PROJECT DELIVERABLE REPORT

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

D2.7 PALAEMON Architecture (v2)

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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1.0	2021/07/19	ATOS	Version 1.0 (submitted to EC portal)

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Abbreviations

AE	Acoustic Emission
AIS	Automatic Identification System
API	Application Program Interface
ASM	Application Specific Message
BRMS	Rules Management Service
CCTV	Closed-Circuit Television
COLREG	Convention on the International Regulation for Preventing Collisions at Sea
CRC	Cyclic Redundancy Check
CSV	Comma-Separated Values
DPA	Designated Person Ashore
DSS	Decision Support System
ETSI	European Communications Standards Institute
FFE	Fire Fighting Equipment
FTP	File Transfer Protocol
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GUI	Graphical User Interface
HMI	Human Machine Interface
HUD	Heads-Up Display
ICT	Information and Communication Technology
IMEI	International Mobile Equipment Identity
IMO	International Maritime Organization
IMSI	International Mobile Subscriber Identity
IMU	Inertial Measurement Unit
ISM	International Safety Management
ISO/OSI	International Standard Organization / Open System Interconnection
JOLT	JsOn Language for Transform
LSA	Life-Saving Appliances
MAC	Medium Access Control
MEE	Maritime Emergency Evacuation
MEV	Massive Evacuation Vessel
MSIDN	Mobile Station International Subscriber Directory Number

NGSI-LD	Next Generation Sensors Initiative – Linked Data
NMEA	National Marine Electronics Association
OSS	Open Source Software
PaMEAS	PALAEMON Mustering and Evacuation Process Automation System
PIMM	PALAEMON Incident Management Module
PMS	People Management System
PUN	Photon Unity Networking
RAN	Radio Access Network
RGB-D	Red Green Blue + Depth
RTLS	Real-Time Location System
S&R	Search and Rescue
SHM	Structural Health Monitoring
SMS	Safety Management System
SOLAS	Safety Of Life At Sea
SOPEP	Shipboard Oil Pollution Emergency Plan
SRAP	Smart Risk Assessment Platform
SSL	Secure Sockets Layer
SSS	Smart Safety System
SST	Ship Stability Toolkit
UAB	Unmanned Aerial Vehicle
VDES	VHF Data Exchange System
VHF	Very High Frequency
WFT	Weather Forecast Tool

1 Summary

This deliverable comes to close WP2's (*Use Case Driven Requirements Engineering and Architecture*) cycle and definitively yields the token to the actual integration of the PALAEMON platform (i.e., WP7 – *PALAEMON Integrated System and Technology Validation Trials*) and its subsequent assessment in real scenarios (i.e., WP8 – *PALAEMON Application Field Trials, Evaluation and Outcomes*). Framed within Task 2.4, this document is the official continuation of D2.6 [1] and present the final version (v2) of the PALAEMON Reference Architecture.

Throughout this report, the readers will be able to identify the following outcomes:

- Breakthrough between the first and the second version of PALAEMON Reference Architecture, mainly motivated by the issues that were left open in D2.6.
- Mapping and correlation between the different states during a Maritime Emergency Evacuation (MEE) and the operation modes of the PALAEMON components.
- A comparison between the legacy evacuation process versus the innovation carried out through the PALAEMON system.
- Update of the system requirements gathered from technology owners and end users.
- Index between components and deliverables that individually address them.
- Individual description of all PALAEMON components, identifying their main features, inputs/outputs and connections with other modules.
- Representation of the end-to-end flows that cover the main data-related use cases.

As a starting point, it makes sense to differentiate between PALAEMON Reference Architecture and PALAEMON Communications Platform. Whilst the former concept aims at the description of the components and the interaction among them from a logical standpoint (i.e., WP2 approach), the second case focuses on a more tangible or deployment view, where we deploy the system over a real hardware (i.e., WP7 approach). As a matter of fact, we carried an initial assessment of the first version of the Communications platform on a Virtual Machine allocated in a server in the cloud; however, the final version of the PALAEMON system will be deployed and tested on ANEK's Hellenic Spirit.

The document is structured as follows: Section 2 compiles all the modification the PALAEMON Reference Architecture have undergone since the release of its first version. Section 3 acts as an index and connects each of the components to their respective sections (in this document) and the dedicated deliverables. Section 4 covers all the individual components that shape the PALAEMON system and present their main features and connections with others. Section 5 wraps all this information and presents PALAEMON as a holistic system. Section 6 zooms into the platform and illustrates the main end-to-end data flows that are undertaken by the main components of the platform. Finally, Section 7 concludes the document and wraps up the main breakthrough and decisions taken in the scope of T2.4.

Moreover, we have compiled additional material that comes to complement the rest of this report. Annex I displays the traceability matrix that connects all the different system requirements with the components that have a direct or indirect interplay. Annex II compiles the whole list of IT requirements captured during the architecture definition phase.

Last, but not least, we must state that some components, interfaces or technologies may be subject of change after the submission of this deliverable. Of course, in such a case, all modifications will be duly reflected in forthcoming reports (mainly, those of WP7 and WP8).

2 PALAEMON Architecture v1 overview and changelog towards v2

2.1 Open issues handling from D2.6

The best way to start this document is precisely from where we left the previous iteration. At the end of D2.6 [1], we formulated a handful of questions that we committed to address in this report, since we assumed that, at the time of closing the first release of the PALAEMON Reference Architecture (M14, July 2020), many of the individual developments were at an early stage, thus deterring us from connecting all the dots and come up with the full picture. Hence, the next lines summarize all the architectural design decisions we left on hold some months ago.

- **MEV digitalization.** Beside the main vessel, we cannot forget about one of the main pillars behind the PALAEMON concept. In the context of WP4, there are active tasks on the choice of the composite material for the appliance, as well as the design of its interior. However, there is a lack of explicit activities (and technical partners) on the introduction of innovative ICT technologies as part of the final specification of the MEVs. As an alternative to palliate this setback, we pose the possibility of harnessing the PaMEAS system to emulate the people counting (and identification) boarding on the MEVs. With this, we mean that we do not plan to install any PaMEAS-N Access point as part of the MEV-I prototype [2], but we will dedicate a particular area of the ship (e.g., a room near a muster station) during the evacuation field trials[1] to mimic this feature.
- **Security/privacy**. Since the task devoted to encryption and authentication (i.e., T7.2) mechanisms had just started when we had to close the first iteration of the PALAEMON Reference Architecture, we opted for skipping this (critical) functionality till this second release. To address this, we have included a new component, "*Identity & Access Manager*", whose main role is to secure and protect applications, services and the communication among them. Moreover, it will also permit to support user-based role access, feature that will be applied to deal with User Equipment (UE), e.g., smart bracelets, smartphones, etc. We present this component in Section 4.3. Additionally, all technical specifications and details will be fostered in D7.2 [3].
- **Data models**. Likewise the previous case, this feature does correspond to a dedicated task (i.e., T7.3 – Uniform Data Exchange Modules – Interoperability Layer) [4], which also started in M13 (June 2020). In this case, the main purpose of the task has to do with the homogenization of the information that goes across the PALAEMON Communications platform. Now, for this second release, all data will be transformed in order to be compliant with Next Generation Sensors Initiative – Linked Data (NGSI-LD) interfaces and data models, standardized by the European Telecommunications Standards Institute (ETSI) in this Context Information Management (CIM) NGSI-LD API [5]. Focusing on the main component in charge of bridging this information flow, we describe in Section 4.2.6 the so-called "Context Broker", element that will receive the streamlined data and will forward to the next level of services (e.g., AR googles).
- **High-level services** (Smart Evacuation Management) interconnection. Though we covered the interplay among high level services in D2.6, it is true that we did not have a holistic understanding and vision of all the functionalities would have to offer, and less the exchange of information that they have to do between each other. Now that we have settled down all concepts and interactions, we are in position to present the SEM at a

[1] Application field trials will be carried out under WP8 activities.

glance, where two group of services stand out: Decision Support System (DSS) and PALAEMON Mustering and Evacuation Process Automation System (PaMEAS). Nonetheless, it is worth stating that the rest of the components do present tight bindings with these two and, altogether, will team up to build a holistic smart evacuation framework. More specifically, in Section 5 we span and analyse all the different data flows that connect all these high-level services.

- **Multimedia recording**. Concerning this last point, we intentionally left it open for this second version of the architecture. It went without discussion that many of the components to be deployed in the PALAEMON Communication platform (i.e., AR glasses, drones, smart cameras, even passengers' smartphones) are thought to lean on with this particular type of streaming data (i.e., text messages + audio + video). Therefore, we have included a dedicated server to deal with and centralize these communications, so now it is possible to establish a real-time channel between e.g., crew members, the bridge and the crew, passengers and crew, etc. We will talk about this in Section 4.2.5.

2.2 Other modifications

The first version/release of the PALAEMON Reference Architecture reflected an early integration of a wide variety of heterogenous (and unconnected) assets, brought about by the partners of the consortium. At that time (M14, July 2020), it is fair to acknowledge that the whole picture was far from being completely clear and not all components/technology providers understood what to expect or how to interact with the rest of the pieces that compose the PALAEMON platform.

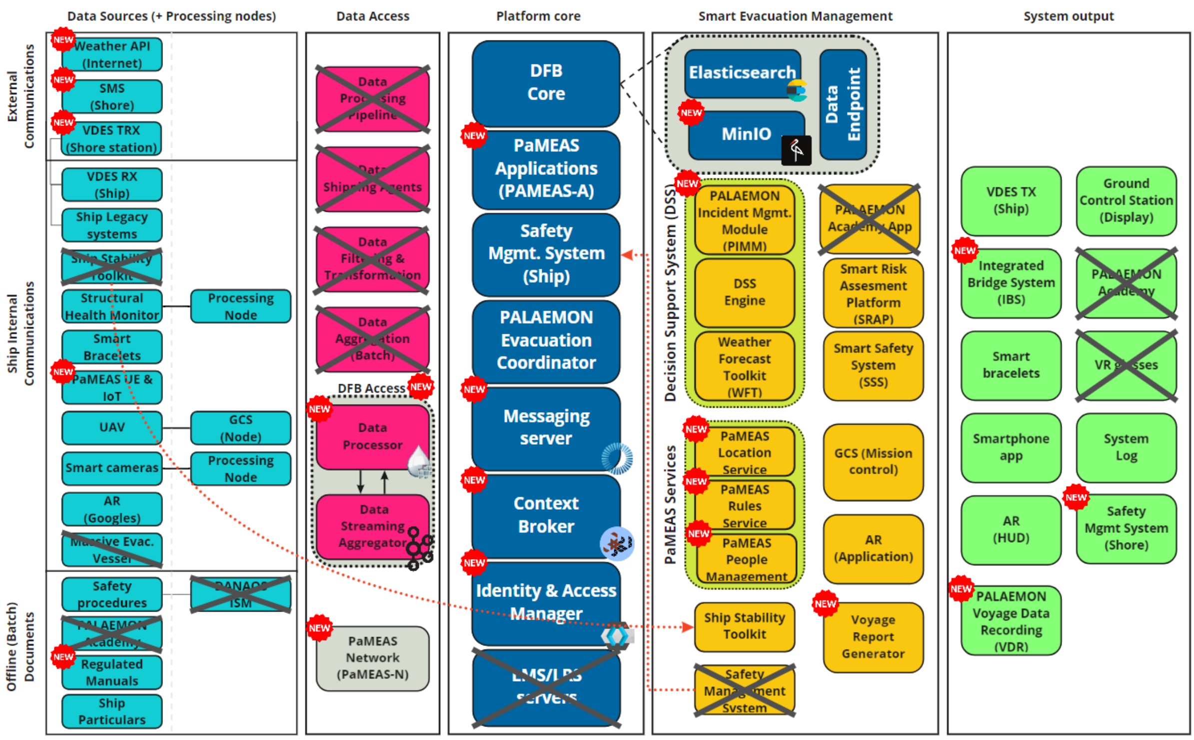

Figure 1. PALAEMON Reference architecture (road to v2)

After the release of this v1, which coincided with the ramp-up of WP7 activities, we proceeded to parallelize the revamping of the Reference Architecture and the deployment of the Communication Platform over a real system. In fact, in this second option, mainly undertaken during the preparation of a proof-of-concepts[2], we spotted a number of modifications to upgrade the system, as displayed in Figure 1, either in something as simple as dragging some components from one layer to another, or directly by aggregating new pieces to the whole puzzle.

In the next lines, we will give the reader a rationale behind these alterations to the legacy reference architecture:

Table 1. PALAEMON Reference architecture components changelog

Component	Action	Rationale
Weather API	New	Due to the lack of weather station on board of the Hellenic Spirit or AIS-based weather data streaming, we will directly get the data from a public Internet Application Program Interface (API)[3].
SMS (Shore)	New	A standalone instance of the Safety Management System is deployed at shore premises. Unlike the local SMS tool installed in the ship, this component holds manuals and procedures that belong to all the fleet.
VDES TRX (Shore)	New	Whilst a transceiver station will be installed in the ship, an equivalent unit will be deployed at shore premises, thus opening a bidirectional communication channels between both extremes.
Ship Stability Toolkit	Shifted	Reference Architecture v1 classified this component as data source; nonetheless, it is actually a service that gets data from other modules (i.e., Ship Health Monitoring, Weather Data) and yields a thorough analysis (and forecast) of the ship's stability.
PaMEAS IoT & UE	New	Specific devices (e.g., user smartphones) that will be used as the user equipment to interact with the PaMEAS system.
MEV	Deleted	As stated above, due to contractual issues, the consortium cannot deal with the integration of digital technologies as part of the MEV infrastructure. However, we will consider the feature of counting and identifying passengers over a dedicated deck, emulating the operation that would have been done in a real MEV.
Regulated manuals	New	The regulatory framework mandates the thorough compliance of different manuals and procedures: International Safety Management (ISM), Shipboard Oil Pollution Emergency Plan (SOPEP), etc. All of them will be properly adapted and stored as part of the PALAEMON (DFB) Core, so high-level service could use this information to produce their results (e.g., DSS).
Data Processor	Aggreg.	This component absorbs the functionalities of the following list of legacy components: Data Processing Pipeline (based on Logstash [6]), Data Shipping Agents (based on Elastic Beats Data Shippers [7]), Data Streaming (Batch) and, finally, Data Filtering

[2] All the architectures, outcomes and lessons learnt will be duly gathered in WP7 deliverables, namely D7.1 [52] and D7.5 [53], due in M32 of the project (January 2022).

[3] Based on Open Weather API [56], which spans both real-time information, as well as a flexible forecasting service (with different time ranges).

		and Transformation. In fact, this component can substitute dedicated Data Adaptation modules (Data source level).
DFB Access	New	We have coined this term to encompass all the operations that precede the access to the PALAEMON communication. At this point, both components (i.e., processor and streaming aggregator) will seamlessly operate before forwarding the (processed) data to the next level.
PaMEAS-N	New	To establish connection with PaMEAS UE & IoT and provide the physical means to perform its main features (i.e., location and real-time notifications), a grid of WiFi access points and 4G/LTE/5G Radio Access Network (RAN) will be deployed throughout the ship.
DFB Core	New	Aside Elasticsearch to store structured (i.e., JSON-like) objects and DFB Data Endpoint as the interface to exchange data between the databases and the high-level services (SEM), we add a new open-source component, MinIO for a generic object storage.
PaMEAS-A	New	PaMEAS ecosystem core component, including the software modules in charge of the passenger identification, location, counting, notifications, databases, etc. Besides, the interfaces between PaMEAS and the rest of the PALAEMON platform are located at this level.
Messaging server	New	Real-time multimedia communications (messages + audio + video) are a new feature introduced in the second release of the PALAEMON Communications platform. To offer these services, an open-source server will centralize all the streaming traffic.
Context Broker	New	This component comes to add, on the one hand, a standardization layer on top of the legacy data that we are injecting to the PALAEMON system, thus converting all the information to NGSI-LD data models. Besides, we also offer an alternative way to subscribe to real-time notifications (i.e., AR glasses and their intrinsic limitation to connect to the Kafka Broker with Secure Socker Layer – SSL - certificates).
Identity & Access Manager	New	To protect and keep a private and secure communication channels among the components that populate the PALAEMON platform, we have introduced a dedicated module responsible for the authentication, authorization and role-based access control.
PaMEAS Location Service	New	PaMEAS specific service that aims at automatically identify and locate people through their smart bracelets and/or PaMEAS UE devices (smartphones). To make this possible, PaMEAS will use the deployed grid of WiFi access points and Bluetooth Low Energy (BLE) beacons to triangulate the user's signal and estimate their position.

PaMEAS Rule Service	New	Another service from PaMEAS that focus on the underlying generation and execution of complex rules (e.g., automatic guidance to the safest muster station), including a notification service that will be directly communicated to each of the passengers.
PaMEAS People Management	New	Also known as “Registration Service for passengers”. Through this function, passengers bind their actual identification (100% GDPR compliant) to their associated devices (smart bracelets, smartphones) and the main PaMEAS system.
SMS (Ship)	Shifted	Initially seen as a service, the Safety Management System actually makes more sense as part of the core level, since it is in fact a fully-fledged infrastructure (databases, specific interfaces, visualization, logging system, etc.).
Voyage Report Generator	New	Software component responsible for the preparation of a post-voyage/post-incident report, gathering all data from the PALAEMON system (e.g., DFB, Messaging server, PaMEAS, etc.) and forwarding the output to the PALAEMON VDR.
Integrated Bridge System	New	We have coined this new naming from the legacy “Bridge Dashboard” that we used in D2.6. In essence, all the visual SEM services (i.e., DSS, SSS, PAMEAS) will be displayed on an array of monitors (the number is still under analysis) in the bridge, so that officers and masters can get direct feedback (and act in consequence) from the PALAEMON Communications Platform.
SMS System (Shore)	New	This shore-based instance of the SMS tool running in all the ships acts as a hub that centralizes and stores the updates policies, practices and procedures of all the fleet, according to ISM regulation.
PALAEMON Voyage Data Recording	New	Following the example of legacy shipboards’ VDR, all the information generated through the PALAEMON system will be recorded, wrapped (i.e., a zip-like file), stored and sent to external sources (e.g., cloud repository, ship owners, maritime authorities, insurance companies, etc.). As a matter of fact, all the records generated by this component will be used only for internal purposes and will not reach external audiences without ship owners and their lawyers acknowledgement.
VR Glasses	Deleted	Over a real scenario, and though crew members will wear mixed reality glasses, the use of Virtual Reality environments does not make any sense, and they will only display Augmented Reality-based information.
PALAEMON Academy	Deleted	The training platform for crew members is not part of the PALAEMON Communications Platform anymore. As a matter of fact, it counts on a standalone deployment (either in the cloud or in Johanitter’s premises), as stated in Section 5.1.

In addition to this list of modifications, it is worth bringing up at the end of this section a feature that we did not contemplate (at least we did not give it the importance we are endowing now) in the first version of the architecture. For the sake of the context, in D2.6 we did mention two concepts: on the one hand, as part of the maritime ship evacuation status flow, we appended a last state name “Post-incident analysis”, referring to the actions taken (i.e., at shore) to evaluate the (mis)actions taken during the course of a evacuation. Moreover, throughout these months, we have gotten a deeper acquaintance on how modern ships actually work, and stumble upon the concept of Voyage Data Recording (VDR), a recording system that must follow the International Maritime Organization’s (IMO) Safety Of Life At Sea (SOLAS) convention [8]. Applying the exercise to the PALAEMON Communications Platform, the idea is to mimic this feature and generate a fully-fledged report of all the information gathered during a voyage (regardless it has undergone an incident or not). To deal with such operation, we present the Voyage Report Generator in Section 4.4.10, a dedicated piece of software that reaps all system data, wraps it and yields the final report, which will be handed to the company’s Designated Person Ashore (DPA), link between ships and shore staff. As the output of the system, we coin the term PALAEMON VDR to refer to it (Section 4.5).

2.3 Ship evacuation process update

As we have already addressed in multiple deliverables (e.g., D2.2 [9], D2.4 [10] and D2.6 [11]), the PALAEMON evacuation platform shows a tight liaison with the actual maritime evacuation process and regulation, as reflected in e.g., SOLAS guidelines [12]. Throughout a voyage on a ship, certain situations (i.e., incidents) might unleash a change in the evacuation status, thus leading to emergency measurements to cope with a potential incident (or in plural in case of multiple casualties). In this sense, the PALAEMON platform keeps track of the whole evacuation process, dynamically changing the operation mode of all data sources and services.

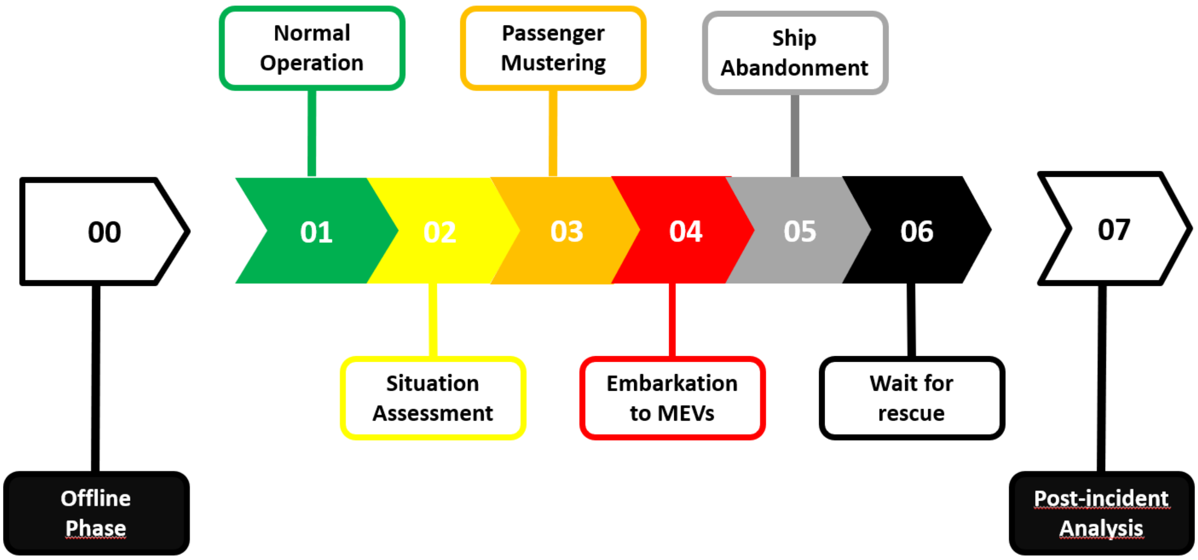

Figure 2. Maritime Emergency Evacuation status flow applied to PALAEMON

For the sake of illustration and acting as a refresher, the PALAEMON platform encompasses up to 8 phases, as we outline in Figure 2. As a matter of fact, it is worth mentioning that the extreme states do not correspond to an actual evacuation state but do play an essential role in the PALAEMON ecosystem. Namely, phase 0 (“*Offline phase*”) embraces all the operations carried out at shore, i.e., before the ship gets unmoored (e.g., passenger list creation, generation/update of safety procedures, crew training, etc.). At the other side, phase 7 ("*Post-incident analysis*") contemplates all actions done after (i.e., can be days, weeks or even years) an incident has occurred, mainly devoted to a thorough "forensic" analysis of all the information captured (e.g., sensors, voice and video recordings, etc.) during the voyage.

It is easy to infer that the critical part of the system is the one that actually copes with the evacuation process, i.e., steps 2-6, since the first phase ("*Normal status*") corresponds to the standard operation of the ship and all its underlying systems and stakeholders. In the event that a incident occurs, an officers' alert would be triggered and spread through the direct public alert system, thus switching from normal phase to "Situation Assessment". As we can see in the upper part of Figure 3, as long as the situation get worsened, the evacuation status increases its criticality level, to the point that, after the Master's "Abandon Ship" command, all people (passengers + crew members) must leave the vessel. It is worth highlighting that all these evacuation shifts are heavily intertwined with bridge orders, mainly coming from the Master, seconded by the rest of the officers and bridge command team. It is mandatory by Maritime Law that all major decisions going on in a ship are officially given by the Master, so the PALAEMON Evacuation Status changes will be dependent on such alarms.

Translating this evolution of the evacuation phase to the PALAEMON Communications Platform, there are some components that show a direct binding with the current evacuation phase, as displayed in Figure 3, where we represent the different operation modes of all the "depending" components. As can be seen in the figure, not all components have to necessarily switch their operation mode at every evacuation state shift.

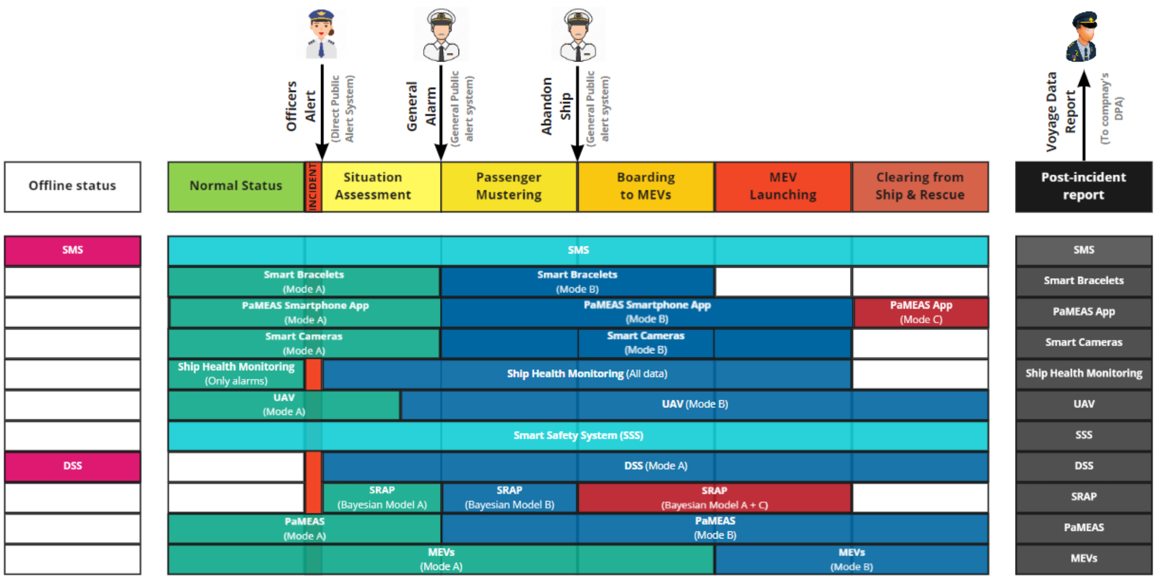

Figure 3. PALAEMON Components Dependency on Ship Evacuation Status

In order to settle down all these concepts on the evacuation process, we compile and compare in Table 2 the typical actions legacy actions carried out in modern vessels to the novel elements brought about by the PALAEMON Communication platform and all its underlying technologies. In particular, we stick to an arbitrary case where a fire is detected at the open car deck on a Ro-Pax Ferry. The reader may complement this table with a deeper explanation present in D2.5 [13].

Table 2. Evacuation phases action comparative over a fire-based scenario (traditional vs. PALAEMON)

#	Legacy operation (based on fire scenario)	PALAEMON new actions
Offline phase	• Crew training for evacuation is performed via periodic drills according to regulatory provisions • Passenger list is available onboard in hard copy format • Ship particulars are digitally loaded to the vessel's computers (e.g., Loadicator [14], etc.) and are also available in hard copy format (blueprints) on the bridge • The ship's documentation (e.g., SMS, Contingency Plans, etc) are available onboard in hard copy and digital format (e.g. pdf), but not fully digitalised (e.g. searchable text)	☑ Crew training using the PALAEMON Academy app ☑ Passenger list loaded to PALAEMON System ☑ Ship particulars loaded on the PALAEMON System, as well as the AR googles (as they need to be environment-aware) ☑ Preparation of the document repository (Safety Management System - SMS) ☑ Initial configuration of data sources and services
Normal status	• Stability is monitored by using dedicated software (e.g., Loadicator) available on the ship's bridge • The structural integrity of the is monitored by the calculation of bending moments and shear forces for specific loading scenarios (according to the loading condition of the vessels, e.g. number of passengers on-board, bunkers, etc.) via the dedicated software (e.g., Loadicator) • The exact location of the passengers is unknown to the crew members • Crowd monitoring and control or planning is performed by the crew members (physical presence) and by using visual information from cameras • People count is (manually) conducted by the crew members via passengers list	☑ Structural Health Monitoring (SHM) monitors the static and dynamic stability of the ship and notifies if a potentially dangerous threshold has been passed ☑ Ship Stability Toolkit monitors the stability of the ship and notifies any anomaly, in conjunction with SHM and shipboard legacy system data ☑ PaMEAS provides information about the location of passengers and crew, which allows performing crowd control or planning for ship services (anonymized, respecting GDPR rules) ☑ Smart Cameras count the people on corridors or common rooms, allowing for further crowd control.

Situation Assessment	• The ship's Master assigns responsibilities to response teams and retains control of the situation by assessing the available information • The structural integrity of the vessel is monitored either through physical inspection by the crew members or through the cameras • Physical inspection is performed by the response team to assist Bridge Command Team to assess the severity of the incident • Cameras may be exploited only if they are placed near the location of the incident • Scenario based assessments by using onboard tools for calculation (e.g., Loadicator, etc.) are performed for evaluating the stability and structural integrity of the ship • Communication among the crew members is conducted via VHF radio	☑ Data sources start generating information at pre-configured rates ☑ SRAP determines the potential risk of the situation ☑ DSS shows recommendations depending on the nature of the incident ☑ SMS suggests tasks to mitigate the situation ☑ AR glasses give crew insight on the incident analysis ☑ The Master can rely on the additional information sources brought about by the PALAEMON system to bolster his/her decisions ☑ The Bridge can communicate with crew members (via AR glasses) and connect to watch the streaming content from the Smart Cameras
Passenger Mustering	• Escapes routes are marked by dedicated signs and emergency lights • Crew members are positioned on pre-defined locations along the evacuation routes to assist the passengers to proceed to their assigned Muster stations • Communication among the crew members is conducted via VHF radio. • Passengers are informed about the situation via the Public Address (PA) system of the vessel and receive instructions verbally by the crew members • Crew members inspect all areas of the ship for any passengers that may have been left behind. Crew members employ a systematic way of checking, for example, the cabins by marking checked and cleared spaces • Passengers with health issues are identified visually by the crew members	☑ Crew starts directing the passengers to the mustering stations ☑ PaMEAS helps crew by showing all passengers location and potential incidents ☑ PaMEAS yields a personalized and dynamic routing to the safest muster station (i.e., smart bracelets + smartphones) ☑ Passengers can use their smart bracelets to notify about an accident (e.g., accidental fall) ☑ AR glasses will lead crew members to locate and find stranded, disoriented or injured passengers ☑ Smart Cameras start sending data at a higher rate and stream their video feed to help the bridge crew with decision making

MEV embarkation	• Passenger counting on Life Saving Appliances (LSAs) is performed manually by the crew members	☑ Passengers who enter the MEVs are identified and accounted (via PaMEAS service) ☑ Smart Cameras can spot passengers lagging behind, blocked corridors, etc. ☑ Smart Bracelets, along with AR glasses collaborate to help crewmembers find any lost/missing/injured passengers ☑ UAV is activated to inspect the ship and look for any man-over-board situations
MEV	• All LSAs are lowered from the ship • LSAs navigate to a safe distance away from the ship	☑ Main PALAEMON services are stopped ☑ UAV is activated to inspect the ship and look for any man-over-board situations
Wait for rescue	• Once safely cleared from the ship, passengers, and crew members on LSAs wait for Search and Rescue (S&R) authorities	☑ VDES will continually broadcast a distress to help authorities find the incident site ☑ UAVs fly close to the MEVs to keep track of their positions ☑ UAVs inspect the ship and look for any man-over-board situations
Post-incident	• All data generated by the shipboard legacy systems (e.g., AIS, sensors, communications, weather, etc.) is stored in the Ship's VDR. • Incidents and accidents are investigated by shipping companies and relevant authorities (e.g. national accident investigation boards), depending on the incident severity and consequences. The objective of the investigation is to identify the causes and contributors	☑ PALAEMON Voyage Report Generator compiles the evacuation data, complementing the information stored by the legacy VDR, including new sensors, video streams, software modules logging, etc.

2.4 System requirements revisited

Beside all the modifications on the PALAEMON Reference Architecture and the Maritime Evacuation Process we have described so far, it is worth highlighting at this point that we have also revisited the system requirements we presented in D2.6. Alongside the validation of the stakeholders' requirements conducted under the umbrella of T2.2 (i.e., "*Stakeholders requirements*"), which gave rise to D2.3 [15], from the PALAEMON consortium standpoint, all technology owners and naval partners have combed the legacy requirements table and have come up with a new (and definitive) list.

As a refresher, we enumerate and outline in Table 3 the main attributes that are used to define a requirement.

Table 3. Requirements attributes description table

Field	Description
ID	Requirement unique identifier
Type	One between these two: *Functional / Non-functional*
Description	A short statement describing the requirement
Category	One (or more) from the following list: *Integration, Performance, deployment, Interfaces/Data access, Interoperability, Security and Authentication, Visualization, Communications, Individual Components, Usability, Others*
Rationale	A short description that justifies the necessity of the requirement and the goals achieved from its implementation
Priority	One of these: *MUST / MUST NOT/ SHOULD / SHOULD NOT / COULD*
Dependencies	List of requirements that directly or indirectly depend on the subject of analysis
Stakeholder(s)	One (or more) from the following list: *authorities, other ships, ship owners, Master, Bridge Command Team, Crew, Office, Passengers, Crew (UAV controller), System Admin, IT team, Post-incident forensic, System developers, Technology providers*

Due to the size of the list (the number of requirements totals more than 200), we have opted to keep (likewise we did in D2.6) both Traceability Matrix and the integral requirements table to Annex I and Annex II, respectively. In order to highlight the main modifications between Reference Architectures v1 and v2, we have coloured them according to the following code:

- **Green**: New requirement (v2).
- **Yellow**: Requirement that has been modified between v1 and v2.
- **Red**: Deprecated requirement that does not take part of v2.

3 PALAEMON architecture connections and index

For the sake of giving the reader a holistic reference and outline of the PALAEMON Reference Architecture, we compile in Table 4 the list of individual components, following the layered approach presented before. Besides, we link to their respective sections throughout this report. Beyond this, should the reader want to delve into more technical details, we have also included the deliverables that have to do with each particular module.

Table 4. PALAEMON Individual component index table

Layer	Component	Section	Deliverable (date)
Sources	Weather Data	4.1.1	N/A
Sources	Shipboard Legacy Systems	4.1.2	N/A
Sources	Smart Bracelets	4.1.3	D.5.1 [16], D5.2 [17]
Sources	Smart Cameras	4.1.4	D5.17 [18], D5.18 [19]
Sources	PaMEAS UE & IoT	4.1.5	D5.15 [20], D5.16 [21]
Sources	UAVs (Drones)	4.1.6	D5.5 [22], D5.6 [23], D5.7 [24], D5.8 [25]
Sources	Structural Health Monitoring	4.1.7	D6.1 [26]
Sources	VDES	4.1.8	D7.4 [27]
Sources	AR Googles	4.1.9	D5.3 [28], D5.4 [29]
Sources	MEVs	4.1.10	WP4 deliverables
Sources	Offline data	4.1.11	N/A
Access	DFB Access	4.3.1	D6.2 [30], D6.3 [31]
Access	PaMEAS-N	4.3.2	D5.9 [32], D5.10 [33], D5.13 [34], D5.14 [35], D5.15 [20], D5.16 [21]
Core	DFB Core	4.2.1	D6.2 [30], D6.3 [31]
Core	PaMEAS-A	4.2.2	D5.9 [32], D5.10 [33], D5.13 [34], D5.14 [35], D5.15 [20], D5.16 [21]
Core	Safety Management System (SMS)	4.2.3	D3.7 [36], D3.8 [37]
Core	PALAEMON Evacuation Coordinator	4.2.4	N/A
Core	Messaging Server	4.2.5	N/A
Core	Context Broker	4.2.6	D7.3 [4]
Core	Identity and Access Manager	4.3	D7.2 [3]
SEM	Smart Safety System (SSS)	4.4.1	D3.1 [38], D3.2 [39]

Layer	Component	Section	Deliverable (date)
SEM	Ship Stability Toolkit	4.4.2	D3.3 [40], D3.4 [41]
SEM	Smart Risk Assessment Platform	4.4.3	D3.9 [37], D3.10 [42]
SEM	Decision Support System (DSS + PIMM + WFT)	4.4.4	D6.4 [43], D6.5 [44], D3.5 [45], D3.6 [46]
SEM	PaMEAS Real-Time Location System (RTLS)	4.4.5	D5.9 [32], D5.10 [33], D5.13 [34], D5.14 [35], D5.15 [20], D5.16 [21]
SEM	PaMEAS Rule Management System (BRMS)	4.4.6	D5.9 [32], D5.10 [33], D5.13 [34], D5.14 [35], D5.15 [20], D5.16 [21]
SEM	PaMEAS People Management Service	4.4.7	D5.9 [32], D5.10 [33], D5.13 [34], D5.14 [35], D5.15 [20], D5.16 [21]
SEM	Ground Control Station Mission Control	4.4.8	D5.5 [22], D5.6 [23], D5.7 [24], D5.8 [25]
SEM	AR Application	4.4.9	D5.3 [28], D5.4 [29]
SEM	Voyage Report Generator	4.4.10	N/A
Output	System outputs	4.5	N/A
Others	PALAEMON Academy	5.1	D3.11 [47], D3.12 [48], D3.13 [49], D3.14 [50], D9.6 [51]

After a quick look at the last column (deliverables), we can extract two things. On the one hand, we can see that WPs definition do not match the layered approach we have followed when defining the PALAEMON Reference Architecture. Namely, we do observe a mixture between WP3, 4, 5, 6 and even 7's deliverables throughout the different layers of the system. This heterogeneity heightens the importance of the activities carried out in this task, as it yields the holistic and transversal vision that partners need.

Moreover, we can also appreciate as some components lack a specific deliverable to cover their respective breakthroughs. In this case, we can differentiate between two different groups: 1- Legacy technologies/components that did not belong to any particular technical partner and do not have a direct match with any deliverable; their outcomes can be straightforwardly embedded into other deliverables (i.e., Weather Data, Shipboard Legacy Systems, Offline Data, Messaging Server, System outputs). 2- New modules that arose during the definition of the PALAEMON platform and were not contemplated at proposal time (i.e., PALAEMON Evacuation Coordinator, and Voyage Report Generator).

On top of this granular approach, it is worth highlighting the role of WP7 as system integrator and validator hub, where all the individual paperwork and developments converge and derive into a holistic Communications Platform. Acting as the perfect complement of this report, WP7 integration-oriented activities[4] are responsible for the actual deployment (and instancing) of the PALAEMON Reference Architecture onto a real hardware infrastructure.

Table 5 gathers and summarizes the work to be done in these tasks.

Table 5. WP7 tasks and main

Task	Name	Description	Deliverable
T7.1	PALAEMON Communication Platform	The purpose of this task is to take the PALAEMON Reference Architecture (recall, a layered approach and logical interconnection of components) and go a level deeper, describing the process, implementation and deployment strategies carried out during the process.	D7.1 [52]
T7.3	Uniform Data Exchange Modules – Interoperability Layer	Data homogenization that guarantees the interoperability among the different components of the PALAEMON platform. In this particular scenario, the Context Broker will be in charge of storing and forwarding all notifications according to NGSI-LD specification.	D7.3 [4]
T7.5	Integration of PALAEMON Prototype System	In parallel to T7.1, the objective of this task is to bring the PALAEMON Communication Platform to a real hardware infrastructure. As a matter of fact, a first release was tested on a cloud-based scenario, and the second and final version will be directly executed on Hellenic Spirit's premises.	D7.5 [53]
T7.6	PALAEMON Ecosystem Testing	As a final step, once all the system is in place, it is utmost important to assess the performance and reliability of the whole platform before proceeding to the execution of the validation phase (WP8).	D7.6 [54]

4 PALAEMON Components update

Whereas in Section 2.2 we specified all the modifications the PALAEMON Reference Architecture has underdone since the release of the first version, in this one we span all the components that shape the system, highlighting their main features and bindings to other modules. It is worth highlighting that this section is thought to be self-explanatory, that is, the reader would not need to refer to D2.6 to check a particular component description, so components may include excerpts that had been reflected in the previous document. Nonetheless, all of them are updated and aligned with the final version of the architecture.

With this said, we will follow a layered "round table", alike we did in D2.6, spanning all components from the data generation to the system output. A brief explanation/refresher of the levels can be found next:

[4] Since T7.2 (Encryption and Authentication Mechanism) and T7.4 (VDES Deployment) focus on a completely different scope and have to do with individual components, as reflected in Table 4, we have left them out the list.

- **Data sources**: Components that act as information sources, either through real-time streams or by means of static information (e.g., procedures, lists, etc.).
- **Data access**: Transition layer that acts as an entry point to the raw information coming from the sources. Its main role is to adapt (i.e., aggregate, filter, transform) the data and forward it to the next level.
- **PALAEMON core**: The heart of the system, where all the main services undertake critical functions for the correct operation of the whole platform.
- **Smart Evacuation Management**: Service layer that brings the intelligence to the system on top of the data generated in the previous levels.
- **System outputs**: Final "stop", with two main purposes: direct interaction with ship's users, i.e., Human Machine Interface (HMI), and connection to external stakeholders (ashore tools, maritime authorities, insurance companies, etc.).

4.1 Data Sources

4.1.1 Weather data

It goes without saying that an accurate and real-time monitoring of data is utmost relevant when sailing. In the context of the PALAEMON Communications Platform, we lean on OpenWeather service [55], which supports a free API [56] where we can receive not only the current weather information (Table 6), but also a minute forecast for the next hour, an hourly forecast for the next 48 hours and, finally, a daily forecast for the next 7 days. Moreover, they also broadcast government weather alerts.

To obtain this weather data, the only parameter we have to set as input is the ship location, through the well-known tuple latitude + longitude. This way, the service will send back the information from the closest weather station to that particular point. When it comes to fetch this information, we have two different and complementary ways to get the data:

1. At an initial and remote phase (before we go and integrate the system in the actual ship – Hellenic Spirit), we will get the data via well-known RESTful API. For that, a regular Internet connection is needed.
2. In the final stage of the project (framed within WP8's activities), the PALAEMON Communications Platform will be completely deployed over the real ship (i.e., Hellenic Spirit), and all its legacy shipboard systems will be integrated. Besides, we will install a VDES transceiver in the ship, as well as an emulated VDES station at shore (Section 4.1.8). With this particular setup, as described with more detail in Section 6.8, the query to the API will be carried out at shore and the information will be transmitted from the shore station to the ship transceiver.

Table 6. Weather data main features

Connectivity	▪ Internet connection (to access the API) ▪ VDES (shore to ship channel)
Measurements	▪ Temperature (ºC) ▪ Feels like temperature (ºC) ▪ Atmospheric pressure (hPa) ▪ Relative Humidity (%) ▪ Wind speed (m/s) ▪ Wind direction (degrees) ▪ Wind gust (m/s) ▪ Cloudiness (%) ▪ Rain (mm)

4.1.2 Shipboard Legacy Systems

At the time of putting down in writing all the content of PALAEMON Reference Architecture v1 (i.e., D2.6 [1]), we did not have an official ship that could have been used as reference to stick to. In consequence, we did not have absolute certainty of all the off-the-shelf information sources we could find during this second version of the platform.

However, now the situation is rather different and we have been acquainted with the situation we are going to tackle, that is, when it comes to integrate our system as part of ANEK's Hellenic Spirit [57]. Trying to summarize the main features of this vessel in a nutshell [58], the ship was built in 2001 and its main route connects Patras (Greece) with Ancona (Italy), with an intermediate stop at Igoumenitsa (also Greece). In terms of ICT technologies, we can categorize the different data sources into three main groups. Table 7 compiles the connectivity technologies and type of data we can find on Hellenic Spirit.

1. **AIS data.** According to SOLAS [12], all passenger ships, regardless their size, must incorporate AIS transponders on board. They have to broadcast periodically messages containing the ship's ID, position, course, speed, etc. to equipped shore stations and all surrounding vessels (provided that they are within the same coverage area).
2. **National Marine Electronics Association (NMEA)** [59]**.** As a Ro-Pax ferry, Hellenic Spirit carries a number of built-in sensors that monitor the ship conditions in real time. To illustrate the reader with a handful of examples, we can find: automatic fire fighting system status, fire & smoke detectors, flooding sensors, bilge pump status, Public Announcement system status, wayfinding system status, etc. All this information is compliant with NMEA 0183 specification [60], which defines a serial transmission to exchange information with a central system.
3. **Offline data**. Beside the streaming of data, the PALAEMON platform needs some "static" information that we be gathered even before the voyage starts. Elements like passenger and crew lists, ship particulars and blueprints or safety procedures and manuals will be subsequently used by the Smart Evacuation Management system services. We will get back to this type of information in Section 4.1.11.

Table 7. Shipboard legacy systems main features

Connectivity	▪ Wired/Ethernet ▪ WiFi (mesh of hotspots available) ▪ Cellular (e.g., 4G) ▪ Satellite ▪ Automatic Identification System (AIS) transponders
Measurements / Data	▪ [AIS] Ship position ▪ [AIS] Ship speed ▪ [AIS] Ship direction heading ▪ [NMEA] To be decided[5] ▪ [Offline] Passenger/crew lists ▪ [Offline] Ship & deck blueprints ▪ [Offline] ISM Manuals ▪ [Offline] SOPEP Manuals ▪ [Offline] Evacuation procedures / contingency plans ▪ [Offline] LSA Drawings

[5] The usage of off-the-shelf sensors from the Hellenic Spirit is still under discussion at the time of submitting this report (M25, June 2021).

Another point that was not clear in the previous iteration was the Internet connectivity issue, since we could not guarantee that the real ship would be able to guarantee 100% Internet coverage throughout the voyage. After checking this issue with ANEK (i.e., Hellenic Spirit's owner), we can confirm that, due to the short distance between ship and shore along the way, a cellular link will be always available all the time. Moreover, a satellite connection is also ready as a backup channel.

4.1.3 Smart Bracelets

PALAEMON proposes a wearable Internet of Things (IoT) device for passengers and crew. A Smart Bracelet (SB) will be developed in order to support PaMEAS to identify (anonymously) and localize passengers and crew and establish adequate evacuation routes in the ship.

As a matter of fact, the main functionality of PaMEAS indoor location system will be described more thoroughly in Section 4.3.2. SB will consider both indoor and outdoor conditions operating as a beacon with bidirectional communication capabilities. Initially, the approach to be followed is based on Ericsson 4G-LTE/5G hybrid cellular technology (Radio Dot Network) and RANs. The fusion of different technologies, i.e., Bluetooth Low Energy (BLE), WiFi 6.0, outdoor positioning such as Global Positioning System (GPS) and, potentially other technologies will be evaluated. The SB will provide WiFi/Bluetooth beaconing to assist PaMEAS in the localization of passengers and crew members, as well as showing relevant information regarding the evacuation on its screen (text or signs for routes). The SB will also feature an emergency button that passengers can use to actively inform the crew of problems during the evacuation (Table 8).

As for its operation mode, SBs will be constantly listening to the ship evacuation status, transmitted by the PALAEMON Evacuation Coordinator (Section 4.2.4). Likewise, many other components, it will switch from a default to another "evacuation" mode as soon as the alarm signal has been generated.

Table 8. Smart Bracelet main features

Connectivity	▪ 4G LTE/5G hybrid (via Radio Dot System) ▪ BLE ▪ GPS (to be confirmed) ▪ RFID (to be confirmed)
Measurements	Optional ▪ body sensor (HR) ▪ body sensor (SpO2) ▪ fall detection (accelerometer, gyroscope) ▪ GPS / Global Navigation Satellite System (GNSS)
Action	▪ Notification/alarm button

4.1.4 Smart Cameras

PALAEMON proposes the use of smart cameras (SC) to monitor people in indoor areas. For the sake of illustration, during an emergency situation, the system will detect the people flow direction or whether a particular corridor is congested/overcrowded.

Smart Cameras' output raw data (defined in Table 9) will be reported to the Smart Evacuation Management system (e.g., PIMM, DSS) to use them adequately. SC will consider 3 different areas: long corridors, large open indoor areas and deck stairs. SC will have 2 different modes, i.e., normal and evacuation, having different data rates, performance, and image analysis. As explained in Section 2.3, the ship evacuation status, updated and broadcasted by the PALAEMON Evacuation Coordinator (Section 4.2.4), will send the cue to switch between these operation models. Besides, the SC will inform about abnormal flow of people. The project embraces 2 different type of devices: new installation and legacy systems. The new installation of SCs will use Red Green Blue + Depth (RGB-D) cameras, which not only include RGB images but also Depth information, which will be used in the developed algorithms to provide better results and performance. The algorithms will be based on Intel OpenVINO libraries [61] that can be executed on new SC nodes at the edge or standard processing computers placed in the Closed-Circuit Television (CCTV) room. To ease the installation of the system, each SC node will process the information separately, without overlapping images in the scene to provide fused results. At a later stage, the upper-layer services will interpret what the data from the static SC nodes mean. The SC will have a Graphical User Interface (GUI) required to configure the different parameters of the analysis, surveillance area, etc. The SC node could have 2 cameras and only one processing system if the performance is enough; this efficiency/saving will be evaluated.

Other considerations should be taken into account:

- The cameras will be connected with the PALAEMON platform preferably with >1Gbps wired Ethernet, because it is a standard, cheap and has enough bandwidth to transmit video information (the reader must recall that all multimedia streaming will be integrated in the next iteration of this document).
- New nodes should be firmly installed as a ship infrastructure as it is required that the camera maintain the installed orientation.
- The SC node can be configured to send the video clip and data in the desired format, coding, size, and other parameters of data communication, considering the existence of standard libraries or code to be used in the Intel processor.
- In the event of an incident, a real-time video streaming will be offered to the bridge (via PIMM), so that the Master and Bridge Command Team may visually inspect the current situation on their own (of course, the video will be complemented with the legacy outputs of the SC system).
- Following the previous case, in case of emergency, all video clips will be locally recorded in the SC nodes. Subsequently, these videos will be part of the post-incident analysis managed by the Voyage Report Generator (Section 6.12).

Table 9. Smart Camera main features

Connectivity	▪ Camera → Processing node: Ethernet ▪ Processing node → Core: Ethernet/WiFi (to be decided)
Measurements	Optional (to be confirmed at design & specific. phase) ▪ people count on the surveillance area ▪ occupancy ratio of the surveillance area ▪ people flow detection ▪ trapped people (if anyone)

4.1.5 PaMEAS UE & IoT

PaMEAS is a multi-component system combining the functionality of an indoor positioning system with the capacity of providing, to passengers and crew, notifications and navigation guidelines during evacuation. Specifically, it permits tracking and monitoring of the position of passengers and crew within the ship and automatically launches, in the case of an emergency, a predefined evacuation plan (the evacuation of a ship is based on pre-established plans and procedures). This plan will be: a) will be communicated directly to passengers' UEs (mobile phones and other devices such as smart bracelets, smartwatches, etc.) – via simple notifications but also data and video transmission, whenever this is needed or is applicable (PaMEAS Notification Service) and, b) projected to the physical ship space, by using the appropriate signage indicating the suggested evacuation paths (with help from PaMEAS-IoT networked services).

To be tracked, passengers' and crew's UEs should have registered before with the System and linked to a passenger or crew PALAEMON identity (People Management System – PMS). As a result, the PaMEAS will recognize connected devices on the basis of their core identification features (MAC: Medium Access Control address, IMSI: International Mobile Subscriber Identity, MSISDN: Mobile Station International Subscriber Directory Number, IMEI: International Mobile Equipment Identity. Additionally, the are requested to PaMEAS mobile app which will attribute to users a "Client Notification Address" (their recipient address for evacuation notifications). In normal conditions, the passengers' UE position identified only for passengers providing such a consent (it can be withdrawn by the passenger at any time and re-activated again via a simple Verifiable Digital Credentials). In evacuation conditions, tracking becomes ubiquitous and the tracking service extend to cover identified and mon-identified devices.

The UE equipment will be integrated to PaMEAS Smart Evacuation Management architecture and functionality includes smartphones, tablets and other personal networked devices with operational independence such as smart bracelets, smart watches etc. Currently, all these devices are coming with the network components that allow them to seamlessly connect to various wireless, mobile and bluetooth networks and, consequently, to PaMEAS-Network (PaMEAS-N) infrastructure, i.e, to PaMEAS Wireless Network (WiFi Access Points and Beacons) and to PaMEAS-Cell (4G LTE- 5G Radio Dots).

PaMEAS notification and evacuation guidelines will be forwarded to passengers' and crew UE through PaMEAS-N. PaMEAS-IoT will complete the operation by activating specific IoT signage equipment, such LED emergency lighting, that will signal to passengers the suggested routes of escape. For the activation of ship IoT signage evacuation infrastructure, PaMEAS-IoT makes use of an IoT-enabled multimedia controller (IoT2MMD) which "subscribes" to PaMEAS Notification Service.

Table 10. PaMEAS UE & IoT main features

Connectivity	▪ WiFi 5 and 6, 4G LTE – 5G, Bluetooth
Measurements	▪ Tracking Position Accuracy (within a Geofence with high probability) ▪ Low Notification Delivery Time (Low Network Latency)

4.1.6 Unmanned Aerial Vehicle (UAV)

The UAV (Unmanned Aerial Vehicle) is the main sensor node of the UAS (Unmanned aerial System) for the PALAEMON system. It is a semi-autonomous device able to execute orders received from a remote station and is used as a remotely steerable sensor. It provides the ability to cover areas that are out of reach to the other sensors of the system due to its ability to navigate in the three-dimensional space.

The vehicle usual sensors such as the Global Positioning System (GPS), Inertial Measurement Unit (IMU) or compass of the vehicle generate data that is used for its own in-air navigation but also sent to the ground to allow the operator to follow the execution of the mission (Table 11).

The main sensor carried by the UAV is the electro-optical camera sensor. It is mounted on a gimbal, providing stabilization and allowing the camera to be oriented independently of the flight dynamic and destination of the vehicle.

It produces a video stream that is transmitted to other parts of the system for observation and further analysis. It is aggregated with the navigation data from the UAV to enhance localization of the generated images.

The UAV uses the ship's location and orientation data to perform its flight around the vessel.

Table 11. UAV main features

Connectivity	▪ UAV → GCS: Proprietary protocol (@2.4 GHz) ▪ GCS → Core: WiFi
Measurements	▪ Magnetic field ▪ GPS signal ▪ Optical data ▪ Acceleration ▪ Attitude ▪ Pressure ▪ Current/Voltage
Output	▪ Video streaming (@H264) ▪ UAV telemetry (Location, dynamic, orientation) ▪ Gimbal telemetry (orientation) ▪ Extra telemetry information (battery level. etc.)

4.1.7 Structural Health Monitoring (SHM)

The SHM (structural health monitoring) system (Table 12), comprises of two sensor systems, i.e., the motion sensor system, accompanied by an application (i.e. within an independent processing node), and the AE (Acoustic Emission) system. The former one is used to measure the structural integrity and stability of the ship, while the AE system is used to identify local damages or events which can be produced by an accident or incident.

In this sense the motion sensor system is for monitoring the global structural health and stability of the ship, while the AE system is for local structural health. Both systems are real time CM (Condition Monitoring) systems and also have the capability to store data and also transmit to Shore (Company Head Quarters) but also to technical teams for post analysis.

The SHM software is being developed by ESI in the framework of the PALAEMON project will offer angles (stability), accelerations (rate of change of angles) and structural health of the ship, in the form of longitudinal deflections which can be translated to bending moments and shear forces if the ship data (Section Modulus of the ship and particulars) are available and inserted in the software. These are offered in real-time, in order to bring insight on possible deteriorating situations or other events after an accident or an incident.

The SHM software of the motion sensors offers the possibility to transmit to the PALAEMON core and the Shore HQ status reports at specified time intervals, alarms when a critical incident might occur, identified when a parameter exceeds a specific value, e.g. when healing angle exceeds 25 degrees. It can also offer the possibility to record and transmit the data to the PALAMEON core continuously.

On the other hand, the AE system is for monitoring and identifying local damages such as cracks, and defects which can be caused by collisions, grounding and other similar events. The AE system can also monitor and inform in a case of a propagating crack. The AE system will offer alarms in the form of critical event status or reports to the PALAEMON core, whenever an event occurs, e.g. cracks, propagating defect, etc.

Table 12. Structural Health Monitoring main features

Connectivity	▪ Sensors → Processing node: Ethernet ▪ Processing node → Core: Ethernet/WiFi
Input parameters (sensor-based data)	▪ Ship's stability angles ▪ Ship's motion ▪ Ship's heave (local hull displacement) ▪ Acoustic signals
Output parameters (processed data)	▪ Roll and trim of ship ▪ Deflection of Ship (translated to bending moments and shear forces) ▪ Crack initiation ▪ Crack/defect formation and propagation ▪ Provide alarms when the aforementioned variables get over critical values

4.1.8 VDES

VHF[6] Data Exchange System (VDES) is a communication system that operates between ships, coastal stations and satellites[7], by means of three different data channels (services): i) Automatic Identification System (AIS); ii) Application Specific Messages (ASM); iii) VHF Data Exchange (VDE).

- AIS channels are used to transmit the position of each vessel to the whole maritime monitoring network (already operational).
- ASM channels will transmit messages, currently sent on the AIS frequencies, not related to the positions of the ships, lightening the traffic on the AIS frequencies.
- VDE channels will enable the exchange of higher data volume, thanks to wider bandwidths w.r.t. AIS and ASM ones and consequently higher throughput.

[6] VHF stands for Very High Frequency, range of the radio frequency electromagnetic spectrum that spans frequencies between 30 and 300 Megahertz (MHz).
[7] The VDES satellite connection is out of the scope of the project and will not be implemented.

In the receiver mode, VDES transceiver (Table 13) will be able to receive analogue signals at VHF frequency channels [62] convert them from analogue to digital, process them at different ISO/OSI levels, i.e., physical, data link, network and transport layers and pass them to PALAEMON application. At each ISO/OSI (International Standard Organization / Open System Interconnection) level the following operations are carried out: i) data synchronization by means of specific signals/indicators; ii) removal of layer overhead; iii) verification of data correctness by means of Cyclic Redundancy Check (CRC), if any; iv) data extrapolation. In the transmission mode the operations are dual of those listed for the receiver mode, i.e. data encapsulation, addition of CRC, addition of layer overhead and delivery to the bottom ISO/OSI layer.

VDES technology will be used to feed PALAEMON platform with data from coastal stations or other vessels, e.g., weather or environmental conditions, buoy position monitoring, berthing data. At the same time, VDES technology may be used in the opposite direction, by conveying messages from PALAEMON platform to coastal stations and vessels, actions that come to assist during the S&R operations. Some possible examples of data from PALAEMON platform to spread are the evacuation plan, passenger list, ship waypoints and/or route plan report.

Table 13. VDES main features

Connectivity	▪ VHF antennas with SMA connectors (TBC), Ethernet cable to PALAEMON platform.
Input parameters	▪ Weather station message ▪ Weather forecast ▪ Route information ▪ Tidal window ▪ Route suggestion ▪ Etc.
Output parameters	▪ Evacuation procedures and analysis ▪ Mayday signal

4.1.9 AR Googles

Augmented Reality (AR) will have a crucial role in supporting the execution of evacuation processes (Table 14). During an evacuation, Augmented Reality will support the crewmembers in multiple ways, as shown below:

- It will be able to provide real-time assistance and guidance throughout the bespoken scenarios.
- It will be able to supply the users with real-time information about the ship systems.
- Provide a list of recommended actions.
- Provide changes or updates on the evacuation strategy.
- Provide text and audio communication between different crew members. By encapsulating these modules, the AR headset will enable the crew to maintain real-time communication during the scenarios, facilitating just in time information exchange between the participants.

The AR component connects and exchanges data with the following systems:

- Data Fusion Bus (gets information related to SSS (Ship Stability toolkit), DSS (Decision Support System), SRAP (Smart Risk Assessment Platform) but also positioning information about detected alerts, hazards or passengers.

- Audio server (for real time audio communication).

The AR glasses component is required to seamlessly integrate with the AR application itself (see Section 4.4.9).

Table 14. Augmented reality main features

Connectivity	▪ WiFi
Measurement	▪ Text and Audio[8] conversations from the crew (PALAEMON Architecture v2)

4.1.10 Massive Evacuation Vessel (MEV)

The digitalization of these live-saving appliances was one of the main issues we did not concrete at the time of closing D2.6. Unfortunately, as we have stated in Section 2.1, we will not directly address the integration of any ICT technology on the MEVs. Notwithstanding, what we will do as an alternative is the emulation of one of the most sought features as if it was carried out inside an actual evacuation vessel. Technically speaking, we will harness the indoor location system of the PaMEAS framework to not only count how many people boards on the MEVs, but also support an identification binding[9], thus knowing who is inside which MEV at any time. To make this exercise possible, we will "reserve" a particular area of (at least) one of the Hellenic Spirit's deck(s) that will "play the role" of a MEV. Please note that this identification binding can be only carried out if GDPR is disclosed, that is, when the evacuation process has been triggered. Otherwise, sensitive information is enabled and that would deter us from mapping people and their actual identification (we should keep the data anonymized).

Anyway, it is up to WP8 activities the definition of the trial scenarios and the elements and features to be assessed during the very last phase of the project.

4.1.11 Offline information

Finally, we cannot forget about a handful of data sources that are loaded onto the PALAEMON system at the "Offline status" phase, that is, before the voyage gets started (Table 15). Namely, this category spans all the static information that the Smart Evacuation Management system need to operate and complement with the real-time streaming data that we have described in the previous subsections.

The tag "offline" also means that the information is loaded/ingested once and will remain the same throughout the course of the voyage. Nonetheless, it is worth mentioning that some of the documents may be subject of change and end up with some modifications that will be updated as soon as the ship gets back to shore. For instance, in Section 4.2.3 we talk about the Safety Management System (SMS), mandatory tool that stores critical practices, policies and procedures that must be respected in order to ensure a safe operation of ships at sea. One of the main features of this module permits a dynamic modification or revision of the manuals on-the-fly, which leads to a subsequent update in the shore repository (whereas the SMS' ship instance only keeps information of the particular vessel, shore's service acts as a sink that stores the information of all the fleet).

[8] Due to the technical limitations of the open-source frameworks we are going to use to develop the AR-based services, it is impossible to support real-time video streaming between the goggles and i.e., the bridge monitors.

Now it is worth focusing on the technical translation of these manuals, tables, etc. to the "language" spoken in the PALAEMON platform. In this case, data is presented in a sort of user-oriented output (i.e., PDF documents, Excel-based spreadsheets, etc.). Of course, these formats are far from being seamlessly integrated as part of the PALAEMON datasets, and must be transformed before catering the main system. In this case, each of the information sources are individually addressed and adapted. To give the reader a couple of illustrative examples, safety procedures are translated as JSON objects following a tree-like hierarchy, where high-level services can easily query the data and e.g., get the contingency plan of a particular type of incident. Moreover, tables (i.e., passengers/crew lists) are mapped as JSON documents and then forwarded to the Data Fusion Bus Main Storage system.

Table 15. Offline data compilation list

Data ingestion procedure	▪ All information is manually adapted and stored into the PALAEMON Platform core (i.e., Data Fusion Bus & PaMEAS-A internal repository)
Datasets	▪ Passengers list ▪ Crew list ▪ Ship blueprints ▪ Safety procedures ▪ Contingency plans ▪ ISM Manuals ▪ SOPEP Manuals

4.2 PALAEMON Core

4.2.1 Data Fusion Bus Core

In a nutshell, the Data Fusion Bus (DFB) will be the cornerstone of the PALAEMON platform (Table 16). Basically, any kind of information either generated or consumed by data sources or high-level services (respectively) must go across this module. DFB is a component that provides a trustworthy way of transferring data between the connected elements and the persistent system. As a matter of fact, it is composed of a collection of open-source components which allows easy deployment and configuration as needed, thus following the global requirements (this can be also seen as a prerequisite here) defined along this task. Among the principal components that will compose the first version of the PALAEMON platform, we have (as shown in Figure 4).

Within PALAEMON, data produced by any module become available to other modules via Kafka. Apache Kafka [63] is a message broker, used within PALAEMON as a Pub/Sub system for asynchronous intercommunication between the PALAEMON components. Data collected in the central Kafka broker is persisted in Elasticsearch [64], a distributed RESTful search engine built for cloud-based applications. It resembles a NoSQL database [65] being able to store data as JSON documents, but also works as a powerful search engine. Data is stored in the indices, which can be separated into shards and stored into a distributed system with replicas if needed. In contrast to traditional databases, the stored documents can have different format.

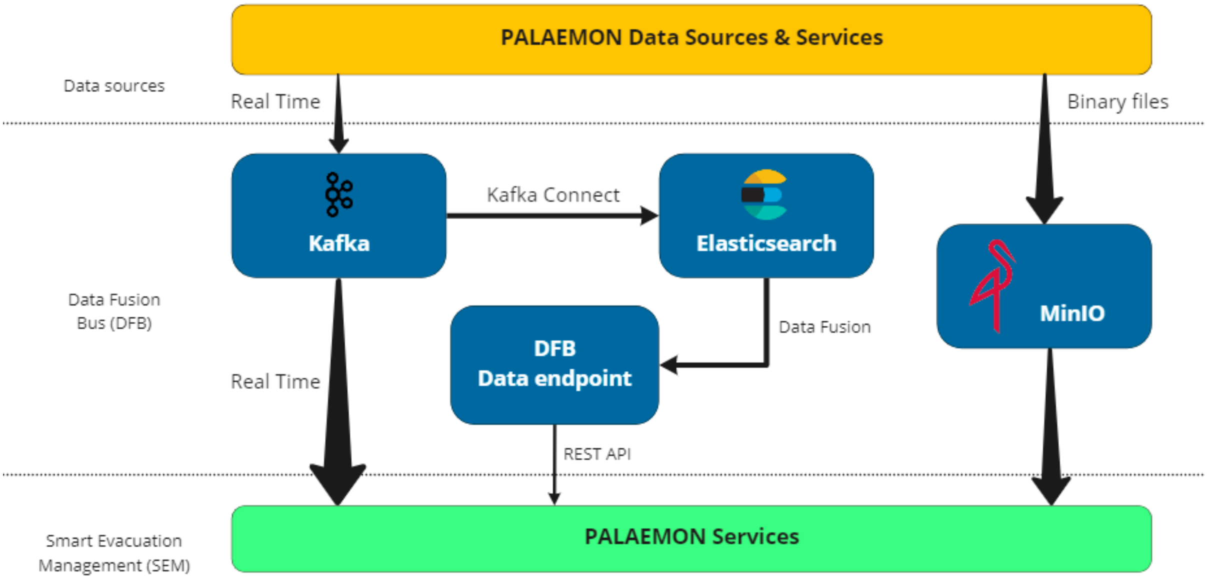

Figure 4. Data Fusion Bus overview and interplay with data sources and high-level services (SEM)

Within PALAEMON, data collected in the central Kafka broker is persisted in the Elasticsearch cluster.

DFB Data Endpoint provides a REST API for management and monitoring of the rest DFB components (Kafka and Elasticsearch clusters). The DFB UI provides a GUI that acts as a client to the DFB Core. The key features are:

- Health monitoring (Kafka broker status, ES cluster status, replication status).
- Kafka Performance metrics (e.g. broker status, messages in/out per topic, bytes in/out per topic, consumer lag).
- Elasticsearch Usage metrics.
- Kafka Topic management (creation, configuration, persistence by Elasticsearch, client authorization & authentication).

MinIO provides a High-Performance Object Storage service that is compatible with Amazon S3 buckets. This allows storage of multiple file types, such as audio, text, video, Machine Learning models, etc. Data is stored on different buckets, with different access permissions for each user of the MinIO service, allowing for multiple data sources or services to inject their generated data or outputs. On the PALAEMON platform, MinIO will serve as object storage for multiple types of binary data, such as audio transmission files, generated PDF report files or gathered datasets, to be later used by the Voyage Report Generator (see Section 4.4.10).

Table 16. Data Fusion Bus main features

Input parameters	▪ Structured datasets: CSV files ▪ Semi-structured data: log files, JSON files ▪ Data streams (e.g. MQTT) ▪ Multimedia objects (i.e., video, audio files) ▪ Other objects (e.g., machine learning models, etc.)
Output parameters	▪ SQL interface ▪ Data streams ▪ Web services (e.g., RESTful API)

4.2.2 PaMEAS

PaMEAS is one of the key components for the deployment of PALAEMON Smart Evacuation Management approach, i.e. an IT technology-aided and real-time monitored evacuation operation. PaMEAS essential objective is to optimize the evacuation process via an "augmented", technology-aided evacuation process redesign. PaMEAS is the main automation engine of the evacuation process and the essential evacuation management component of the SEM system. PaMEAS provides the means of execution of the Standard Evacuation Functions: a) tracking the status & location of passengers, b) marking the Evacuation Path, c) engaging the Notification process and providing directions to and through the Evacuation Paths and, d) tracking the status and location of resources (crew support, etc.) and reassessing response plans. It also performs Incident Management Functions, i.e. the real-time management of incidents, such as a passenger's injury case, if they occur during the evacuation process. PaMEAS establishes a spanning service layer that covers the whole evacuation process from the activation of the Evacuation Plan until the use of the Mass Evacuation Vessel (MEV) and the clear of the ship.

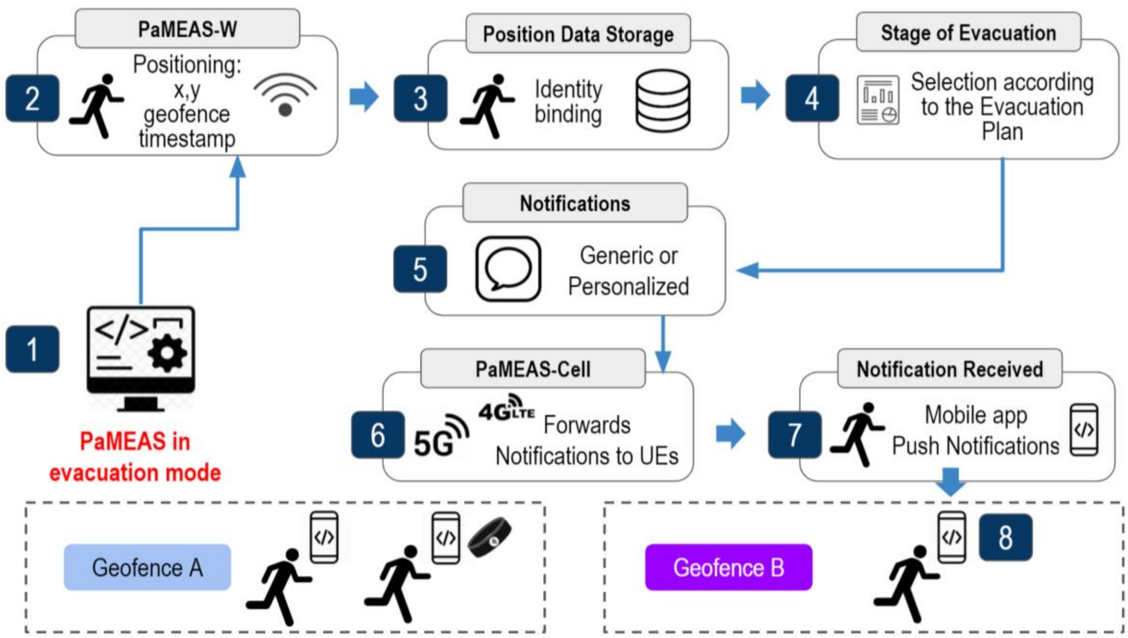

Figure 5. PaMEAS core functionality

PaMEAS is a multi-layer system and a composite IT structure that should include two major parts, a network and an application part, PaMEAS-N and PaMEAS-A.

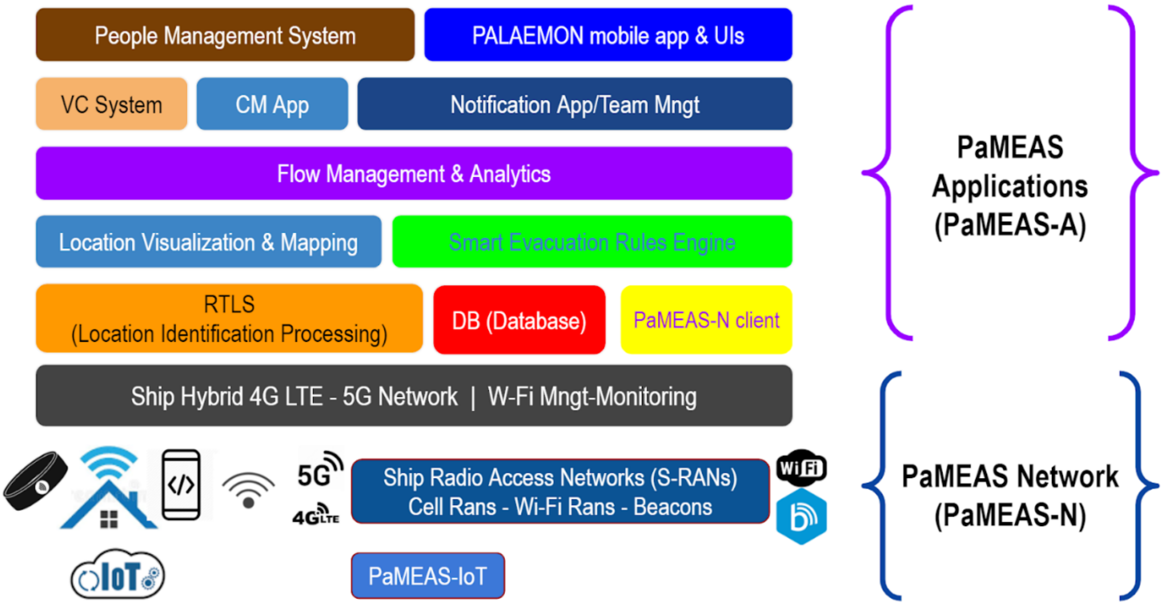

Figure 6. PaMEAS core architecture

PaMEAS-A is a software suite and microservices architecture delivering the following critical functionalities:

- Evacuation Rules Management.
- Prepare Evacuation Notifications, Sounds and Voice Message announcements (EN - local Lan).
- Location Monitoring for Passengers and Crew.
- Crew Teams Management during Evacuation (includes post assignment / reassignment).
- Passengers grouping and group management (evacuation to MEVs).
- Passenger Identification under PALAEMON Security and Privacy Policy (i.e. privacy safeguards)
- Evacuation Route planning / re-planning according to real evacuation conditions.

PaMEAS-N is the network part of PaMEAS system. It should satisfy accurate indoor positioning and fast notification delivery requirements with high levels of efficiency, especially as far as the following parameters are concerned:

- Passenger and Crew Positioning accuracy (as High as possible) in conditions of High Device Density.
- Passenger and Crew tracking (flow monitoring and analytics).
- Delivery of simplified but reliable Communication to Passengers about Evacuation paths (Text-Voice-Video Notifications).
- Delivery of consistent evacuation Route Indication to Crew, especially as far as the guidance of Crew towards an Incidence location is regarded.
- Possibility of two-ways video communication between the Evacuation Coordinator and the Crew teams (in special conditions also with a passenger in danger).

The PaMEAS-N is composed from a WiFi network of Access Points and beacons that captures the location of passengers and crew and a 4G LTE - 5G Network for low latency notification and evacuation guidelines delivery. The PaMEAS system architecture both embraces and positions on top of these two in-situ networks, to offer “orchestrated” smart evacuation services to passengers and crew connected to these networks.

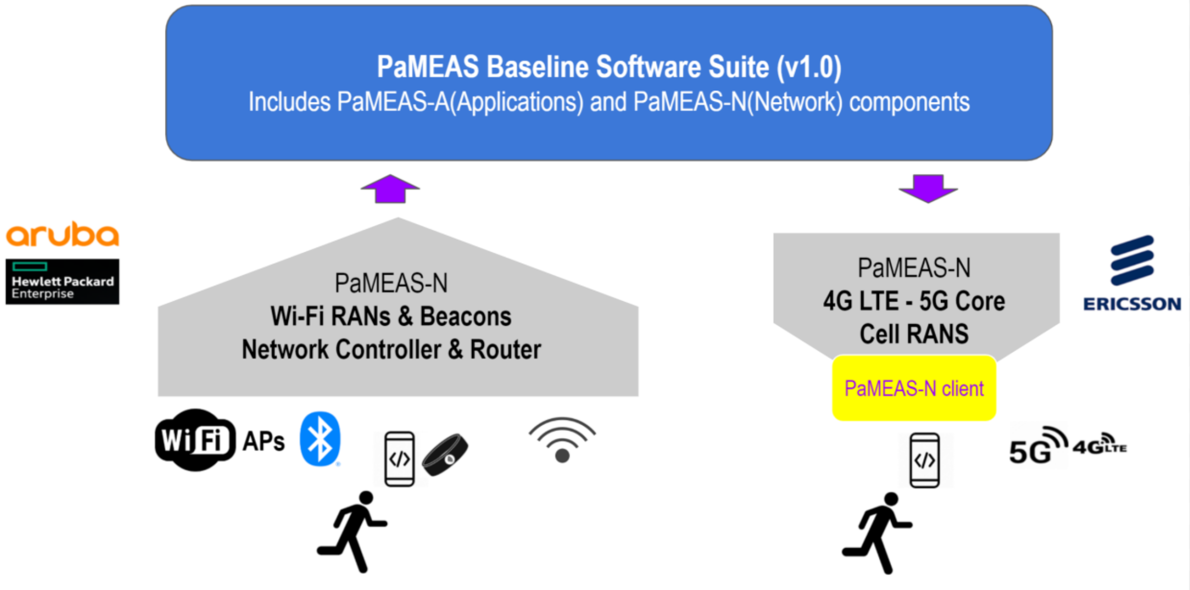

Figure 7: PaMEAS baseline architecture and underlying networks (PaMEAS-N)

Table 17. PaMEAS main features

Input parameters	▪ Smart Bracelets ▪ Smart Cameras ▪ Cellphones ▪ Passengers’ list
Output parameters	▪ Passengers’ location ▪ Smart route calculation ▪ AR location info

4.2.3 Safety Management System (SMS)

The SMS (Table 18) is an organized system planned and implemented by the shipping companies to ensure safety of the ship and marine environment. SMS is an important aspect of the International Safety Management (ISM) code and it details all the important policies, practices, and procedures that are to be followed in order to ensure safe functioning of ships at sea [66].

Safety procedures are documented in safety manuals and filed onboard in hardcopies to be easily accessible to crew for direct reference. Procedures are also dynamic in time while undergoing changes and revisions following upgrading of best practices or updating of policies and guidelines. PALAEMON will offer a marine-specific document management tool where safety practices, policies and guidelines will be digitalized, stored and processed under a user-configured workflow engine enabling communication between management company at shore and the vessel. SMS tool will offer a panel where documentation with standard safety procedures associated with any operation onboard will be designed, completed, manually or automatically, and circulated in between users with different level of authority for review, revision and approval. Configuration of safety procedures ashore (SMS tool shore instance) will be reflected on-board (SMS tool ship instance) and vice versa.

SMS tool will have the following applications in PALAEMON ecosystem:

1. It will be integrated with the Decision Support System (DSS) working as a component of PALAEMON Incident Management System (IMS). DSS will advise the Master in decision making during an emergency event. Upon Master's decision or, in other words, following his confirmation over the derived DSS advice, SMS tool (ship Instance) will populate and visualize through PIMM (working as Master interface), prescribed treatment or documented order of safety actions that are associated with the decision of the Master. Setup of predefined order of safety actions against emergency is configured and revised in SMS tool shore instance in fleet level and synchronized with the ship instance (for each vessel in the fleet). Each digitized safety action will be linked with an action owner (crew member) to support effective flow of procedures for efficient respond against emergency. Dynamic electronic forms (checklists) will work as a digital advisor for crew designed to be also displayed in AR glasses during evacuation procedure enhancing reaction in emergency.
2. In post-incident analysis (investigation of the event), SMS tool will assist in versioning update of documents to support any revision of safety procedures following change management and suggestions for improvements in company's safety policy. Embedded workflow engine will leverage document management flow between ship and shore and facilitate administration of reviewing and approving amendments.
3. Bridging SMS with PALAEMON DFB core (via Restful API) will trigger automatic incident report registration during post-incident analysis supplementing any manual record of the incident in embedded pre-defined report templates. Also, relevant incident and voyage records sourced from ship legacy systems and other PALAEMON components will be managed through DFB core and stored to a common PALAENON incident repository in order to be consumed from both SMS tool instances (shore and on-board) so to provide complementary information to the defined report templates for a more thorough investigation and record of the incident.

Under the aforementioned scope of tool functionalities, PALAEMON SMS will be at the same time reactive and responsive to decision making in emergency as well as proactive following a *"plan-do-measure-act"* approach where safety procedures will be modified against lessons learnt from incidents on-board.

Table 18. Safety Management System main features

Input parameters	▪ Electronic checklist ▪ Safety Documents ▪ Incident records
Output parameters	▪ Safety procedures (structured format) ▪ Incident Reports ▪ Document Management / Configuration

4.2.4 PALAEMON Evacuation Coordinator

During an evacuation situation, it is critical that all components and agents involved are well aware and synchronized of all the different operations and orders given by the bridge and crew. The PALAEMON Evacuation Coordinator will be developed as a component that takes charge of notifying all the interested services and data sources of the changes in operation modes carried out during an evacuation process (Figure 8).

The PALAEMON Evacuation Coordinator's job will be to listen to major events occurring during a voyage and dispatching the correct orders and evacuation status changes to the different components of the PALAEMON platform. These orders will lead to different operation modes and data generation rates for each component, guaranteeing a dynamic and adaptive evacuation process (Table 19).

The main input for the PALAEMON Evacuation Coordinator will be the PIMM service, which will serve as the interface through which the bridge command crew can send the evacuation orders to the PALAEMON platform. When an evacuation order is issued, the PALAEMON Evacuation Coordinator will broadcast a new message updating the evacuation status of all components, ensuring that all data sources and services are properly coordinated and working as intended. In case any component needs to access the current evacuation information at any point, an on-demand query is also configured.

As well, the PALAEMON Evacuation Coordinator will listen to all the component operation changes, allowing it to control the data flow at any point in an evacuation situation. In case any component is not working at the intended operation, the bridge crew will be able to fix it.

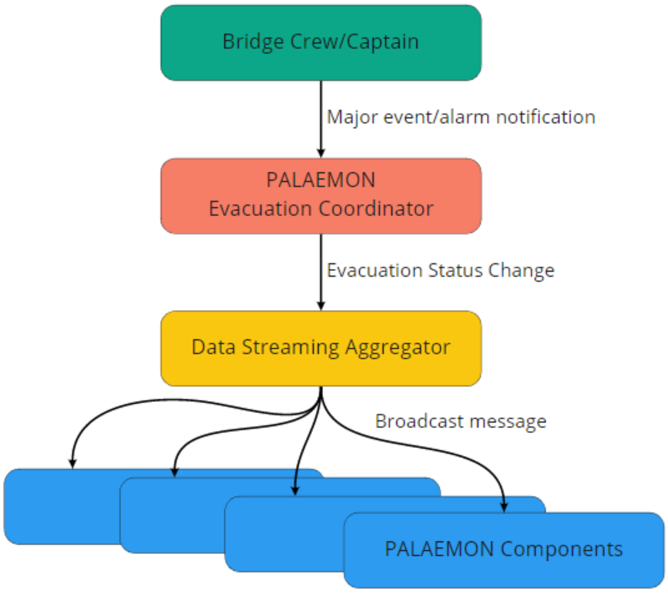

Figure 8. PALAEMON Evacuation coordinator overall concept

Table 19. PALAEMON Evacuation Coordinator main features

Input parameters	▪ Evacuation commands ▪ Status change and operation mode confirmation from PALAEMON components
Output parameters	▪ Evacuation process notifications (To all components) ▪ Logging data (System Log)

4.2.5 Messaging Server

The Voice communication between the AR headsets will make use of Photon Unity Networking (PUN) [67] and Photon Voice [68]. The PUN builds on top of the Photon.Net client and all of the OOS (Open Source Software) used by it.

The PUN will connect to Photon Cloud using the authentication flow as shown in Figure 9.

The AR Glasses passes info about which authentication provider to use and the necessary data to the communication server using the *Connect()* method.

Once the server gets the desired authentication provider for the AR application, it calls the authentication provider. The authentication provider processes the authentication information and the crewmember is authenticated.

All the data and messages between crew members will be encrypted. In our case the transport protocol will allow the AR application to encrypt keys with the server using Diffie-Hellman Key Exchange with AES encryption upon connection.

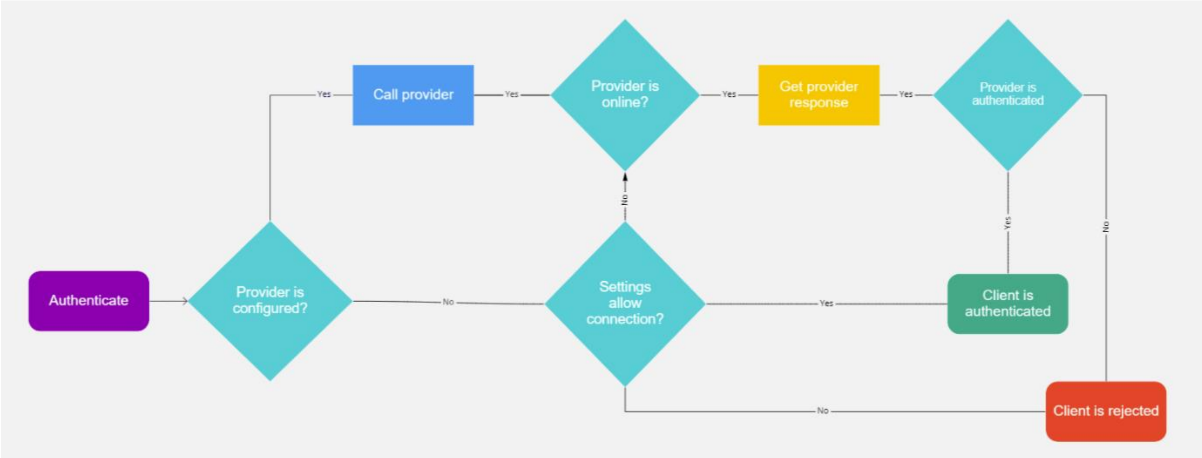

Figure 9. Messaging Server workflow

4.2.6 Context Broker

As part of the PALAEMON platform, a way to access and stream real time data from the sensors and devices deployed on the ecosystem must be provided. This way, components and services can be aware of the latest values generated by the data sources and thus provide their functionalities in an adequate way.

A Context Broker will be deployed on the PALAEMON platform in order to collect the data generated by the Data Sources and offer it to the different services via HTTP notifications. In this case, FIWARE Scorpio Broker [69] will be used, allowing the platform to make use of its NGSI-LD [5] standardization capabilities. This Context Broker uses a subscription-notification data flow, sending a notification to the subscribed services every time there is a value change in a relevant topic.

Table 20. Context Broker Main Features

Input parameters	▪ Interested parties' (services) subscriptions to certain topics. ▪ Data sources data modelling configuration ▪ Real-time data generated by data sources.
Output parameters	▪ Real-time data generation notifications to subscribed services.

The Scorpio Context Broker will mainly cooperate during the evacuation process by gathering the localization information of all passengers and notifying the interested services (mostly AR glasses and Smart Safety System) of the latest changes in the localization. Thus, it will provide a necessary interface for operating with the real-time data generated during the different evacuation phases.

4.3 Data Access

4.3.1 DFB Access

The first release of the PALAEMON Reference Architecture (i.e., D2.6 [1]) introduced a handful of different modules and solutions to cope with the delivery of the data from its source to the core of the PALAEMON system. In this second iteration, we have concentrated all the functionality we presented in the original work into a couple of components that abridge all the set of features requires at access level.

4.3.1.1 Data Processor

In order to ensure data standardization and interoperability among components, it is extremely useful to insert a middleware component that performs operations like data curation and transformation before inserting it into the platform. Besides, for the sake of interoperability, goal that we are pursuing in the context of PALAEMON, mainly framed in Task 7.3 (*Uniform Data Exchange Modules – Interoperability Layer*), this becomes even more critical. This Data Processor will carry out the tasks of cleaning the data, aggregating different data sources as needed, and modelling it appropriately before storing it and sending to the related services.

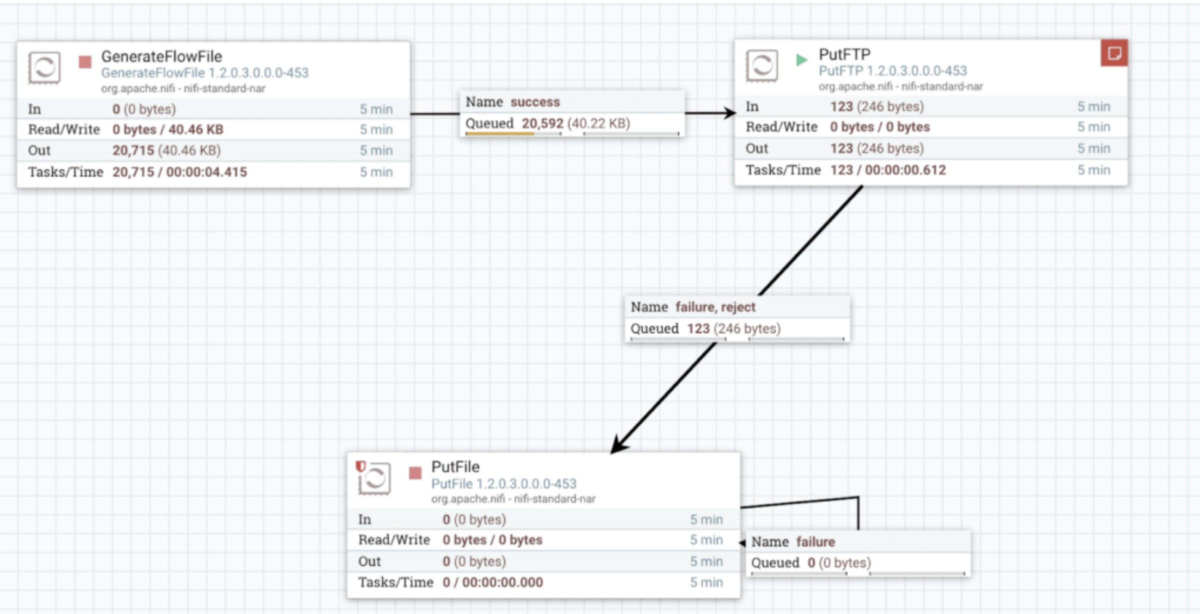

Figure 10. Apache NiFi basic data flow (arbitrary example)

In the case of PALAEMON, Apache NiFi [70] undertakes the role of Data Processor. It is tool for straightforward data pipeline configuration; moreover, its seamless integration with Apache Kafka (i.e., Data Fusion Bus Access key component) makes NiFi a suitable choice to use in the project. In addition, it is presented to the user as a low-code approach, where a good share of the operations can be done with simple drag-and-drop actions, as illustrated in the generic example shown in Figure 10. In this basic graph (example taken from the Internet and not part of the PALAEMON's FlowFile), we observe three different operations, whose outputs are connected to the next ones, whether the operation was successful (generation of a random file in the first block) or not (attempt to upload this random file to a File Transfer Protocol – FTP – server in the second box).

This Data Processor component will provide data sources with the appropriate means to transform their data in the intended way, allowing them to insert all their generated information without the need to develop specific data connectors for the platform. Amongst the main operations supported by this Data Processor, we can enumerate the following ones:

- Subscribe to Kafka topics
- Perform transformations on the input JSON object, mainly using JsOn Language for Transform (JOLT) filters [71]
- Publish a new (transformed) message as a new topic to Kafka Broker
- Use the Elasticsearch API (Data Fusion Bus core) to directly store data
- Connect to Scorpio Context Broker and forward the streaming data
- Forward data to MinIO (Data Fusion Bus core)
- Connect to remote FTP servers (e.g., Smart Cameras processing nodes) to get the recorded video clips

4.3.1.2 Data Streaming

One of the most challenging parts of ICT infrastructures has to do with the way real-time (or near real-time) data streams are processed and stored. In the context of PALAEMON, we count on a number of different devices and sensors (e.g., smart bracelets, cameras, ship stability toolkit sensors, UAVs, etc.) that will be continuously generating and delivering more and more information to the system. At this point, having a scalable tool that guarantees the correct forwarding of all this with the minimum latency is more than critical. In the context of PALAEMON, we have chosen Apache Kafka[10] (henceforth, simply Kafka) as the “glue” that will be used as streaming platform, attending to two broad classes of applications:

- Real-time streaming data pipelines that reliably get data between systems or applications.
- Real-time streaming applications that transform or react to the streams of data.

Therefore, in PALAEMON, Kafka will act as a messaging system, as a stream processing tool as well as a storage system.

In the scope of PALAEMON, Apache Kafka will play a twofold role: on the one hand, it will “funnel” the data (to the extent possible) that comes from data sources (e.g., shipboard legacy systems, field devices, etc.) and deliver it to the persistence plane (based on Elasticsearch in this case, as we will see in Section 4.2.1); on the other side, real-time communications among components will lean on the possibilities brought about by this powerful pipeline. Just to illustrate and complement this with an illustrative example, every time a message goes across this streaming platform, it will be *1)* stored as part of the Data Fusion Bus persistence system; *2)* broadcasted on a particular Kafka topic (a topic is a category that labels the records/messages that are published) so that any component “subscribed” to it could receive the message with the minimum latency.

[10] Apache Kafka homepage: https://kafka.apache.org/

Moreover, Kafka will form the technical foundations behind the PALAEMON Evacuation Coordinator (Section 4.2.4), which will basically broadcast any evacuation-status switch to all components (i.e., subscribers).

4.3.2 PaMEAS-N

PaMEAS-N is the network component of PaMEAS system organized in two parts:

- PaMEAS-N uses a WiFi RAN infrastructure as the main channel for location tracking
- Benefit from the high reliability, high bandwidth and low latency of 5G network to establish a rich communication between the Evacuation Coordinator and the Passengers and Crew.

Figure 11 summarizes PaMEAS-N architecture at a high-level view.

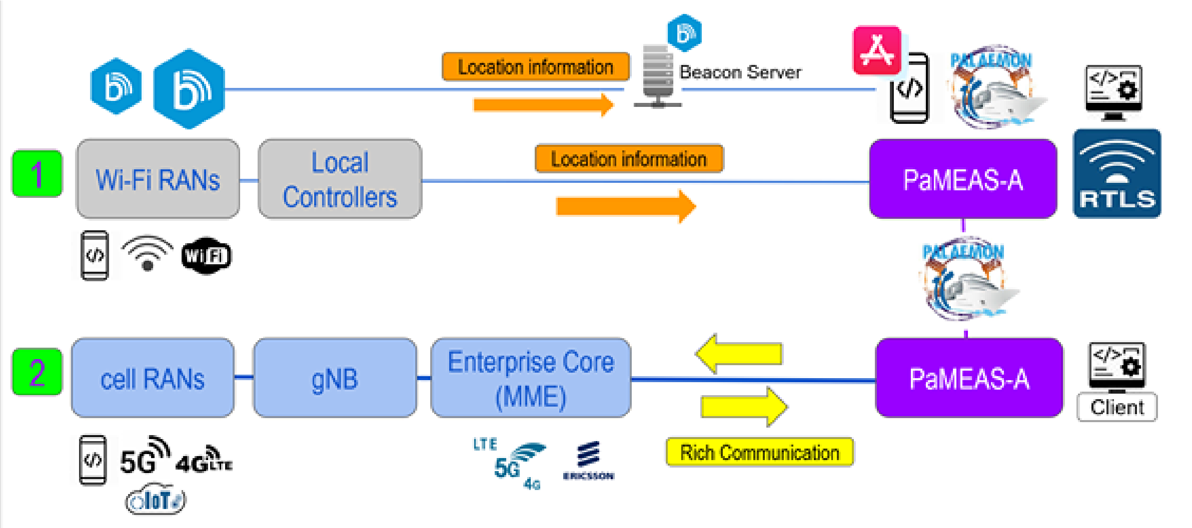

Figure 11. PaMEAS-N architecture overview

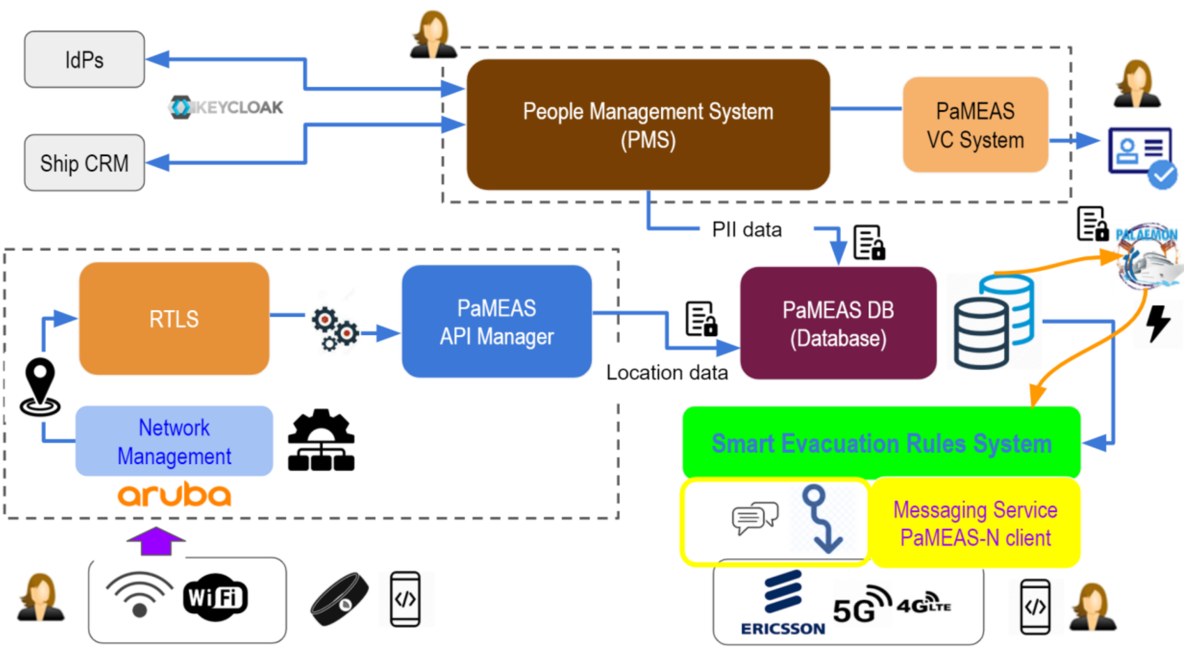

Figure 12. PaMEAS baseline architecture and components in detail

The location data received from the WiFi network are processed from a RTLS application while the notification information is delivered to 4G LTE – 5G network through a Messaging Service directly connected (through an Application Server) to the 4G LTE – 5G Network provided by Ericsson.

4.3.3 Identity & Access Manager

Given the variety of modules within the PALAEMON platform, and the information that they have to exchange, user digital identities become more and more important and, with it, the means to accurately verify them. This means that the PALAEMON platform has to manage user identification and access in a secure and concrete way.

An identity and Access Management (IAM) module will be implemented, in order to secure application and services. As a solution of choice, we have opted for Keycloak application [72] to play this role of authenticate and authorize users and components to get access to the PALAEMON platform.

Generally, an IAM aims to verify the identity of a user or system requesting access to an environment, such as one or more application within PALAEMON, and evaluates a set of rules that indicate which features and resources the user / system has access to.

Identity management and access management are two different matters. Normally, access management relies on an identity provider to verify the user and relies on it to map the user / system identity to what it can do in an environment. Typically, role-based access control (RBAC) is a standard concept followed to establish an access control level. A level of support is added for using this access management, basically a set of protocols for using it with other applications. Usually the protocol used is OAuth, which is a standard suitable for managing the access control parameters on the authorization software side, as well as establishing the guidelines that must be followed by applications that use the authorization service.

Keycloak combines the power of an identity provider and an authorization server to give us a complete IAM solution. It also has built-in integrations with social login sites, other identity providers, and federated external user databases such as LDAP servers. Keycloak therefore can be software that we would like to use to reduce our IAM overhead.

Keycloak provides several useful features that can be evaluated for use in PALAEMON system, among which:

- **Single-Sign On and Single-Sign Out**, allowing users authenticate with Keycloak rather than individual applications. In this way once logged-in to Keycloak, users don't have to login again to access a different application. Also, users only have to logout from Keycloak to be logged-out of all applications that use Keycloak.
- **User Federation**: in case users are stored in other databases, Keycloak has built-in support to connect to existing LDAP servers, Active Directory servers or Relational Databases (RDBMS) such as My-SQL.
- **Admin Console**: Keycloak provides a GUI, namely Admin Console, through which administrators can manage and configure features, identity brokering and user federation; they can also create and configure authorization policies and user permissions.

- **Account Management Console:** Through the account management console users can manage their own accounts. They can update the profile, change passwords, setup two-factor authentication and manage their sessions**.**
- **Authorization Services:** in addition to role-based authorization, Keycloak provides also fine-grained authorization allowing to manage permissions for all services from the Keycloak admin console and to specific policies.

4.4 PALAEMON Smart Evacuation Management (SEM) system

4.4.1 Smart Safety System

The main purpose of the Smart Safety System (SSS) is to assist the Master and Bridge Command Team during the evacuation process by graphically displaying the progress without the need of extended VHF/Radio communication between the members of the evacuation and the bridge teams.

The Smart Safety System (SSS) consists of two main components, as shown in Figure 13.

The Main Unit includes the **Logic Unit**, is the base application, which is responsible for the central data processing and validation of the user data inputs from the HMI Units. In addition, the Logic Unit is also the interface to Palaemon Data Fusion Bus, from where it reads the events generated by other Palaemon systems und publishes the own events generated on the HMI Units. The second part of the Main Unit is the **Broker** which task is the data distribution between the central logic unit and the various HMI Units.

The **HMI Units** are responsible for the graphical presentation of SSS information and for the manual input of evacuation related information. It will be installed on the main unit on the Bridge to support the Master and Bridge Team in the evacuation process and on mobile units like tablet computers for the on-scene crew.

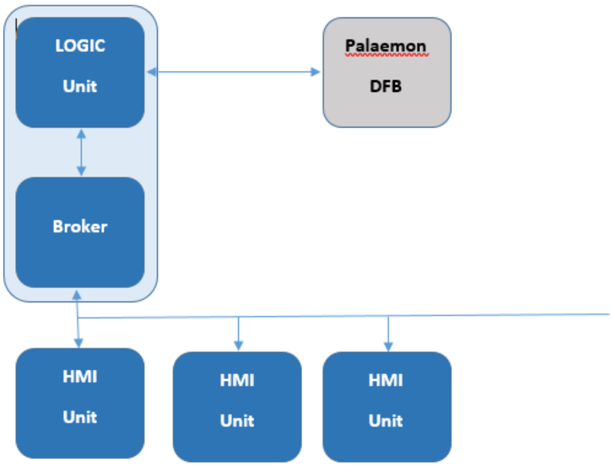

Figure 13. Smart Safety System Architecture

To illustrate the look and feel of the Smart Safety System (work in progress), Figure 14 displays the main layout of the application.

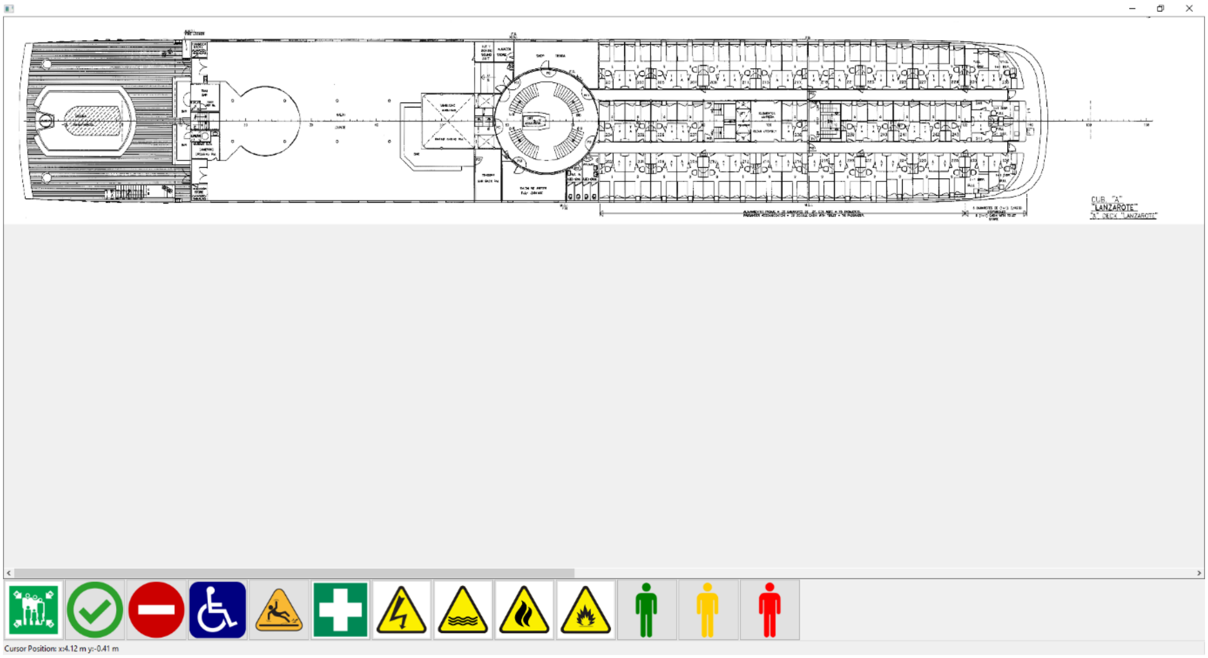

Figure 14. Example of HMI Unit (screenshot)

Table 21. Smart Safety System main features

Input parameters	▪ Position of incident on board ▪ Coordination info issued by Master
Output parameters	▪ Position/present situation of evacuation process

4.4.2 Ship Stability Toolkit

The Ship Stability Toolkit (SST) service consists of three individual functionalities: the determination of the ship's intact stability based on its loading condition, the near-real-time description of the ship motions in the six degrees of freedom and the determination of damage stability. These three functionalities are designed to build on each other and together give an overview of the ship's actual and future floating position and capability.

The calculation of **intact stability** is rather straightforward. It relies on the position of the center of all masses of the ship, the center of buoyancy and the ships shape. From this calculation the lever arm of righting moments at different angles of heel, the heeling angle of vanishing stability and the overall range of stability can be determined. These calculations are used as an input for the other components.

The calculations of **ship motions** are based on pre-calculated Response Amplitude Operators (RAOs) of the ship for different angles of incidence of the sea state. In combination with detailed weather forecasts these can be used to determine ship movements to be expected in the next few hours. This module is intended to serve as a decision-making aid for better route planning in order to increase passenger comfort and safety.

The determination of the ship’s stability in case of hull damage (**damage stability**), in combination with the aforementioned modules, the watertight subdivision of the ship and the permeability of the individual compartments, determines the new floating position of the ship in case of damage. The influence of free liquid surfaces on the overall stability of the ship is also considered here.

After completion of the development of the individual modules, they will be part of the ship's DSS (Section 4.4.4). The development is done with the software MATLAB[11] and WAMIT[12] for the shore-based calculations and in Python for the modules to be installed as part of the Palaemon System on board. The communication with the other Palaemon components will be by Kafka.

Table 22. Ship stability toolkit main features

Connectivity	▪ Ethernet/WiFi (Kafka)
Input parameters	▪ Hull parameters ▪ Weather forecast ▪ Status of ship
Output parameters	▪ Present floating position ▪ Expected future ship motions

4.4.3 Smart Risk Assessment Platform

Smart Risk Assessment Platform (SRAP) is a real-time risk-based monitoring software component that will provide a colour coded risk level indication on the PALAEMON dashboard. Its purpose/goal is to assist the Master as well as the Bridge Command for:

1. the initial assessment of the situation, to take the decision of sounding the General Alarm (GA) or not.
2. the monitoring and evaluation of the mustering process to take any additional actions (if necessary), following the GA.
3. the final assessment of the situation, i.e. to take the decision to abandon the ship or not.

SRAP consists of three (3) separate risk models that correspond to the three decisions that will be supported. For each model, the objectives are the following:

- **Situation assessment model**: Assess the risk related to the severity of the incident.
- **Mustering assessment model**: Assess the development of the mustering process with respect to time and passenger/crew safety.
- **Pre-abandonment assessment model**: Assess the risk related to the severity of the incident given the mustering process has been completed and the success of the incident mitigation efforts.

To achieve that the data that will processed by SRAP will be distinguished in the following main categories: Incident Information, Ship Condition and Passenger/Crew Data. It will take advantage and combine data taken from ship's legacy systems (e.g. smoke detectors, flooding sensors, etc.) and the main output of other PALAEMON components, including[13]: PaMEAS, Structural Health Monitoring Toolkit, Smart Safety System, Smart Bracelets, and Decision Support System (DSS). The data exchange between SRAP and the PALAEMON platform will be conducted through the Data Fusion Bus (DFB). SRAP will subscribe to the PALAEMON

[11] MATLAB homepage: https://www.mathworks.com/products/matlab.html
[12] WAMIT homepage: https://www.wamit.com/
[13]The interplay among components may vary in the future.

Evacuation Coordinator status updates (via Kafka). Table 23 lists the input parameters for each data category and the corresponding data source, as well as the output parameters.

All output parameters of SRAP will be in numerical and colour-coded form and will be visualized on the PALAEMON dashboard.

Table 23. Smart Risk Assessment Platform main features

Input parameters	▪ **Incident Information** o Incident type and location (Smart Safety System) o Time of day (Legacy Systems) o Weather conditions (DSS) ▪ **Ship Condition** o Structural integrity (Structural Health Monitoring Toolkit) o Incident, i.e. fire or flooding, spreading (Legacy Systems) o Status of critical systems (Legacy Systems) ▪ **Passenger/Crew Data** o Passenger localization data (PaMEAS) o Passenger health monitoring data (Smart Bracelets) o Response teams on-site (DSS) o Congestion points and blockages (Smart Cameras)
Output parameters	▪ **Situation assessment model**: Risk level related to incident severity o Mustering assessment model: Risk level related to the mustering process o Pre-abandonment assessment model: Risk level related to incident severity

4.4.4 Decision Support System (DSS)

4.4.4.1 PALAEMON Incident Management Module (PIMM)

The PIMM is a corner hub for managing (and displaying information) from different modules during an incident. Through its friendly Graphical User Interface, access is provided to critical PALAEMON components, to be used by the Master and the Bridge Team. For example, should an incident occur, the Master can use the PIMM to view the suggested plan of action proposed by the DSS and WFT. Following the same example, Master's decision (i.e., in the form of e.g., evacuation orders) will be visually caught through this service and will lead to the corresponding event generation at the Ship Evacuation Coordinator.

As a matter of fact, DSS and Weather Forecast Toolkit (WFT) is directly integrated as part of the PIMM layout in the PALAEMON platform. More components such as the Smart Cameras system will be integrated into the final version.

Through the use of hyperlinks, the PIMM can link to other modules' dashboards (e.g., PaMEAS). This way, a unified workflow can be achieved, and the Master/Bridge crew can navigate through all components/visuals in a seamless manner.

Figure 15 displays the PIMM's layout at the time of the Midterm Review of the PALAEMON Platform.

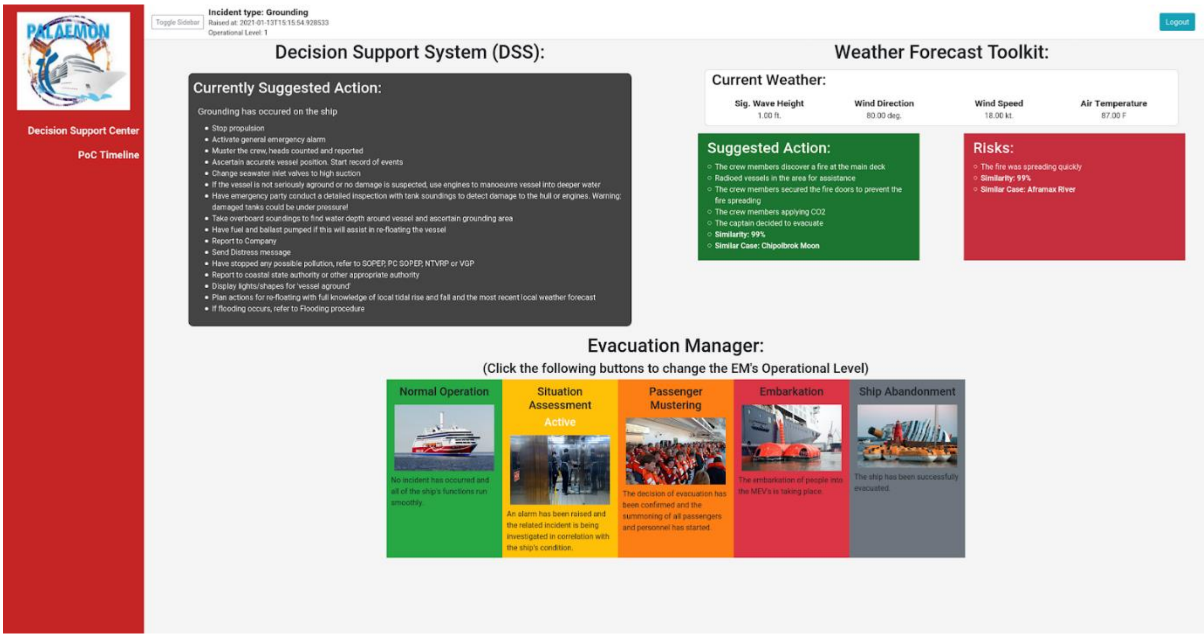

Figure 15. Sample screenshot of PIMM taken before the mid-term review (Jan 2021)

Moreover, Table 24 represents the input and output parameters/features that are displayed on the PIMM's main layout.

Table 24. PIMM main features

Input parameters	▪ DSS ▪ WFT ▪ PALAEMON Evacuation Coordinator ▪ Smart Safety System (Incident Data) ▪ Structural Health Monitoring (Incident Data) ▪ Shipboard Legacy Systems (Data/Status from ship's onboard systems) ▪ Smart Cameras (video streaming)
Output parameters	▪ Graphical User Interface displayed on the bridge

4.4.4.2 DSS engine

PALAEMON DSS is an innovative system for assisting specific crew members (e.g., Master, Bridge Team, etc.) to deal with an emergency on-board incident. The main target of this component is the identification of the incident and, besides, the support to the user with suggestions of decisions and actions to be taken, in order to avoid any critical mistakes that will result in further damages to the ship (or even worse, putting people's lives at risk).

The DSS provides the following main functionalities:

- **Actions per incident based on the ISM Code and SOPEP:** Depending on the emergency on-board incident, the DSS will suggest appropriate actions to the Master based on the International Safety Management Code. The ISM Code provides an international standard for the safe management and operation of ships and for pollution prevention. In addition, the SOPEP (Ship's Oil Pollution Emergency Plan) of the

Hellenic Spirit has been integrated to the DSS, providing the needed actions in case oil pollution occurs.

- **Integration with other modules:** It will receive information from various modules such as the PALAEMON Evacuation Coordinator, Smart Risk Assessment Platform, Safety Management System, Ship Structural Monitoring Ecosystem, Weather Forecast Toolkit, PALAEMON Incident Management Module, etc. through the Data Fusion Bus and will combine this information to produce the most suitable suggestions according to the situation that takes place at that moment.
- **Graphical Interface**: It will have a dedicated dashboard (part of the PIMM layout, as will be described in Section 4.4.5) which will display the results from the analysis of the information that will be available either real time or offline.
- **Access to information:** Apart from the suggestions that will be made, data will be displayed on the PIMM's dashboard as this will be helpful for the bridge to have an overview of the ship's condition.

It will generate alerts when an incident occurs and suggestions on decisions to be made towards mainly the Master and the Bridge Team. The DSS suggestions will be categorized and separated according to the individual incident and will be displayed on the dedicated dashboard provided by the PIMM. Suggestions will also be broadcasted to other components capable of displaying them to other crew members (AR Glasses).

Table 25. Decision Support System main features

Input parameters	▪ Location of incident / Ship stability data (Ship Structural Monitoring Ecosystem) ▪ Weather forecast (WFT) ▪ Risk level (SRAP) ▪ Risk level indication (SRAP) ▪ International Safety Management Code and Ship Specific Checklists (ISM)
Output parameters	▪ Safety procedures (SMS) ▪ Recommendations to Master/Bridge/Crew

4.4.4.3 Weather Forecast Toolkit (WFT)

Weather conditions are very important for the progress of the evacuation plan. An evacuation plan may not be effective without taking into consideration the weather conditions. For example, in a fire at an open deck the wind speed and direction play the most critical role in the fire spreading.

The Weather Forecast Toolkit will correlate the weather conditions with the evacuation actions/plans. Evacuation actions that were successful in previous incidents will be more correlated with the weather conditions at the time of the incident. These actions will be displayed at the PIMM dashboard and will give a first insight for the actions that took place at the past for a successful evacuation. We define an evacuation as successful if there were no fatalities/casualties.

In the first place, information retrieval techniques are used to retrieve from the most similar case the action plan that was effective (i.e., none was injured), and will be converted to vectors using NLP techniques. The vectorized action plan and the weather conditions and ship's technical characteristics will be used as input for the machine learning supervised model to predict if this plan will be effective. Also, this component can identify risks that occurred in a similar past accident to the post-incident management.

This module will help the crew take quick actions during an incident in order not to waste valuable time. In many past incidents, delayed response has resulted in human losses, as was the well-known case of Costa Concordia [73]. Also, we will create a dataset based on the National Transportation Safety Board (NTSB) Database. The attributes of this dataset are the weather conditions, the ship's technical characteristics and the evacuation plans/actions during past incidents. The WFT component will retrieve the input parameters from DFB through the Kafka topic and also communicate with the PIMM and DSS with an API.

Table 26. Weather Forecast Tool main features

Input parameters	▪ Ship's technical characteristics (pre-defined ANEK) ▪ Real-Time weather conditions (VDES component) ▪ Accident type (SSS, SHM components) ▪ Accident dataset (developing under T3.3)
Output parameters	▪ Recommended actions and possible risks (to DSS and displayed on PIMM)

4.4.5 PaMEAS Location Service (RTLS)

It is the service providing real time indoor positioning for passengers and crew. It is organized around three main components:

- **RTLS System (Real Time Location System)** is the PaMEAS component for automatically identifying and tracking the location of people in real-time, inside the area covered by the connected Wireless LAN infrastructure. The RTLS system integrates in a seamless way the network of WiFi Access Points and beacons with the passengers' devices (smartphones and smart bracelets) and mobile apps.
- The **PaMEAS API Manager**: collects data for the RTLS System, stores it in PaMEAS Database, and distributes it to other interested parties, inside PaMEAS (such as the Location Visualization Tool, a feature that will be added in the next version of PaMEAS Software Suite). The API Manager is automatically triggered either from a "location event"[14] or a "geofence event"[15].

The **PaMEAS Database:** periodically stores (every time a passenger changes location) information about the passengers' precise locations and geofences where passengers come and go. It also stores the Personally Identifiable Information (PII) data of the passengers and creates cross-references for location and PII data.

4.4.6 PaMEAS Rules Management Service (BRMS)

It is the Service which implements a semi-automated evacuation operation in connection with the PaMEAS-Cell (the 4G LTE – 5G component of PaMEAS-N), as illustrated in Figure 16.

[14] A Location Event takes place when the location of a passenger is changing when moving in the designated geographical area. This event triggers the process of registering the process of processing and storing timestamped location information in the PaMEAS DB.

[15] A Geofence Event is similar to a location event, but the triggering action activates when a passenger leaves and enters a geofence boundary.

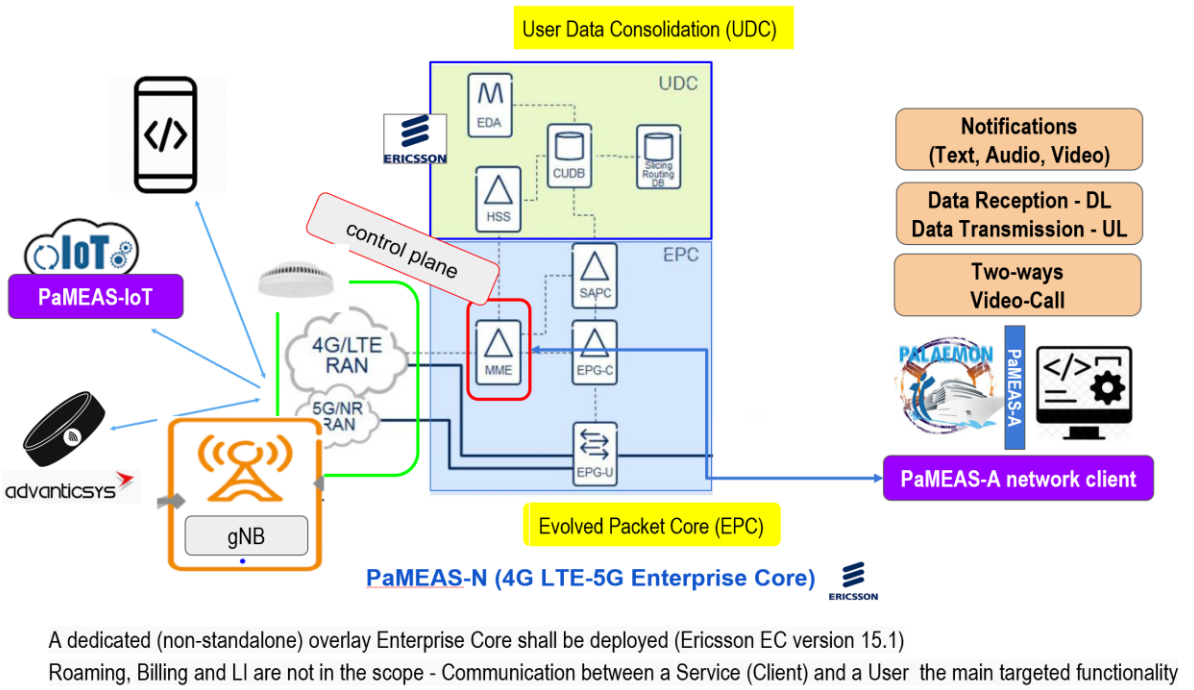

Figure 16. 4G LTE-5G core intercooperation with PaMEAS infrastructure

- The **PaMEAS BRMS** (Smart Evacuation Rules Management System) generates and executes complex decision logic as “evacuation management rules” and “evacuation notification policies” in order to achieve a certain level of automation of the evacuation process and provide navigation guidance during the evacuation process (PaMEAS BMRS receives information about the current safety conditions in the ship from other components of the PALAEMON Communication Infrastructure -- mainly from the PALAEMON Incident Management Module/PIMM, which triggers an immediate action in the case of a declared emergency).
- The **PaMEAS Notification Service** receives structured messaged from the BMRS component and forwards push notifications either directly to the passengers UEs (smartphones, bracelets, etc.), or to their PALAEMON mobile app (a component that will be also added in the next PaMEAS release), alerts, warnings or instructions depending on the situation and the respective signal that needs to be conveyed. In certain situations, direct voice calls to passengers should/can be also initiated, for the needs of the urgent assessment of a situation, or to provide direct help and support.

The **PaMEAS Mobile Network Client (PaMEAS-N client)** is the interface of the Notification Service with the “on premises” 4G LTE - 5G Enterprise Core Network.

4.4.7 PaMEAS People Management Service

At the entry point, the PaMEAS baseline architecture places a **Registration Service for passengers (People Management System - PMS)**. Passengers can register with PMS through their official Identity Providers (national eID Providers, eIDAS Network[16], eMRTD/ePassport[17], etc.). Next, their identity is bound to the ticketing information which is provided through the interconnection of PMS with the Customer Relationship Management

[16] eIDAS Network is the European common identification network, in connection with the MS identity infrastructures.

[17] International standards for digital passports (ePassports), eMRTD defines an MRTD (Passport, Visa or Card) that has a contactless integrated circuit (IC) imbedded in it and the capability of being used for biometric identification of the MRTD holder in accordance with the standards specified in the relevant Part of ICAO Doc 9303.

(CRM) System of the Ship Owner Company. Finally, PMS allows for the registration of associated devices (mobile phones, smart bracelets, etc.) to passengers.

- Directly connected with the Passenger Management System is the **Verifiable Credentials Issuer and Verifier Service (VC System)** which issues VCs to passengers. They use these VC to get electronic and mobile-enabled access to ship services. Passengers can also use their VCs to deactivate the process of collecting personal location data for them and their non-adult family members (thus temporarily stopping the collection of personal location data).

4.4.8 Ground Control Station (GCS) Mission Control

The GCS (Ground Control Station) is the centre node of the UAS and the component that communicate with the UAV and the rest of the PALAEMON system. The main UAV operator uses it to send commands to the drone and to follow the execution of the current mission. Its main goal is to ease the job of the UAV operator by automating flights that cannot easily be done with a radio-controller.

The GCS provides the following main features to the operator:

- **Mission planning**: The operator creates missions using tools adapted to the execution of PALAEMON oriented missions. These missions are automated and the UAV performs them without the need of radio-controller operator's inputs. That way, the operator can focus on its main objectives such as identifying risks or finding men over-board. The RC operator is also able to retake control of the UAV at any moment of the flight if convenient.
- **Video feedback**: The GCS shows the video feedback from the embedded camera from the drone. The operator has full control over the gimbal during the execution of the mission and can freely orientate it to look at points of interest.
- **Situation overview**: The GCS gives the operator an overview of the current environment using three dimensional representation and textual information allowing him to understand what is the drone's location, what is the camera looking at, the current mission state as well as other telemetry information.

The GCS is also connected to the PALAEMON system. It provides transformed real-time data to the PALAEMON core such as the UAV telemetry (e.g., location, status, etc.) or video feedback. It also uses information received from the core, such as current ship's status or weather data, to enhance the flight safety and execution.

Table 27. GCS Mission Control main interfaces

Input parameters	▪ Weather information ▪ Ship’s location and attitude ▪ PALAEMON Evacuation Coordinator status change notifications
Output parameters	▪ UAV telemetry (location, battery level, status) ▪ Camera video stream (@h264)

4.4.9 Augmented Reality (AR) application

The AR application will be the supportive framework for the AR glasses hardware and will require to work seamlessly in between them but also with other standalone systems. In the same time, the AR app will support administrative functions, content recording tools but also data transfer with external systems. The Application will be able to support a series of administrative functionalities, vital for initiating, running and concluding the scenarios. From the account oversight perspective, the AR app will allow crew members to set up their own accounts; login through encrypted channels but also to update, change or personalize their profiles. From an authoring tool perspective, the app will be able to display specific AR items and objects but also impose content and information such as instructions or guidelines.

Another vital function of the app represents the ability to communicate through closed WiFi network with external systems such as: Data Fusion Bus and Messaging server. This will enable AR glasses to exchange data but also receive inputs during the scenarios as crew members will be able to communicate and network information in real time.

Furthermore, the AR app will also be ready to load specific blueprints; view and display ship's passengers as markers or identify other's location on the ship's map. The AR app will be able to record the communications internally. The information can be used by the crew members for personal improvement or for analytics purposes. In case of any communication problems between the systems, the app will display such issues, informing the crew members.

Table 28. AR main features

Input parameters	▪ Ship blueprints ▪ DSS output ▪ Safety Procedures ▪ PaMEAS Indoor Positioning
Output parameters	▪ Visual interface for crew members – Heads-up Display (HUD)

4.4.10 Voyage Report Generator

One of the most important outputs of the PALAEMON platform will be its capabilities to generate a post-voyage/post-incident report, where the company's (in this case, ANEK) DPA will be able to analyze, understand any even rate the response to a particular accident, in case one occurs.

The Voyage Report Generator (VRG) component will collect all the information gathered during each voyage (e.g., sensor readings, passengers' locations, bridge orders, etc.) and organize it in a usable way for later analysis.

This generated Voyage Report will prove to be very useful, allowing DPA's to identify key behaviors than can lead to dangerous or unstable situations. Thus, their ability to analyze the situations leading to an accident and the decisions taken to solve while on an evacuation will be extremely improved.

Input parameters	▪ Database stored data ▪ Stored audio transmissions ▪ Generated video files
Output parameters	▪ Curated voyage report ▪ Relevant incident information

4.5 System outputs

All the elements that we have touched upon so far embrace the end-to-end information flow, from the source (where the data is generated), to the Smart Evacuation Management system, that is, a bunch of services that consume this data and produces an added-value with it.

However, there is another level atop these services and addresses the way stakeholders interact with all the PALAEMON system. In the event of a ship evacuation, we support a number of different outputs, briefly depicted in the list below. As we will see, some of these elements play a twofold role and act simultaneously as sources (i.e., inputs) and outputs of the PALAEMON Communications Platform.

- **VDES Transmitter**. Beside the legacy AIS enriched tracking system present in most of large passenger ships, according to SOLAS [12], we will deploy a VDES transceiver as part of the ship communications infrastructure. In terms of functionality, it will play a twofold role: on the one hand, it will be used to “eavesdrop” all AIS transmissions, thus acting as a bridge between this legacy system and the PALAEMON platform, since it will accommodate the data format making it compliant with our interoperable solution. On the other hand, if and only if the Master approves the command, a distress (Mayday) signal[18] will be broadcasted across a VDE channel transmission.
- **Integrated Bridge System**. Monitor or group of monitors where we plan to display all the graphical outputs of the PALAEMON system (e.g., SSS, PIMM, PaMEAS, etc.) to the Master and all crew members present at the bridge. Though not contemplated in this project, this layout could be replicated in the ship’s safety center, where specific and well-trained operators may analyse the situation in parallel to the bridge and complement their standpoint. In the specific context of PALAEMON, the final layout is still subject of analysis and may vary during the next months (this final setup will be reflected in further WP7 and WP8’s deliverables).

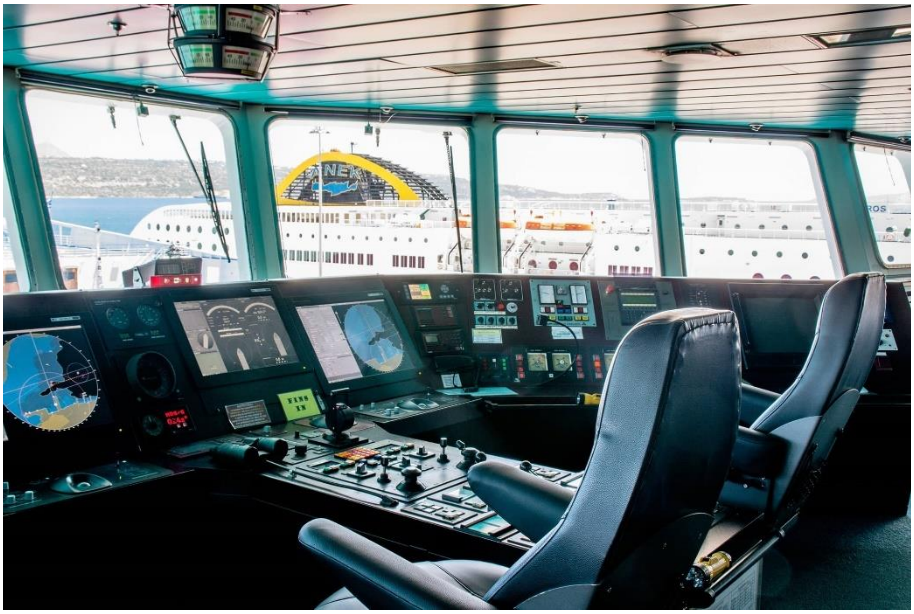

Figure 17. Hellenic Spirit Integrated Bridge System

- **UAV Ground Control Station**. The UAV operator is a crew member specialized in UAV piloting operations and uses the GCS interface plan and overview missions. The GCS software is running on a laptop and is part of the UAS. The GCS operator is usually accompanied by another specialized crew member who enforces the safety on the flight using the UAV radio-controller. To give the reader an illustrative example of the information displayed on the GCS, Figure 18 displays the current version of the

[18] As stated in Rule 37 of the Convention on the International Regulations for Preventing Collisions at Sea [77].

layout used in PALAEMON. We can observe four different areas: *1*- PALAEMON status, where the UAV operator checks the ship's status; *2*- A 3D map of the vessel where he/she can also know the real-time position of the drone and the predefined route (in case of automatic mission); *3*- Real-time video streaming captured by the drone; *4*- Mission planning, with all the information relative to the current mission.

Figure 18. Ground control station layout (sample screenshot from simulation)

- **Smart Bracelets**. The basic use of this wearable addresses the precise real-time indoor location of passengers and crew members (via PaMEAS). In addition to this, the devices count on a physical button that generates a tailored signal or notification. In the context of PALAEMON, this action would indicate the accidental fall of a passenger, leading to the corresponding assistance actions carried out by the indicated seafarer. As an illustrative example that may help the reader visualize the concept of a smart bracelet and its interaction with humans, Figure 19 shows a well-known commercial activity tracker, whose functionality and features are very alike to the prototype we have under development. Unfortunately, the prototype is still at an early stage and do not have a visual representation. For additional information about its breakthrough, the reader should refer to D5.1 [16]

Figure 19. Smart Bracelet commercial representative model (Xiaomi Mi Smart Band 6[19])

[19] Xiaomi Mi Smart Band 6 official webpage: https://www.mi.com/global/product/mi-smart-band-6/overview

However, the communication with the bracelets can follow a downlink sense, i.e., where the PALAEMON system (i.e., PaMEAS) sends real-time feedback to users, suggesting them the best path to the safest muster station. It is worth noting that these recommendations are completely personalized and are calculated from the user's current position. As a side not, the way these indications will be displayed is not defined yet at the time of closing this report and will be reflected in the future D5.2 [17].

- **Smartphone app (PAMEAS UE).** Likewise, the case of smart bracelets, passengers' smartphones are a complementary devices to carry out people's indoor location via PaMEAS (outdoor locations is solved through regular GPS positioning). Besides, these devices can be used to display information on the evacuation route they should follow to get the muster station in the fastest and safest conditions. The main difference between these devices lies in the flexibility of the Human Machine Interface (HMI), where the possibilities supported by smart bracelets are much more limited than those of smartphones. As for this latter case, dynamic maps can be displayed with the routes, a complete messaging system (via notifications) can complement it, etc. Again, the way this feedback will be displayed is still under development and we cannot state anything else at the time being. For additional details, the reader should go to the last iteration of PaMEAS-related deliverables, i.e., D5.10 [33], D5.14 [35], D5.16 [21].
- **AR glasses Heads-up Display (HUD)**. Some specific crew members (e.g., evacuation support, search & rescue, etc.) will wear a pair of AR googles to get real-time extra information and a new level of assistance during an evacuation. As we can see in Figure 20, the visual feedback of the seafarer is enriched with an additional level of real-time data. The range of visualization possibilities is very wide: from current information about ship and weather status to the location of close passengers, the layout of the AR HUD can be straightforwardly configured. The reader can find much more information on the widgets and their scope in Deliverables D5.3 [28] and D5.4 [29].

Figure 20. AR Glasses HUD sample (screenshot taken from VR environment)

As a side note, to pinpoint the crew members' location, these googles need to work in collaboration with PaMEAS-compatible devices (i.e., smart bracelets, smartphones, etc.), since as these are the devices that are used to calculate the user's location.

- **PALAEMON VDR.** Every voyage (with or without casualties) will be accompanied with a dedicated report that abridges the information of all the components that compose the PALAEMON Communication Platform. From a technical viewpoint, this record is made of all the data available in the system: DFB core databases content (i.e., Elasticsearch and MinIO), video clips recorded by the smart cameras, audio conversations captured by the Messaging Server, debugged/logging data from software components, etc. All this information will be encapsulated into a single "zip-like" file and uploaded to different services that we cannot confirm at the time of writing this report. For instance, we are posing the possibility of sending the report to a cloud-based repository, to the SMS ashore (next point), to save a copy in the on-board VDR, etc. In case a further analysis is needed, i.e., an accident investigation, experts will have a thorough compilation of data to delve into.
- **Safety Management System (Shore)**. In Section 4.2.3 we touched upon the SMS instance deployed as part of the ship infrastructure. Moreover, this module has its counterpart at shore, where the information of all the fleet is duly persisted. It is worth mentioning that both components are duly synchronized, and every modification in any manual, procedures, etc. carried out ashore or on-board will be automatically reflected at the other side. In addition to this, we are currently analysing the possibility of automatically registering the PALAEMON VDR as part of the SMS repository. Nonetheless, this implementation is under development and will have to face not only technical hurdles, but also regulatory, since the information stored follows a quite strict format/standard.
- **System log**. Probably the least "appealing" output of any ICT infrastructure. Any kind of data (either in the form of "actual" information or just debugging messages from the various software modules) will be properly managed and saved. Beside the actual information from sensors, this "low-level" data can be used to spot misbehaviours in any of the software components, which may lead to a whole system malfunctioning.

5 PALAEMON system as a whole

Up to this point, we have talked about the current (and final) version of the PALAEMON system, emphasizing the main modifications that have streamlined the system from v1 to v2. Now, in this section, we wrap up all the information we have compiled so far and present the holistic vision of the PALAEMON platform. On the one hand, the PALAEMON Academy, a separated framework[20] that operates on its own and is conceived to train crew members before they go into the sea. On the other hand, we sum up and give a holistic outline of the Reference Architecture v2.

[20] In D2.6 we did consider that the PALAEMON Academy was intrinsically linked to the "main" PALAEMON Reference Architecture; however, now we see it as an independent and standalone platform.

5.1 PALAEMON Academy

The PALAEMON Academy is primarily focused on training and education for the crew. Moreover, safety procedures and how to act in emergencies on a ship provide a topic for the passengers as well, though it is out of the scope of the activities carried out in this project.

The PALAEMON Academy for the crew designed to be available before the crew boards the ship. As a training before going aboard, the crew can train on the ship-related procedures for evacuation but also on the use of the PALAEMON System on the bridge. Therefore, VR models of the cabin area, lounge area, muster station and bridge have been gathered and adapted to the VR training programme. The Integration of the PALAEMON system follows the idea of providing browser windows in the VR environment for showing the data of the PALAEMON System components on the bridge. This allows an “optical” integration for training. The full VR System [74] is provided by Master Mind Development GmbH (Austrian Ltd.) [75] and compatible with SIMAVI’s VR/AR developments.

The PALAEMON Academy is designed to address the crew in specification of their roles (Captain, Officers, Crewmen) and their related actions (decision making, coordination and reporting, operative search, mustering, handling of passengers and reporting). Beside the VR System, an eLearning platform is integrated so that participants have a knowledge base and are prepared for their tasks and actions on board.

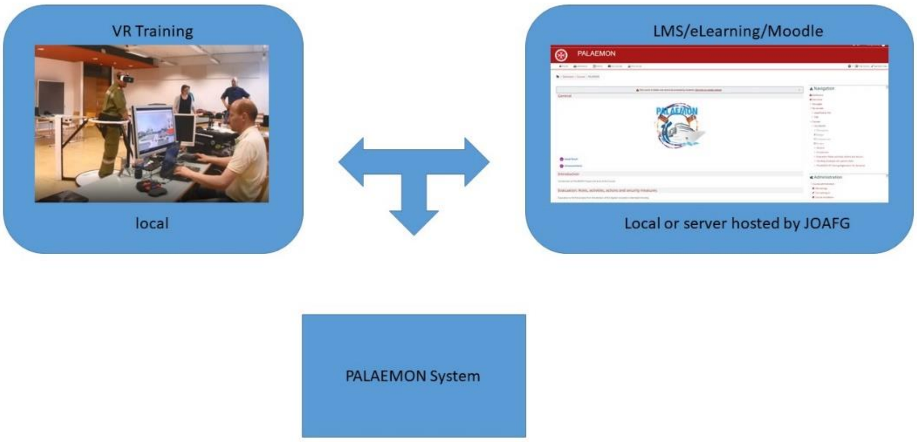

Figure 21. PALAEMON Academy platform overview

As technical standards, the PALAEMON Academy uses Moodle [76] as open license model for eLearning system. For the VR development of the content, a database entry format is developed as an *.accdb* format[21] for easy entry and form development at JOAFG. The graphic specifications for the 3D models are based on Unity engine. This allows a faster integration of new models and content. The output format of the Moodle system, where the results of VR Training are typed in, is Comma-Separated Values (CSV).

[21] Default file format for Microsoft Access.

Table 29. PALAEMON Academy input/output parameters table

Input parameters	▪ Scenario Database ▪ Participant list ▪ Course content ▪ Role system ▪ Ship model ▪ HTML input for PALAEMON Sys training
Output parameters	▪ Individual grades and training status ▪ Overview of training status of crew ▪ Overview of training status of passengers

5.2 PALAEMON Reference Architecture v2

This section shows the current (and definitive) version of the logical Architecture for the PALAEMON platform, as illustrated in Figure 22. Here, after the individual "round table" of every module present in the system, all logical components (i.e., data sources, access layers, platform core, high-level services and platform outputs) are depicted, allowing the reader to have a holistic view of the whole ecosystem for this second version.

The PALAEMON Reference Architecture is divided into several layers: Data Sources, Data Access, Platform Core, Smart Evacuation Management and System Outputs.

The Data Sources layer is composed of the generators of data for the platform. In this layer, the Processing Nodes or software are also presented, to properly differentiate between the actual data generation device, and the processing tools related to it. On this layer we can find devices such as the Smart Bracelets and AR googles, which will ingest important data into the platform that will be used by later services. As well, some static data sources, such as Safety Procedures (via SMS), Manuals, or Ship blueprints, will be fed into the system prior to the ship's departure. Last, a two-way communication between ship and shore is provided by the VDES transceiver, providing static dynamic weather and environment information.

In the Data Access layer, we can find the means to inject the data into the platform. This layer includes the DFB Access layer, which can take data as input and relay it to other components in a pub/sub manner, as well as the PaMEAS network, which will receive the generated data from the Smart Bracelets to be later turned into localization information.

The PALAEMON platform core is made of critical components that provide the central functionalities to the ecosystem. One of the main components in this layer is the DFB Core, that provides persistence to all data sources and services. We can also find utilities such as the PaMEAS Applications, which can calculate localization of passengers and safe routes to follow through the ship, or the Safety Management System that will provide the necessary static files to support the evacuation process, such as safety procedures or evacuation manuals. The PALAEMON Evacuation Coordinator proves to be of a great importance, as it allows all components to be aware of changes in the evacuation status and be synchronized on their proper operation modes. Supporting components such as the Messaging Server or the IAM are also included on this server, as their functionalities are critical to the platform's operation.

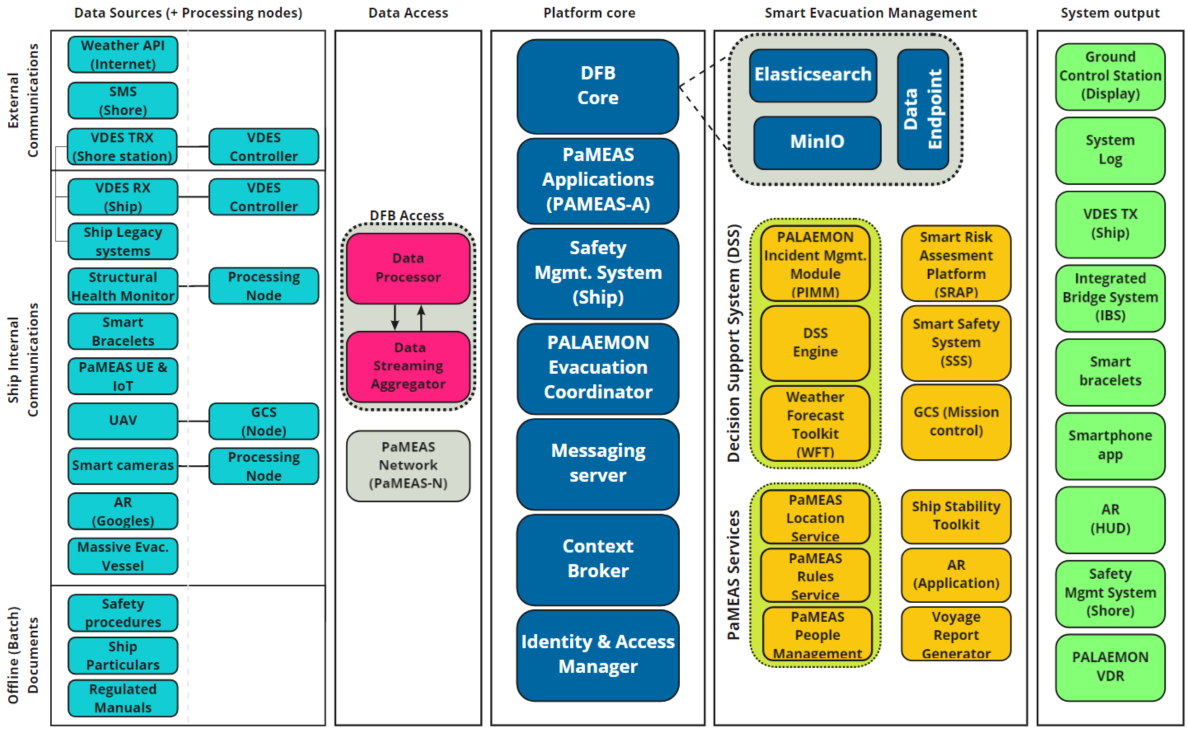

Figure 22. PALAEMON Reference Architecture v2

The Smart Evacuation Management (SEM) layer is composed of the actual services that provide the PALAEMON evacuation functionalities. The DSS macro-service makes use of the current weather conditions and previous similar incidents, as well as the static Safety Procedures, to offer customized suggested actions for each evacuation step. PaMEAS Services oversee the positioning of passengers and Crew members, suggesting routes along the ship. Some other services like SRAP, SSS or the AR application also appear on this layer.

The last layer present is the System Outputs layer. This final level displays the outcomes from the platform that directly interplay with end-users/stakeholders. Some of the outputs, like the GCS Display or the Integrated Bridge System, provide visual feedback to the Bridge Crew through monitors. The AR HUD give Crew members with a dynamic means to access their suggested tasks or rescue missions. During an evacuation situation, the Smart Bracelets will be capable of indicating the safest or fastest route to the passengers. Finally, the PALAEMON VDR will compile the main voyage information, including weather conditions, actions taken and ship integrity conditions throughout the ship’s voyage.

6 PALAEMON Data & Services end-to-end workflows

In this section we represent the main end-to-end flows that take advantage of the PALAEMON Communications Platform. Thanks to the interoperability and data homogenization, all components can interact to each other, hence building a fully-fledged system fed from a wide spectrum of heterogeneous data sources/underlying infrastructures. It should be noted that not all logical connections between components are depicted on the figures of each section, for simplicity’s sake. For example, even though most data exchanges between components are performed through the DFB ecosystem, they are not always present on all the figures.

6.1 Authentication and Authorization (via Identity & Access Manager)

PALAEMON components manage critical and sensitive data, such as passengers' location or personal info. This means that cybersecurity plays a very important role on the platform. For this reason, an Identity and Access Manager (IAM) has been included on the platform, to ensure proper access to each resource for each different user. Figure 23 represents the Authentication flow to be followed when accessing resources from PALAEMON services.

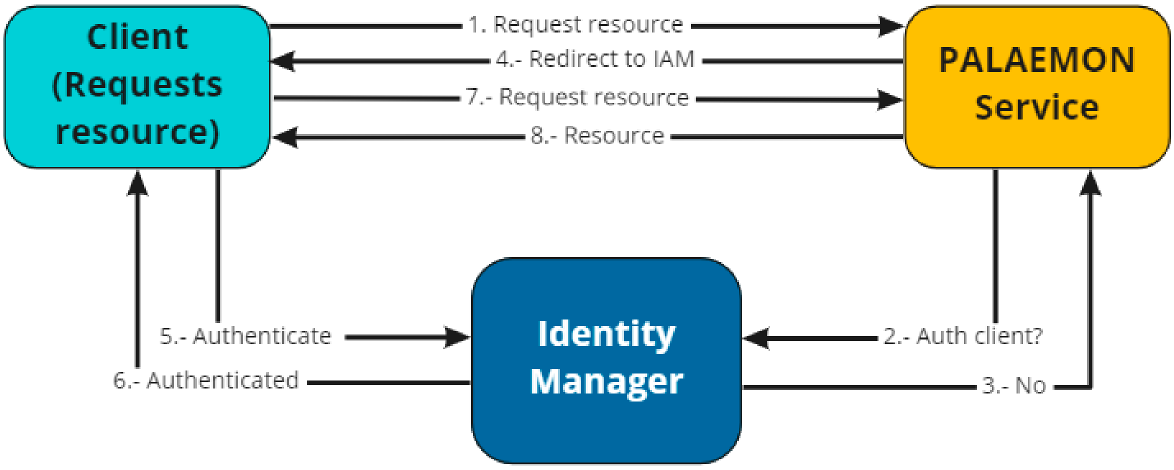

Figure 23. Authentication and authorization operation overview

First, a client (PALEMON device, service or data source) requests a resource to a certain PALAEMON service. This PALAEMON service asks the Identity Manager if the client is authenticated and allowed to access that resource. If it is not, the IAM will respond with a No. Then, the requested PALAEMON service will redirect the client to properly authenticate via the IAM interface.

The client will send their assigned credentials to the IAM in order to receive a login token for further authentication. If the user's credentials are appropriate, the IAM will respond with a temporal token that can be used to access the allowed resources on the PALAEMON platform. It is important to note that each user will have a different set of permissions and resources that can be retrieved.

Once the client has been properly authenticated on the platform, they can proceed to request the resource again and the service will return the proper answer.

6.2 Data Fusion Bus and Context Broker

DFB is used in PALAEMON for enabling intercommunication between different components and for data persistence. The DFB functionality is depicted on Figure 24.

The data generated by data sources and services, such as PaMEAS is shared with the PALAEMON platform using the DFB Access layer, composed by the Data Streaming (Apache Kafka) and Data Processor (Apache NiFi) components. One of the critical components of the system, the PALAEMON Evacuation Coordinator, uses the DFB Access layer to send its notifications to all the other components as well.

Once the data has been introduced into the platform, it can be persisted for further use by use of the Kafka connection to the DFB Core. Then, the SEM services can access this data via the Data Endpoint. In case of real-time solutions, such as SRAP or DSS, services can also directly subscribe to certain Kafka topics, receiving the data as soon as it is generated.

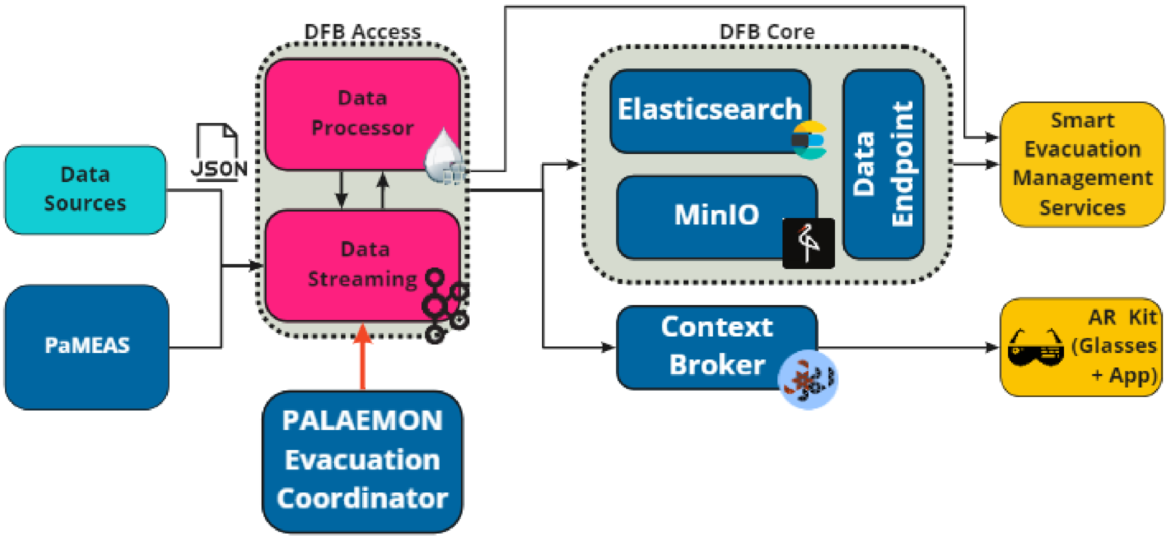

Figure 24. Data Fusion Bus end-to-end flow (including Context Broker)

In case of the sensors present in the system, such as localization readings or stability sensors, the data can be also stored on a Context Broker, which will track the state of each sensor at all times, making the information available for the interested services, such as the AR glasses.

6.3 Multimedia Data Transfer

While carrying out an evacuation process, it is of vital importance that all communications are swift and robust, allowing for orders and action to be carried out in a smooth way. For this reason, a Messaging Server will be deployed for devices to communicate. Figure 25 shows the Multimedia Data flow.

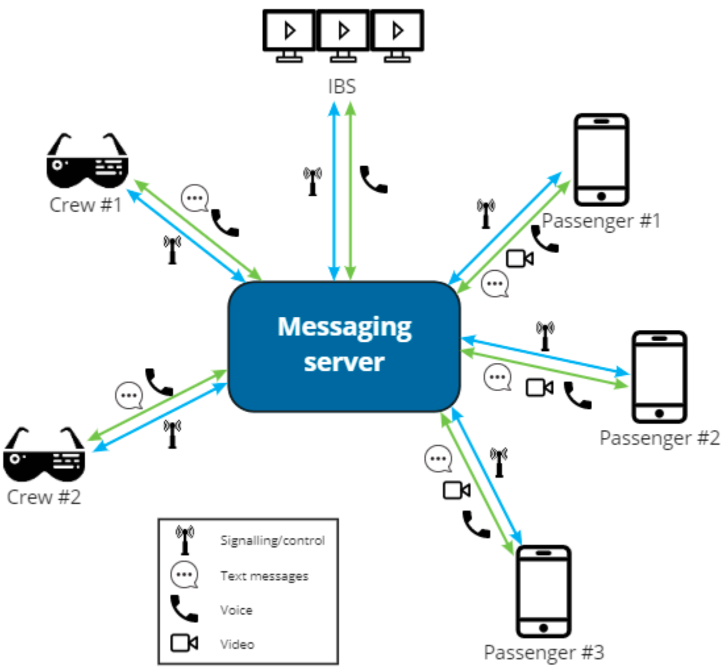

Figure 25. Multimedia data transfer end-to-end flow

The Messaging Server centralizes the communications exchange between devices. All devices (AR glasses and passenger mobile phones) can connect to this server and establish a communication channel (audio, text or video) with any other device on the network. This will allow different agents on the system to provide important information (a passenger giving info about an incident or a crew member passing some instructions to a colleague).

This messaging server will also be able to connect to the Integrated Bridge System to show any relevant communications (i.e., the video feed from a certain crew member) or dispatch orders to any device to improve the evacuation methods.

Once an evacuation situation has ended, the Messaging server will be able to store relevant communications on the DFB Core system in order to perform some further analysis using the PALAEMON VRG.

6.4 PaMEAS

Within the PALAEMON platform, the PaMEAS ecosystem will manage the location of all passengers and crew members, as well as the calculation of the evacuation routes in case of an incident. To manage this, different components are being developed, as shown in Figure 26.

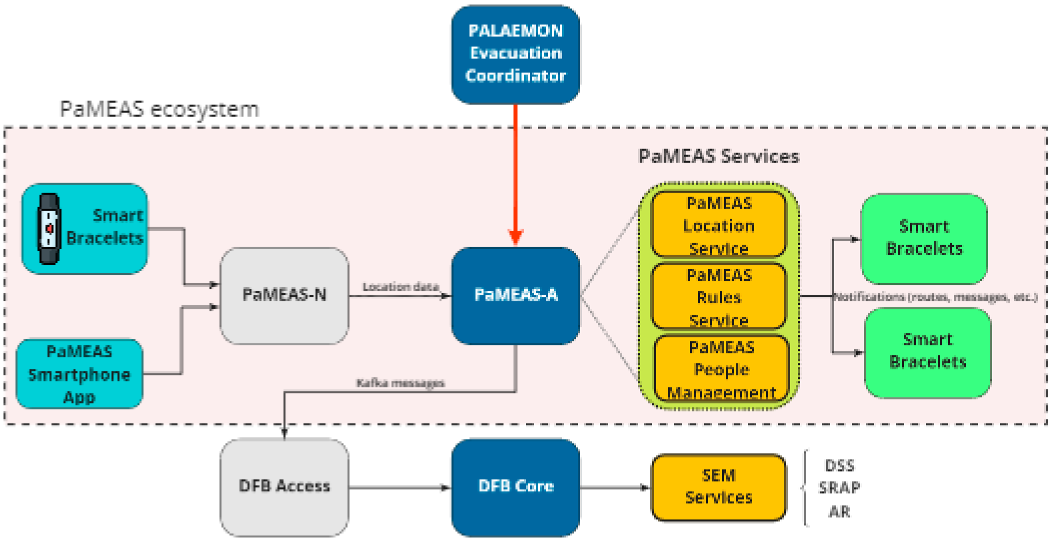

Figure 26. PaMEAS end-to-end flow

The main data for the location calculations comes from the Smart Bracelets that the passengers and crew members wear on their arms and the PaMEAS Smartphone app that they can install on their phones. These devices connect to the PaMEAS network via WiFi, providing the measured RSSI to the different Access Points (APs). This information is then relayed to the PaMEAS application, which represents the main bulk of the PaMEAS ecosystem. This macroservice is composed by the PaMEAS Location, PaMEAS Rules Service and PaMEAS People Management services.

Once the different locations or evacuation routes are properly calculated, they are sent to the Smart Bracelets via Push Notifications, suggesting safe paths along the ship to arrive to the desired destination.

Also, the PaMEAS Application needs to listen to the PALAEMON Evacuation Coordinator messages, in order to activate different protocols according to the current evacuation status.

The information generated by the PaMEAS ecosystem (localizations, routes, obstacles...) is stored into the DFB service as well, via DFB Access layer. This data can then be used by other SEM services, such as DSS, SRAP or AR glasses using the DFB Data Endpoint.

6.5 UAV + GCS

Once an evacuation order has been issued, the UAV will start flying around the ship to analyse the structural status and look for any passengers that may fall overboard. The UAVs are controlled by Ground Controlled Stations placed on the ship and the MEVs. The dataflow for the UAV functionality is as follows (Figure 27).

While the UAV is on the air, it needs to send its video feed and sensors' data to the GCS on the ship or MEVs. The GCS analyses the received data and recalculates the routes, sending back relevant information or new orders to the UAV. This calculated data is sent to the PALAEMON platform via DFB Access layer in a JSON format. The GCS is subscribed to the PALAEMON Evacuation Coordinator notifications and is capable of reacting to evacuation phase changes. In critical phases, the GCS can transmit the recorded video to be stored on the DFB Core.

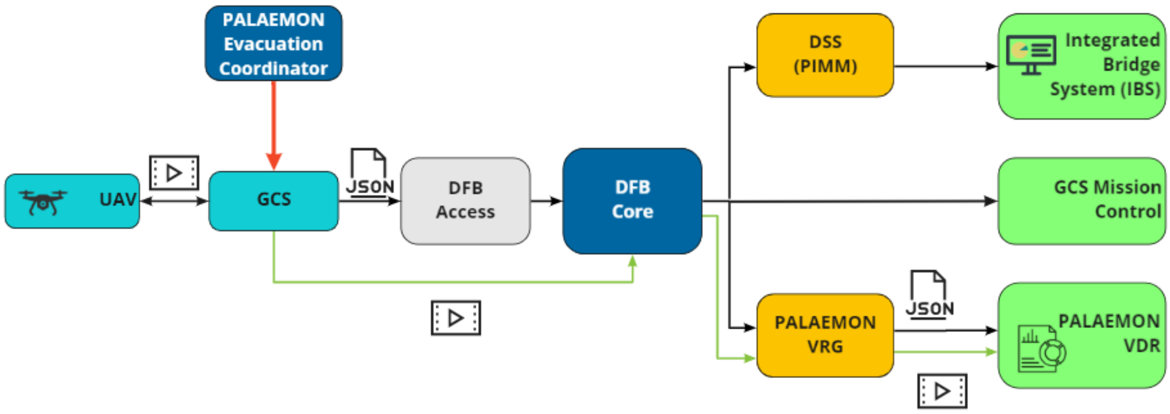

Figure 27. UAV end-to-end flow

The data generated by the UAV (man over-board or structural damage) can be shown on the IBS via PIMM. The GCS Mission Control component can also show relevant information about the UAV flight, such as battery level or wind strength. Once the evacuation situation is finished, the stored data and video files are collected by the PALAEMON VRG to allow later analysis by the pertinent authorities.

6.6 AR glasses

The AR Glasses prove to be an extremely useful tool during the evacuation stages, allowing crew members to safely navigate the ship looking for stragglers or missing people, all the while keeping track of the current status of the ship and the instructions provided by the bridge. In order to clearly show all the relevant information on the glasses, it is vital that all components relay the proper information, as shown on Figure 28.

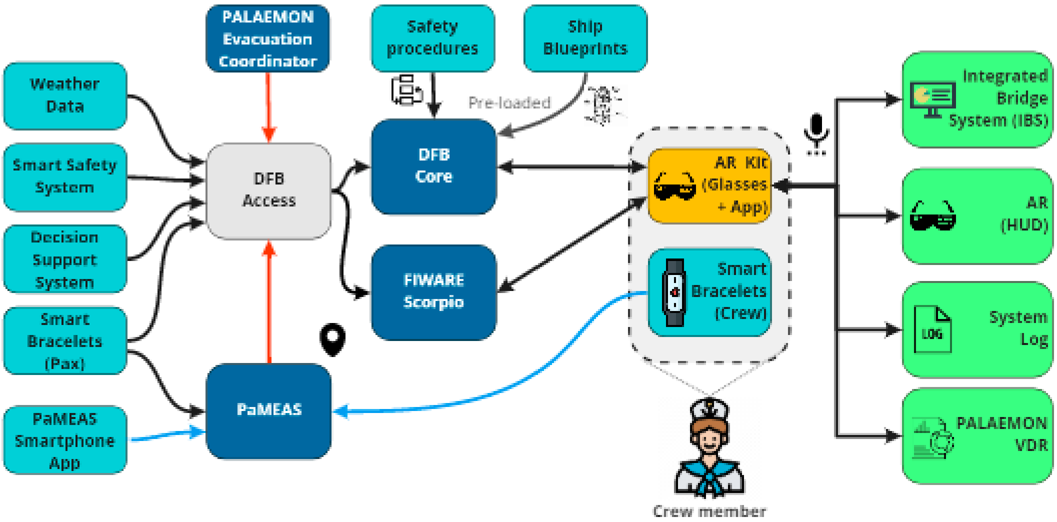

Figure 28. AR Glasses end-to-end flow (overview)

One of the main inputs for the AR glasses is the PaMEAS generated locations for passengers. Also, the glasses show the data generated by the SSS, the DSS, and the passengers' Smart Bracelets, as well as the Weather Data captured from the Weather APIs. In order to properly show the ship's critical points (fire extinguishers, corridors, etc) and the proposed tasks to undertake while rescuing passengers, the AR glasses need to get the Ship Blueprints and Safety procedures from SMS.

All this information is stored on the DFB system, and can be accessed either through the DFB Data Endpoint, in the case of static data (Safety procedures, Ship Blueprints), or through the FIWARE Scorpio Context Broker, in the case of rapidly changing data (passenger locations, SSS notifications, etc).

The result of all this information gathering will be an AR HUD that will show all the relevant information on the crew members' glasses, allowing them to complete tasks or communicate with the bridge or other crew members. As well, all the audio communications and the operation logs will be stored on the PALAEMON system, for later analysis using the PALAEMON VDR service.

6.7 Smart Cameras

The Smart Cameras provide a means to perform some crowd control on overly populated areas of the ship, as well as being able to detect obstacles or accidents on main rooms or corridors. Figure 29 represents the data flow to manage the video feeds and the generated data.

The video captured by the Smart Cameras is directly sent to the Processing Node, which will be in charge of calculations and video analysis. The data generated by the video analysis (people counting in rooms or corridors) will be sent to the DFB service via the DFB Access layer. This data will be stored on the platform to be later collected by the PALAEMON VDR and shown on the Integrated Bridge System via PIMM.

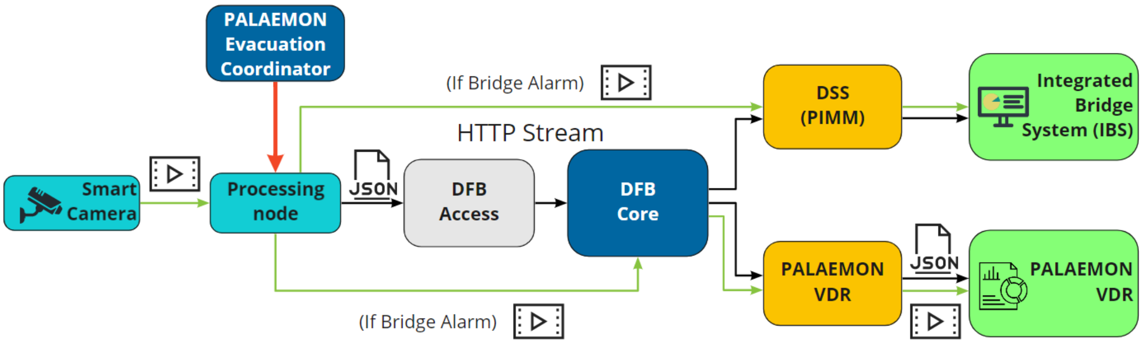

Figure 29. Smart Cameras end-to-end flow

Same as other components, the Smart Cameras Processing Node is always listening to Evacuation Status changes on the PALAEMON Evacuation Coordinator. In case a Bridge Alarm is triggered, the video streaming protocol is activated, resulting in the video being sent to different components. First, the recorded video can be shown on the PIMM via HTTP Streaming. Also, the buffered video during an accident is stored on the DFB Core, and the PALAEMON VDR can collect it after the incident ends.

6.8 VDES

During a ship's voyage, it is of utmost importance to carry the proper interfaces to communicate with the outside world, both during normal operation and on evacuation situations. On the PALAEMON platform, VDES will provide this functionality, allowing for constant feedback from the shore stations and distress signals in case of accident. The data is shared among the components as shown in Figure 30.

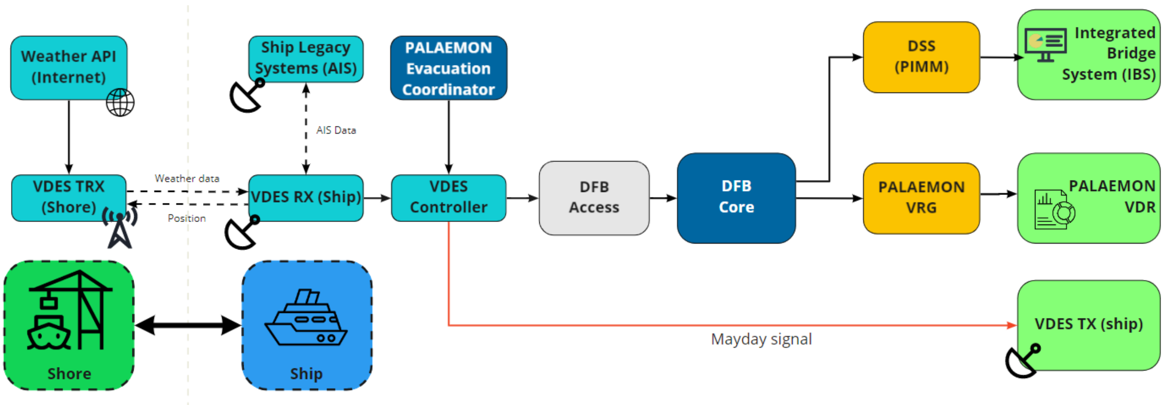

Figure 30. VDES End-to-end data information and communication flow

The (emulated) VDES transceiver at shore is communicating at all times with ships at sea. These communications are captured by the ships, which provide them with relevant information about weather or ship conditions, as well as other ships' locations and routes. In the particular case of weather, the data is retrieved ashore through public APIs (see Section 4.1.1 to refresh the content) and relayed to the ships via satellite connection. The data received this way is shared on the PALAEMON platform using the DFB system. It is worth highlighting some intermediate steps to be carried out before querying the proper weather data.

1. As the current ship position is an essential input for the weather service, PALAEMON VDES prototype with catch, from Hellenic Spirit's legacy AIS system, attributes like ship location, speed, heading direction, etc. As a matter of fact, the dynamic weather conditions of the weather conditions oblige us to frequently update the location and request new weather data.
2. Amongst all this data, we will forward (via ship's VDES) the position to the shore station.
3. At shore, the current coordinates are used as input parameters to get the weather information from the API (i.e., OpenWeather).
4. Finally, the weather data object is sent back to the ship through the VDE channel.

The VDES software is subscribed to the notifications from the PALEMON Evacuation Coordinator, allowing it to be aware of evacuation phase changes. If a grave evacuation situation arises, the VDES transceiver present on the ship can broadcast a Mayday signal that will notify nearby ships and shore authorities of the problems and let them send help.

The relevant information received through the VDES will be shown to the Bridge Crew using the PIMM interface. Once the voyage is over, all the generated information will be curated and dumped into a post-analysis report via the PALAEMON VRG.

6.9 Safety Management System

The SMS will provide the critical role of storing the Safety Procedures to follow during a ship's voyage. In the case of an evacuation situation, the Bridge Crew and Master will heavily depend on the measures provided by this component. For this reason, the SMS will present strong connections to other components in the PALAEMON platform. Figure 31 represents the dataflow for the SMS component:

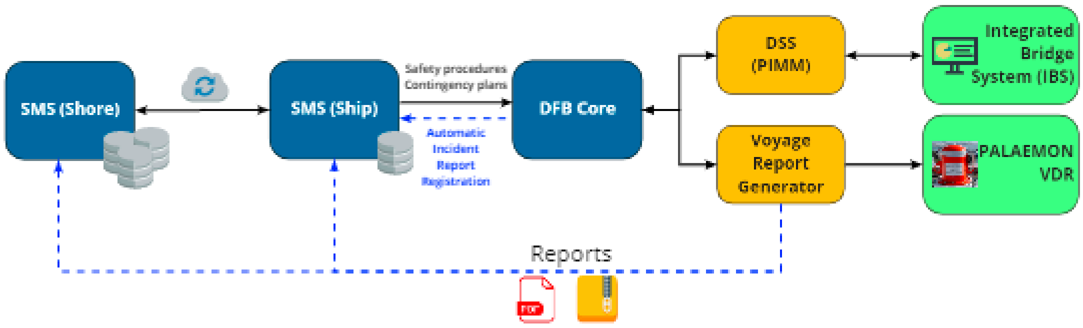

Figure 31. SMS end-to-end flow

The first step is the recompilation of Safety Procedures and documentation relevant to the type of ship and its characteristics. These documents will be stored on the SMS service before the ship's departure and will need to be continuously checked and updated in case of changes in regulation or improvement on procedures. Once the ship sails, the documents will be digitalized and safely stored on the DFB Core in a "parseable" JSON format. These documents will be available for services to use.

If an evacuation situation arises, the DSS will calculate the most appropriate suggestions and show them to the Bridge Crew using the PIMM. The suggested actions will make the evacuation process much smoother and improve the quality of the actions taken. The suggested actions taken, as well as its results, will be stored on the PALAEMON Platform to be later gathered by the PALAEMON VRG.

When the ship arrives at its destination, the reports generated by the VRG are sent to the SMS service, in order to register the measurements taken through the course of the voyage and keep them properly organized.

6.10 Smart Risk Assessment Platform

In order to effectively perform its risk level recommendations, the SRAP service needs to get the data from several other services that are present on the PALAEMON platform. The data flow for this component is as follows (see Figure 32).

The SRAP service takes as input the data generated by the Shipboard Legacy Systems, as well as the output of the DSS, SSS and SHM services. As explained before, this information is stored in the platform by using the DFB Access layer, which in turn sends it to the SRAP via Kafka notifications. As do all components, the SRAP service needs to know at all times the evacuation status for the system, in order to perform its different operations. In order to know the locations of passengers and crew for the risk level calculation, SRAP also needs to access the data generated by the PaMEAS application (PaMEAS-A).

As well as the previously mentioned inputs, the SRAP also needs to read the evacuation methodologies stored on the SMS. This static data is stored on the DFB Core, and can be accessed via the DFB Data Endpoint.

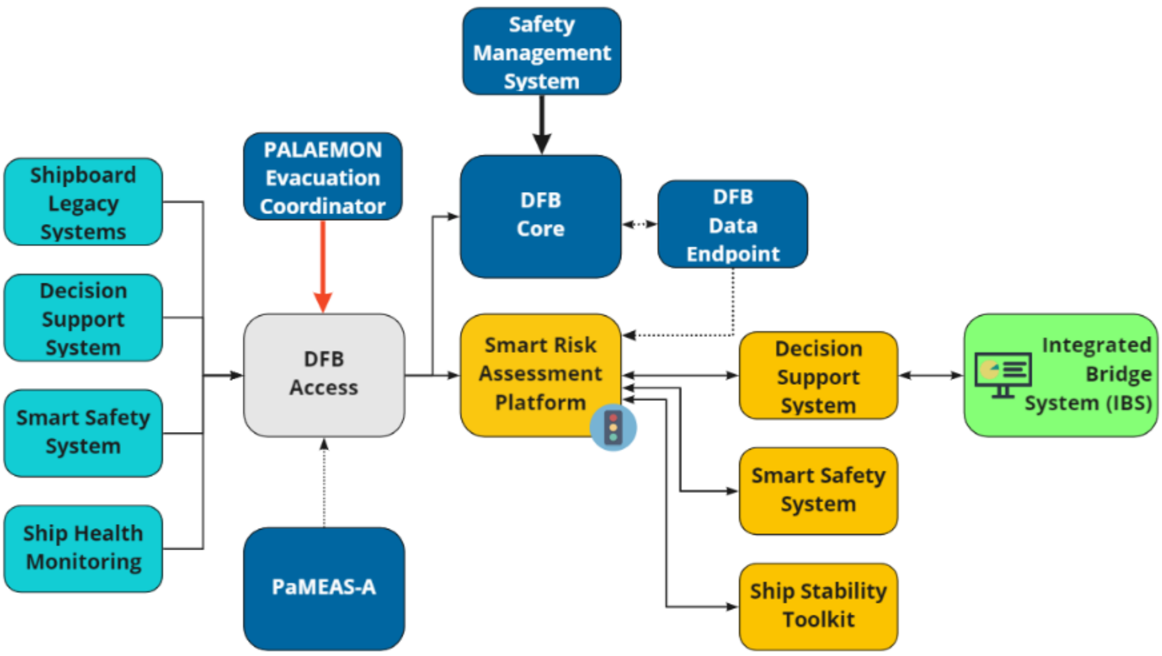

Figure 32. SRAP end-to-end-flow

Once the SRAP service has calculated the estimated risk level for the system, it feeds the calculations of the DSS, SSS and SST services (via Kafka notifications as well). This output will be shown on the Bridge screen via the PIMM (integrated on the DSS).

6.11 Decision Support System

During an evacuation situation, it is quite important that the Bridge Crew can promptly respond to different incidents and quickly deploy different orders and actions to mitigate the damages. For this reason, the Decision Support System must be able to suggest different actions according to the current conditions and evacuation status. The DSS ecosystem takes input from several other components from the PALAEMON platform, as shown on Figure 33, below.

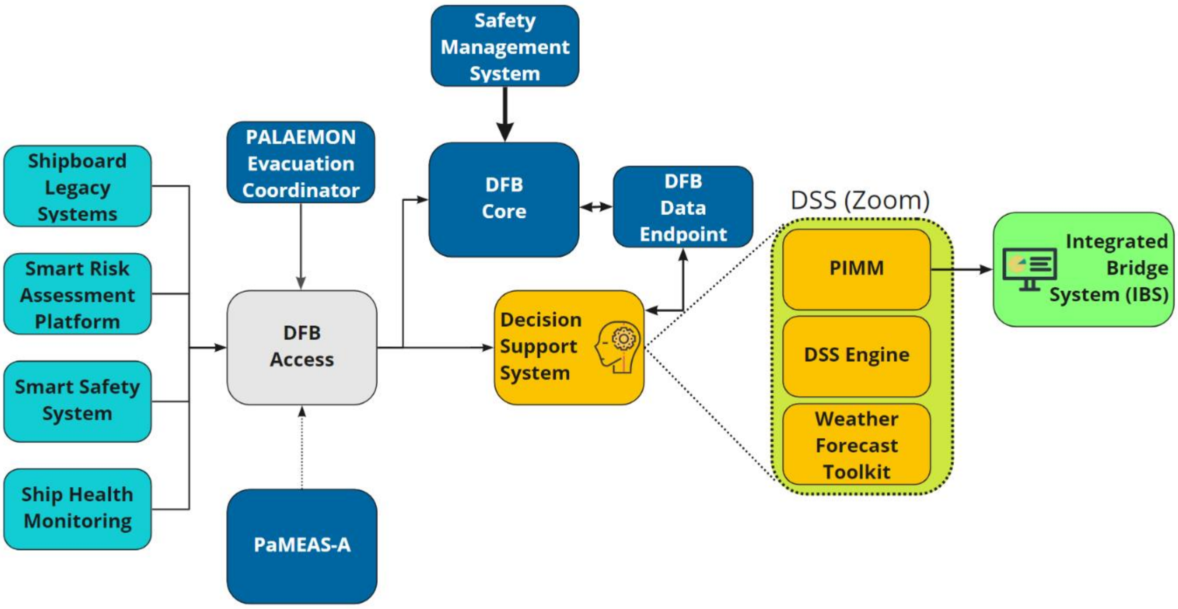

Figure 33. DSS end-to-end flow

The DSS takes input from the SRAP, SSS and SHM services, as well as from data generated by the Shipboard Legacy Systems. This information is shared with the PALAEMON platform through the DFB Access layer. The information generated by the PaMEAS Application is also stored on the DFB system. As all other components, the DSS listens to the PALAEMON Evacuation Coordinator messages to notice any change on the Evacuation Status.

The DSS also needs some static data provided by the SMS, previously stored on the DFB Core during the Offline Phase. This data can be retrieved using the DFB Data Endpoint.

Once the DSS has calculated the suggested actions, they are shown on the Bridge via the PIMM. These suggested actions are also stored on the PALAEMON platform for further use with the AR glasses and any service that needs to access it. The actions taken during an incident will be collected by the VRG at the end of the ship's voyage for further analysis.

6.12 Voyage Report Generator

In case an evacuation situation happens, the maritime and civil authorities, shipping and insurance companies, etc. need to deeply analyse the procedures and validate the decisions taken by the Bridge Crew, Master and seafarers. In order to make the process smoother, the PALAEMON VRG aims to collect the relevant information gathered during the voyage, either by sensors, services, or devices connected to the network. Figure 34 represents the dataflow.

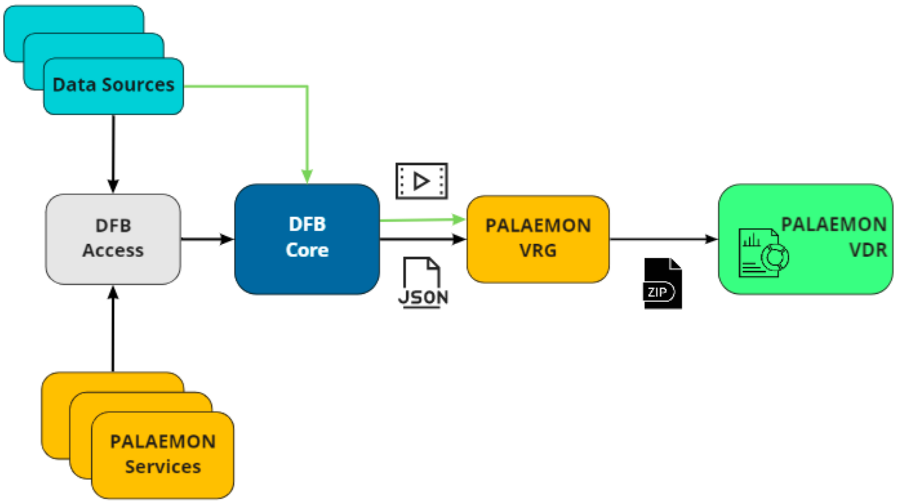

Figure 34. PALAEMON Voyage Generator operation data flow

While carrying out their respective tasks, the components in the PALAEMON platform store their generated data on the DFB Core, via the DFB Access layer. The binaries (e.g., videos, audio files, images, etc) generated during the execution are also stored directly on the DFB Core object filesystem. Periodically, the PALAEMON VRG will access the DFB Core and retrieved the stored data in order to generate a compiled report with the most relevant information in the system. This Voyage Data Report will later be sent to the company's DPA to carry out the proper post-incident analysis.

7 Conclusions

This deliverable corresponds to the second iteration on the definition of the PALAEMON Reference Architecture. Seen as a continuation of the legacy work on the architectural design, i.e., D2.6 [1], we started the report by addressing all the issues we left open in our initial approach. As a direct consequence, we adapted the system to fill all these gaps; we have added of a so-called “Identity & Access Manager” to support encryption and authentication mechanisms; we have added a component named Scorpio Broker to ensure the interoperability and compliancy with ETSI NGSI-LD standard; we have settled down the relationship between all the services that shape the Smart Evacuation Management layer; finally, one of the points that we left on hold had to do with the support of multimedia streaming (e.g., text messaging, voice calls, video sharing, etc.). To deal with this, we have included a Messaging server that centralizes all this traffic and provides this highly demanded feature.

Alongside the evolution that the architecture has undergone, we have revisited all the system requirements and have come up with a definitive compilation (Annex I and Annex II presented the requirement/components traceability matrix and the full list of requirements, respectively). In parallel to all these modifications, we accompanied the analysis with a mapping between the PALAEMON platform and the maritime ship evacuation status flow, where we have observed a clear connection between the evacuation state and the operation mode of some (most) of the individual components. To illustrative this, we stuck to one of the most frequent (and more difficult to tackle) maritime incident types, i.e., fire, and compared, side by side, the traditional measures undertaken by current vessels, to the innovative actions brought about by the PALAEMON system and all its underlying technologies, components and smart evacuation services.

After this holistic approach to the evacuation process and how the PALAEMON Reference Architecture has been designed to significantly enhance its legacy performance, we presented each of the components, its main features and inputs/outputs (if any). Aside the main framework, it is worth mentioning the new role of the PALAEMON Academy, formerly seen as another component of the analysed architecture. Nonetheless, as it targets at a completely different scope, in terms of space (e.g., ashore learning centres/academies, deployed in dedicated hardware infrastructure), time (i.e., before sailing) and even stakeholders (i.e., trainers and crew members trainees), we have taken the decision to take it out the final PALAEMON Reference Architecture and keep it as an independent platform.

Finally, though this report officially concludes the activities framed under the umbrella of WP2, the breakthrough of the PALAEMON platform will be continued and the main focus shifts to the actual integration over a real scenario (i.e., Hellenic Spirit). After this, a thorough testing campaign will be carried out to assess the behaviour/performance of the whole system. As the icing of the cake, the platform will be applied to real evacuation scenario trials, where all the lesson learnt during these years will be put in practice (and evaluated).

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Annex I Traceability Matrix

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
Platform-001	x																									
Platform-002	x																									
Platform-003	x																									
Platform-004	x																									
Platform-005	x																									
Platform-006	x													x		x			x							
Platform-007	x																									
Platform-008	x																									
Platform-009	x																									
Platform-010	x																									
Platform-011	x																									
Platform-012	x																									
Platform-013	x																									
Platform-014	x																									
Platform-015	x																									
Platform-016	x																									
Platform-017	x																									
Platform-018	x																									
Platform-019	x																									
Platform-020	x																									
Platform-021	x																									
Evacuation-Coord-001												x														
Evacuation-Coord-002												x														

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
Evacuation-Coord-003												x														
Evacuation-Coord-004												x														
Evacuation-Coord-005												x		x												
Evacuation-Coord-006												x		x												
Evacuation-Coord-007												x														
AR-001				x																						
AR-002				x																						
AR-003	x																									
AR-004	x																									
AR-007				x																						
AR-008	x																									
AR-009	x																									
AR-010	x																									
AR-011	x																									
AR-012	x																									
AR-013				x																						
AR-014				x																						
AR-015				x																						
AR-016				x																						
AR-017				x																						
AR-018				x																						
AR-019				x																						
AR-020				x																						
AR-021				x																						
AR-022				x																						

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
AR-023				x																						
AR-024				x																						
AR-025				x																						
AR-027				x																						
AR-028				x																						
AR-029				x																						
LMS/LRS-001				x																						
VR-001											x															
VR-002											x															
VR-003											x															
VR-004											x															
VR-005											x															
VR-006											x															
VR-007											x															
VR-008											x															
VR-009											x															
VR-010											x															
VR-011											x															
VR-012											x															
VR-013											x															
VR-014											x															
VR-015											x															
VR-016											x															
VR-017											x															
VR-018											x															

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
VR-019											x															
WFT-001															x											
WFT-002															x											
WFT-003															x											
WFT-005						x																				
WFT-006														x												
WFT-007															x											
PIMM-001														x												
PIMM-002														x												
PIMM-003														x												
PIMM-004														x												
PIMM-005														x												
PIMM-006														x												
PIMM-007														x												
PIMM-008														x												
PIMM-009														x												
PIMM-010														x												
UAV-1																								x		
UAV-2																								x		
UAV-3																								x		
UAV-4																								x		
UAV-5																								x		
UAV-6																								x		
UAV-7																								x		
UAV-8																								x		

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
UAV-9																								x		
DFB-1							x																			
DFB-2								x																		
DFB-3								x																		
DFB-4								x																		
DFB-5							x	x																		
DFB-6								x																		
DFB-7							x	x																		
DFB-8								x																		
DFB-9							x																			
DFB-10								x																		
DSS-001														x												
DSS-002													x													
DSS-003													x													
DSS-005													x													
DSS-006													x													
Safety-onboard-1																						x				
Safety-onboard-2																						x				
Safety-onboard-3																										
Safety-onboard-4																						x				
Safety-onboard-5																						x				
Safety-onboard-6													x													
Safety-onboard-7													x													
Safety-onboard-8													x													
Safety-onboard-9																						x				

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
Safety-onboard-10													x													
Safety-onboard-11									x																	
Safety-onboard-12									x																	
Safety-onboard-13									x																	
Safety-onboard-14									x																	
Safety-onboard-15										x																
SMART_CAMERAS-001																							x			
SMART_CAMERAS-002																							x			
SMART_CAMERAS-003																							x			
SMART_CAMERAS-004																							x			
SMART_CAMERAS-005																							x			
SMART_CAMERAS-006																							x			
SMART_CAMERAS-007																							x			
SMART_CAMERAS-008																							x			
SMART_CAMERAS-009																							x			
SMART_CAMERAS-010																							x			
SMART_CAMERAS-011																							x			
SMART_CAMERAS-012																							x			
SMART_BRACELET-001																						x				
SMART_BRACELET-002																						x				
SMART_BRACELET-003																						x				
SMART_BRACELET-004																						x				
SMART_BRACELET-005																						x				
SMART_BRACELET-006																						x				
SMART_BRACELET-007																						x				

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
SMART_BRACELET-008																						x				
SMART_BRACELET-009																						x				
SMART_BRACELET-010																						x				
SMART_BRACELET-011																						x				
SMART_BRACELET-012																						x				
SMART_BRACELET-013																						x				
SMART_BRACELET-014																						x				
SMART_BRACELET-015																						x				
SMART_BRACELET-016																						x				
SMART_BRACELET-017																						x				
SMART_BRACELET-018																						x				
SMART_BRACELET-019																						x				
SMART_BRACELET-020																						x				
SRAP-01																				x						
SRAP-02																				x						
SRAP-03																				x						
SRAP-04																				x						
SRAP-05																				x						
SRAP-06																				x						
SRAP-07																				x						
VDES_001																									x	
VDES_002																									x	
VDES_003																									x	
VDES_004																									x	
VDES_005																									x	

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
VDES_006																									x	
VDES_007																									x	
VDES_008																									x	
VDES_009																									x	
VDES_010																									x	
SSS - 001																			x							
SSS - 002																			x							
SSS - 003																			x							
SSS - 004																			x							
SSS - 005																			x							
SMS_01																					x					
SMS_02																					x					
SMS_03																					x					
SMS_04																					x					
SMS_05																					x					
SMS_06																										
PaMEAS_001																x										
PaMEAS_002																x										
PaMEAS_003																x										
PaMEAS_004																x										
PaMEAS_005																x										
PaMEAS_006																x										
PaMEAS_007																x										
PaMEAS_008																x										
PaMEAS_009																x										

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
SHM_001																		x								
SHM_002																		x								
SHM_003																		x								
SHM_004																		x								
SHM_005																		x								
SHM_006																		x								
SHM_007																		x								
SHM_008																		x								
SHM_009																		x								
SHM_010																		x								
SST_001																	x									
SST_002																	x									
SST_003																	x									
SST_004																	x									
VRG-001																										x
VRG-002																										x
VRG-003																										x
VRG-004																										x
VRG-005																										x
VRG-006																										x
VRG-007																										x
VRG-008																										x
Context_Broker_001					x																					
Context_Broker_002					x																					
Context_Broker_003					x																					

	All	Security	IAM	AR	C. Broker	DFB	DFB Access	DFB Core	MEV	A. eLearning	Academy VR	Evac. Coord.	DSS	PIMM	WFT	PaMEAS	SST	SHM	SSS	SRAP	SMS	SB	SC	UAV	VDES TRX	VRG
Context_Broker_004					x																					
IAM-001	x		x																							
IAM-002	x	x																								

Annex II System Requirements (complete)

UNIQUE ID	Type	Description	Category	Rationale	Priority	Stkhs
PALAEMON-Platform-001	Non-functional	The PALAEMON platform must work in a centralized manner (i.e., with all components physically hosted within the ship's premises)	Integration	All the workload must be integrated in ship's premises, since we cannot rely on cloud-based solutions (e.g. latency, network breakdowns, etc.)	MUST	IT team
PALAEMON-Platform-002	Non-functional	The integration and deployment of all components must work in the off-the-shelf hardware provided by the actual scenario(s)	Integration	Legacy systems on a real ship might have limited computational capacity (e.g., storage, connectivity, memory, etc.). Nonetheless, the whole PALAEMON platform must fit and run smoothly regardless these limitations.	MUST	IT team
PALAEMON-Platform-003	Non-functional	Shipboard legacy systems complementarity	Integration	PALAEMON System has not come to replace the legacy deployment and behavior of the ship operation; on the other hand, it has been designed to complement and support during the evacuation process. Besides, it introduces (and combines) new information sources that will enhance the whole process.	MUST	IT team
PALAEMON-Platform-004	Non-functional	Communication infrastructure	Communications	The ship (and intrinsically, the PALAEMON system) will offer all the communication interfaces (e.g., Ethernet, WiFi, LTE/5G, etc.) required by the different components of the platform.	MUST	
PALAEMON-Platform-005	Non-functional	PALAEMON system handling overhead for crew members/management stakeholders	Usability	The controlling and manipulation of the PALAEMON system should not generate a significant overhead on the crew workload	SHOULD NOT	Master; Bridge; Bridge Command team
PALAEMON-Platform-006	Non-functional	Dedicated displays/monitors to show Graphical User Interfaces (GUIs) in the bridge	Deployment	Apart from the legacy displays/monitors that can be seen in a real scenario (e.g. AIS, etc.), some of the PALAEMON components do require to (graphically) present their outputs in the bridge in order to support the master's decision, centralize crew's activities, etc.	MUST	Master; Bridge Command Team
PALAEMON-Platform-007	Functional	The system must work even under extreme/adverse conditions	Operation	Even though regular ICT infrastructures are not conceived to work under extreme conditions, the particularities of the scenario (i.e., ship) makes of utmost relevance to guarantee the correct operation of the system at any circumstance	MUST	IT team
PALAEMON-Platform-008	Functional	System redundancy	Deployment	To prevent potential system outages, PALAEMON system should be replicated / have a redundant deployment that comes to the foreground in case of sudden system halt.	MUST	IT team
PALAEMON-Platform-009	Functional	Subscription to PALAEMON Evacuation Coordinator Notifications	Integration	All components (i.e., with behavioural dependency on the ship evacuation status) must be aware of the current ship state machine, managed by the PALAEMON Evacuation Coordinator	MUST	System developers; technology providers

UNIQUE ID	Type	Description	Category	Rationale	Priority	Stkhs
PALAEMON-Platform-010	Functional	Component logging	Deployment	All components should record all their underlying logging, for the sake of, on the one hand, help spot potential misbehaviours; on the other hand, keep track of user(s) actions and shape a historical recording of their commands	SHOULD	IT team; system developers; technology providers;
PALAEMON-Platform-011	Functional	Log (e.g., file, audio, video) all actions for post-incident analysis	Deployment	Upon the emergency flag is hoisted, all multimedia streams from PALAEMON components (e.g., AR glasses, Smart Cameras, etc.) should record their activities.	SHOULD	IT team; system developers; technology providers;
PALAEMON-Platform-012	Non-functional	GDPR-compliance system	Security and Privacy	All the personal/sensitive information introduced in the PALAEMON platform must respect and be 100% with GDPR regulation	MUST	IT team; system developers
PALAEMON-Platform-013	Non-functional	GDPR disclosure upon emergency status hoist	Security and Privacy	Once the evacuation alarm has been triggered, and according to GDPR's Recital 46, "Some types of processing may serve both important grounds of public interest and the vital interests of the data subject as for instance when processing is necessary for humanitarian purposes". In other words, as of this moment, GDPR restrictions are disclosed and the use of sensitive data is permitted	MUST	Authorities; system developers; technology providers
PALAEMON-platform-014	Non-functional	Single access to database (e.g., DFB service)	Interfaces	All the information generated in the scope of PALAEMON must be persisted into the same persistence system or component (i.e., Data Fusion Bus)	MUST	System developers; technology providers
PALAEMON-platform-015	Non-functional	Single access point for field devices (e.g., Apache Kafka)	Interfaces	All data sources will go across the same data streaming aggregator (i.e., Apache Kafka) in order to persist their respective information	MUST	System developers; technology providers
PALAEMON-platform-016	Non-functional	Homogeneous data model (e.g., NGSI-LD)	Interoperability	For the sake of interoperability, a common and unique interface and data models will be defined.	MUST	System developers
PALAEMON-platform-017	Non-functional	Access to shipboard legacy systems	Integration	Modern Ro-Ro and Ro-PAX vessels bring timely ICT-infrastructures, with sensors and actuators deployed throughout its decks. Besides, they manage additional static information (e.g., ship particulars, passengers and crew lists, ship blueprints, etc.) that might be used by PALAEMON-specific services	SHOULD	Ship owners; IT team; System developers
PALAEMON-platform-018	Functional	User-based role access	Security and Authentication	Different stakeholders (e.g., system administrator, master, bridge crew members, passengers, etc.) must have different rights in the eyes of the PALAEMON system	MUST	IT team
PALAEMON-platform-019	Non-functional	Data latency (Near-real time data availability)	Performance	The interval between a message is generated at its source and is made available to other components must not exceed 5 seconds	MUST NOT	IT team

UNIQUE ID	Type	Description	Category	Rationale	Priority	Stkhs
PALAEMON-platform-020	Non-functional	Micro-service oriented architecture	Deployment	Follow a micro-service architecture (e.g., Docker-like images), together with a Platform Orchestrator (e.g., Kubernetes or similar) will lead to a common and widespread software development methodology	MUST	IT team; system developers
PALAEMON-platform-021	Non-functional	Easy-to-deploy and scale the whole PALAEMON platform	Deployment	Thanks to the way the architecture has been designed, the whole PALAEMON platform must be straightforwardly replicated and managed	MUST NOT	IT team
PALAEMON-Evacuation-Coord-001	Functional	Digitalization of the ship evacuation status (i.e., normal operation, situation awareness, alarm, mustering, embarking, evacuation)	Deployment	The PALAEMON Evacuation Coordination has, as primary task, to map in real-time, the current evacuation status of the ship. Namely, this means that all master's commands generated at the bridge have to be translated and updated accordingly	MUST	System developers
PALAEMON-Evacuation-Coord-002	Functional	Evacuation status switch notification	Interfaces	Every transition between states will be notified (via Kafka streaming) to all subscribed components	MUST	System developers; technology providers
PALAEMON-Evacuation-Coord-003	Functional	Periodic broadcast messages	Interfaces	In case a component does not properly receive a notification, the Evacuation Coordinator will periodically re-send the message status (e.g., increasing the rate as long as the evacuation level gets higher)	MUST	System developers
PALAEMON-Evacuation-Coord-004	Functional	Component situation awareness	Integration	Communication between components should be carried out via Kafka topics. The PALAEMON Evacuation Coordinator will keep track of the main updates generated by the underlying components. Update: Upon the reception of these notifications, subscribed components must send and acknowledgement message to the PEC	MUST	System developers; technology providers
PALAEMON-Evacuation-Coord-005	Non-functional	PEC Visualization	Visualization	For the sake of usability, the PEC will be part of the PIMM, which will be displayed in the bridge; this way, master and crew members will be able to directly map status transitions	MUST	Master; Bridge Command Team; Technology providers; system developers
PALAEMON-Evacuation-Coord-006	Non-functional	PEC graphical management via PIMM	Interfaces	The main operation of the PEC must be accessible via PIMM	MUST	Master; Bridge Command Team; Technology providers
PALAEMON-Evacuation-Coord-007	Functional	Component logging	Logging	All events handled by the PEC will be persisted in the Data Fusion Bus	MUST	System developers

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PALAEMON-AR-001	Functional	The AR application will have an intuitive user interface that can be easily learned.	Integration	The rationale for this requirement is that the application will be used by any crew member with varying capabilities	SHOULD	Crew
PALAEMON-AR-002	Functional	The AR application will have a training tutorial embedded that will clearly explain each section of the interface and its functions.	Integration	The rationale for this requirement is that the application will be used by any crew member	SHOULD	Crew
PALAEMON-AR-003	Functional	New members can create their own accounts and the user data will be validated to make sure there are no other users with the same credentials. Therefore, each user will be associated with a unique ID and user role	Security and Authentication	The application can only be used by registered users	MUST	Crew
PALAEMON-AR-004	Functional	Crewmembers will be logged into the AR application by using authentication interface, only authorized users will be allowed to use the application	Security and Authentication	For safety and security purposes, the application can only be used by registered users	MUST	Crew
PALAEMON-AR-005	Functional	Authoring tool will be used to add AR descriptions or instructions to existing areas, objects, panels, switches.	AR Application	Authoring tool for configuring the AR dashboard and AR training application	MUST	Crew / Trainees
PALAEMON-AR-006	Functional	The tool will also allow the users to add AR 3D objects and instruments. The added resources will be used to create AR scenarios for training purposes.	AR Application	Authoring tool for configuring the AR dashboard and AR training application	MUST	Crew / Trainees
PALAEMON-AR-007	Functional	The app will allow the customisation of the user interfaces for the evacuation plan and team coordination	AR Application	Authoring tool for configuring the AR dashboard and AR training application	MUST	Crew / Trainees
PALAEMON-AR-008	Non-functional	The application must be able to flawlessly get data from the Ship Stability Toolkit (get data from Data Service bus), in order to assist and convey crewmembers the relevant information	Integration	The other system components provide teams, information regarding on-going mustering; ship stability but also structural issues, thus, aiding them to safely guide all the passengers to the designated evacuation areas and MEVs;	MUST	Crew
PALAEMON-AR-009	Non-functional	The application must be able to flawlessly get information from the Weather/forecast system (via Data Service bus), in order to assist and convey crewmembers the relevant information	Integration	The other system components provide teams, information regarding on-going mustering; ship stability but also structural issues, thus, aiding them to safely guide all the passengers to the designated evacuation areas and MEVs;	MUST	Crew
PALAEMON-AR-010	Non-functional	The application must be able to flawlessly get data from the Smart Bracelets (via Data Service bus), in order to assist and convey crewmembers the relevant information	Integration	The other system components provide teams, information regarding on-going mustering; ship stability but also structural issues, thus, aiding them to safely guide all the passengers to the designated evacuation areas and MEVs;	MUST	Crew
PALAEMON-AR-011	Non-functional	The application must be able to flawlessly communicate with Incident Management Module (get data from Data Service bus), in order to assist and convey crewmembers the relevant information	Integration	The other system components provide teams, information regarding on-going mustering; ship stability but also structural issues, thus, aiding them to safely guide all the passengers to the designated evacuation areas and MEVs;	MUST	Crew
PALAEMON-AR-012	Non-functional	The application must be able to flawlessly communicate with Decision Support System (get	Integration	The other system components provide teams, information regarding on-going mustering; ship	MUST	Crew

UNIQUE ID	Type	Description	Category	Rationale	Priority	Stkhs
		data from Data Service bus), in order to assist and convey crewmembers the relevant information		stability but also structural issues, thus, aiding them to safely guide all the passengers to the designated evacuation areas and MEVs;		
PALAEMON-AR-013	Functional	Loading the 3D map of the vessel	AR Glasses	The AR application needs to emulate and render, the close to physical environment of the ship. This includes obstacles and walls coordinates, rooms and hallways dimensions but also doors and windows positions	MUST	Crew
PALAEMON-AR-014	Functional	Loading the procedure maps (if available)	AR Glasses	The AR application needs to emulate and render, the physical environment of the ship. This includes obstacles and walls coordinates, rooms and hallways dimensions but also doors and windows positions	MUST	Crew
PALAEMON-AR-015	Functional	Loading the contextual help (if available)	AR Glasses	The AR application needs to emulate and render, the physical environment of the ship. This includes obstacles and walls coordinates, rooms and hallways dimensions but also doors and windows positions	MUST	Crew
PALAEMON-AR-016	Functional	Loading augmented reality temperature widget (that will appear on the user interface)	AR Glasses	Building a rich user interface that will provide all the information needed for the user, at any given time	MUST	Crew
PALAEMON-AR-017	Functional	Loading augmented reality alert messages widget (that will appear on the user interface)	AR Glasses	Building a rich user interface that will provide all the information needed for the user, at any given time	MUST	Crew
PALAEMON-AR-018	Functional	Loading augmented reality AudioCall widget (that will appear on the user interface)	AR Glasses	Building a rich user interface that will provide all the information needed for the user, at any given time	MUST	Crew
PALAEMON-AR-019	Functional	Loading augmented reality Ship parameters widget (that will appear on the user interface)	AR Glasses	Building a rich user interface that will provide all the information needed for the user, at any given time	MUST	Crew
PALAEMON-AR-020	Functional	Loading augmented reality Weather widget (that will appear on the user interface)	AR Glasses	Building a rich user interface that will provide all the information needed for the user, at any given time	MUST	Crew
PALAEMON-AR-021	Functional	AR Technology provides a “first-person” perspective and enables users to explore the physical environment with simultaneously over imposed digital content;	AR Glasses	AR Glasses application assists and provide crewmembers with essential digital information regarding evacuation procedures throughout a realistic environment;	MUST	Crew
PALAEMON-AR-022	Functional	Each participant will be able to see on its user interface all the messages received from the connected system components;	Visualization	This functionality will be used for ensuring good tasks execution within the evacuation plan;	MUST	Crew
PALAEMON-AR-023	Functional	The main goal of the AR application is to provide a visual guidance and instructions to the crewmembers to follow the evacuation plan	AR Glasses	The vital information that will help the intervention team will include evacuation tactics guidelines, environment details but also passenger’s condition	MUST	Crew
PALAEMON-AR-024	Functional	The application will be able to provide real-time text communication between the crewmembers	AR Glasses/Communication	In order to better support and organise the evacuation procedures the crewmembers will be able to communicate with each other in real-time, therefore enhancing the coordination factor.	MUST	Crew

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PALAEMON-AR-025	Functional	The application will be able to provide real-time audio communication between the crewmembers	AR Glasses/Communication	In order to better support and organise the evacuation procedures the crewmembers will be able to communicate with each other in real-time, therefore enhancing the coordination factor.	MUST	Crew
PALAEMON-AR-026	Functional	The application will be able to provide real-time video communication between the crewmembers	AR Glasses/Communication	In order to better support and organise the evacuation procedures the crewmembers will be able to communicate with each other in real-time, therefore enhancing the coordination factor.	MUST	Crew
PALAEMON-AR-027	Functional	Each crew member will be able to visualise system information of the current evacuation plan, crewmembers or passenger's condition but also guidance messages from Decision Support System.	AR Glasses/Communication	This feature will enable crewmembers to better coordinate and synchronize actions and decisions.	MUST	Crew
PALAEMON-AR-028	Functional	The application will provide real-time information about the position of each crew member on the vessel's map;	AR Glasses/Communication/Localization	This functionality can be used for a better team management and staff deployment to certain areas on the vessel. For example, the Captain can choose to send, recall or relocate staff based on their real-time location.	MUST	Crew; Master; Bridge Command Team
PALAEMON-AR-029	Functional	The application will be able to provide real-time information regarding passenger's concentration on the vessel's map;	AR Glasses/Communication/Localization	This functionality will help to successfully assess location, volume and direction of groups or individuals, enabling for agile evacuation procedures.	MUST	Crew; Master; Bridge Command Team
PALAEMON-LMS/LRS-001	Non-functional	The application will be able to send to a designated LMS/LRS server, all the relevant information during the evacuation mission on the vessel;	AR Glasses/Communication	Based on the findings of the first missions, future initiatives could be continuously improved in terms of project size, scenarios, applications, etc.	MUST	Crew; Master; Bridge Command Team
PALAEMON-VR-001	Functional	crew members will be able to create user accounts	Palaemon Academy	This is designed to ensure safety of: login; user information and data.	MUST	Crew / Trainees
PALAEMON-VR-002	Functional	crew members will need to login by using authentication interface	Palaemon Academy	This functionality will allow for safe and secure access into the application.	MUST	Crew / Trainees
PALAEMON-VR-003	Functional	crew members will be able to customize their user profile	Palaemon Academy	Each learner profile is unique therefore users have the ability to customise them based on their specific characteristics: rank, role, responsibilities, tasks, etc.	MUST	Crew / Trainees
PALAEMON-VR-004	Functional	The application will include an authoring tool to create simple scenarios	Palaemon Academy	This feature will enable development of various scenarios that can cover a multitude of situations and risks.	MUST	Crew / Trainees
PALAEMON-VR-005	Non-functional	The application will communicate with a web server to upload or download scenarios	Palaemon Academy/Communication	This functionality will allow import or export of different scenarios frameworks that can be either used as such or edited for more accurate exercises.	MUST	Crew / Trainees
PALAEMON-VR-006	Functional	The application will allow download of virtual 3D environments depending on the scenario type	Palaemon Academy/Communication	3D environments will be vital as they have the ability to replicate as much as possible complex ship environments.	MUST	Crew / Trainees

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PALAEMON-VR-007	Functional	The application will allow the users to free roam within each part of the VR world	Palaemon Academy	This option will enhance the simulation factor but will also push the scenarios as close as possible to reality.	MUST	Crew / Trainees
PALAEMON-VR-008	Functional	User interface will display information similar to the one received by actual sensors or systems (information may change from one scenario to another)	Palaemon Academy	This functionality will be vital in launching the exercises as various scenarios will have different characteristics; conditions and data	MUST	Crew / Trainees
PALAEMON-VR-009	Functional	The users will be able to receive all the information about the summary for a scenario before starting the simulation	Palaemon Academy	This requirement will provide the much needed briefing before the exercises. Much of the simulation success will be linked to this phase.	SHOULD	Crew / Trainees
PALAEMON-VR-010	Functional	The application will send all relevant data (progress reports) to LMS/LRS server	Palaemon Academy/Communication	This feature will enable collection of relevant data for the analysis; maintenance and improvement of the scenarios and exercises.	MUST	Crew / Trainees
PALAEMON-VR-011	Functional	The metrics will have a special section within the application to display all data collected through graphical reports	Palaemon Academy	Data projection and dashboards would help asses the impact of various metrics and therefore will support potential adjustments.	COULD	Crew / Trainees
PALAEMON-VR-012	Non-functional	The application will run on VR glasses	VR Glasses	VR glasses have the ability to run and display the scenario and the complexity of its 3D graphical environments.	MUST	Crew / Trainees
PALAEMON-VR-013	Non-functional	User interface should be clean and compatible with VR glasses;	Palaemon Academy	Incompatibility between VR glasses and user interface would seriously impede the scenario flow.	MUST	Crew / Trainees
PALAEMON-VR-014	Non-functional	Users can access the tutorial at any moment;	Palaemon Academy	This functionality will enhance the flexibility of learning.	MUST	Crew / Trainees
PALAEMON-VR-015	Non-functional	The application should be able to connect to internet for uploading/downloading scenarios;	Palaemon Academy/Communication	Data transfer between application and web is vital for expanding the scenarios portfolio but also updating and maintaining the existing scenarios.	MUST	Crew / Trainees
PALAEMON-VR-016	Non-functional	The application should be capable to load 3D environments	Palaemon Academy/Communication	3D environments have the ability to enhance the simulation through accurate replication of ship's environment.	SHOULD	Crew / Trainees
PALAEMON-VR-017	Non-functional	The application should be capable to load the 3D objects defined in the scenarios;	Palaemon Academy	3D objects of the ones commonly found on the ship will increase the "close to reality" factor, therefore enhancing simulation overall effect.	SHOULD	Crew / Trainees
PALAEMON-VR-018	Non-functional	The application should to able to allow the users to personalize their interface with elements like (fonts, widgets, colours and language..	Palaemon Academy	This functionality will enhance the user friendly and customisation factor.	COULD	Crew / Trainees
PALAEMON-VR-019	Non-functional	The LMS/LRS server should capable to store all the relevant data from all participants.	Palaemon Academy/Communication	This function will allow to keep data and records for analytics and improvement options.	MUST	Crew / Trainees
PALAEMON-WFT-001	Functional	The WFT (WEATHER FORECAST TOOLKIT) application will have an intuitive user interface that can be easily learned. Moreover, the application comes with a tutorial that will clearly explain each section of the interface and its functions.	Usability	The rationale for this requirement is that the application will be used by any crew member with varying capabilities.	SHOULD	Crew / Captain
PALAEMON-WFT-002	Functional	The WFT application will have a user interface that allows the users to identify the correlation between	WFT Usability	The rationale for this requirement is that the application will be used by any crew member with varying capabilities.	MUST	Crew / Captain

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		the weather conditions at the time of the incident and the evacuation plan/actions.				
PALAEMON-WFT-003	Functional	The user will be able to sign in using the integrated PALAEMON SSO (Single Sign On) System. Therefore, each user will be associated with a unique ID and user role.	Security and Authentication	The application can only be used by registered users.	MUST	Crew / Captain
PALAEMON-WFT-004	Functional	Crewmembers will be logged into the WFT application by using authentication interface, only authorized users will be allowed to use the application.	Security and Authentication	For safety and security purposes, the application can only be used by registered users.	MUST	Crew / Captain
PALAEMON-WFT-005	Functional	The WFT application will send to the DSS a correlation index during an incident among the weather conditions and the evacuation plan.	WFT Usability	This usability will help the DSS to suggest actions. The correlation index takes values from 0-1, if this value is close to 1 this indicates very strong correlation among the weather conditions and the evacuation plan.	MUST	Crew / Captain
PALAEMON-WFT-006	Functional	The WFT application will send the output to the PIMM dashboard	WFT Usability	This usability will provide the appropriate actions and possible risks for the post-incident management based on the accident conditions (e.g., weather).	MUST	Crew / Captain
PALAEMON-WFT-007	Functional	The WFT will get the weather data from the PIMM.	WFT Usability	This will function as a single point of truth for weather data.	MUST	Crew / Captain
PALAEMON-PIMM - 001	Functional	The Palaemon Incident Management Module (PIMM) will have an intuitive user interface that can be easily learned. Moreover, the application comes with a tutorial that will clearly explain each section of the interface and its functions.	Usability	The rationale for this requirement is that the application will be used by the bridge crew members with varying capabilities.	SHOULD	Captain / Bridge
PALAEMON-PIMM - 002	Functional	The PIMM will have an interface for managing some of the modules of the Palaemon ecosystem, and will be the first component issuing an evacuation order. Subsequent components will feature their own management interfaces.	PIMM Main Function	As it's an incident management module, this will be one of the main features.	MUST	Captain / Bridge
PALAEMON-PIMM - 003	Functional	The PIMM will integrate and provide a user interface for managing and monitoring the On-Board Decision Support System.	PIMM Main Function	As it's an incident management module, this will be one of the main features.	MUST	Captain / Bridge
PALAEMON-PIMM - 004	Functional	The PIMM will integrate and provide a user interface for managing and monitoring the WFT (Weather Forecast Toolkit)	PIMM Main Function	As it's an incident management module, this will be one of the main features.	MUST	Captain / Bridge
PALAEMON-PIMM - 005	Functional	The PIMM will integrate and provide a user interface for monitoring the Smart Cameras System.	PIMM Main Function	As it's an incident management module, this will be one of the main features.	MUST	Captain / Bridge
PALAEMON-PIMM - 006	Functional	The PIMM will integrate and provide a user interface for managing and monitoring the Evacuation Coordinator.	PIMM Main Function	As it's an incident management module, this will be one of the main features.	MUST	Captain / Bridge
PALAEMON-PIMM - 007	Functional	The PIMM will integrate and provide a user interface for managing and monitoring the Smart Safety System (SSS).	PIMM Main Function	As it's an incident management module, this will be one of the main features.	MUST	Captain / Bridge

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PALAEMON-PIMM - 008	Functional	The PIMM will integrate with the main Palaemon Single Sign On (SSO) Service and the user will be authenticated by it.	PIMM Main Function	The PIMM should use the central authentication system and not require a separate user management system in place.	MUST	Captain / Bridge
PALAEMON-PIMM - 009	Functional	The PIMM will integrate notifications from DSS, WFT, SSS, Evacuation Coordinator, SRAP	PIMM Main Function	This feature will notify the captain and the bridge for various sub-incidents relating to the WFT and the DSS.	MUST	Captain / Bridge
PALAEMON-PIMM - 010	Functional	The PIMM will provide a Weather Data endpoint that can be used by other components, as necessary.	PIMM Services	This will function as a single point of truth for weather data.	MUST	Captain / Bridge
PALAEMON-UAV-1	Functional	The UAV will provide automatic flight modes to ease safely navigating around the ship	Navigability	Manually flying a drone around a ship in movement can be complicated for a human operator, especially considering parallax and distance appreciation.	MUST	Crew
PALAEMON-UAV-2	Functional	The UAV will automatically adapt its position/flight in order to obtain required camera angles	Observation	The operator will need to inspect specific areas around the ship, so the system have be able to point a camera on them (e.g. Man Over Board situation, damage inspection)	MUST	Crew
PALAEMON-UAV-3	Functional	The UAV will provide automatic search patterns and inspection	Navigability	In case of MOB (Man Over Board) or rescue situation, the UAV needs to enter search mode and scan the most surface in the search area to provide extensive camera feedback	MUST	Crew
PALAEMON-UAV-4	Functional	The UAV system shall be able to approximately locate a place pointed by an operator from the camera stream	Observation	In case of MOB, the ground station operator might locate the individual to rescue on the camera stream. The system shall then approximate location information necessary to send a MEV to the location.	MUST	Crew
PALAEMON-UAV-5	Functional	The System should provide give the option to the crew to manually pilot the UAV	Visualization	In emergency situation, the operator might need to operate the UAV beyond its flight planning capabilities, to the point where he might endanger the UAV.	MUST	Crew
PALAEMON-UAV-6	Functional	The system will provide a GCS (Ground Control Station) to operate the UAV, make plan flights and monitor the flight	Visualization	The operator needs an interface to set up flight plans for the UAV and monitor the mission.	MUST	Crew
PALAEMON-UAV-7	Non-functional	The GCS shall be simplified to the point it can be easily used in stressed situations	Visualization	In stressed situation the operator could take confused decisions or hardly read. The GCS shall then be as simple graphic as possible without compromising the mission safety	SHOULD	Crew
PALAEMON-UAV-8	Non-functional	The GCS should be portable	Visualization	The operator might need to move to the MEV while continuing to operate the UAV. In this case a portable GCS would be suited.	SHOULD	Crew
PALAEMON-UAV-9	Non-functional	The UAV shall imply high availability rate/low preparation time	Performance	In emergency situation, the UAV should be ready to fly as soon as possible, in most situations.	SHOULD	Crew
PALAEMON-DFB-1	Non-functional	DFB must be able to support all input/output requests from other components	Interfaces	DFB must be robust enough to withstand spikes of data throughput without loss of information	MUST	
PALAEMON-DFB-2	Non-functional	DFB must provide redundancy mechanisms for stored data	Deployment	DFB should have redundancy mechanisms for avoiding data loss in case of hardware failure	SHOULD	

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PALAEMON-DFB-3	Functional	Health Monitoring of Palaemon Core infrustructure (Kafka, Elasticsearch, MinIO, Shared FS)	Performance	DFB must provide monitoring of its core infrastructure because of its criticality	MUST	
PALAEMON-DFB-4	Functional	Monitoring of Palaemon Core usage (load metrics, throughput per Kafka topic/consumer/producer, disk usage)	Performance	DFB must provide monitoring of its core infrastructure because of its criticality	MUST	
PALAEMON-DFB-5	Functional	Provision of common interface for data input in Palaemon Core (Kafka subscribe/consumer, MQTT)	Interfaces	Providing common interfaces for data input in the platform	MUST	
PALAEMON-DFB-6	Functional	REST api: Provision of interface for retrieving historical data from Palaemon Core and performing queries	Interfaces	Providing common interface for data querying in the platform	MUST	
PALAEMON-DFB-7	Functional	Authentication/authorisation for data input/output: Kafka ACLs per topic, client credentials management for REST service	Security and Authentication	Providing Palaemon Core security mechanisms	MUST	
PALAEMON-DFB-8	Functional	Binary files (i.e., objects) persistence	Deployment	The second version of the PALAEMON communications platform includes some binary files (e.g., audio/video clips, machine learning models and scalers, etc.), which are not suitable for traditional databases (like Elasticsearch). Hence, we need an object storage to save this information and link to forthcoming Voyage Reports (new feature)	MUST	
PALAEMON-DFB-9	Functional	Platform entry point (Data Access)	Deployment	A dedicated ETL (Extract, Transform, Load) module will be deployed to receive all the (real-time) raw data from sources. Technically speaking, this component, called "Data Processor" in the PALAEMON Reference Architecture, will be based on Apache NiFi (open source platform)	MUST	
PALAEMON-DFB-10	Functional	On-the-fly data aggregation and transformation	Deployment	Data Processor will process the raw information and perform a number of operations, e.g., filter, aggregate, transform, etc. before forwarding the flow of data to the next level, i.e., Data Streaming Aggregator	MUST	
PALAEMON-DSS - 001	Functional	The DSS module will be integrated to the PIMM's software stack in order to provide the captain with useful suggestions.	Visualization		MUST	Bridge, Master, Crew
PALAEMON-DSS - 002	Functional	The DSS will generate alerts and suggestions on action to be taken during an incident on its dedicated dashboard.	Integration		MUST	Bridge, Master, Crew
PALAEMON-DSS - 003	Functional	The DSS will receive information from the SRAP, Shipboard Legacy Systems, PIMM, SSS and the Ship Stability Toolkit and use that to produce a helpful output for decisions to be taken.	Integration		MUST	Bridge, Master, Crew
PALAEMON-DSS - 004	Functional	Each member will have it's own user account according to the role they hold.	Security and Authentication		SHOULD	Bridge, Master, Crew

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PALAEMON-DSS - 005	Functional	The DSS will receive weather information from the PIMM.	Services		SHOULD	Bridge, Master, Crew
PALAEMON-DSS - 006	Functional	The DSS shall broadcast suggestions to be used by other components, as needed.	Services		COULD	Bridge, Master, Crew
SAFETY-ONBOARD-1	Non-functional	Skin friendly material of wristband	Individual component	user experience	MUST	Crew; Passengers
SAFETY-ONBOARD-2	Non-functional	Multiple usage needed to guarantee wearing	Individual component	User experience	SHOULD	Passengers
SAFETY-ONBOARD-3	Non-functional	Information about usage of drones needs to be provided to passengers	Individual component		MUST	Passengers
SAFETY-ONBOARD-4	Non-functional	GDPR conform data storage of movement patterns	Individual component	Mandatory by law	MUST	Passengers
SAFETY-ONBOARD-5	Non-functional	Clear and easy usage, no battery no maintenance	Individual component	Usability	SHOULD	Passengers
SAFETY-ONBOARD-6	Non-functional	Database on handicaps of passengers ready to allow better support during evacuation (mobility constraints)	Individual component	Better estimation of evacuation time	SHOULD	Bridge, Master, Crew
SAFETY-ONBOARD-7	Non-functional	Adjust availability of evacuation support staff on deck according to mobility needs of passengers	Individual component	Reduces the general time of evacuation when people with disabilities are on board	SHOULD	Bridge, Master, Crew
SAFETY-ONBOARD-8	Non-functional	Early warning for passengers to go to cabin and take necessities and utter most important belongings like medication as precaution.		Supports that people get ready and are prepared for a potential evacuation	SHOULD	
SAFETY-ONBOARD-9	Non-functional	Emergency alarm for people that fell during the evacuation and need help. this feature should be available during the full cruise.	Wristband	Establish inner ship communication for sending a call for help to the crew.	SHOULD	
SAFETY-ONBOARD-10	Functional	Gait speed needs to be fed into the DSS algorithms. Variable is the physical status of passengers.	Performance	This has a strong impact on the time for evacuation. one or more handicaped people slow down the time for evacuation dramatically.	SHOULD	Bridge, Master
SAFETY-ONBOARD-11	Functional	MEV needs mounting holes for wheelchairs, durability for up to 10G	Individual Component	This a for safety reasons on the MEV. OR decision is taken that no wheelchairs will be taken onto the MEV, which has further implications for practicability	MUST	
SAFETY-ONBOARD-12	Functional	Entrance to MEV needs a low or no stair.	Individual Component	This will reduce the time for evacuation	SHOULD	
SAFETY-ONBOARD-13	Functional	Seats in MEV need a belt to secure the passengers	Individual Component	Safety reasons	MUST	
SAFETY-ONBOARD-14	Functional	MEV needs to be exerciseable in a regular pace. (e.g. each month)	Safety	Mandatory by law	MUST	
SAFETY-ONBOARD-15	Functional	PALAEMON Academy eLearning should be partly available for passengers to support the Muster drill	Individual component	Muster Drill is a short exercise. If people have potentially more information, they normally use it. This supports in the situation the evacuation.	COULD	
SMART-CAMERAS-001	Functional	Communication system with enough bandwidth to transmit the information at the intended data rate	Integration	Establish the type of communication	MUST	

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SMART-CAMERAS-002	Non-functional	Installation as a ship infrastructure is required for the camera to maintain the orientation	Integration	The field of view of the camera must be maintained and fixed correctly to the ship structure	MUST	
SMART-CAMERAS-003	Functional	There will be only one service entry point (i.e. Kafka) to communicate results, information, images and videos	Integration	Establish the type of communication	MUST	
SMART-CAMERAS-004	Functional	The format, coding, size, and other configurable parameters of the data communication must be done prior to operation in a previous configuration stage.	Integration	Establish the type of communication	MUST	
SMART-CAMERAS-005	Functional	Each camera must have defined the surveillance area where people is counted (installation step).	Installation	Installation requirement	MUST	
SMART-CAMERAS-006	Functional	To install the smart camera a developed GUI must be used to configure the video processing and control all the features	Installation	Installation requirement	MUST	
SMART-CAMERAS-007	Functional	The server will have enough data capabilities to store the information sent without asking for retransmission.	Integration	HW requirements of other components	MUST	
SMART-CAMERAS-008	Functional	The processing platform will provide information periodically according to a given format and communication protocol	Integration	Define the format of information to be send, where and when.	MUST	
SMART-CAMERAS-009	Functional	The processing platform will provide information by demand according to a given format and communication protocol	Integration	Define the format of information to be send, where and when.	COULD	
SMART-CAMERAS-010	Functional	The processing platform will send an alert when detecting anomalies in the people flow or coverage area of people in the surveillance area.	Integration	Define the format of information to be send, where and when.	COULD	
SMART-CAMERAS-011	Non-functional	Use of CCTV legacy systems if there is available a commercial gateway to feed-in the video streaming	Integration	The developed SW can process the images from CCTV legacy systems already installed in the ship	MUST	
SMART-CAMERAS-012	Functional	Automatic flow speed of people on the floor to estimate evacuation time	operation		SHOULD	
SMART-BRACELET-001	Functional	SB connectivity to PALAEMON system is supported by 4G LTE / BT/ WiFi	Communications	ship networking connection	MUST	
SMART-BRACELET-002	Functional	SB positioning info/data will be extracted from 4G LTE / BT/ WiFi connectivity and routing parameters	Integration	PaMEAS input parameters (SB connection/routing/tracking info) are generated by 4G LTE /BT/WiFi	MUST	
SMART-BRACELET-003	Functional	SB positioning info/data will be extracted from 4G LTE / BT/ WiFi networking server	Integration	PaMEAS input parameters (SB connection/routing/tracking info) are generated by 4G LTE / BT/ WiFi	MUST	
SMART-BRACELET-004	Functional	SB positioning info/data (4G LTE / BT/ WiFi connectivity and routing parameters) will be processed by PaMEAS	Integration	PaMEAS input parameters (SB connection/routing/tracking info) are generated by 4G LTE / BT/ WiFi	MUST	
SMART-BRACELET-005	Functional	SB localization/tracking info will be generated by PaMEAS	Integration	PaMEAS localization and evacuation services	MUST	
SMART-BRACELET-006	Functional	data model/format must be defined to encapsule SB sensor readings	Integration	TBD	MUST	

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SMART-BRACELET-007	Functional	SB will provide periodically readings from the body sensors attached (i.e., HR. BP, Temp)	operation	health/bio-sensors	MUST	passenger / crew
SMART-BRACELET-008	Functional	SB will receive evacuation instructions/ escape route information from PaMEAS in case of emergency (sequence of msg)	operation	PaMEAS localization and evacuation services	MUST	passenger / crew
SMART-BRACELET-009	Functional	SB will provide periodically readings from the GPS module attached	operation	only outdoor (deck/MOB)	MUST	passenger / crew
SMART-BRACELET-010	Functional	SB will detect falls based on accelerometer & gyroscope readings	operation	fall detection	MUST	passenger / crew
SMART-BRACELET-011	Functional	SB will notify events (automated fall-detection)	operation	alarm	MUST	passenger / crew
SMART-BRACELET-012	Functional	SB will notify events (user triggered alarm - emergency button-)	operation	alarm	MUST	passenger / crew
SMART-BRACELET-013	Functional	evacuation route msg will be displayed by the SB (test/signs)	operation	PaMEAS localization and evacuation services	SHOULD	passenger / crew
SMART-BRACELET-014	Functional	DISCARDED / evacuation route msg will be played by the SB (audio)	operation	PaMEAS localization and evacuation services	COULD	passenger / crew
SMART-BRACELET-015	Non-functional	IP67 waterproof housing	physical characteristics	ship/pool/water	SHOULD	passenger / crew
SMART-BRACELET-016	Non-functional	rechargeable battery	physical characteristics		SHOULD	passenger / crew
SMART-BRACELET-017	Non-functional	BLE	physical characteristics	TBD	SHOULD	passenger / crew
SMART-BRACELET-018	Non-functional	alarm button	physical characteristics	user enabled alarm	SHOULD	passenger / crew
SMART-BRACELET-019	Non-functional	**TBC / dimension 43(L)*23(W)*13(H) mm**	physical characteristics	wristband/bracelet	SHOULD	passenger / crew
SMART-BRACELET-020	Non-functional	**TBC / weight <100g**	physical characteristics	estimated	SHOULD	passenger / crew
PALAEMON-SRAP-01	Functional	Provide risk level indication regarding the condition of the ship after an incident occurrence	Operation	To assist the Master to decide whether to start the mustering process during the initial assessment after an incident has occurred	MUST	Crew (Master)
PALAEMON-SRAP-02	Functional	Provide risk level indication regarding the progress of the mustering process per deck and per main verical zone	Operation	To support the Master (and Bridge/Command Team) in monitoring the mustering process to take any additional actions (if necessary)	MUST	Crew (Master/Bridge Command Team)
PALAEMON-SRAP-03	Functional	Provide risk level indication regarding the condition of the ship following the commence of the mustering process	Operation	To assist the Master to decide whether to order the abandonment of the ship	MUST	Crew (Master)
PALAEMON-SRAP-04	Functional	Risk level indication regarding the condition of the ship, the progress of the mustering process that will trigger (provide input to) the DSS	Integration/Operation	SRAP will provide a risk-based criterion that will signal the DSS to provide specific recommendations to the Master	MUST	Crew (Master)
PALAEMON-SRAP-05	Non-functional	Risk level indication shall be colour coded and shown on the PALAEMON dashboard	Usability	The information provided by SRAP should be easily understandable and clear	MUST	Crew (Master)

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PALAEMON-SRAP-06	Non-functional	Should operate continuously after an incident has occurred with a specific sampling and output rate	Operation	This requirement will enable real-time, risk-based monitoring of the evacuation	MUST	Crew (Master)
PALAEMON-SRAP-07	Non-functional	Shall exploit the data generated by other PALAEMON components and ship legacy systems to calculate the risk level	Integration	This requirement will enable a fast evaluation of risk based on readily available (real-time) data	MUST	Crew (Master)
PALAEMON-VDES_001	Functional	VDES transceiver shall not support the satellite link	Communications	Satellite link is out of the scope of PALAEMON project.	SHOULD NOT	**Technology providers**
PALAEMON-VDES_002	Functional	VDES transceiver shall support VHF terrestrial communications	Communications	Terrestrial link is the core of VDES activities within PALAEMON project.	SHALL	**Technology providers**
PALAEMON-VDES_003	Functional	VDES shall operate in VHF band, following frequency plan specified in IALA G1139 document	Individual component (VDES)	In order to guarantee compliance to VDES standard frequency plan.	SHALL	**Technology providers**
PALAEMON-VDES_004	Functional	VDES transceiver shall transmit with a power within the range 1÷12.5 W, as specified in IALA G1139 document	Individual component (VDES)	In order to guarantee compliance to VDES standard transmit power.	SHALL	**Technology providers**
PALAEMON-VDES_005	Functional	VDES transceiver shall be able to receive an analogue signal at VHF frequencies, extract digital information and deliver digital data (bits) to PALAEMON platform	Individual component (VDES)	VDES transceiver output to PALAEMON platform	SHALL	**Technology providers**
PALAEMON-VDES_006	Functional	VDES transceiver shall be able to receive digital inputs (bits) from PALAEMON platform, encapsulate them in the VDES packet and transmit them at VHF frequencies.	Individual component (VDES)	VDES transceiver input from PALAEMON platform	SHALL	**Technology providers**
PALAEMON-VDES_007	Functional	VDES transceiver should be synchronized with UTC time.	Individual component (VDES)	UTC minute coincides with a VDES frame. The availability of UTC time in the VDES transceiver simplifies the SW waveform.	SHOULD	**Technology providers**
PALAEMON-VDES_008	Functional	VDES transceiver shall support AIS, ~~ASM~~ and VDE data channels.	Individual component (VDES)	In order to guarantee compliance to VDES standard data channels/services	SHALL	**Technology providers**
PALAEMON-VDES_009	Non-functional	VDES transceiver should operate in accordance with the following priorities: Priority 1: (highest) AIS; ~~Priority 2: ASM;~~ Priority 2: VDE.	Individual component (VDES)	In order to guarantee compliance to VDES standard data services and their priorities.	SHOULD	**Technology providers**
PALAEMON-VDES_010	Non-functional	VDES transceiver shall transmit a maximum amount of data of 65 KB over VDE channels for single VDE session.	Individual component (VDES)	In order to select the most suitable applications within PALAEMON project to be transmitted over VDE channels.	SHALL	**Technology providers**
PALAEMON-VDES_011	Non-functional	VDES transceiver shall transmit a maximum amount of data of 1056 bits over ASM channels for single ASM session.	Individual component (VDES)	In order to select the most suitable applications within PALAEMON project to be transmitted over ASM channels.	SHALL	**Technology providers**
PALAEMON-SSS - 001	Functional	SSS will include a graphic user interface, which will display information for evacuation	Visualization	Reduce VHF communication by graphic presentation during evacuation	MUST	Bridge, Master, Crew
PALAEMON-SSS - 002	Functional	Evacuation information are shared between SSS units	Individual component (SSS)	Gives an overview over the actual process and situation of the evacuation	MUST	Bridge, Master, Crew

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PALAEMON-SSS - 003	Functional	SSS should share information with other Palaemon systems	Integration		COULD	Bridge, Master, Crew
PALAEMON-SSS - 004	Functional	Display the position of crew members	Integration	In order to assign to most suitable/nearest crew member to a task	SHOULD	Bridge, Master, Crew
PALAEMON-SSS - 005	Functional	Connection to Ships alarm system	Integration	In order the get and overview of dangerous areas du to fire, flooding etc. and avoid them during evacuation	SHOULD	Bridge, Master, Crew
PALAEMON-SMS_01	Functional	SMS will populate order of predefined safety procedures against an emergeny and following master call for action	Integration	Populates the order of associated safety actions crew should take to respond to an emergency on-board	MUST	Master, Crew
PALAEMON-SMS_02	Functional	SMS will digitize and support control of documented safety procedures under company's safety management policy	Services	Filing of manuals, safety checklists, policies etc. Allows document revision and versioning	MUST	Master, Crew, Office
PALAEMON-SMS_03	Functional	SMS will offer a workflow engine for document management	Services	Circulate documents to users with different level of authority for review, revision and approval in case of amendments/updates	SHOULD	Master, Crew, Office
PALAEMON-SMS_04	Functional	SMS will offer an interface to user to create dynamic electronic checklists	Services	Create order of safety actions and associate/group procedures with responsible crew member	COULD	Master, Crew, Office
PALAEMON-SMS_05	Non-functional	SMS should support agility and change management	Services	Following post-incident root cause analysis should be able to trigger an alert for revision of safety policy	SHOULD	Master, Crew, Office
PALAEMON-SMS_06	Functional	Automatic incident registration to SMS during post-incident analysis	Integration	Bridging SMS with PALAEMON DFB core (via Restful API) will trigger automatic incident report registration during post-incident analysis supplementing any manual record of the incident in embedded pre-defined report templates. This service will support a comprehensive incident investigation	SHOULD	
PALAEMON-PaMEAS_001	Functional	Passenger accurate positioning output	Individual component (PaMEAS)	The System will provide accurate location positioning information to ship management for passengers and crew	MUST	Technology providers
PALAEMON-PaMEAS_002	Functional	Location positioning cost/accuracy enhancement	Individual component (PaMEAS + Radio Dot System)	The System will improve the location positioning cost (Network Access Points coverage)/accuracy curve with the use of algorithmic functionality (e.g. machine learning etc.)	MUST	Technology providers
PALAEMON-PaMEAS_003	Non-functional	Indoor positioning partial operation (normal status)	Individual component (PaMEAS)	The system functions only partially in normal conditions and activates periodically for testing purposes (an activity that is constrained by PII data encryption requirements)	MUST	Technology providers
PALAEMON-PaMEAS_004	Functional	Indoor positioning full operation (evacuation status)	Individual component (PaMEAS)	The system works in full operation mode in emergency situations and during ship evacuation to offer indoor real-time location positioning-on-demand"	MUST	Technology providers

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PALAEMON-PaMEAS_005	Non-functional	PaMEAS communications with other high-level services	Interfaces	The System operates on information received from the Incidence Management System (Module) and the DSS	SHOULD	System developers; technology providers
PALAEMON-PaMEAS_006	Functional	PaMEAS service outputs	Individual component (PaMEAS)	Based on the collected positioning information, the System: - Returns emergency navigation information to passengers (in the form of alerts, notifications and navigation instructions) - Manages a connected IoT signalling infrastructure for evacuation (such as emergency led indicators pointing to safe evacuation routes etc.)	MUST	Technology providers
PALAEMON-PaMEAS_007	Functional	PaMEAS privileged interaction extra features	Individual component (PaMEAS + Radio Dot System)	The System establishes "privileged interaction" (through notifications) and direct high bandwidth video links with crew members and, eventually, with "passengers-in-danger" whenever this is possible	SHOULD	Technology providers
PALAEMON-PaMEAS_008	Functional	PaMEAS flow management extra features	Individual component (PaMEAS)	The System provides detailed "flow management" functionality for passengers, crew and rescue teams (i.e., use the location data of people to distinguish between people in a safe situation and persons-in-danger, by defining for each of them a level of risk...)	SHOULD	Technology providers
PALAEMON-PaMEAS_009	Functional	PaMEAS aggregate visualization	Individual component (PaMEAS)	The System offers visualization at an aggregate level of evolution of an emergency plan in real time, as far as mustering and evacuation processes are regarded – including people counting	MUST	Technology providers
PALAEMON-SHM_001	Non-functional	SHM sensors location	Integration	SHM motion sensors located on the main deck of the ship	MUST	IT team, technology providers
PALAEMON-SHM_002	Non-functional	SHM sensor distribution throughout the ship	Integration	Distance of placement of sensors depending on length of the ship	MUST	IT team, technology providers
PALAEMON-SHM_003	Non-functional	SHM configuration	Individual components (SHM)	SHM will include a software with GUI for displaying for information	MUST	Technology providers
PALAEMON-SHM_004	Non-functional	SHM to PALAEMON core communication	Individual components (SHM)	SHM will connect with middleware through Kafka	MUST	Technology providers
PALAEMON-SHM_005	Non-functional	SHM usage in high-level services / Smart Evacuation Management system	Interfaces	SHM will communicate with the DSS system and the middleware	MUST	Technology providers
PALAEMON-SHM_006	Non-functional	SHM accousting sensor selective location	Individual components (SHM)	SHM acoustic emission sensors will be placed on locations which are prone to cracking	MUST	IT team, technology providers

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PALAEMON-SHM_007	Functional	Accoustic sensors output	Individual components (SHM)	Acoustic Emission sensors will read signals from steel structure of ship and offer information on developing defects (cracks)	MUST	Technology providers
PALAEMON-SHM_008	Functional	Motion sensors output	Individual components (SHM)	SHM Motion sensors output: - List and trim angles of ship - Rate of change of ship angles - Deflection of ship (quasistatic and dynamic)	MUST	Technology providers
PALAEMON-SHM_009	Functional	SHM asynchronous output	Individual components (SHM)	SHM will offer alarms to PALAEMON core when critical values are exceeded	MUST	Technology providers
PALAEMON-SHM_010	Non-functional	SHM physical infrastructure	Integration	SHM sensors will be connected with wires (ethernet cable) but wireless connection is available and functional	MUST	IT team, technology providers
PALAEMON-SST_001	Functional	Graphic User Interface of Ship Stability Toolkit	Individual component (SST)	Displays the expected motion of the vessel	MUST	Bridge, Master, Crew
PALAEMON-SST_002	Functional	Reading of live motion information	Integration	Using the data of the motion sensors as input to calculate max. motion to be expected	SHOULD	Bridge, Master, Crew
PALAEMON-SST_003	Functional	Input of weather forecast	Integration	Prediction of motion change due to change of the weather	MUST	Bridge, Master, Crew
PALAEMON-SST_004	Functional	Connection to SB legacy system	Integration	Reading of navigational data (speed, heading) and climate sensors	SHOULD	Bridge, Master, Crew
PALAEMON-VRG-001	Functional	Generation of voyage ID	Operation	Generation of a unique ID for every voyage (e.g., hash with the name of the ship and the timestamp of the departure time)	MUST	System developers; DPA
PALAEMON-VRG-002	Functional	After-voyage report generation	Operation	After every voyage (regardless it has an incident or not), the Voyage Report Generator will reap all the information generated in the PALAEMON Communications Platform and will proceed to generate a complete report of the trip	MUST	System developers; DPA
PALAEMON-VRG-003	Functional	System core (ship premises) flush after every voyage	Operation	Once the voyage is over, the generator will proceed to erase all the information stored in the system, thus saving space to the limited capacity (i.e., memory) of the ship's hardware infrastructure	MUST	System developers; DPA
PALAEMON-VRG-004	Functional	Subscription to PALAEMON Evacuation Coordinator events	Operation	The Voyage Report Generator will trigger its actions based on the evacuation ship status signals propagated by the PALAEMON Evacuation Coordinator	MUST	System developers; DPA
PALAEMON-VRG-005	Non-functional	Internet connection for report uploading	Operation	When it comes to upload the report outwards, the system needs a stable Internet connection	MUST	System developers; DPA
PALAEMON-VRG-006	Functional	Report upload and preserved on cloud-based repositories	Operation	When the report is generated, the output file(s) will be forwarded to a central repository out of the ship's premises	MUST	System developers; DPA

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PALAEMON-VRG-007	Functional	Incident report uploaded to Safety Management System	Operation	The incident reports will be uploaded to DANAOS' Safety Management System, via RESTful API (interface to be defined)	MUST	System developers; DPA
PALAEMON-VRG-008	Non-functional	Access to all "reportable" components and data spaces	Operation	To carry out the operations related to generate (and clean) the PALAEMON communications platform, the Voyage Report Generator needs to either have access/visibility to all component which will be part of the report (i.e., DFB, Smart Cameras, GCS, Voice Comms Server, etc.), or, as an alternative, they should be capable of sending their files to a common volume	Must	System developers; DPA
PALAEMON-Ctxt_Broker_01	Functional	Scorpio Context Broker deployed to the platform	Deployment	This Context Broker will serve as a Subscription-Notification server to broadcast the sensors/data sources data across the interested services.	MUST	
PALAEMON-Ctxt_Broker_02	Functional	Context elements (device) registration	Operation	Before sending data to Scorpio LD, all devices transmitting data to this context broker should be registered so that Scorpio can start its functionalities	MUST	
PALAEMON-Ctxt_Broker_03	Functional	REST API-based subscriptions for interested services	Operation	Services need to be able to subscribe to changes in sensor or device values, and react to the changes via REST API	MUST	
PALAEMON-Ctxt_Broker_04	Functional	Data stored on the Context Broker needs to adhere to conventional data models	Operation	It is crucial that data is stored and accessed in a standardized manner, so that it can be understood by all components	MUST	
PALAEMON-IAM-001	Functional	Identity and Access Management component	Security and Authentication	An Identity and Access Management component shall be deployed, as part of the container orchestrator cluster, in order to secure Palaemon applications and services.	Must	
PALAEMON-IAM-002	Functional	Anonymization module	Security and Privacy	Anonymization module shall protect the Passenger's list according to GDPR, during Palaemon's Normal Status (in terms of Evacuation)	Must	