PROJECT DELIVERABLE REPORT

Introducing advanced ICT
and Mass Evacuation Vessel design
to ship evacuation and rescue systems

D8.7 : Operation Manual, Recommendations and Best Practices: SEM Trial

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814962"

Document Information

Grant Agreement Number	814962	Acronym	PALAEMON
Full Title	A holistic passenger ship evacuation and rescue ecosystem		
Topic	MG-2-2-2018: Marine Accident Response		
Funding scheme	RIA - Research and Innovation action		
Start Date	1st JUNE 2019	**Duration**	44 months
Project URL	www.palaemonproject.eu		
Project Coordinator	AIRBUS DEFENCE AND SPACE SAS		
Deliverable	Operation Manual, Recommendations and Best Practices Guide		
Work Package	WP8 – PALAEMON Application Field Trials, Evaluation and Outcomes		
Date of Delivery	**Contractual** M44	**Actual**	M44
Nature	R - Report	**Dissemination Level**	PU-PUBLIC
Lead Beneficiary	UAegean & OELS		
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Keywords	ICT, Ship Evacuation, Intelligent Evacuation Management Systems, Smart Evacuation, Integrated Safety Systems. Software Platform Design, Indoor Positioning, Digital Mustering, Emergency Messaging, Privacy Management, Microservices, 5G Strandalone, Artificial Intelligence, WiFi6, Beacons, RTLS		

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● Executive Summary

Safety of crew and passengers is a very critical issue for the shipping industry. The study of recent accidents such as the Costa Concordia, the Express Samina, and more recently the Normal Atlantic and the Euroferry Olympia, show that if the evacuation process is not working effectively the number of fatalities will be high. Of course, passenger ships are less involved in marine casualties and accidents than cargo ships and more than any other type of vessel. But, despite the significant progress in the safety regulation framework and in the design of consistent evacuation plans and procedures, the development and use of automation techniques in the emergency preparedness and response, and specifically in the evacuation management process, which complete the prevailing methods relying on human power and manual coordination, remains a challenge.

Emergency response failures frequently point to trapped passengers in staterooms and damaged public ship areas. PALAEMON Smart Evacuation Management approach provides a solution to such failures. It shows how new technology can be deployed to obtain significant improvements in the performance of the evacuation response. This document presents the lessons learnt and recommendations for future evolutions as those were derived from the project work and the analysis of feedback gathered by the shipping and ICT industry, and the potential end-users, during the field trials of the PALAEMON major outcomes.

1. Introduction

This is the Deliverable entitled “Operation Manual, Recommendations and Best Practices: SEM Trial”, WP8 is about the pilot application of the main project achievements, as they have been summarised in the Deliverables of the following WPs:

- WP4: PALAEMON Mass Evacuation Vessel
- WP5-WP6-WP7 (WP5: PALAEMON on-board mustering tools and services - WP6: PALAEMON Back-End Infrastructure - WP7: PALAEMON Integrated System and Technology Validation Trials.

In essence, as described in the GA and explained in the first Deliverable of WP8[1], the pilot activities should prove the feasibility and maturity of the outcomes of previous WPs through demonstration and testing in a relevant ship environment. Since the project has the two-fold objective of developing:

a) a mass centralised evacuation system, “based on a radical re-thinking of Mass Evacuation Vessels (MEVs)” and,
b) an intelligent ecosystem of critical components “providing real-time access to and representation of data to establish appropriate evacuation strategies for optimising the operational planning of the evacuation process on damaged or flooded vessels”,

the pilot action has been implemented in two locations, under different settings:

I. In Spain, in the shipyard of Astander, a key Consortium participant, where the PAALEMON MEV construct has been tested through simulations and trails in close sea
II. In Greece (Port of Piraeus) where an operational version of PALAEMON Data Ecosystem supporting the needs of the evacuation operations has been successfully deployed onboard of a passenger ship provided by ANEK Lines, an international shipping company, operating in the South of Europe, and end-user member of the Consortium (ELYROS F/B).

As a result, the work in WP8 has been splitted into two parts, carried out by different actors and under different demonstration and testing principles. Consequently, the reporting on WP8 piloting action has been also organised in two groups of deliverables:

WP8 Deliverables - Series A (MEV)	PALAEMON Application Field Trials, Evaluation and Outcomes - Mass Evacuation MEV
WP8 Deliverables - Series M (SEM)	PALAEMON Application Field Trials, Evaluation and Outcomes - Smart Evacuation Management | SME (where the term Smart Evacuation Management refers to the operational version of PALAEMON Data Ecosystem

This Deliverable summarizes the results of PALAEMON operations, especially the piloting and field testing activities, draws lessons learnt from the project work and the piloting experience and provides recommendations for the future.

[1] PALAEMON D8.1 Report on Pilot Sites Preparation and Assessment [1]

- **2. The Challenge to Address in Ship Emergency Management: the Role of the Efficient On-board Information Management in the Redesign of the Emergency Response**

Ship evacuation is a complex procedure in which many people work closely together and depend on each other to ensure safe and efficient operations. Today's approaches to emergency management evolve around the passengers and the ship's crew. EU and global; legislation on passenger safety has been put in place over time. regularly and following accidents. The shipping companies and the practitioners have accumulated important knowledge on how to plan, maintain and operate specific procedures for passengers safety and frequently test the evacuation process through the training of crew members and regular drills. More importantly, the IMO guidelines now require new passenger ships to conduct evacuation analysis, that means providing estimations about passenger flows and possible congestion conditions and determining the total evacuation time, all based on computational simulation of crowd dynamics, pedestrian movement & behaviour. This human-centric emergency approaches made ship voyages remarkably safe in the last years.

However, with the increase in the number of carried passengers, and the increased size and variety of materials used in vessels, it is reaching its limits. Passenger ships progressively include more hotel accommodation facilities, and large multi-deck public spaces that should be fitted and operated inside the constrained vessel structure. The use of aluminium and the construction of extensive glass edifices may easily cause a deterioration of onboard safety. The management of high numbers of passengers, a problem by itself, can be challenging in these conditions. Coupled with factors such as the passengers' movement on board, unpredictable weather and navigation in conditions of traffic and waterway complexity, and the effect this may have on the vessel's motion, the risk of incidents occurring can be higher. Especially when dealing with a fast-escalated emergency, which may require a partial or complete evacuation of the ship. In fact, and albeit the progress made, the study of the evacuation cases through the history of marine incidents and emergency response provided, shows that the performance and efficiency of the evacuation process (which is the "last line of defence against human losses") remains a critical challenge and a complex "problem-to-solve".

Transforming safety management and emergency response into the "next generation" requires complex human-integrated systems that provide better monitoring of the evacuation process and create situational awareness on ships. At both levels, Previous observational, experimental and simulation studies on passengers' evacuation showed that during an emergency, passengers may pay attention to an alarm but they also have the tendency to investigate the situation before they take the decision to move to the designated assembly stations. They usually look for information that could explain to them what the alarm signal is about, asking other passengers, or wait until they hear the confirmation on the ship's Public Address (PA) system, or from the crew. Furthermore, passengers do not react uniformly; their attitude depends on their individual characteristics (sex. age, body mass, language, reasoning, perseverance, anxiety etc.), particularly when the impact of the emergency is not yet visible.

Other observations, from evacuation drills and experimental trials, reveal the fact that the "response time" of passengers, i.e. the time needed to select the pathway to the assembly stations also depends on several factors, such as the type of vessel (for example, cruise vs RoPax), the surrounding environment, the presence of crew that provides instructions and, in the absence of such instructions, the behaviour of neighbouring passengers, the location of the passengers when the alarm is sounded (public space or cabin) and of course, their personal characteristics and cognitive abilities.

In brief, the capacity of passengers to move quickly to the assembly station via a short pathway increases as they accumulate information and from the information value received by other informational sources. At another level, the amount of data that the command team has to deal with increases proportionally with the number of passengers on board and the complexity of the emergency situation. Consequently, information overload combined with a lack of overview and the resulting stress from a shocking event such as the evacuation of a ship, can severely reduce cognitive performance and impair decision-making ability. A further difficulty is the dispersion of duties during evacuation. A ship is fragmented in zones. Each zone contains sectors overseen by different emergency or response teams. Direct voice communications via radio are generally the norm to make tactical interventions, provide the crew with the necessary information throughout the entire evacuation process and coordinate their action. For decades, ships' captains and command teams have depended on walkies-talkies as means for necessary intra-communication during emergencies. But new technologies now deliver enhanced communications and connectivity. such as MCPPT and MCX (MCData, MCVideo), that emergency teams need to improve situational awareness, increase collaboration, simplify operations and monitor task distribution in real-time.

The PALAEMON project highlighted the complexity of the ship evacuation problem and introduced a large scale digital assistance system called Smart **Evacuation Management platform** to detect friction points in the emergency response and the evacuation process by systematically analyzing passenger surveillance data to provide the command team and crew with better situational awareness onboard and ensure safe operations. The SEM platform provides, in addition, a standardised data interface layer to integrate with other vessel's systems of sensors and radars to provide an **Integrated Safety System** for risk monitoring and performance management.

● 3. Smart Evacuation Management Approach to Emergency Response: Architecture and Functionality (in brief)

The Smart Evacuation Management (SEM) platform combines advanced passenger traceability with online crew operation management to make real-time adjustments to the Marine Emergency Evacuation response. It impacts the ship's evacuation capacity through semi-automated process management, continuous monitoring, instant crew coordination and decision support. The platform provides sufficient flexibility to cope with the broad range of incidents that may occur during marine emergencies such as fire, flooding, or other hazards that pose a threat to the safety of people on board. More specifically, the SEM platform uses

a combination of Bluetooth Low Energy (BLE), Wi-Fi 6 and 5G technologies to provide state-of-the-art location and low-latency data transmission services to make evacuation response in passenger ships more efficient.

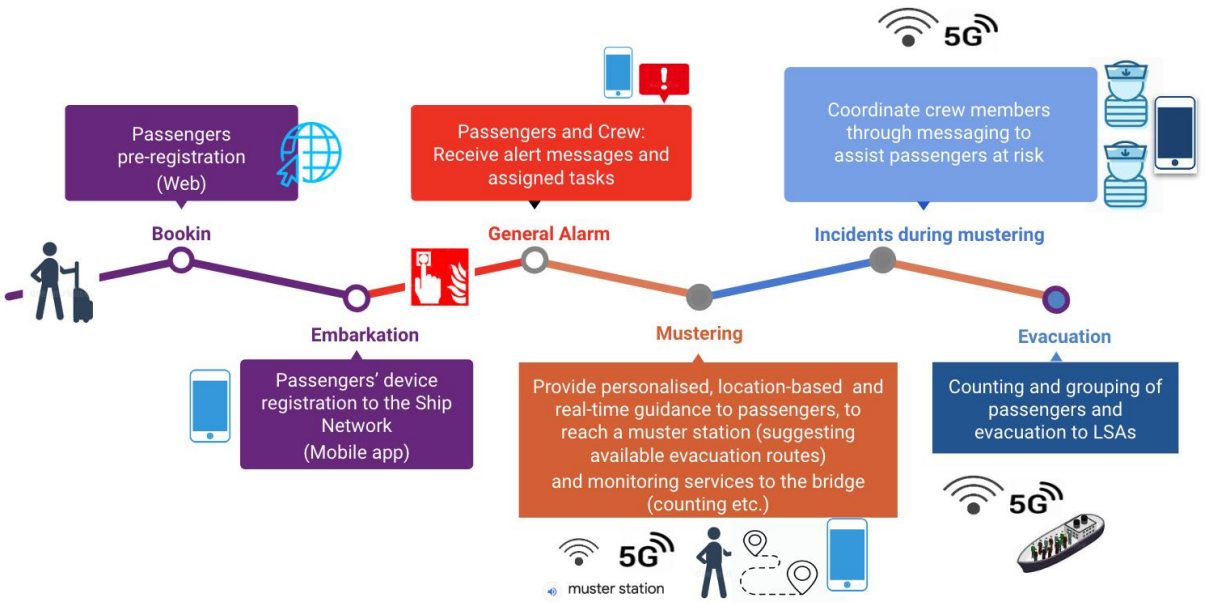

Figure 1:

In more details, the SEM platform utilises a microservices application architecture to facilitate semi-automated process management, monitoring, and decision support after an emergency is detected, and throughout the evacuation management process, The application architecture (SEM Core platform or SEM platform applications) orchestrates two onboard network infrastructures (PaMEAS-Network) that are specifically suitable for emergency situations:

- A "sensing" Wireless Network for real-time people location tracking, made of beacons and Wireless Access Points (APs) - PaMEAS-Cell.

- A private 5G Standalone Cell Network for emergency messaging (alerts, notification etc,) and real-time communication between the Bridge (and/or the land-based control authorities), the crew and the passengers (enabling passengers to send emergency feedback messages - PaMEAS-Cell.

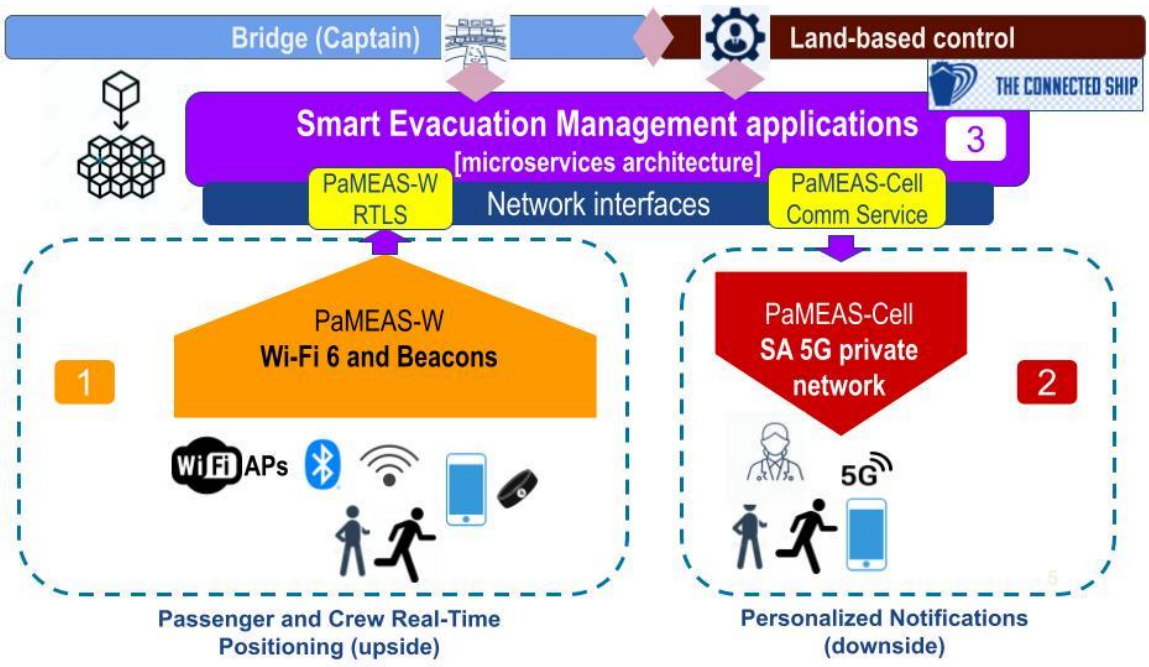

Figure 2:

In fact, the Smart Evacuation Management (SEM) approach to emergency management shows how new and cutting-edge ICT technology can be "embedded" in a platform and deployed onboard a ship to provide new functionality, to obtain significant improvements in the quality of the emergency response and the performance of the evacuation process in passenger ships (Ro-Pax etc.). The SEM platform:

- Instantly tracks the location and identifies passengers during the evacuation of dense crowds on passenger ships, while enabling personalised, high-reliability, low-latency emergency messaging notifications to be sent to passengers in an effort to:
  - Alert the passengers of the emergency situation,
  - Guide them to their designated mustering stations (based on their current location and in accordance to the ships evacuation plans).

- Allows for real-time task assignment to crew members via a Mission Critical Push to Talk (MCPTT) infrastructure (which replaces traditional walkie-talkie devices), and monitors their task performance, to optimise the coordination between the Bridge and the crew.

- Provides the Bridge and Land-based control authorities with a clear picture of the evolution of the evacuation process through continuous monitoring of the mustering and evacuation operations, during the whole emergency management process (from the initial stages of accident reconnaissance to the embarkation of passengers and crew to LSAs).

- **4. Lessons Learnt (from a Field Trial)**

The SEM platform architecture provides an improved responsiveness for real-time passengers and crew location tracking and offers the possibility of a very fast emergency communication service to interact with the passengers and crew in different formats (messaging, voice, video) and service types (emergency alerts and notifications, emergency feedback messages, reverse-PTT, MCPTT-MCX etc.). To evaluate the performance and impact of the SEM platform in the emergency response, the platform has been deployed and tested in a trial field, onboard a passenger ship, the ELYROS Ferry, offered by ANEK Lines, an international shipping company operating in the South of Europe, and end-user member of the PALAEMON Consortium.

Figure 3:

The trial was carried-out as a typical evacuation drill, which started with a smoke alarm, shown on the Bridge Dashboard of the SEM platform, which was immediately investigated by the emergency response team, under the supervision of the Bridge. Based on their report, the Master decided to immediately launch the evacuation plan. Next to the activation of the sound alarm, crew and passengers were required to implement their emergency procedures, and move into the designated mustering stations, and later on to the embarkation areas, before they get in the available LSAs. In short, the trial simulated the handling of a fire situation breaking but with the assistance received from the onboard deployment of the Smart Evacuation Management platform.

Figure 4: Technology-assisted mustering with passengers using their mobile app to be alerted and oriented towards the designated muster station

The whole operation was observed by invited experts in the field and the Pilot Execution and Evaluation Team (PEET) which registered and evaluated the outcomes (qualitatively and quantitatively), collected the experts' feedback and reported on proceedings. The experts followed and reviewed the contribution of the SEM platform in the execution of the evacuation management tasks via a pilot deployment of the platform on a part of Deck 9 of ELYROS Ferry, in an area of 300 m^2 which mainly includes blocks of passenger cabins, recreational rooms, service rooms, staircase landings etc., all spread along corridors of more than 40m each.

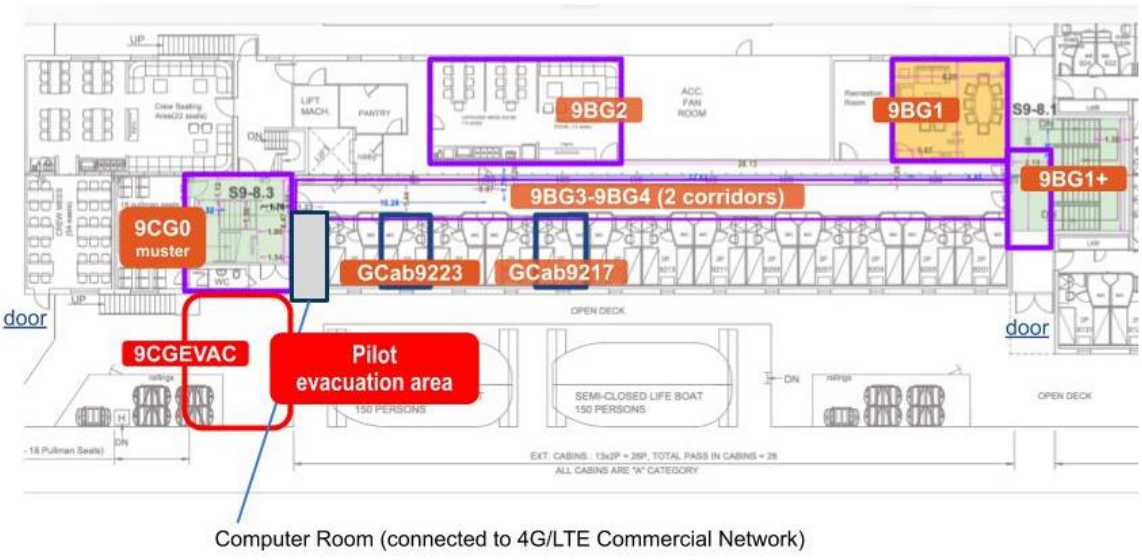

Figure 5:

Within the pilot area, two different types of network have been deployed: a) a Wireless network for people tracking consisting of 10 BLE beacons and 5 Wi-Fi Access Points, b) a 5G Standalone private network for low latency and high reliability , composed from a 5G Core component (5G Core) and a RAN network with 3 Radio Dots.

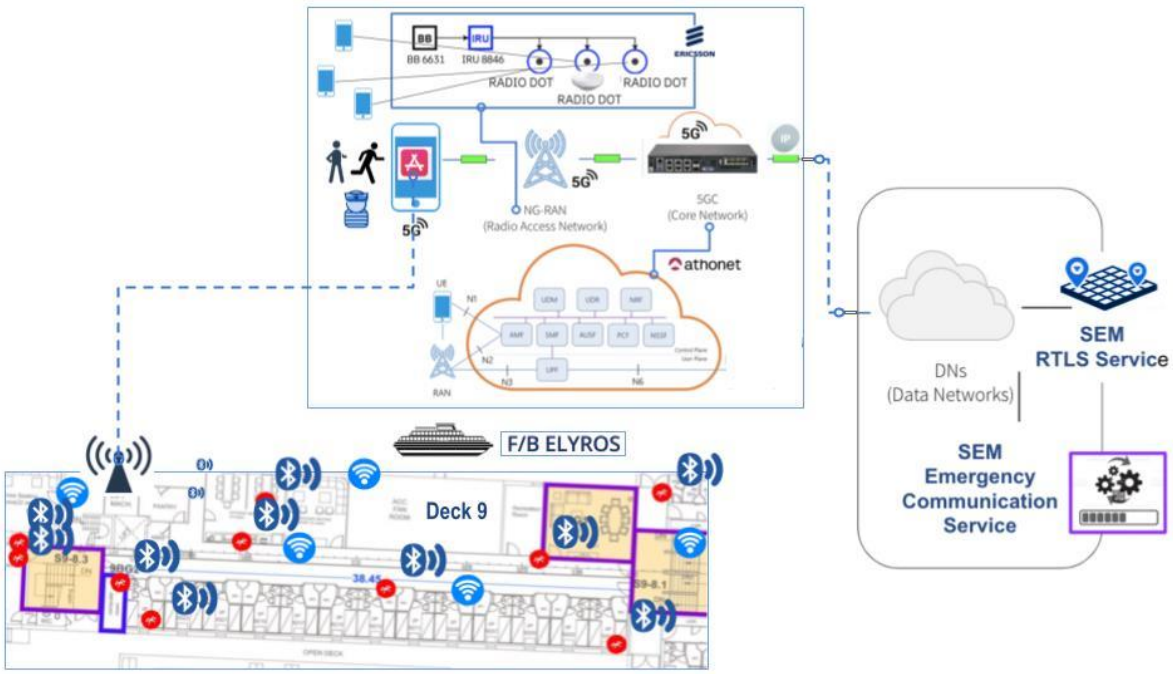

Figure 6:

These two networks work together with the software applications that make the platform as shown in the following Figure:

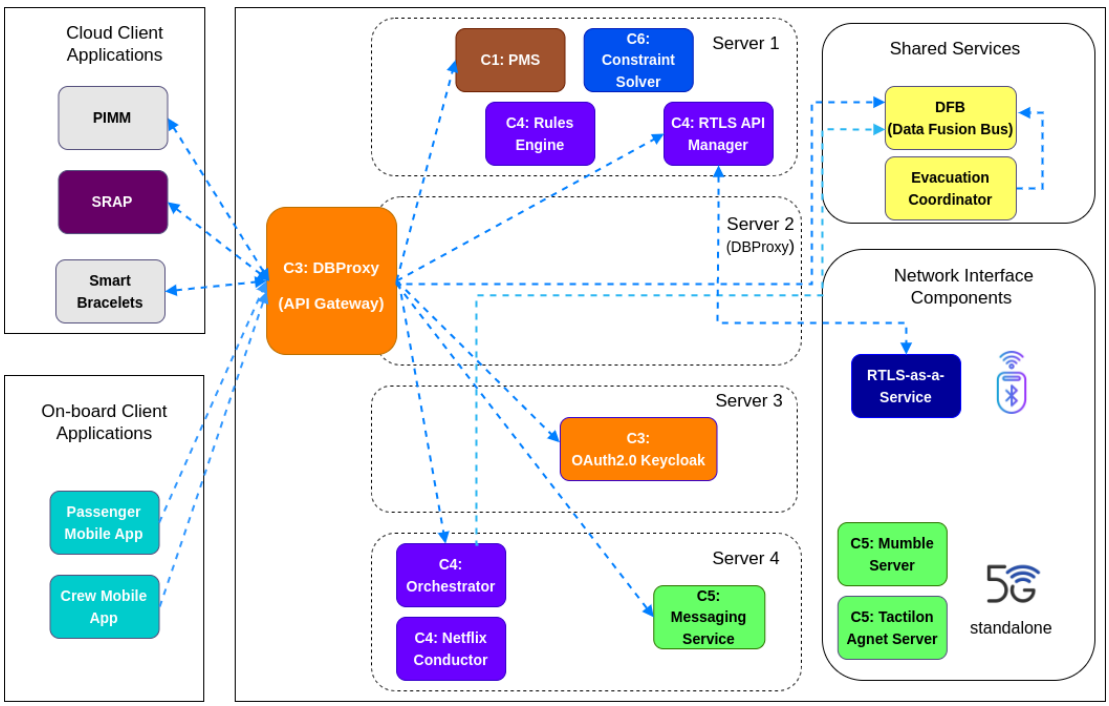

Figure 7:

(*) Note:

A video recording from the pilot implementation which illustrates the different deployed scenarios (Handling a fire incident detection, Instructing the crew to assume emergency posts, passengers receive emergency alerts, Real time personalized mustering instructions, A trapped passenger requests help, Alert a lost passenger to avoid a damaged area, Identifying rogue passengers, Preparation for Embarkation to the LSAs etc,) and captures the feedback of experts is available on YouTube: [(The Movie) PALAEMON Smart Evacuation Management on-board v2.0 March 2023]

The PEET team held a short "Lessons Learnt and Conclusions Workshop" after the end of the pilot to analyze observations and data, from which most of the insights in this document are drawn. The first issue to highlight is that there are several components and technologies already available in the market, from the Decision Support Systems to location tracking technologies and 5G private networks for industry 4.0 applications. However, their integration in an Intelligent Evacuation Management System (IEMS), which can interoperate with ship legacy systems, sensors for monitoring of critical equipment and fuel consumption and ship-shore communications systems, is still a challenge with a lot of open applied research issues that need to be addressed. PALAEMON makes clear that digital technologies are mature enough to enhance safety and emergency management but an Integrated Safety System, aligned with human-centred design, robust and resilient, would need: a) additional focus to system integration, eventually under the perspective of using AI in microservices and, b) a research-innovation-application iterative process in place for continuous safety improvements. It is also important to recognize at the early stage of projects like the Smart Evacuation Management platform, that further involvement from the policy-making community, maritime authorities and shipping industry, and study/experimentation with various adoption strategies (in the form of advanced pilot applications with TRL 7), should be put in place to increase visibility and impact.

In general, the original project timelines have proven to be optimistic, the time from design to implementation and testing needs is not always short and one delay at one level could cause unforeseen project roll-on effects. We understand now that this type of integration projects would be not considered as a single project, but as a portfolio of several small interdependent projects, managed by a project management board, focusing on clearly defined design, development and testing documents that follow the project progress.

Having said that, we consider that the feasibility proof for the Smart Evacuation Management integration approach, as shown in the pilot, to be a strength, and as such it has been perceived by the invited field experts. More specifically, the lessons we draw from the field trial. helped us to identify issues that need more focus and additional research effort.

First, we believe that these technologies need to be deployed and tested in a real “industrial environment” but perhaps onboard pilots are not the best place for that given the operational constraints imposed by the maritime regulation on passenger ships when they navigate at sea. It is therefore necessary to build research and experimentation facilities on the ground that simulate a ship with multiple decks, its internal structure and the effect of the weather and sea conditions, to be used as testbeds for technology trials.

Second, the users evaluate the use of their mobile phones positively as the primary source of interaction with the Smart Evacuation management platform. However we must stress that this evaluation should take in consideration other issues such as the life of battery, the level of battery consumption due to the activation of a passenger mobile app etc, which has not been investigated by the pilot. Further validation is required and research towards applications that can monitor the battery life and the activation of the mobile app in the mobile devices of passengers and crew, alert them in the case of any interruption, and inform the Command Team, periodically and when an emergency appears, about the status of the passengers’ mobile devices.

Third, the modern communications networks, such as the Standalone 5G infrastructures and the high speed/low latency Wi-Fi 6 technologies, operate in a ship environment according to the expectations, in a highly reliable manner without requiring very costly investments in new facilities. They are a very efficient provider of ultra-efficient two-ways emergency communication services for both interacting with the passengers and for the intra-communication between Bridge and the crew (and between the crew).

Fourth, current location “sensing” technologies, such as BLE beacons, can be deployed onboard a passenger ship, to effectively cover very different areas, from the upper decks hosting accommodation and recreational facilities, amenities and services (including the open spaces accessible to passengers) to the very low decks garages, at an affordable cost. In addition, RTLS systems for precise indoor location tracking are very cost-effective, easily integrated with other safety and emergency management technologies, and increasingly provided as-a-service. The location accuracy we have obtained was slightly under 3 metres in most cases. Furthermore, the location of the persons tracked was updated approximately every 5 seconds enabling the generation and transmission of appropriate mustering instructions from the SEM platform. However, to achieve these results extensive calibration actions were required. Also, the surfaces of the ship pose significant challenges for the state-of-the-art location systems (causing extensive scattering of the signals reducing the accuracy achievable). Signal reflections have been studied as part of the effect of increased crowd densities causing the reflection and attenuation of the radio signals to change constantly. In ship environments, the degree of reflections due to the materials of the ship’s walls is much more significant and reflections play a much bigger role for the training of good models than in other types of venues. As a result, the network deployment needs to be specifically designed to take reflections into account, to ensure the minimization of the propagation of the reflections to achieve good results. Further research in this regard is certainly required.

- **5. Reflections and Recommendations for the Future**

Finally, we reflected on the hybrid deployment approach of the Smart Evacuation Management platform with some ICT modules deployed on the cloud, the applications part (accessible over the internet) and some on-board the ship (the networks part).

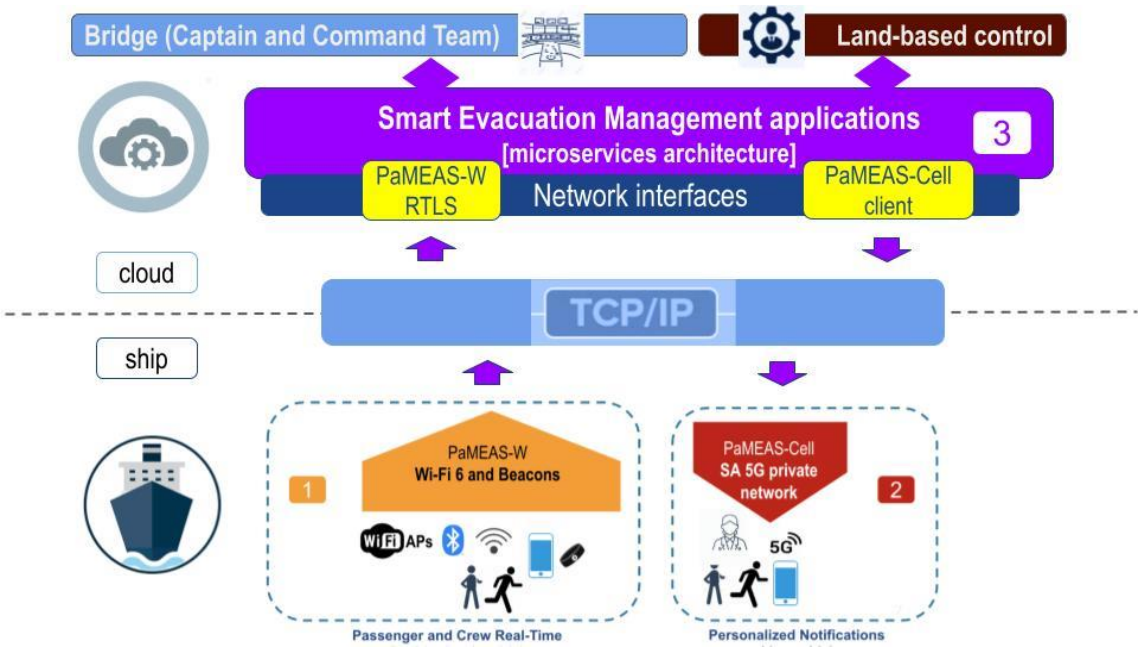

Figure 8:

Given the extreme conditions that prevail during the implementation of the emergency response, and of course in a ship evacuation event, human cognition and judgement (although critical for the right operation of the system) can be blurred or totally obscured from stress and/or panic, eventually leading to wrong decisions. The PALAEMON research has found that for the proper functioning of a technology-aided evacuation management system there must be sufficient collaboration between the cognitive agents of the system. We therefore propose a collaboration mechanism grounded on the concept of distributed cognition, where intelligence does not lie just in the single entity but also in the interaction with the other cognitive components in a system. We apply this idea to ship emergency response and evacuation management, proposing a system distributed into two cognitive entities: the crew on board (the Bridge and the Command Team) and, a Land-based Control Authority (LbCA), ashore, that could respond in a more cool-headed and organized manner in a distress situation. The two entities together contribute to the safe evacuation of a vessel assisted by the Smart Evacuation Management platform. This account of evacuation management intelligence differs from the mainstream research effort on highly crew-centric systems and integrates with the concept of a Shore-based Control Centre (SCC) which can remotely operate an “autonomous ship.

Applying the idea of distributed cognition to emergency response and ship evacuation means that the Bridge and Land-based Control Authority (LbCA) entity ashore must collaborate

actively, under the prime responsibility of the Captain. This requires establishing and maintaining enough intelligence onboard (not necessarily with a high degree of cognition) to provide: (a) an “ear to the ground” when coordinating a response to emergency events, and (b) the ability to relay the necessary information ashore in real time.

The network part of the Smart Evacuation Management platform is the “ear of the ground”, as the pilot application on ELYROS Ferry reveals. The development of advanced network infrastructures (5G, Wi-Fi 6, BLE beacons) is technically feasible with state-of-the-art technologies and economically affordable. We expect that in most cases these networks will be deployed by the telecom operators to provide Internet connectivity to the passengers which are their subscribers. The shipping companies should claim and eventually bear the cost of using a “network slice” exclusively for the emergency communications. As far as the relay infrastructure is regarded, the PALAEMON research proves that the VHF Data Exchange System of Thales (VDES[2]), an emerging radio-communication system which operates between ships, shore stations and satellites at higher rates compared with the existing AIS system (Automatic Identification System).

With the support of Smart Evacuation Management platform, Agnet[3] for mission-critical group communications and VDES for ship-shore communications, the evacuation task can be more effectively achieved through the interaction of the two cognitive entities, as each contributes with a different (if not complementary) set of cognitive skills. In a ship emergency and evacuation event the remote agents should avoid overwhelming the Command Team while they are performing well, and gently intervene (not to cause additional stress or panic) if there is needs for specialised rescue services in complex incidents, or if the crew leads the evacuation process to an unsafe condition (the remote agents act generally in a more rational manner from the safety of their distance).

[2] See: (7) (PDF) VHF Data Exchange System (VDES): An enabling technology for maritime communications (researchgate.net)

[3] Agnet - professional communication solution from Airbus (securelandcommunications.com)

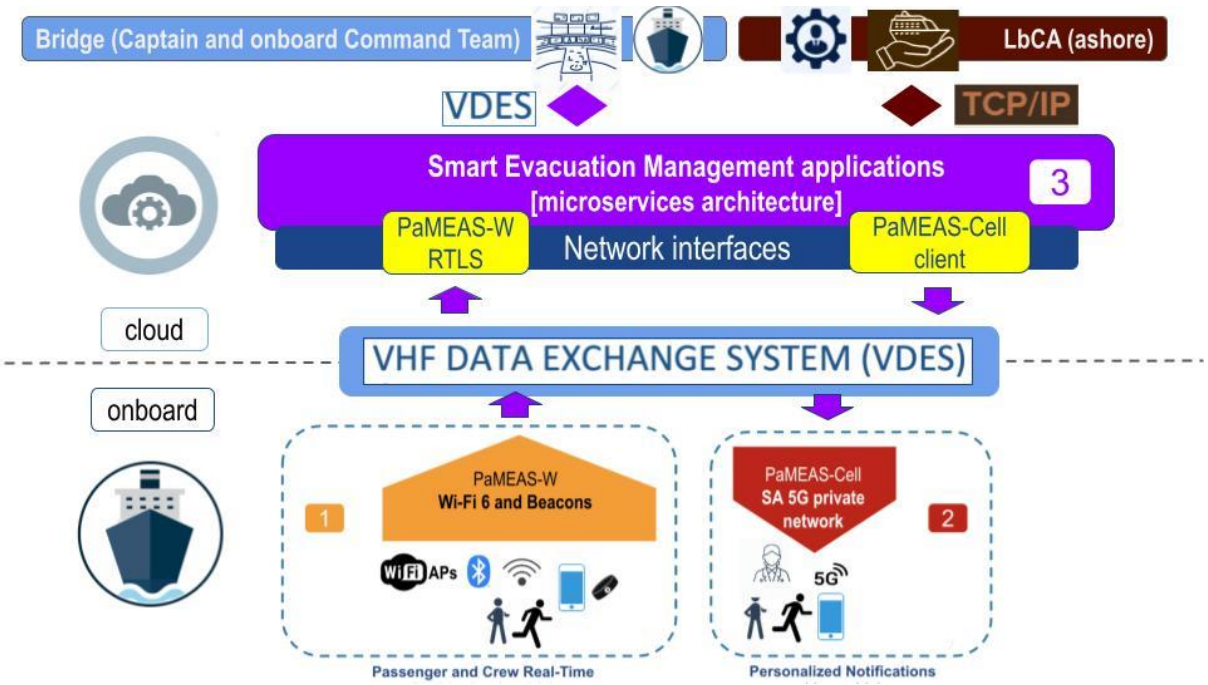

Figure 9:

It stems from the above that with the aid of the Smart Evacuation Management platform and VDES system, the distributed cognition concept can be applied in the case of ship evacuation. Although technologically the realization of such a system is seemingly feasible, however, the greater challenge lies in how to structure the remotely operating Land-based Control Authority for emergency governance, to effectively contribute to the safe evacuation of a vessel. This requires a concept and a framework for governing complex emergencies at sea.

Our recommendation is that this framework should be implemented as a mechanism that reconciles the need for centralized coordination among different responders to an emergency situation (crew on board ship in distress, coast guard, S&R teams, medical response units, etc.) while retaining flexibility to mutually adjust evacuation operations to quickly changing conditions. However, for such an undertaking to be successful, it should have significant governmental and industry support, perhaps not only at the national but also at the European level. In fact, a separate “emergency governance” entity as such would likely take the form of a hybrid public-private partnership. Another possibility is the formation of a European Commission (EC) chartered, not-for-profit corporation that would operate “locally”, in collaboration with the Member States.

In the EU, passenger shipping policy, system management, and infrastructure planning and procurement are deeply intertwined. The European Commission has consistently promoted safety at sea as a fundamental goal of European policy. This policy goal finds expression in the numerous decisions and rules that collectively govern the cruise industry, coastal shipping, shipbuilding, seafarers training, and sea traffic control operations. It is common ground among these industries that the European Commission is not contemplating turning over sea safety operations to a for-profit company seeking to earn a return on investment. However, giving up

some control of the maritime emergency operations to a number of carefully selected, local Land-based Control Authorities, coordinating at the EU level, could more easily develop effective performance measures regarding evacuation management that would also encourage shipowners to invest in upgrading their onboard safety systems. Of course, such an emergency governance entity, whatever “distributed” form it may take, would be financially self-sufficient, allowing the entity to be independent from any appropriations cycle.