simultaneously multiple aspects of the problem. The SafePASS system, aims to radically redefine the evacuation processes, evacuation systems and international standards for passenger ships in all environments by developing a combination of innovative systems that will collectively monitor, process and inform during emergencies both safety personnel and passengers of the optimal evacuation routes, coupled with advanced, intuitive and easy to use lifesaving appliances, well beyond current state-of-the-art. The SafePASS system will be tested by developing and implementing pilots and evaluated by quantifiable validation metrics.

2. SafePASS Objectives and Architecure

2.1. Objectives

The first objective of the project is the development of a comprehensive post-incident approach from ALARM to RESCUE, including mustering and abandonment in pertinent extreme flooding and fire scenarios, leading to risk estimation and impact of appropriate Risk Control Options (RCOs) post-flooding/fire emergencies. The cost-effectiveness of any measure proposed (software, hardware, procedural, human factors, technological) will be assessed against its effectiveness in reducing the mustering and abandonment time and the individual evacuation risk for passengers. This weighting between RCO's effectiveness and cost is of paramount importance to the overall risk management.

The second objective is related to the development of the next generation of LSAs, designed specifically for large passenger ships. The new concepts for lifeboats and Personal Survival Equipment (PSE) will incorporate the best characteristics of the existing LSAs while implementing on them technologies from other fields. The final outputs of these objectives will include i) novel ship architectural layouts that will increase efficiency of LSA operations, ii) PSEs like lifejackets and other wearables that will be equipped with haptic actuators to assist in the guidance of passengers during evacuation and iii) novel lifeboats with increased passenger capacity, comfortable and secure interior and easily accessible during extreme environmental conditions.

The third objective is focused on the creation of a smart environment based on sensors, actuators, simulation, monitoring elements and smart devices. The integration of these features will enable indoor localization and analysis of the emergency in real time. In addition, via embedded earplugs, vibration sensors and an AR app, crew and passengers guidance will be personalised so that the overall evacuation process will be improved. Essentially, this objective involves the design and development of the evacuation support tools and methods that will have a significant effect on the enhancement of the evacuation operations and situational awareness of the evacuees.

Based on the data produced by the elements of the previous objective, an advanced overarching platform will be introduced. The core of this platform will be a novel real time-domain software that will calculate the optimal evacuation route based on the current and evolving circumstances. This Location-based Dynamic Evacuation route will be able to address the safety needs of passengers and assist in the coordination of the crew. Passenger guidance will be achieved via multiple means including, screens, dynamic exit signs, speakers and haptics from smart devices. Furthermore, under this objective, a 3D Common Operational Picture (COP) of the vessel will be produced accompanied by its holographic COP version that will help visualise and highlight important information, hence increasing awareness for both passengers and crew.

Finally, SafePASS will also provide social and behavioural-driven solutions compatible with international legislation, standards and regulations to be recommended for future adoption while the SafePASS developments will be validated and demonstrated on industrially relevant environments. The system and subsystems of SafePASS will be tested in a shipyard environment on board a ship under construction for validation of its performance in a real environment.

2.2. High-level Architecture: SafePASS five Ecosystems

The solutions and subsystems proposed by SafePASS are discrete innovations from diverse application areas, which when combined will radically change the existing evacuation process and offer a safer, faster and more dynamic approach to the marine accident emergency response problem. Moreover, special thought has been given in making the integration of the SafePASS subsystems modular in order to enable gradual and efficient implementation.

The overall SafePASS system is designed to be passenger-centric so that it can address individual needs. This entails a thorough record and analysis of their demographic characteristics (e.g. gender, age), mobility issues or sensing impairments, current location and vital semantics that will be used as an input in crowd dynamics algorithms together with information regarding the state of the accident (current and foreseen). These two inputs and their post-processing analysis by crowd dynamics algorithms will allow for the replacement of static evacuation with a dynamic optimal route finding for each individual based on his/her location. In addition, the new LSA concepts will independently assist in the further reduction of the evacuation time and increase their operational availability. In addition, the COP and an AR application that will be available for the crew on spot guidance, for equipment handling or training, are measures aiming to reduce the Human Error Probability (HEP).

The aforementioned subsystems are components of the overarching SafePASS integrated system, comprising the following ecosystems:

- Next generation of lifesaving-appliances;
- Smart environment elements;
- Core platform;
- Risk modelling;
- An evidence-based assessment and socio-technical modelling methodology.

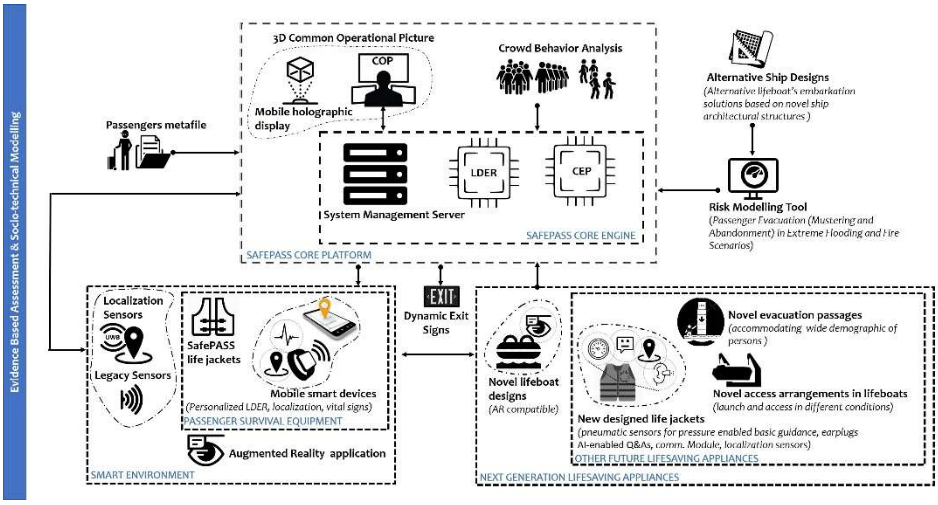

Fig. 1 SafePASS high-level Architecture

3. SafePASS Ecosystems

3.1 Next Generation of LSAs

Within the context of this ecosystem, the research efforts will be focused in the development of i) novel lifeboat designs, ii) smart life jackets and iii) alternative lifeboat embarkation solutions, based on novel ship architectural structures.

The next generation of lifeboats will communicate with the passengers PSE and send real-time information to the Core Engine about the availability status of each lifeboat and its remaining passenger capacity. In addition, innovative access arrangements and novel evacuation passages will be investigated for the purpose of making access to LSAs easier for a wider range of demographics (e.g. children, elderly, people with mobility issues) while increasing evacuation flow and timely boarding in a variety of weather conditions and hazards. The lifeboat design requirements are set to be high performance, de-skilled operation and improved inhabitability in case of extreme weather conditions. The crew ability in controlling the evacuation and confidence in using the LSA-related equipment will be supported via modern AR training techniques and real-time guidance via the Core Engine and mobile COP.

The SafePASS smart life jackets, will be fitted with an Ultra- Wideband (UWB) tag that will allow accurate indoor localisation (Al-Ammar *et al.*, 2014; Alarifi *et al.*, 2016). The life jacket will also be equipped with an earplug with a translator smart bot and be able, together with vibration actuators embedded in the jacket, to offer direction guidance to each passenger via haptics and customised audio instructions. Moreover, the lifejacket will be in communication via either Bluetooth or Wi-Fi with the core platform and SafePASS smart environment. With the exception of the lifejacket, a 'smart bracelet' and a mobile app, will ensure redundancy in terms of indoor localisation and have the potential to also provide information regarding the physiological state and walking speed of the passengers. The devices created by SafePASS will build on the knowledge derived from projects such as the FP7 eVACUATE (eVACUATE, 2017) and focus on the minimisation of cost and power consumption of the 'smart' devices.

At the same time, ship design elements that are highly relevant to the evacuation time will be reviewed to ensure the minimization of the latter. This part of the first ecosystem will examine the effect of alternative designs in the evacuation performance and will be closely associated with the novel LSAs. The method of attachment of LSA to the superstructure, the location of LSAs in conjunction with their effect on the evacuation routes and mustering will be considered and RCOs will be proposed.

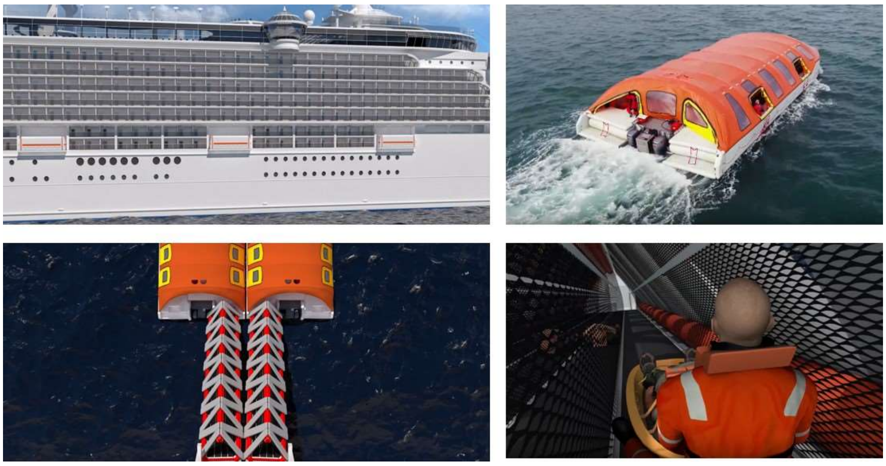

Figure 2: (up left): Possible integration of LSAs within the ship superstructure, (up right), Novel LSAs, (down left) Novel LSA Evacuation Passage exterior, (down right) Novel LSA Evacuation passage interior

2.3. SafePASS Smart Environment Elements

The purpose of this ecosystem will be the integration of localisation sensors from the wearables for the passengers (lifejacket, bracelet) with the ship legacy systems the AR- enabled crew and passenger application. The focus of this ecosystem can be classified into three subcategories: i) SafePASS PSE- enabling personalised evacuation route by using mobile smart devices and physiological monitoring, ii) SafePASS sensing sensors allowing indoor localisation techniques and iii) SafePASS Augmented Reality application. Accuracy in the position monitoring is of paramount importance in safety-related procedures and SafePASS will overcome the shortcomings of existing technologies by utilising the UWB technology in combination with Bluetooth BLE beacons proximity sensing and Wi-Fi fingerprinting. The AR application for the crew will be a tool of significant importance since it will offer advance visualised information for the handling of equipment and LSA. This app could be deployed either on a smartphone or on interactive screens/glasses. The mobile application for the passengers will be in sync with the passengers bracelet, which will be based on a developing prototype from the IN-PREP project (IN-PREP, 2018) and will display an arrow pointing the route, which leads to the muster station based on the direction the device is turned on.

2.4. SafePASS Core Platform

The Core Platform will comprise the following subsystems: i) 3D Common Operational Picture, ii) the Core Engine and iii) Crowd Behaviour Analysis.

The 3D COP will be continuously displaying a complete mock-up of the ship enriched with real time data produced and gathered by the other SafePASS components. The rationale behind the COP is to develop a tool that will aggregate, fuse and display clear and easy-to-understand information such as passenger flows and status of equipment. The primary COP system will be placed in the bridge of the vessel to enhance knowledge on situational awareness for the decision makers. The COP will be designed for cross-platform usage to make it available for use on standard flat touchscreens as well as in the form of a holographic display, permitting a radical improvement on the perception of the physical environment on-board (Tashakkori *et al*, 2015). In addition, the crew will be able to receive visual information about the location of trapped passengers and blocked escaped routes in real time. COP is intended to permit scenario-building capabilities that will assist in the visualisation of simulations and training, thus further enhancing the preparedness of the crew in safety procedures.

The Core Engine is the processor of the SafePASS system. Its main function is to run crowd dynamic simulations and calculate in real time the Location-based Dynamic Evacuation Route. The calculation of LDER is being estimated within seconds and is being forwarded for display on the COP, on the Active Exit Signs and on the mobile application for safety personnel and passengers. A Complex Event Processing (CEP) mechanism and System Management server are also included so that alerts will be issued in threating cases and for SafePASS subsystem monitoring, respectively. The Core Engine involved in all the operational stages: preparedness, detection, response and for the entire evacuation phase (Alarm to Rescue).

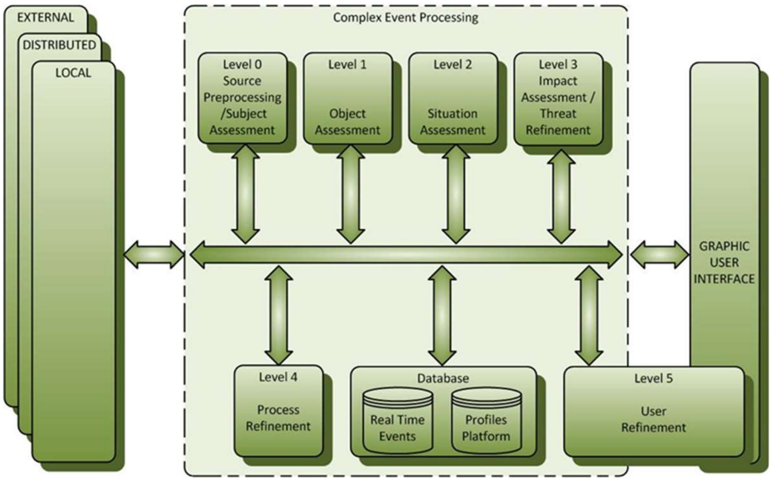

Figure 3: Typical CEP Reference architecture

The crowd behaviour analysis and the dynamic-evacuation-route simulation models will take into account the output from incident propagation forecasting models. The optimal route for each passenger not only based on the shortest route finding but also by considering the potential propagation of the hazard (flooding or fire) as this is forecasted from data from sensors or estimated a priori from relevant software. The ability to have dynamic evacuation planning based on the incident propagation forecasting and real time availability status of the LSAs, radically transforms the existing evacuation procedures.

2.5. SafePASS Risk Modelling Tool

SafePASS will develop an enhanced risk model for the passenger evacuation process, addressing both fire but also flooding incidents and covering the pre-accident, during accident and post-accident phases. It will go beyond the existing regulatory requirements, covering escape, abandonment and survival at sea, until the people reach a Safe Haven. It will utilise a mixture of qualitative and quantitative measures and assessments, depending on the data, information and knowledge available, especially in the maritime industry where quality information on accidents is lacking. The existing fault and event trees will be updated in a novel holistic risk model based on data from the ship operators and the LSA manufacturers. The Potential Loss of Life (PLL) or estimated actual loss of life in accidents will be determined based on state-of-the-art numerical simulations tools for flooding and fire scenarios. Depending on the area of operation (environmental scenario) and the performance of the LSA, the probability of survival-at-sea will be estimated. The proximity to marine traffic and Search & Rescue capabilities based on the ship location will also be accounted for in the estimation of expected fatalities, creating an overarching methodology covering the whole event from the occurrence of casualty to abandonment of the vessel and reaching safe haven. The Risk Modelling Tool will also be used within the project to quantify the impact of the proposed RCOs (novel LSAs and other SafePASS systems), assess the corresponding risk reduction and determine their feasibility after a Cost-Benefit analysis. . The RCOs will be benchmarked based on their risk reduction potential in order to provide feedback to the designers for them to rank and prioritise the solutions available.

2.6. SafePASS Evidence-Based Assessment & Socio-Technical Modelling

In order to ensure a harmonisation between the technologies/tools, that are to be developed within SafePASS, with the social, behavioural and human aspects of the evacuation problem, a socio-technical model will be introduced. The passenger behaviour in stressful situations and extreme weather conditions will be examined by employing the SCOPE methodology (Corrigan *et al.*, 2015). The stakeholders requirements will be derived to ensure that all the demographic, behavioural and social aspects are represented in the SafePASS Community of Practise (crew, safety personnel, passengers, decision makers, regulators etc). Furthermore, a Social License to Operate (SLO) will be defined to ensure that the SafePASS technical innovations can withstand social and behavioural change beyond the project's lifecycle.

3. Conclusions

The challenge of radically re-defining the evacuation process and the associated systems on large passenger ships is serious. This involves people, process, technology, organisation, management, science and engineering, all seamlessly integrated in the presence of challenging circumstances, namely serious incidents necessitating mustering and abandoning of, potentially, thousands of people in extreme circumstances and environments. Tackling this effectively, will have a significant impact on the industry as a whole. SafePASS will lead to an easier access to Marine Evacuation Systems, especially for elder people even in the presence of extreme weather conditions. The systems developed in the project will be less complex and safer to operate by the crew. With the development and evaluation of new advanced features introduced to the personal survival equipment, SafePASS will radically transform future design of several other maritime applications. All these will increase safety onboard ships and help raise confidence on LSAs among passengers and crew.

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