PROJECT DELIVERABLE REPORT

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

D8.4-D8.5 PALAEMON application trial SEM (Greece)

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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Contents

Abbreviations

6DoF	6-degree-of-freedom
AE	Acoustic Emission
API	Application programming interface
AR	Augmented Reality
CMS	Condition Monitoring System
CPRI	Common Public Radio Interface
COTS	Commercial Off-The-Shelf
DFB	Data Fusion Bus
DoA	Description of Action
DSS	Decision Support System
eCPRI	Evolved Common Public Radio Interface
EMSA	European Maritime Safety Agency
EPC	Evolved Packet Core
FMAGDM	Fuzzy Multi-Attribute Group Decision Making
GA	General Alarm
GCS	Ground Control Station
HMI	Human Machine Interface
ICT	Information Communications Technology
IMO	International Maritime Organization
IMU	Inertial Measurement Units
IOT	Internet of Things
ISM	International Safety Management
ISO	International Organization for Standardization
LCA	Life cycle assessment
LSA	International Life-Saving Appliance Code
MEV	Massive Evacuation Vessel
MOB	Man Overboard
NDT	Non-destructive tests
PaMEAS	Passengers Mustering and Evacuation Process Automation System
PIMM	PALAMEON Incident Management Module
RCC	Rescue Coordination Centres
SB	Smart Bracelet

SHM	Structural Health Monitoring
SME	Small and medium-sized enterprises
SMS	Safety Management System tool
SOLAS	International Convention for the Safety of Life at Sea
SOP	Standard Operating procedure
SRAP	Smart Risk Assessment Platform
STCW	Standards of Training, Certification and Watchkeeping for Seafarers
TOPSIS	Technique of Ordered Preference by Similarity to Ideal Solution
TRL	Technology Readiness Levels
UAS	Unmanned Airborne System
UAV	Unmanned Aerial Vehicle
USAR	Urban Search and Rescue
VDR	Voyage data report
VHF	Very High Frequency
VR	Virtual Reality
VRG	Voyage Report Generator
VTOL	Vertical take-off and landing
VTS	Vessel Traffic Services
Weather Forecast Tool	WFT
WSM	Weather Service map

Executive Summary

The objective of deliverable D8.4-D8.5, titled "PALAEMON application trial SEM (Greece)", is to provide a detailed account of the steps taken to carry out the Evacuation and Mustering Piloting exercises on the F/B ELYROS of ANEK, including any necessary preparations leading up to it. Additionally, this deliverable aims to document the outcomes and insights obtained from these exercises and provide an evaluation of the results of the runs.

Specifically this deliverable, "PALAEMON application trial SEM (Greece)," is the verification of the Milestone 11 of the PALAEMON project (Pilot Use Cases Demonstration), associated with the tasks 8.4 (Passengers Evacuation Demo) and 8.5 (Passenger Mustering Demo). Although Evacuation and Mustering were originally assumed to be separate processes, it became clear that they are closely connected and must be evaluated together. To achieve this, the two tasks were unified and validated in the context of a single Mustering and Evacuation scenario, which was executed on a single vessel (ANEK F/B ELYROS) instead of two separate vessels (as was originally planned).

The objective was to test the performance of the PALAEMON Smart Evacuation Management (SEM) platform in an integrated manner by configuring and integrating the system on ANEK F/B ELYROS and deploying specific equipment in controlled areas (Wi-Fi Access Points, BlueTooth Beacons, Radio Dots etc). In addition, two mobile applications were provided to passengers and crew members to interact with the SEM platform. The piloting actions were carried out in two separate runs. The first run, called the pre-piloting phase, aimed at the testing of targeted aspects of the system and together with validation tests ensuring that the deployed system supported the second run. The second pilot run involved the execution of specific mustering/evacuation scenarios on board F/B ELYROS to validate the system in vivo. By conducting these two separate runs, we were able to confirm the feasibility of the assessment activities planned (first run) and evaluate how effectively the system optimised the passenger evacuation process, as tested by end users (second run).

1. Introduction

This is the Deliverable entitled “PALAEMON application trials 2 and 3: SEM Trial”, part of PALAEMON WP8 “Application Field Trials, Evaluation and Outcomes”, the last Work Package of the project. WP8 was 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 and explained in the first De;liverable 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 PALAEMON 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 organized in two groups of deliverables:

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

[1] PALAEMON D8.1a Report on Pilot Sites Preparation and Assessment: SEM Trial

In short, the Deliverables of WP8 are segregated in two distinct groups, the first reporting to the MEV pilot action and the second one to the SEM pilot, as shown in the following Table:

WP8 Deliverables - Series A (MEV)					
#	**Deliverable Title**	Lead beneficiary	Type	Dissemination level	Due Date[2]
D8.1a	Report on Pilot Sites Preparation and Assessment: MEV Trial		R	Confidential	M44
D8.2a	Operational Pilot Sites: MEV Trial		R	Confidential	M44
D8.3	PALAEMON application trial 1: MEV Trial		R&DEM	Confidential	M44
D8.6a	PALAEMON Consolidated Pilots Evaluation: MEV Trial		R	Public	M44
D8.7a	Operation Manual, Recommendations and Best Practices: MEV Trial		R	Public	M44
D8.8a	Public release WP8: MEV Trial		R	Public	M44

WP8 Deliverables - Series B (SEM)					
#	**Deliverable Title**	Lead beneficiary	Type	Dissemination level	Due Date[3]
D8.1b	Report on Pilot Sites Preparation and Assessment: SEM Trial	UAEGEAN	R	Public	M44
D8.2b	Operational Pilot Sites: SEM Trial	UAEGEAN	R	Public	M44
D8.4-5	PALAEMON application trial 2 and 3: SEM Trial	UAEGEAN	R&DEM	Public	M44
D8.6b	PALAEMON Consolidated Pilots Evaluation: SEM Trial	UAEGEAN	R	Public	M44
D8.7b	Operation Manual, Recommendations and Best Practices: SEM Trial	UAEGEAN	R	Public	M44
D8.8b	Public release WP8: SEM	UAEGEAN	R	Public	M44

[2] See Second GA amendment
[3] See Second GA amendment

The document that follows is Deliverable D8.4-5, entitled: “PALAEMON application trial 2 and 3: SEM Trial”, the **third of Series B (SEM) of the WP8 Deliverables** (submitted subsequently to D8.1b Report on Pilot Sites Preparation and Assessment: SEM Trial and to D8.2b Operational Pilot Sites: SEM Trial). It provides a detailed overview of the pilot implementation from a technical and process automation perspective. An important part of this Deliverable is to illustrate the actions that have been taken to:

a) **Deploy the SEM platform onboard a passenger ship, within a specific area of a ship deck which represents the typical layout of a modern vessel accommodation space**. The designated area for pilot deployment includes blocks of passenger cabins, recreational rooms, service rooms etc. Usually, cabins and rooms are spread along corridors of more than 40 m each. Corridors are connected on both sides with lobby areas or large staircase landings. These intermediary spaces serve as gateways between two compartments of the same deck, or between decks.
b) Demonstrate and validate the capacity of the SEM platform to act as an effective support to the realisation of the evacuation scenarios/exercises described in D2b “D8.2b Operational Pilot Sites: SEM Trial". The successful implementation of these scenarios/exercises will make the SEM platform capable of reaching a Technology Readiness Level TRL5 (“technology validated in a relevant environment”).

From this point of view, D8.4-5 is the cornerstone of the WP8 Deliverables, the essential report on the pilot implementation (together with Deliverables 8.1b and 8.2b), and the basis for extracting more generic conclusions on the applicability of the Smart Evacuation Management approach in the two Deliverables that follow: D8.6b “PALAEMON Consolidated Pilots Evaluation: SEM Trial” (detailed validation results, feedback from the end-users and impact assessment); D8.7b “Operation Manual, Recommendations and Best Practices: SEM Trial” (lessons learnt and recommendations for future developments); D8.8b Public release WP8: SEM.

This Deliverable is the outcome of Tasks T8.4 and T8.5 (entitled “Passenger Evacuation Demo|” and “Passenger Mustering Demo”, respectively) which, in the progress of the project, have essentially merged in one single Task. Although the evacuation and mustering capacity of PALAEMON Smart Evacuation Management approach were originally assumed to be demonstrated in two different vessels and conditions, it became clear that they are closely connected and must be implemented together. In fact, the project has progressively developed a finer perception of the whole evacuation process and its multiple stages and facets, which starts with the report and reconnaissance of an accident and ends, in the case that the evacuation plan is launched, with the embarkation of passengers and crew to the available life-saving appliances. The SEM platform has the capacity to support the whole life-cycle of a ship evacuation process, including the management and monitoring of the mustering sub-process, and every other evacuation procedure in accordance with the ship evacuation plan[4].

[4] See also: D8.1b Report on Pilot Sites Preparation and Assessment: SEM Trial

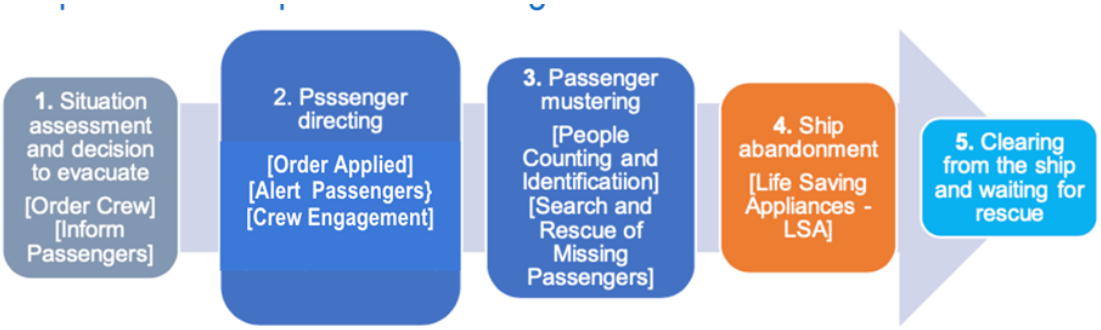

Figure 1: The evolution of a ship evacuation process

In more detail, this Deliverable includes the following chapters:

Chapter 2 briefly presents a short overview of the PALAEMON SEM platform, the software/hardware project ecosystem supporting the Pilot Action.

Chapter 3 presents an operational definition of the implemented Pilot (Trial), in terms of objectives, expected results, context and location.

Chapter 4 offers an overview of the Pilot Core scenario (a fire on board) and illustrates in detail the pikot implementation ecosystem.

Chapter 5 defines how the Pilot Core (Fire) Scenario was implemented via specific scenario/exercise executed on the premises of ELYROS F/B (Pilot Demonstration)

Chapter 6 presents a short report from the Pilot Demonstration (an extended evaluation of the Pilot results is presented in D8.6 “PALAEMON Consolidated Pilots Evaluation: SEM Trial”).

2. Smart Evacuation Management (SEM) Platform: overview and functionality

2.1 The “puzzle” of the evacuation process performance and the concept of Intelligent Evacuation Management Systems

The PALAEMON project has as its main goal the provision of a comprehensive solution for the evacuation management of passenger ships (Ro-Pax). Currently, the evacuation process is mainly carried out manually and faces significant constraints. Emergency tools rely on sound alarms and vocal messages, which do not always provide clear indications and guidance on how to reach a muster station. Emergency communications between the Bridge, accident frontline personnel, and crew members are limited by the capabilities of traditional (or digitised) walkie-talkies. Emergency response monitoring is spontaneous and weak, not systematic. The factual information obtained from the situation by the Bridge during the evolution of an emergency is neither aggregate nor consistently accurate, and the guidance and further information from the Bridge to the passengers, beyond the generic messages announced by the Public Address & Voice Alarm System, was quasi-absent in the these cases where an accident evolved to a disaster and imposed the rapid evacuation of a ship.

In fact, the evacuation process can quickly bifurcate to a "coordination failure"[5] among the Bridge, the crew and the passengers, as exemplified by the surrounding confusion in the recent case of the evacuation of the Greek-Italian ferry Olympic which burst into flames after a fire. As *The Guardian* reported, *"the Italian finance police vessel's captain, Simone Cicchetti, told the Italian news agency Ansa (describing the dramatic moments when passengers were told to evacuate as flames licked the sides of the ferry): "When the fire broke out, the ship's commander went around the cabins and brought the passengers together on a single desk. Then he gave the order to abandon ship (but the evacuation wasn't a stroll in the park)…" [6]. Besides, s*everal days after the fatal accident, the authorities did not have a clear view on the number of missing people: *"... When asked about the prospect of missing passengers, a spokesman at the Greek shipping ministry overseeing the rescue operation told the Guardian nothing could be ruled out.. We don't have a clear picture and until everyone is counted and identified we won't have one", the spokesman said…"[7].* In another evacuation case, in the ravaging sinking of the MS Estonia, one of the deadliest maritime tragedies of the recent years, the Joint Accident Investigation Commission which has been appointed to investigate the causes and the conditions of accident, has identified the delay of the announcement of the alarm, and the absence of further guidance and information from the Bridge, as the "first major mishaps of the evacuation"[8]. It is evident that if the evacuation process is not working effectively the number of fatalities will be high.

Admittedly, the last years prove the significant progress in the safety regulation for passengers and crew and the procedural clarity of the ship evacuation plans. The IMO guidelines now require new passenger ships to conduct evacuation analysis. It is about a method providing estimations about passenger flows, appreciating the congestion details and determining the total evacuation time, all based on computational simulation of crowd dynamics, pedestrian movement & behaviour etc[9]. Additionally and beyond this improvement of the vessel design, the shipping companies and the practitioners have meanwhile accumulated important knowledge on how to plan, maintain and operate specific evacuation models and "levels of safety". However, despite this progress, the study of the evacuation process, through the history of marine incidents and emergency management, shows that the performance and efficiency of the evacuation process in passenger ships, which is the "last line of defence against human losses", remains a critical challenge and a complex "problem-to-solve".

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[5] Due to "incomplete information" provided to passengers and to the lack of real-time process monitoring mechanisms on the side of emergency responders…

[6] See: https://www.theguardian.com/world/2022/feb/18/fire-ferry-greece-italy-euroferry-olympia-288-people-on-board

[7] ibid.

[8] A. Andreadakis & D. Dalaklis, 2022, Evacuation of ships: Discovering the mishaps behind the casualties, in Journal of International Maritime Safety, Environmental Affairs, and Shipping, 6(2-3):135-140, available at https://www.tandfonline.com/doi/pdf/10.1080/25725084.2022.2129200

[9] R. Brown, 2022, An overview of the SAFEGUARD project and main findings, presentation at the Workshop (Online): The Digital Transformation of the Evacuation Process in Passenger Ships, organized by the PALAEMON project and UAegean, Workshop (Online): The Digital Transformation of the Evacuation Process in Passenger Ships | Futurium (europa.eu)

Several years now, the research in the field of maritime safety explores the concept of Intelligent Evacuation Management Systems[10], in contrast with current evacuation management methods that depend mainly on human power and manual coordination effort. The term points to a combination of early anticipation methods of a disaster through sensorized real-time Decision Support Systems, crowd monitoring technologies, evacuation modelling techniques, and evacuation path guidelines that "may aid in developing better automated evacuation systems that would be able to assist the evacuees during an emergency evacuation scenario"[11]. The PALAEMON project has extended the research in this area to define and implement a Smart Evacuation Management (SEM) approach and technology infrastructure that (partially) automates and monitors the whole ship evacuation process, while dynamically changing the operation mode of all data sources and services. Rather than managing the "evacuation experience" through simulations, the Smart Evacuation Management approach proposes a layer of functionality, on top of the existing IT systems and services, which supports, streamlines and transforms the evacuation process. It increases the stock of "evacuation intelligence" through collecting and processing data from different ship resources and by tracking the location of passengers and crew, and notifying them in real time about the available evacuation options and paths (in accordance with the evolution of the evacuation plan).

2.2 Smart Evacuation Management in context

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

- I**nstantly 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 and.
    - 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**[12] (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**[13] **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

[10] A. Ibrahim et al, 2016, ACM Transactions on Intelligent Systems and Technology, 793):1–27, available at https://doi.org/10.1145/2842630
[11] ibid.
[12] See Network_2020_Mission_critical_communications.pdf (gsma.com)
[13] We assume a ship digitally connected to the shore;. see: U. Iscimura et al, 2022, Shipping in the era of digitalization: Mapping the future strategic plans of major maritime commercial actors, Digital Business, 2(1), available at https://www.sciencedirect.com/science/article/pii/S2666954422000023

process (from the initial stages of accident reconnaissance to the embarkation of passengers and crew to LSAs).

In more details, the SEM platform utilises a microservices application architecture[14] to facilitate semi-automated process management, monitoring, and decision support after an emergency is detected, and throughout the evacuation management process, The application architecture orchestrates two onboard network infrastructures that are specifically suitable for emergency situations:

a) A **"sensing" Wireless Network for real-time people location tracking**[15], made of beacons and Wireless Access Points (APs) and,
b) A **private 5G Standalone[16] Cell Network** for emergency messaging (alerts, notification etc,)[17] 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

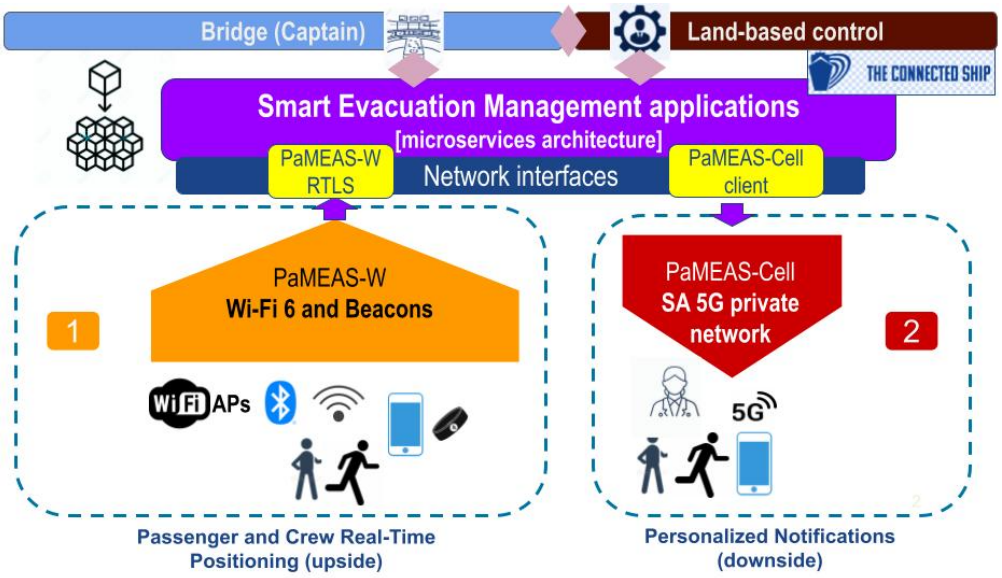

Figure 2: The organisation of SEM platform and the two levels of use, Bridge and Land-base control authorities

[14]A. Bucchiarone et al, Microservices: Science and Engineering, Springer Link, available at Microservices: Science and Engineering | SpringerLink

[15] For a comprehensive, generic, analysis of the Indoor Positioning Systems allowing for real time people location tracking, see: R. Bernard, 2017, Indoor Positioning Systems, Security Industry Association, available at https://www.securityindustry.org/wp-content/uploads/2017/11/Indoor-Positioning-Systems.pdf

[16] 5G Standalone (SA) is an implementation of 5G architecture that solely uses a core network with no dependency on 4G LTE network control function, for signalling and data transfer, as it happens with the public mobile communications networks, transiting progressively to 5G. 5G SA networks are ultra-low latency and high reliability networks, currently serving the needs of the industry and knowledge-based services for very fast access to higher data rates. For a generic presentation of the issue, see: 5G NR Standalone - network for the future - Ericsson

[17] To design alerts and notification messages for the needs of the evacuation, we followed the guidelines provided by the NIST (US); for a short presentation, see: https://www.nist.gov/system/files/documents/2017/09/28/05_kuligowski_joplin_recommendations_iii.pdf

The SEM platform has been first developed “in vitro” and validated in the lab, and reached the Technology Reading Level (TRL 4)[18] during fall 2022[19]. During the pilot implementation, the SEM platform has reached TRL 5 (technology validated in the field environment, on-board a passenger ship)[20] and underwent operational and functional testing.

3. Pilot objectives, requirements, context and location

3.1 Evacuation-Mustering Pilot: objectives

The objective of the pilot deployment of the SEM platform is to prove the feasibility of an ICT technology-aided evacuation; to demonstrate and validate its capacity to assist the evacuees to move towards the mustering and embarkation areas, safely and efficiently, and coordinate the action of the crew as well, through the provision of: a) personalised and dynamic instructions (i.e., adapted to the specific conditions and following the evolution of the evacuation plan) and, b) interactive emergency communication possibilities. Essentially, **the pilot deployment provides an indication of the ways passenger ships can use process automation methods and technologies, and advanced communication infrastructures, to empower people tracking and emergency messaging capabilities**, in the objective to:

- Improve the overall performance of the evacuation process
- Progressively create an Integrated Safety System

3.2 Evacuation-Mustering Pilot: requirements

The “guiding principle” in the design of the evacuation-mustering pilot was to support a number of passengers to receive, on their mobile phones and other devices, quick, reliable, comprehensible and personalised (in their native language) information on the emergency situation. These **information alerts**, in the form of textual and visual messages, should accompany and frame the emergency messages announced by the public address and emergency sound system. Additionally, the pilot has to demonstrate the capacity of the technology platform to provide to **passengers automated, personalised and location-based guidance** for the evacuation routes, orientation in an escape environment for those who are familiar with the ship structure and deck organisation, alerts to avoid

[18] TRL 4 means “technology validated in the lab”; ref.: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

[19] See WP5 Deliverables and the announcement made on the occasion: https://www.linkedin.com/posts/smart-evacuation-management_palaemon-smart-evacuation-management-system-activity-6988199764802580480-qqZh/?utm_source=share&utm_medium=member_desktop

[20] TRL 5 means “technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies); ref.: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

approaching a damaged area, etc., through notification messages showing the most appropriate exit path. All these messages, emergency information alerts and notifications should be reaching passengers, in a highly reliable manner and with low latency, regardless of whether they seat, stand up, move or run, and wherever they are they are located, in public areas, in recreational rooms, in their cabins, or within the winding web of ship corridors and staircases.

Besides, the pilot **must prove the capacity of the underlying technology to improve the coordination between Bridge and Crew through task assignment and instant real-time communication via a MCPTT application**. Especially i**n the case of an incident that may occur to a passenger after the evacuation has started,** where it is important to:

- Quickly identify the profile and the location of the passenger and alert the nearby and competent crew members to provide accommodation, help or first aid etc.
- Assist trapped passengers and vulnerable passengers who left behind.

Finally, the pilot requirements include **the provision of the Bridge and Land-based authorities of real time data** about the numbers of evacuees within a deck, or a compartment, the list of passengers and crew congregating in muster stations and embarkation areas (including their number and the identity profiles), the number and identity of passengers trapped, injured, impaired people needing assistance etc., as well as the visualisation of real-time flows of people.

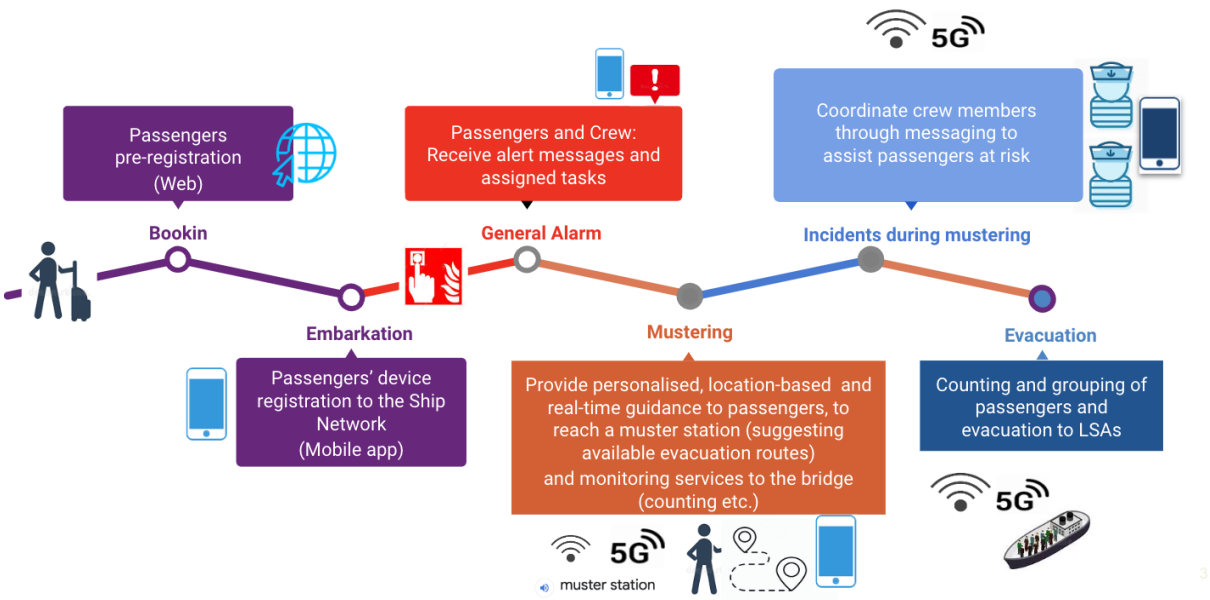

Figure 3: Pilot required operational flow

The response of the SEM platform to these requirements should be evaluated to assess the impact of the Smart Evacuation Management approach, in particular its capacity to complement existing evacuation processes and capabilities (see Deliverable 8.6b: "PALAEMON Consolidated Pilots Evaluation: SEM Trial).

3.3 Evacuation-Mustering Pilot: context and location

The Pilot has been deployed **on-board ELYROS F/B**, a ship provided by ANEK, an active partner of the Consortium and end-user of PALAEMON SEM services. Passenger ships, such as the ELYROS Ferry, are very large and complex structures transporting many passengers and employees (crew) which populate the middle and upper decks, and vehicles parked in lower deck garages. As already mentioned, ship evacuations are currently based on pre-established plans and procedures to be executed during the emergency.

Ship: ELYROS F/B (ANEK Lines) | https://www.anek.gr/en/vessel/fb-elyros/

- Number of Passengers: 1874
- Airplane Seats: 323
- Beds: 776
- Cars: 320
- Length- Width: 192 – 27m

The pilot execution took place the time of the day the ship was **docked at the Port of Piraeus, Greece**. The regulation and the shipping company policy do not allow the conduct of any experiment and trial during travel time at sea. In line with previous work undertaken by the project in WP2, the main evacuation scenario considered was that of a fire which broke suddenly out in one of the upper ship decks. But the extreme conditions which in most real cases affect the evacuation landscape, such as bad weather with strong winds and long waves sinking the ship, could not be simulated during the pilot action, to provide a more realistic evacuation environment. As a result, **the technical system supporting the pilot has only been tested in an unstressed situation**, not in stressed conditions where the smoke, the very possible structural damage of certain areas of the ship, and the panic of passengers create a higher level of complexity and may disrupt the functioning of the main system components.

Similarly to a typical evacuation drill, **the pilot has tried to present the simulation of handling a fire situation, but, in this case, with the assistance received from the on-board deployment of the Smart Evacuation Management platform**. Next to the activation of the fire 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. The evacuation has been observed by a Pilot Execution and Evaluation team (PEET) which evaluated and reported on proceedings.

The **specific area of ELYROS Ferry where the pilot has taken place was a part of Deck** 9, covering MVZ B and MVZ C[21] (ELYROS is a large ferry with four MVZs).

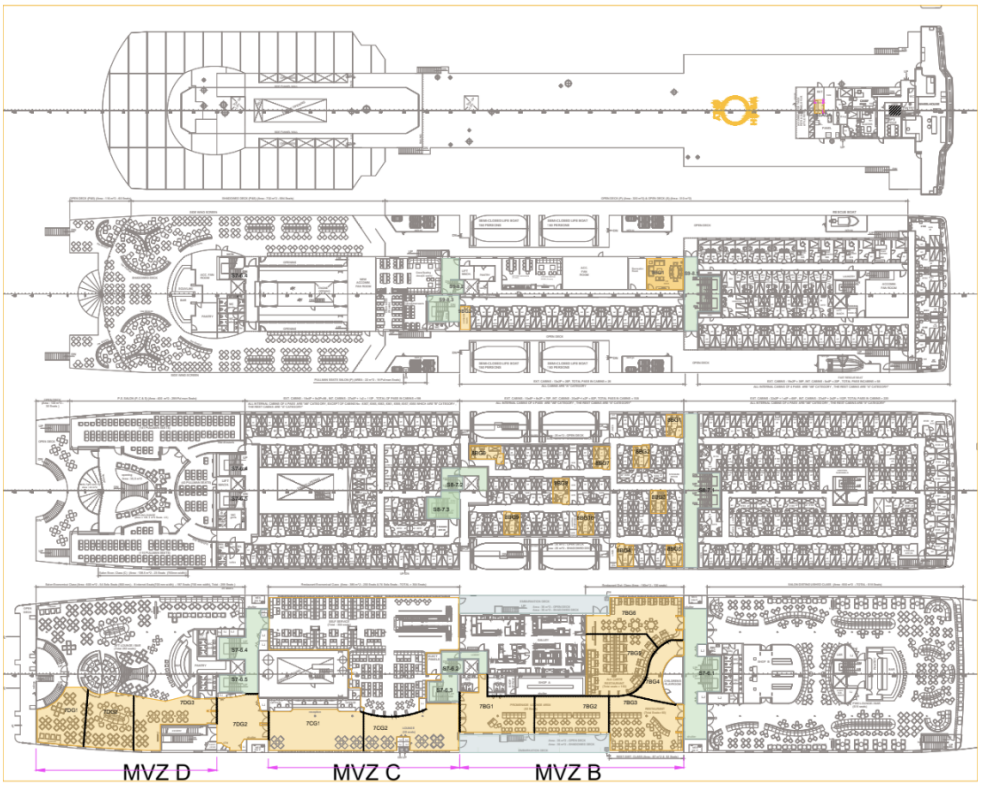

Figure 4: ELYROS F/B Main Vertical Zones

[21] In large ships, the hull, superstructure and deckhouses are subdivided into four and more Main Vertical Zones (MVZs).

The figure below presents the two main areas of the Deck 9 in which the Pilot took place: a) The “Pilot mustering area” where the mustering scenarios were evolved (around 250 m^2) and, b) the “Pilot evacuation area” where the “passengers” have been directed to get in the LSAs (around 50 m^2).

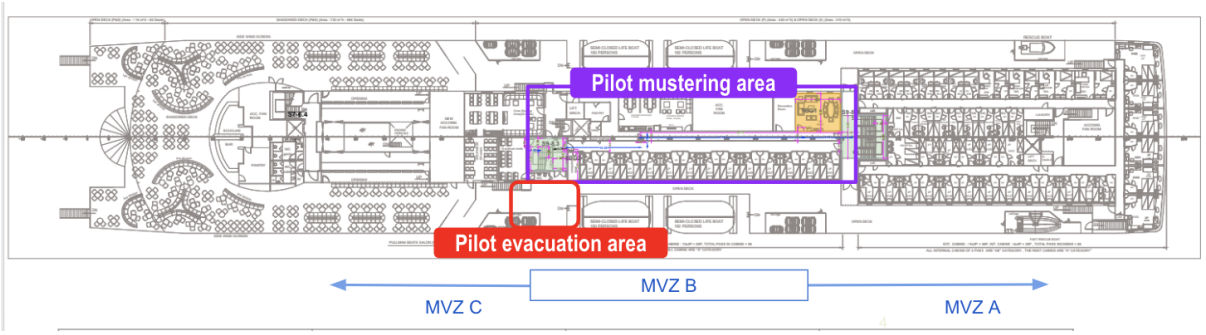

Figure 5: Pilot execution areas

In the Pilot mustering area, the project has made mainly use of the following sub-areas:

- 9BG1 and 9BG2: recreation rooms
- GCab9223 and GCab9217: passenger cabins
- 9BG3 and 9BG4: Long corridors
- 9BG1+: Staircase landing (9-8.1: Feck 9 - Deck 8)
- 9CG0: Staircase landing (9-8.3: Feck 9 - Deck 8) | used as Muster Station for the need of the Pilot

Geofence	Length (m)	Width (m)	Surface (m^2)	Height (m)
9BG1	6.54	5.30	34.66	2.40
9BG1+ (S9-8.1)	4.00	6.00	24.00	2.50
9BG2	10.30	5.30	54.59	2.20
9BG0 (S9-8.3)	5.27	4.27	22.50	2.50
9BG3	38.45	1.20	46.14	2.20
9BG3	38.45	1.20	46.14	2.20
GCab9223	2.75	3.85	10.59	2.10
GCab9217	2.75	3.85	10.59	2.10
SUM-mustering			249.21	
9CG EVAC-evacuation	7.00	7.00	49.0	
Total			300	

These areas have been defined as geofences of the SEM platform, that means virtual perimeter around the underlying specific geographic location, in order to give “geographical meaning” to location tracing parameters (x, y) and deliver targeted messaging.

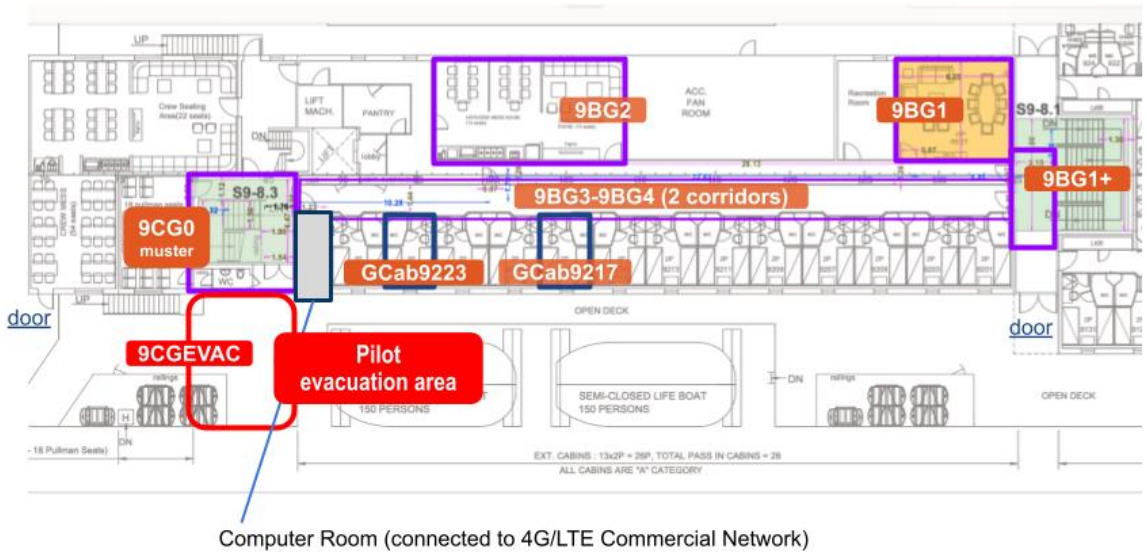

Figure 6: Pilot geofences

Pilot participants:

- 15 extras playing the role of passengers acting in the context of the scenario that follows
- 5 crew members from the ship (ELYROS officers)
- PALAEMON Pilot Execution and Evaluation team (PEET)
- People invited to follow the exercise in real time, joining the Deck 9 of the vessel: PALAEMON teams, end-users and experts, policy makers and media etc.

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4. Pilot implementation ecosystem in detail

4.1 Core Pilot scenario

Initially, a smoke alarm, shown on the Bridge Dashboard of the SEM platform, requires the Bridge to take action. The emergency response team is dispatched to make a visual assessment of the situation. The firefighting team attempts to extinguish the fire but it finally reports that the drencher system has no effect on the fire.

The Master appreciates the severity of the situation and decides to launch the evacuation plan. Before the Master sounds the GA, a series of systematic announcements over their MCPTT application, as well as notification messages, are initiated only for crew members. The location of the crew is tracked and the Bridge sounds the GA only when they verify that crew has assumed positions. The time the General Alarm sounds off, either a simultaneous or a phased evacuation begins. According to IMO guidelines, a fire, even in a limited area, albeit the fact that it will not immediately result in a catastrophic failure, is considered as an important risk factor for sage navigation and for passengers and crew. It may therefore require passengers to move from one zone to another, eventually to the muster station.

- As a result, the Bridge announces to evacuate to the designated areas through the Public Address & Voice Alarm System.
- At the same time, passengers are notified with alert messages to their mobile device about the emergency situation (received by their passenger mobile app, which has been downloaded earlier, during their registration or when they embark to the ship).

From that point on, they receive further notifications on regular time intervals. Evacuation guidance is provided through notification messages, in a personalised manner

- depending on their language, age, health status and mobility capabilities,

while taking into consideration

- the physical design of the reference deck, the evacuation routes defined by the evacuation plan, any obstacles that might exist, and the capacity of the evacuation routes to safely re-allocate people (areas/geofences that are identified as affected by the fire spreading are marked in a red colour, thus making some of the evacuation routes unavailable and excluding them from the list of evacuation options0.

Figure 7: Technology-assisted mustering using mobile apps, back-end applications, an array of Beacons and Wi-Fi APs for location tracking and a 5G (private) standalone network

To provide dynamic and context specific emergency information to passengers, their location is continuously tracked. The SEM platform can also be explored for early detection of passenger issues (identifying people moving with a certain delay to the muster station, or incapacitated to move)

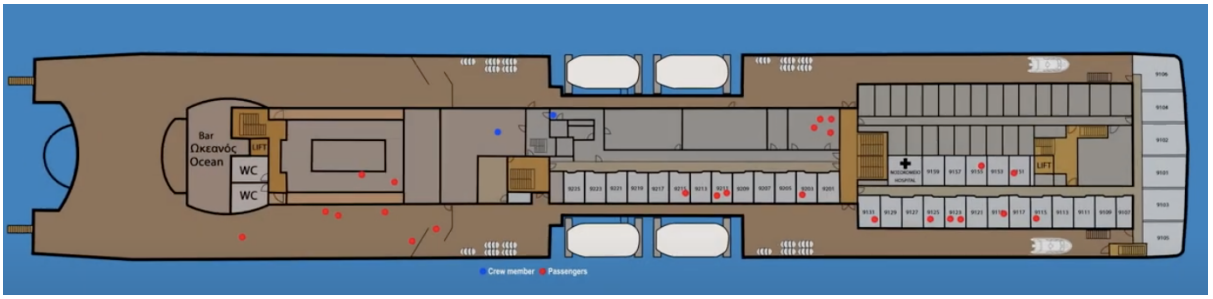

Figure 8: Location Tracking Map

In fact, while the mustering process is in progress, it is observed that:

- Two passengers were blocked in their cabin
- A pregnant needs help from the crew to move to the muster station
- A passenger is injured and the necessary actions should be taken to save him

In all these cases, the Bridge refers to the SEM platform to find the crew members that are near the person Figure 8: Pilot location tracking map (Deck 9 | passengers' dots in red, crew's dots in blue) needing help, and have the capacity or the speciality to provide the specific assistance that is required, and communication with them via their MCPTT application.

They also monitor in real-time the location of the involved people in this incident management process, crew and passengers, which takes place in parallel to mustering.

Finally, passengers and crew get in the muster station and the Bridge can use again the services of the SEM platform, to count the number of the passengers in every different muster station, view their names, access their profile, share this information with the land-based control authorities, and detect eventually missing passengers via their "last position in the map" and their identity.

In the case, a passenger leaves the muster station to return to their cabin to retrieve a personal item, the SEM platform detects the event, alerts the passenger to rejoin the muster station, and notifies the Bridge and the nearest to the muster location crew members about the event and the need for taking action.

As fire goes out of control, the Master orders the ship to abandon the ship. The Bridge uses the services of the SEM platform to create “groups of evacuees” which are directed to the embarkation areas, where they are counted and identified once more.

4.2. Pilot implementation

First, the provided service consists of **two mobile applications** that provide the users, passengers and crew) with powerful communication and interaction tools to be used regularly, during normal navigation conditions, and of course during evacuation, the passenger mobile app and the crew mobile app.

- Passengers can use their mobile app (PALAEMON Passenger mobile app) as an extension of the existing applications provided by the shipping companies, to to require help (at any moment) and, in general, to push immediate assistance requests to the Bridge in the form of “emergency feedback messages” (functionality: SOS (Request immediate help, CallMe, CallMe, My family is at risk, Report an accident: Smoke/Fire/Water/Slippery/Falling from height/Toxic or Flammable Gas/Electrical shock/Machinery explosion/Gangway fall/Victim of an attack/Lifeboat Testing Accident, Text the Bridge). The same application provides passengers with emergency alerts and personalized suggestions to ensure that passengers are real-time and dynamically instructed to follow evacuation paths that safely direct them towards the designated assembly points and muster stations.
- Crew can use a commercial MCPPT app (Tactilon Agnet 500 from Airbus[22]) which has been integrated to the SEM platform, to provide enhanced critical communications between the Bridge and the Crew (as well between the land-based control authorities and crew members, if this is required).

Terminal Equipment Components used by the end-users (passengers and crew) for the needs of the Pilot

- Mobile devices: Samsung A52 5G Dual SIM smartphones provided by UAegean
- SIM cards: 5G SIM cards mobile devices provided by Athonet (Public Land Mobile Network - PLMN: 99999)

Second, to **allow for the use of these mobile applications within the ship environment**, for interaction with the Bridge, voice and messaging communication, a **5G Standalone Network** has been deployed with a Core Module provided by Athonet[23] and a Radio Dots Cell Network provided by Ericsson[24]. In parallel, a **location tracking infrastructure** has been deployed, as an array of Beacons and Wi-Fi 6 Access Points, to collect location data from passengers and crew, and track their location in real-time, in conjunction with the RTLS component (Real Time Location System) of the SEM platform.

[22] Agnet | Secure push to talk service and more (securelandcommunications.com)
[23] 5G Core Network - 5G Standalone core - Product - Athonet
[24] Radio Dots - Ericsson

Third, **two user interfaces** in the form of a **Dashboard** have been provided to the Bridge (accessed through the 5G network) and to the Land-based Control Authorities (accessed via the Web). They are provided by the **PIMM (PALAEMON Incident Management Module)**[25] which is responsible for orchestrating the evolution of the evacuation process, collecting process data from **PaMEAS (the Passengers Mustering and Evacuation Process Automation System)**[26] and delivering dashboard information to users (Bridge and Land-based Control Authorities)

A schematic representation of the deployed architecture is shown in the next figure.

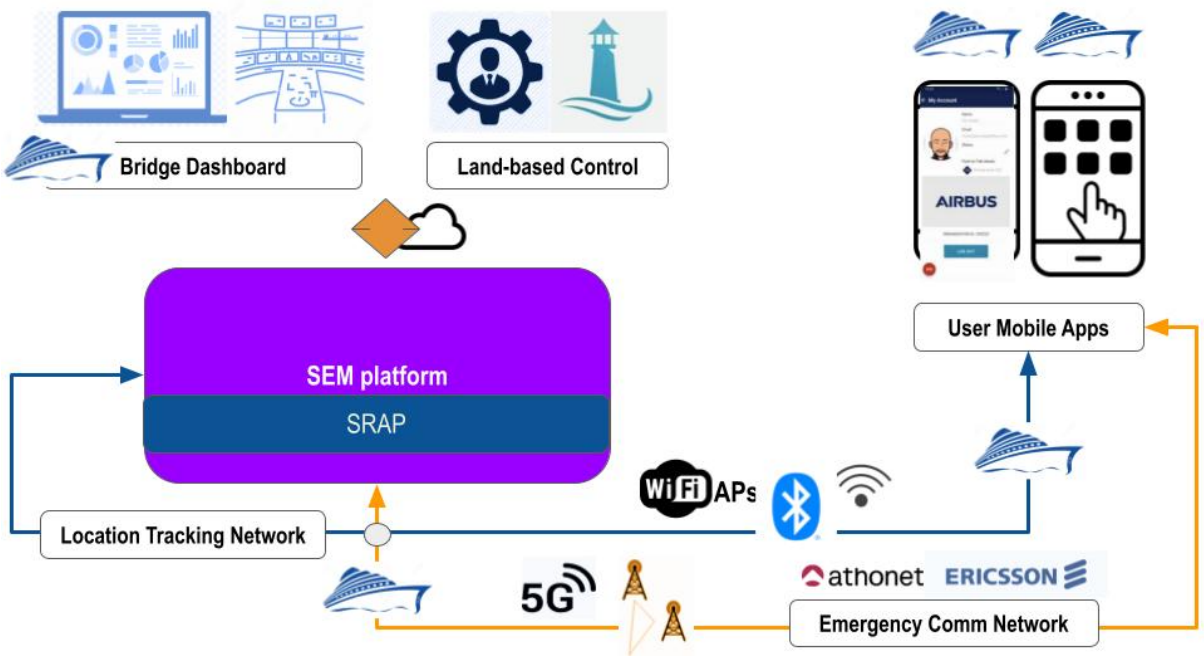

Figure 9: Pilot high level technical architecture

4.2.1 Pilot Core Engine: Smart Evacuation Management platform

As already explained, the WP8 Pilot is supported by the Smart Evacuation Management platform (SEM platform), a software suite composed from various components developed in WP5, WP6, WP7, and WP8, and **deployed on-board ELYROS F/B and over the cloud**. The **platform offers the functionality the Pilot implementation needs,** as described in the previous sections, **and, respectively, the Pilot is the validation of the SEM platform for reaching TRL 5**.

The critical for the Pilot deployment components of the SEM platform are shown in the figure that follows.

[25] PALAEMON WP6
[26] PALAEMON WP5

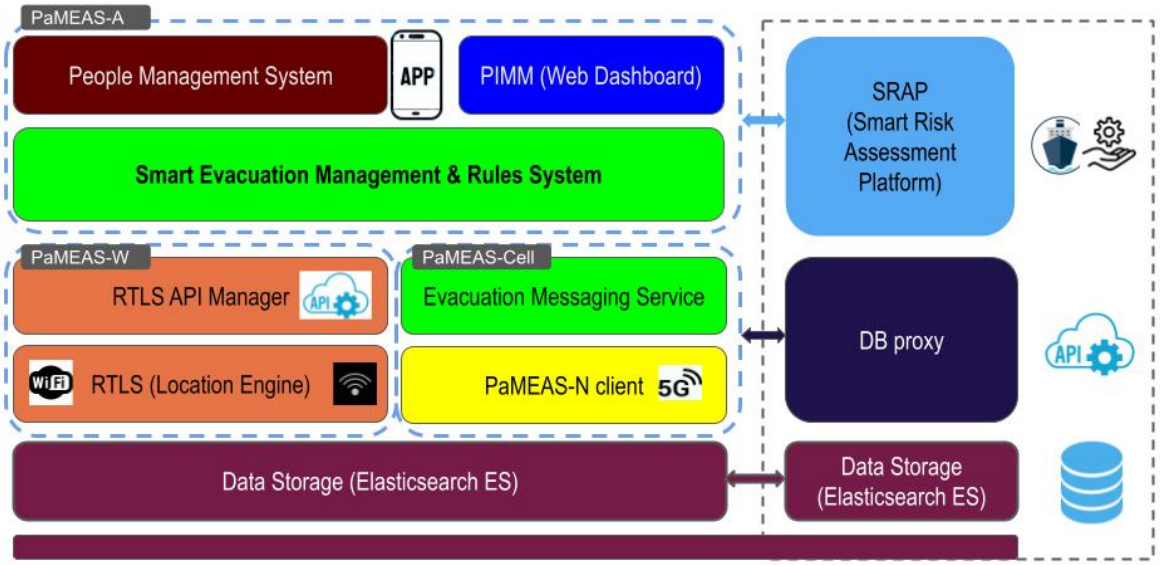

Figure 10: SEM platform main components

where:

- PaMEAS-A (Application) is the software application of SEM.
  - Includes the following software parts: C1 People Management System, C2 PALAEMON Mobile Apps, C3 PaMEAS Access Manager, C4 PaMEAS Evacuation Enabler, C5 PALAEMON Emergency Messaging Service, C6 PaMEAS Incident Manager, C7 PaMEAS-SRAP Integrator, C8 PaMEAS Passenger Location Simulator[27]
- PaMEAS-W (Wireless) is the (interfaces to) Location Tracking Network (an array of Beacons and Wi-Fi Access Points).
- PaMEAS-Cell is the (interfaces to) Emergency Communications Network (a 5G Standalone Network).
- PIMM is the Dashboard application.
- SRAP is the application providing situational awareness to the Master and Bridge Command Team under the adverse prevailing conditions during the evacuation process and structured information for decision support[28].
- DB proxy (Service) provides to SEM components secure and privacy-enhanced access to Data Storage Facility (ES), as far the personal identity and location data are concerned.

[27] See: PaMEAS-A: Microservices & High Level Components
https://docs.google.com/spreadsheets/d/1TBr7PhzFdMk35ZXulG_z8CHQ5ir7D3fAQbVwbVLegr4/edit?usp=sharing

[28] For the integration between PaMEAS and SRAP, see in particular the presentation of UAegean and NTUA at Posidonia2022
https://docs.google.com/presentation/d/1p4Mf4pW9jsXKEQUEEESahGT79LFV3fBFKz7-cCj_qlY/edit?usp=sharing

4.2.2 On-board Pilot Network Components

The two key aspects of the Pilot is the **instant recognition of the position and identity of passengers and crew**, and the **transmission of emergency messages to them**, in **low latency** and **high-reliability conditions**.

The first requirement, i.e. people location tracking, is adequately provided by the **Location Tracking Network**, an array of Bluetooth Low Energy Beacons and Wi-Fi 6 Access Points (APs). The Pilot has tested different combinations of Beacons and APs, but the most effective in terms of location accuracy was the topology with only ten (10) beacons deployed in the reference area.

Figure 11: Location Tracking Network effective topology

The location information obtained from the array of beacons, through the users (passengers and crew) mobile apps is combined then with the personal identity information of the user (both are stored, during normal conditions, under strict privacy safeguards) to provide the Bridge (and the land-based control authorities) with the complete knowledge of the evacuees profiles.

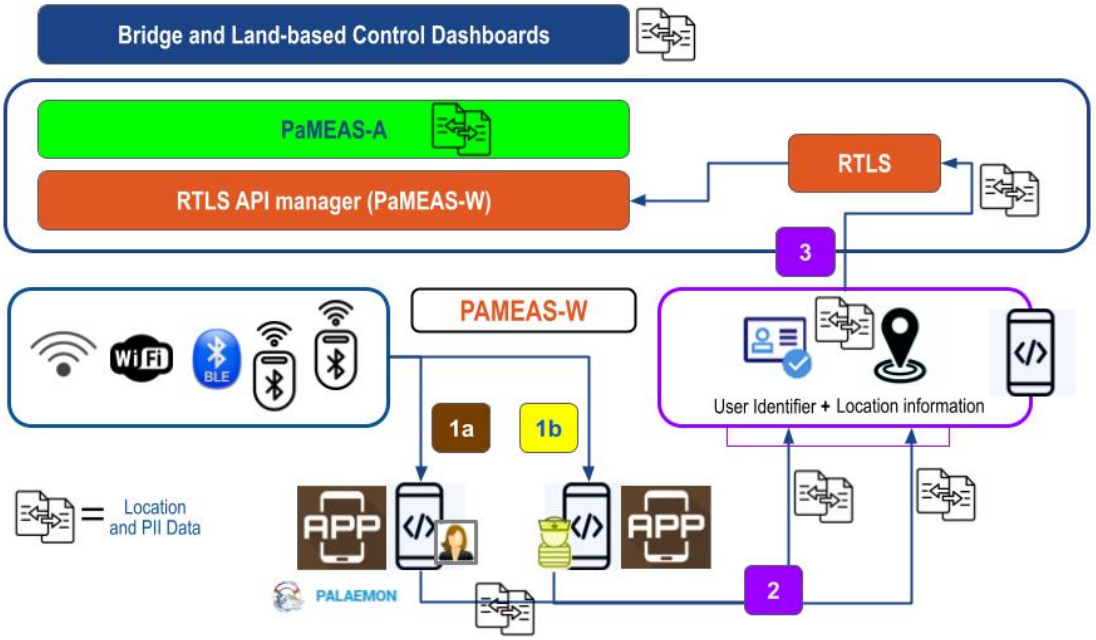

Figure 12: Location Tracking Network architecture

The second requirement, the transmission of emergency messages to them, in low latency and high-reliability conditions, is effectively provided by the **Emergency Communications Network**, The Pilot area. structurally complex, with many cabins and corridors, is entirely covered by a Cell Network with three (3) Radio Dots, providing the user devices with access to 5G Core functionality (Control Plane and User Plane Functions), thus allowing passengers and crew to receive very low latency and high reliability (emergency) messaging and voice services.

5. Pilot Demonstration

This section defines how the Pilot Core (Fire) Scenario was implemented via specific scenario/exercise executed on the premises of ELYROS F/B

- with the participation of the integration of the users (Master, crew members, passengers, Land-based control authority)
- supported by the various components of the SEM platform, as described in the previous sections.

5.1 Core (Fire) Pilot Evacuation in Acts

This section presents the decomposition of the Pilot Core (Fire) Scenario into Core Scenario Acts (and their sub-acts). This decomposition ensures that the design of the piloting scenario/exercises that are presented in the following section (5.3) will covers all functionality/requirements derived from the Pilot Core (Fire) Scenario.

#	Core Scenario Act 1: Emergency reconnaissance	SEM platform support	SEM components
1.1	Initially, a smoke alarm, shown on the User Interface of the SEM platform, requires from the Bridge to take action.	**Visual notification** on bridge Visualisation of **suggested actions** to the bridge according to SOLAS	Bridge Dashboard (PIMM), DSS
1.2	The emergency response team is dispatched to make a visual assessment of the situation	The bridge initiates a MC**PTT session** with the emergency response team	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, MCPTT mobile app, 5G SA Network
1.3	The firefighting team attempts to extinguish the fire but it finally reports that the drencher system has no effect on the fire	The bridge maintains a **PTT** and **video streaming session** with firefighting team	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, MCPTT mobile app, 5G SA Network
1.4	The Master evaluates the severity of the situation and decides to launch the evacuation plan.	Master is presented **risk assessments** about the situation	Bridge Dashboard (PIMM), SRAP
1.5	Before the Master sounds the GA, a series of systematic announcements over their MCPTT application, as well as notification messages, are initiated only for crew members.	Bridge sends **alerts to crew members** to assumes emergency posts Bridge initiates **PTT session** with all crew members	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, MCPTT mobile app, 5G SA Network
1.6	The location of the crew is tracked and the Bridge sounds the GA only when they verify that crew has assumed positions.	Bridge monitors the **real time location** of crew Bridge initiates **PTT session** with all crew members Bridge sounds the GA, **sending alert messages** to all passengers	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, MCPTT mobile app, PALAEMON Mobile App, 5G SA Network

#	Core Scenario Act 2: Mustering-Evacuation	SEM platform support	SEM components
2.1	The Bridge announces to evacuate to the designated areas through the Public Address & Voice Alarm System. At the same time, passengers are notified with alert messages to their mobile device about the emergency situation (received by their passenger mobile app, which has been downloaded earlier, during their registration or when they embark to the ship).	Passenger/Crew **profiles** are generated including the **devices** they use, Bridge sends **personalised alert messages** to the passengers,	Bridge Dashboard (PIMM), People Management System, PaMEAS Evacuation Enabler, PaMEAS Access Manager, 5G SA Network
2.2	Passengers receive further notifications on regular time intervals. Evacuation guidance is provided through notification messages, in a personalised manner (depending on their language, age, health status and mobility capabilities)	Bridge sends **personalised mustering instructions** to the passengers, Bridge monitors the **real time location** of passengers and crew	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, PaMEAS AI, PaMEAS Incident Manager, 5G SA Network, Tracking Location Network
2.3	Notifications are updated in real time taking into consideration the physical design of the reference deck, the evacuation routes defined by the evacuation plan, any obstacles that might exist, and the capacity of the evacuation routes to safely re-allocate people (areas/geofences that are identified as affected by the fire spreading are marked in a red colour, thus making some of the evacuation routes unavailable and excluding them from the list of evacuation options).	Bridge **updates** the availability of the evacuation paths/Mustering Stations, Bridge sends **updates mustering** instructions to the passengers, Bridge monitors the **real time location** of passengers and crew Bridge **alerts crew** for deviations from the main evacuation plan	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, PaMEAS AI, MCPTT app, 5G SA Network, Tracking Location Network
2.4	Finally, passengers and crew get in the muster station and the Bridge can use again the	Bridge monitors the **real time location** of passengers and crew	Bridge Dashboard (PIMM), People Management System,

#	Core Scenario Act 2: Mustering-Evacuation	SEM platform support	SEM components
	services of the SEM platform, to count the number of the passengers in every different muster station, view their names, access their profile, share this information with the land-based control authorities, and detect eventually missing passengers via their “last position in the map” and their identity.	Bridge **automatically counts passengers** at Mustering stations Bridge **reviews passenger profiles and last known** locations	PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking Location Network
2.5	In the case, a passenger leaves the muster station to return to their cabin to retrieve a personal item, the SEM platform detects the event, alerts the passenger to rejoin the muster station, and notifies the Bridge and the nearest to the muster location crew members about the event and the need for taking action.	Bridge monitors the **real time location** of passengers and crew Bridge **automatically counts passengers** at Mustering stations Bridge **automatically alerts passengers** leaving Mustering stations Bridge **automatically notifies** Mustering station officer about the “rogue” passenger	Bridge Dashboard (PIMM), People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking Location Network, MCPTT mobile app,
2.6	As fire goes out of control, the Master orders the ship to abandon the ship. The Bridge uses the services of the SEM platform to create “groups of evacuees” which are directed to the embarkation areas, where they are counted and identified once more.	Master is presented **risk assessments** about the situation Bridge monitors the **real time location** of passengers and crew	Bridge Dashboard (PIMM), SRAP, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, PaMEAS AI, MCPTT app, 5G SA Network, Tracking Location Network

#	Core Scenario Act 3: Incident Management	SEM platform support	SEM components
3.1	To provide dynamic and context specific emergency information to passengers, their location is continuously tracked.	Bridge monitors the **real time location** of crew and passengers	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, PALAEMON Mobile App, 5G SA Network, Tracking Location Network
3.2	The SEM platform can also be explored for early detection of passenger issues (identifying people moving with a certain delay to the muster station, or incapacitated to move) In fact, while the mustering process is in progress, it is observed that: ● Two passengers were blocked in their cabin ● A pregnant needs help from the crew to move to the muster station ● A passenger is injured and the necessary actions should be taken to save him.	Passengers **behavior** is **monitored** Passengers **health profiles** are monitored Bridge is **automatically notified** about **passenger issues**	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, PaMEAS AI, PaMEAS Incident Manager, PaMEAS-SRAP Integrator, SRAP, 5G SA Network, Tracking Location Network
3.3	The Bridge refers to the SEM platform to find the crew members that are near the person needing help, and have the capacity or the speciality to provide the specific assistance that is required, and communication with them via their MCPTT application. They also monitor in real-time the location of the involved people in this incident management process, crew and passengers, which takes place in parallel to mustering.	**Assignment** crew members able to assist passengers is **suggested,** **Bridge** initiates **MCPTT session** and **instant messaging** session with crew members, **Bridge** initiates **PTT session** and **instant messaging** session with crew passengers, Bridge monitors the **real time location** of crew and passengers	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS AI, PaMEAS Incident Manager, Tactilon Agnet mobile app, Tracking Location Network

5.2 Pilot Scenarios/Exercises

The pilot scenarios/exercises presented in the table above were designed to validate that the SEM platform can in fact implement the core pilot scenario in real circumstances (platform deployed and validated on the premises of ELYROS F/B). To achieve this, the pilot exercises were separated into the following groups, described in detail in D8.2b[29]:

- **Exercise Group A (Prevac1, Prevac2)**: The first group of exercises deals with the emergency reconnaissance phase,
- **Exercise Group B (Must1, Must2, Must3, Must4):** the second group defines exercises that implement the functionality of the mustering and dealing with unexpected passenger behaviours
- **Exercise Group C (Inc2,Inc3):** define various passenger related issues
- **Exercise Group D (Embark1, Embark2)**: defines exercises that capture the handling of passenger related issues.

The following table presents in detail the scenario/exercises of each such group.

[29] PALAEMON Deliverable D8.2b Operational Pilot Sites

Scenario/ Exercise Name	Scenario/Exercise Description	Start Event	End Event
PreEvac1 Group A	After the triggering of a smoke alarm the Master dispatches the emergency response team to investigate. After confirmation of the fire the firefighting team is dispatched and the situation is evaluated	A smoke alarm is shown on the the SEM platform Bridge Dashboard	Firefighting team reports that the drencher system has no effect on the fire and the Master evaluates the situation
PreEvac2 Group A	Master decides to initiate the emergency evacuation protocol by instructing the crew members to assume their emergency posts and verifies their status	Master activates the emergency evacuation protocol	Crew members are in emergency posts and Master verifies status
Must1 Group B	Master initiates the GA, sending alerts and mustering instructions to passengers	Master activates the mustering process	Master reviews muster station gathering progression and location of passengers not yet mustered
Must2 Group B	Due to the progression of the fire the Master removes a dangerous area from the evacuation route plan	A fire alarm is shown on the SEM platform Bridge Dashboard	Passengers receive updated mustering instructions, Crew is notified about the deviation from the primary evacuation plan
Must3 Group B	A passenger during mustering leaves the muster station to retrieve a valuable item from their cabin	A passenger leaves the muster station during mustering	Passenger receives emergency alert message to return to the muster station, muster station Officer is notified about the behaviour and location of passenger
Must4 Group B	A passenger fails to follow the evacuation route and wonders in a remote area of the ship	Bridge verifies a passenger not following the evacuation plan	Emergency alert message is sent to passenger instructing the to go immediately to the muster station
Inc1 Group C	A passenger is trapped in their cabin and cannot follow the mustering instructions	Passenger uses their PALAEMON mobile app to request assistance	Trapped passenger safely arrives to the muster station

Inc2 Group C	A passenger is injured and requests help	Passenger uses their PALAEMON mobile app to request assistance	Injured passenger safely arrives at the muster station
Inc3 Group C	A passenger is experiencing a complicated pregnancy and needs help to muster	SEM platform displays an alert on the Bridge Dashboard about a passenger requiring assistance to evacuate	Pregnant passenger safely arrives at the muster station
Embark1 Group D	Passengers receive embarkation instructions containing their embarkation groups	Master initiates the embarkation process	Passengers receive embarkation instructions, which contain embarkation groups
Embark2 Group D	Master overviews the embarkation process	Master initiates the embarkation process	Master monitors in real time the movement of the passengers to the MEVs

5.3 Pilot Scenarios/Exercises mapping Core (Fire) Scenario ACTS

The following table presents how these pilot exercises (executed on ELYROS) are mapped to the Pilot Evacuation Acts presented in section 5.1. This mapping enabled:

- the organisation of the Pilot Core (Fire) Scenario into repeatable and controllable exercises which cover all three Core Scenario Acts;
- their proper execution in a controlled manner supporting the measurements of the KPIs defined in D8.6[30].

[30] PALAEMON Deliverable D8.6 PALAEMON Consolidated Pilots Evaluation

Scenario/ Exercise Name	Scenario/Exercise Description	Scenario/Exercise Actions	Core Scenario Act	SEM Components
PreEvac1	Emergency Assessment Task Management - Dispatch firefighting teams to reduce and contain the fire	• Order the emergency team to move to incident location • Order the firefighting team to move to incident location • Collect feedback from the crew teams • Review the received feedback	1.1 1.2 1.3 1.4	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, PaMEAS Access Manager, MCPTT mobile app, PALAEMON Mobile App, 5G SA Network
PreEvac2	Crew to their Evacuation Positions	• Instruct Crew to reach their designated positions for Evacuation • Obtain the list of emergency teams and their current position • Verify positions	1.5, 1.6	Bridge Dashboard (PIMM), PaMEAS Evacuation Enabler, MCPTT mobile app, PALAEMON Mobile App, 5G SA Network
Must1	Augmented GA alarm - Direct the move of a group of passengers from area x to muster station	• Alert Messages to Passengers (different languages) • Track passenger positions and notify them • Count passengers at Muster Stations • Identify Missing passengers	2.1 2.2 2.4 3.1	Bridge Dashboard (PIMM), People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking location Network, MCPTT mobile app,
Must2	Instruct passengers about alternative escape routes	• Update evacuation plan • Track positions and Notify Passengers • Notify Crew members	2.3	Bridge Dashboard (PIMM), People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network,

				Tracking location Network, MCPTT mobile app,
Must3	Handle “rogue” passenger	• Track passenger positions and notify them • Count passengers at Muster Stations • Identify “rogue” passenger • Notify Muster Station Officer	2.5 3.1	People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking location Network, MCPTT mobile app,
Must4	Passenger becomes Lost and is notified by the bridge	• Track passenger positions and notify them • Send instant personalised alert messages		PIMM), People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking location Network,
Inc1	Face an incident - involvement of a trapped passenger	• Track passenger positions • Calculate abnormal behaviour • Bridge verifies the passenger issue has been resolved - via SEM	3.1 3.2 3.3	People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking location Network, SRAP, MCPTT mobile app,
Inc2	Assist a passenger remained behind/injured passenger (review passenger profile)	• Passenger requesting assistance - via SEM • Track passenger positions • Crew Member assigned • Bridge verifies the passenger issue has been resolved - via SEM	3.1 3.2 3.3	Bridge Dashboard (PIMM), People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking location Network, MCPTT mobile app,

Inc3	Face an incident (complicated pregnancy) - involvement of a medical team/	• Passenger health incident detected - via SEM • Track passenger positions • Crew Member assigned • Bridge verifies the passenger incident has been resolved - via SEM	3.1 3.2 3.3	Bridge Dashboard (PIMM), People Management System, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, 5G SA Network, Tracking location Network, MCPTT mobile app,
Embark1	Evacuations groups and Embarkation Preparation	• Create evacuation groups • Notify passengers about their evacuation group • Verify presence in the embarkation area	2.6	Bridge Dashboard (PIMM), SRAP, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, PaMEAS AI, MCPTT app, 5G SA Network, Tracking location Network
Embark2	Monitor the progression towards the MEVs	• Track passenger positions • Monitor embarkation progress • Automated counting	2.6	Bridge Dashboard (PIMM), SRAP, PaMEAS Evacuation Enabler, PALAEMON Mobile App, PaMEAS Access Manager, PaMEAS AI, MCPTT app, 5G SA Network, Tracking location Network

5.4 Mustering-Evacuation Pilot enhanced experience

For the needs of the pilot scenario/exercises, a top view of the piloting areas of ELYROS was created in the form of a 2D visual map as presented in the figure below.

Figure 13. Location Tracking Map (Passengers represented as red dots, crew members as blue)

This top view implements a **Location Tracking Map** which presents in real time the location of the passengers and crew members on the premises of ELYROS F/B, enabling the Bridge and the land-base control authorities to have a clear overview of the evacuation process. The **monitoring of the execution of the pilot scenario/exercise** was realised primarily via this interface. The visual representation of the evolution of the evacuation process enables also the Bridge to to **act upon this information via specific actions**. For example send emergency alert messages to help passengers to avoid a specific area which may present a risk, or alert them to change direction.

To **initiate** the execution of the pilot scenarios/exercise the Master uses the interfaces of the **Bridge Dashboard (PIMM).** These interfaces provides a visual digital representation of ELYROS to the Bridge and **enables the Master to alter the ships operational state**[31] as presented in the following figure, effectively initiating in this way the flows of the system that implement the scenarios/exercises, and in general the different stages of the evacuation process[32]; for example, send dynamic mustering instructions to the passengers.

Figure 14. Bridge Dashboard: Ships Operational States

[31] As part of the PALAEMON project the operational status of the ship is defined as a five step state model: 0.Normal Operation, 1. Emergency Situation Assessment, 2. Activation of the Evacuation Procedure, 3. Mustering, 4. Embarkation

[32] Essentially this dashboard provides a visual UI via which the Master can initiate all flows supported by the SEM platform described in detail in D8.2

The changes to the ships operational states result in **alert or notification messages** to be sent to the **passengers and crew members mobile apps** (depending on the operation state of the ship). The passengers act upon these messages (for example follow the mustering instructions) and their actions are represented in real time on the Location Tracking Map enabling the Bridge to follow the execution of the scenario/exercise, and in general the evolution of the evacuation process. and take the next applicable steps.

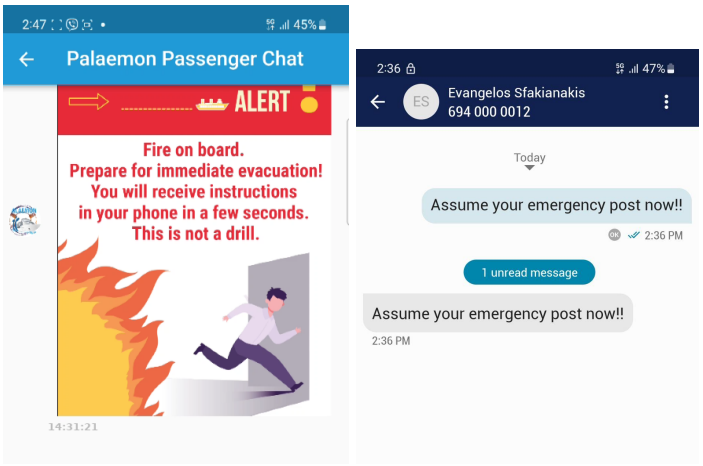

Figure 15. Passenger and Crew mobile apps

In this capacity the SEM platform implemented a "**Digital Twin**" of the Pilot events taking place on ELYROS. For example, when the Master decides to block an area (due to increased smoke being reported in that area) the altering of the evacuation plan takes place over the Bridge Dashboard. However, this action results in updated mustering instructions being sent to the passengers as shown in the figure below:

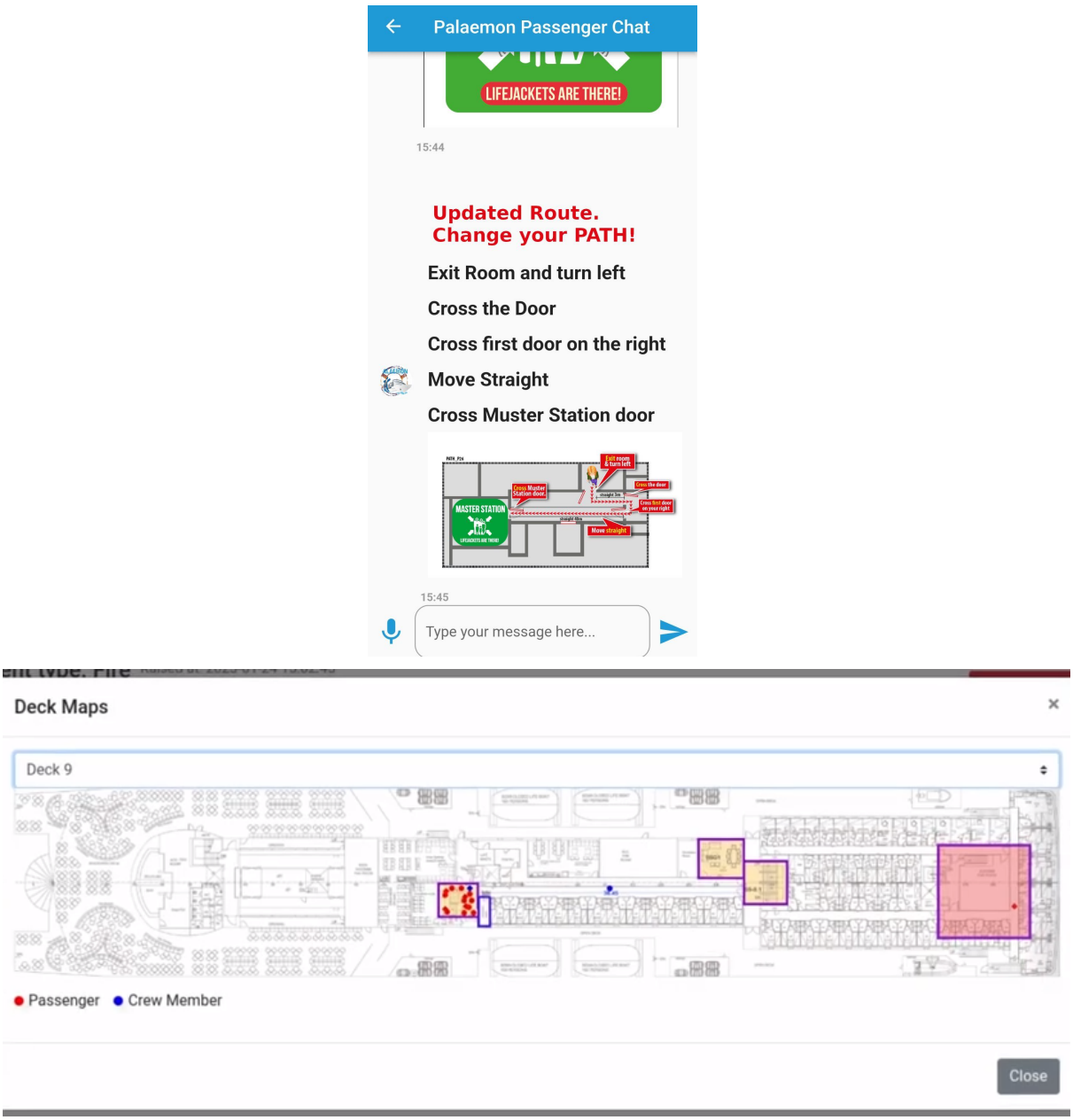

Figure 16. Update Mustering Instructions

The receipt of these messages from the passengers result in the altering of their paths which is displayed on the Location Tracking Map in real time, enabling the verification of the proper execution of the scenario/exercises (and, in general, the monitoring of the evacuation process in real-time).

6. Pilot Demonstration Short Report

The most important issues to report from the Pilot Demonstration are presented in the following table:

Key Issues	Details	Evaluation Result
Support reliable, comprehensible and personalised (in their native language) emergency alerts	No issues reported during the execution of the piloting actions	Yes
Support personalised and dynamic instructions (adapted to the specific conditions taking place at the ship)	No issues reported during the execution of the piloting actions	Yes
Enable interactive emergency communication possibilities between the bridge and the users.	No issues reported during the execution of the piloting actions	Yes
Evaluate the usage of mobile phones in the context of an emergency evacuation process	The users evaluated positively the use of their mobile phones as the primary source of interaction with the SEM platform in a positive way. 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
Evaluate the real time location tracking capabilities	The SEM platform was able to implement location tracking to a relatively satisfactory capacity. Location update times were approximately under 5 seconds and the location accuracy under 3 metres. However, to achieve these results extensive calibration actions were required and only a small area of the ship was covered. 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). An interesting result of the pilot is that a much looser topology of beacons and APs than that assumed by the literature achieved better results.	Further research is recommended

	As a result further research is required.	
Evaluate the capabilities and latency of the 5G SA network in the context of the pilot.	The 5G SA network operated in a highly reliable manner and with low latency	Yes
Evaluate the hybrid deployment approach of the SEM platform with some ICT modules deployed on the cloud (accessible over the internet)	The piloting actions were completed with no major disruptions. However, at times the connectivity to the internet was unstable. This resulted in increased latency in the system which although didn't affect the exercise executed might be problematic. Satellite internet connectivity is an applicable solution to these issues but the cost remains high. In the context of PALAEMON, other connectivity approaches were applied and tested, such as the VDES system[33]. It is recommended that the overall ship's connectivity is evaluated in this light.	Different "connected ship" approaches should be evaluated. In this context, the next version of the SEM platform should deploy and test integration with the VDES system.

[33] See: G1117 VHF Data Exchange System (VDES) Overview - IALA AISM (iala-aism.org)