PROJECT DELIVERABLE REPORT

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

D2.2 PALAEMON Requirement Capture Framework

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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Contents

Abbreviations

AR	Augmented Reality
DSS	Decision Support System
ECDIS	Electronic Chart Display and Information System
EEBD	Emergency Escape Breathing Device
EMSA	European Maritime Safety Agency
EUC	Equipment Under Control
FMEA	Failure Mode and Effects Analysis
GDPR	General Data Protection Regulation
GPS	Global Positioning System
IACS	International Association of Classification Societies
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ISO	International Organisation of Standardisation
LSA	Life Saving Appliances
MEV	Mass Evacuation Vessel
MOB	Man Over-Board
MSC	Maritime Safety Committee
PC	Product Certificate
PLC	Programming Logic Circuits
RF	Radio Frequency
RFID	Radio Frequency Identification
RO	Recognised Organisation
Ro-Pax	Roll-On Roll-Off Passenger vessel
SAR	Search and Rescue
SHM	Ship Hull Monitoring
SOLAS	International Convention for the Safety of Life at Sea
UAV	Unmanned Aerial Vehicle
UID	User Input Device
UML	Unified Modelling Language
UR	IACS Unified Requirement
VDES	VHF Data Exchange System
VHF	Very High Frequency
VR	Virtual Reality
VDU	Visual Display Unit

1 Summary

This report contains the results of the requirements elicitation process implemented in the first iteration of the development of the PALAEMON system. This is the first version of the functional and operational requirements, which will be the reference for the further development of the PALAEMON solution. The requirements were elicited with the PALAEMON Requirement Capture Framework, which is a methodology based on VOLERE.

The PALAEMON Requirement Capture Framework is stakeholder-driven, which means that the functional requirements have a direct connection to identified stakeholder needs. The first set of users and stakeholders needs for the PALAEMON system were identified by utilizing the following techniques:1) workshop, 2) focus group, 3) interviews and 4) the state-of-the art analysis conducted in Task 2.1 of the project. The stakeholders' needs were formalized into corresponding stakeholder requirements, which were then combined with the high-level use cases, the expected operational conditions, and the constraints in the relevant rules and regulations to elicit the functional requirements of the main components of the PALAEMON System. The functional requirements were documented with formal "shall-statements".

The rest of this report is structured in the following sections:

Section 2 describes the process of eliciting requirements based on the rationale of systems engineering. The typical tools and techniques for the identification of the requirements are presented along with the type of requirements that are used for the development of a system.

Section 3 describes the PALAEMON Requirement Capture Framework that was employed for eliciting the functional requirements for the PALAEMON ecosystem, as well as the steps that will be followed in the second version of the PALAEMON requirements.

Section 4 defines the PALAEMON System, including a comprehensive mission statement, its main goals, and the description of the functional dependencies among its main components.

Section 5 presents the results of the process used in PALAEMON to identify the stakeholders that are most relevant in the maritime evacuation process, and which are engaged to elicit the functional requirements for the PALAEMON system.

Section 7 lists the stakeholder needs that have been identified from the focus group that was conducted on the 14th of August 2019 on the premises of Johanniter Austria, the workshop that was conducted in Athens on 25-26 of November 2019, the users/stakeholder's interviews conducted in the context of Task 2.2, as well as the maritime evacuation state-of-the-art analysis conducted in Deliverable 2.1 (NTUA, 2020).

Section 7 contains the high-level use cases that illustrate the utilization of the PALAEMON ecosystem from the perspective of its end users: passengers and crew members. The use cases are described with UML diagrams as an indicative operational scenario. Additionally, the expected operational conditions that could affect the PALAEMON components' performance are presented.

Section 8 describes the design constraints from the relevant regulatory framework that were considered for the first version of the PALAEMON functional requirements.

Finally, Section 9 documents the first version of the functional requirements for the main components of PALEMON in structured "shall-statements".

The Appendix provides details regarding the focus group, workshop, and stakeholder interviews that were conducted for the first version of the PALAEMON functional requirements.

2 Requirements engineering in the context of systems engineering

This section describes the rationale, the tools and the techniques utilised to identify the requirements to develop a system under the framework of systems engineering.

Systems engineering requires the application of a systematic and disciplined engineering approach for the development, operation, maintenance, and disposal of systems integrated throughout the life cycle of a project or program (Shea, 2020). A vital part of this approach is the requirements engineering. According to Dick et al. (2017), requirements engineering is the subset of systems engineering concerned with discovering, developing, tracing, analysing, qualifying, communicating and managing requirements that define the system at successive levels of abstraction. A requirement is a statement that translates or expresses in a very specific, precise and unambiguous manner a need (for a system, software or service) and its associated constraints and conditions (ISO/IEC/IEEE, 2018).

The core activities of requirements engineering are the following (Pohl and Rupp, 2015):

- **Elicitation**: different techniques are used to obtain requirements from stakeholders and other sources and to refine the requirements in greater detail.
- **Documentation**: the elicited requirements are described adequately. Different techniques are used to document the requirements by using natural language or conceptual models.
- **Validation and negotiation**: to guarantee that the predefined quality criteria are met, documented requirements must be validated and negotiated early on.
- **Management**: requirements management is orthogonal to all other activities and comprises any measures that are necessary to structure requirements, to prepare them so that they can be used by different roles, to maintain consistency after changes, and to ensure their implementation.

These core activities can be applied for different levels of requirements abstraction, like stakeholder requirements or system requirements. Their implementation can follow different processes, such as the processes recommended in ISO/IEC/IEEE 29148:2018.

2.1 Requirements elicitation

Requirements elicitation represents an early but continuous and critical stage in the development of a system (Aurum and Wohlin, 2005). It can be a very complex and multidisciplinary process, which involves several multi-technique activities. These activities enable requirement engineers, jointly with the stakeholders, to understand what are the requirements of a given system (Fernandes and Machado, 2016). Many of these activities have essentially a communicational nature. Thus, the origins of the associated techniques are related to the social sciences and organizational theory instead of traditional engineering or science areas. Aurum and Wohlin (2005) underline that requirements elicitation is a multifaceted and iterative process, which relies heavily on the communication skills of requirements engineers and the commitment and cooperation of the system stakeholders. As a result, elicitation is subject to a large degree of error, influenced by key factors inherent in communication problems. For instance, concepts that are clearly defined for one category of stakeholders can be entirely opaque to members of another, and so the agreement on the system requirements can become problematic.

According to Fernandes and Machado (2016) The definition of a universal model for the requirement elicitation process is difficult, since the interests and the type of the stakeholders, as well as the characteristics and the framework of the system under development, greatly restrict the approach to be followed in each case. However, according to the authors, it is possible to define a generic elicitation process that needs to be executed iteratively, with the following steps:

- Study the domain of interest.
- Identify the requirements sources.
- Consult and engage stakeholders.
- Select the techniques to be applied for elicitation.
- Elicit the requirements form the stakeholders and other identified sources.

One of the key aspects of the requirements elicitation process is the requirements construct i.e. the form of the requirements. According to Dick et al. (2017), the use of a consistent language makes it easier to identify different kinds of requirements. The traditional requirements specification uses discrete shall-statements (e.g. “the system shall perform this task”) to document the functions, qualities, and constraints of a system (Sage and Rouse, 2009). Apparently, “shall” is the keyword and when used as part of the verb indicates the presence of a requirement in the text. Some approaches go further and use “shall,” “should” and “may” to indicate different priorities of the requirement (Dick et al., 2017). Nevertheless, the use of “shall” specify requirements that are mandatory binding provisions (ISO/IEC/IEEE 29148). In this report, “shall-statements” were utilized to formulate the user needs and requirements.

2.2 The VOLERE framework

VOLERE[1] was introduced in 1995 by Robertson and Robertson (2013) and is essentially a collection of requirements resources, including courses, templates, books, and processes[2]. The VOLERE techniques provide a common and easily accessible way of discovering requirements, communicating, and connecting them to solutions. The VOLERE approach to requirements has been applied to thousands of projects and is a result of research and application.

The VOLERE requirements process provides a framework for successfully discovering, verifying, and documenting requirements (Robertson and Robertson, 2013). The VOLERE “Requirements Specification Template” is a complete blueprint for describing a product’s functionality and capabilities. The template is designed to serve as a sophisticated checklist; it provides a list of what needs to be included in a requirements specification and suggests on how to write about it. Robertson and Robertson (2013) emphasize that this template, which is a distillation of literally hundreds of requirements specifications, is in use by thousands of organizations all over the world.

The VOLERE “Requirements Specification Template” includes a requirements shell (also called a “snow card”) as a guide to writing each atomic requirement during the initial requirements gathering. The snow card (Figure 1) includes specific attributes of the elicited requirement. Robertson and Robertson (2013) note that each requirement has a structure - set of attributes, where each attribute contributes something to the understanding of the requirement, and to the precision of the requirement, and thereby to the accuracy of the

[1] “Volere” is the Italian word for “to wish” or “to want.”

[2] https://www.volere.org, trademarked brand owned by the Atlantic Systems Guild.

product's development. They also suggest that more attributes can be added to provide the necessary traceability for the specific system/product.

It is worth noting that ISO/IEC/IEEE (2018) also emphasizes the need to use attributes to describe requirements to support requirements analysis. According to the ISO/IEE/IEC standard, to deliver well-formed requirements, descriptive attributes should be used to assist in identifying the requirements and to help in understanding and managing them. The attribute information should be associated with the requirements in the selected requirements repository.

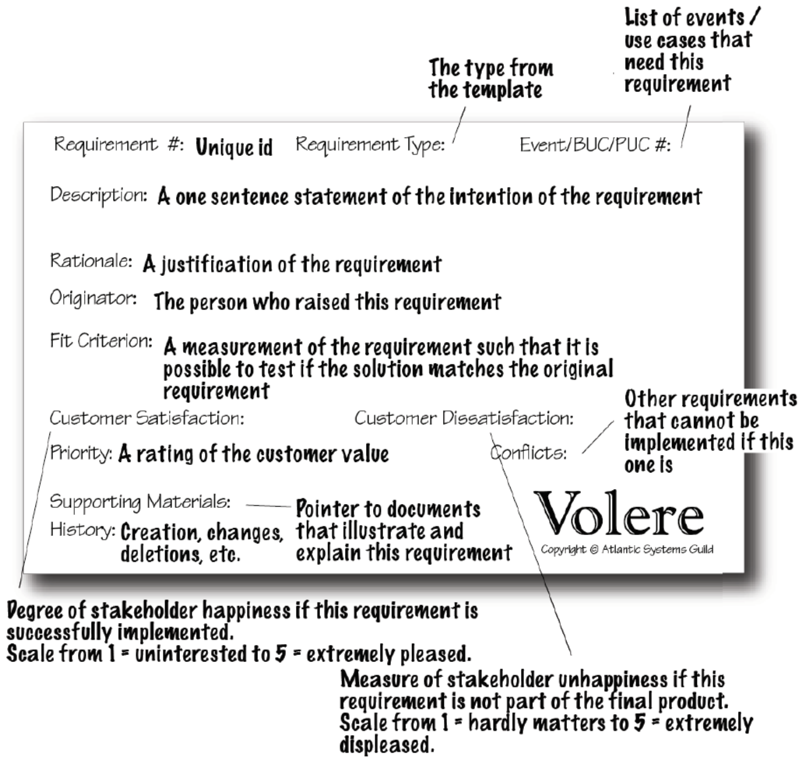

Figure 1: VOLERE requirements shell - "snow card" (Robertson and Robertson, 2013).

Robertson and Robertson (2013) also note that the VOLERE Requirements Process is meant to be a guide for achieving goals in successful requirements projects. Therefore, the suggested process should be regarded as a set of tasks that have to be done (to varying degrees of detail), rather than as a lockstep procedure that requires rigid adherence. The potential users of the VOLERE framework should tailor the suggested process to fit their own needs.

2.3 The path from stakeholders needs to system requirements and use cases

A thorough understanding of the user and other key stakeholder's expectations for a project is one of the most important steps in the system engineering process (Shea, 2020). It helps ensure that all interested parties are on the same page and they agree on system aspects, such as the functions, characteristics, behaviour, appearance, and performance. It also sets more realistic expectations on the stakeholder's part and helps prevent significant requirements creep[3] later in the life cycle of the system.

[3] Requirements creep refers to the process in which new requirements enter the specification after the requirements are considered complete (Robertson and Robertson, 2013).

According to ISO/IEC/IEEE 15288 (2015), a stakeholder is an individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations. Within this context, stakeholders can be the end users, end user organizations, supporters, developers, producers, trainers, maintainers, disposers, acquirers, customers, operators, supplier organizations, accreditors, regulatory bodies, etc. The stakeholders are associated with the life cycle stages of a system, which include concept, development, production, utilization, support, and retirement (ISO/IEC/IEEE, 2018).

System stakeholders can be authoritative sources for requirements of the system that represent their interests or area of expertise (ISO/IEC/IEEE, 2018). However, they are usually not familiar with how to transform their needs and expectations into well-formed requirements statements. Moreover, the initial concerns and often latent needs of the stakeholders cannot be used directly as stakeholder requirements since they often lack definition, analysis and possibly consistency and feasibility. Thus, the stakeholder needs must be processed and refined to be transformed into stakeholder requirements by implementing a systematic approach, such as the Stakeholder Needs and Requirements Definition Process provided by the ISO/IEC/IEEE 29148 International Standard. Once a sound set of stakeholder requirements is produced, it must be utilized to define the characteristics of the system. This process is known as establishing the system requirements. ISO/IEC/IEE 291148 also provides a framework for this process, which is described in the Standard as System Definition Requirements Process.

This report focuses on the Stakeholder Needs and Requirements Definition Process, and System Definition Requirements Process, which are part of the Technical Processes (ISO/IEC/IEEE, 2015). The Technical Processes cover the technical actions through the life cycle of a system. They transform the needs of stakeholders into a product or service; they are applied to create and use a system, whether it is in the form of a model or is a finished product.

Stakeholder Needs and Requirements Definition Process as described by ISO/IEC/IEEE 29148:2018

The purpose of this process is to define the users and stakeholder requirements in a defined environment. The process includes the following activities:

- Preparation for stakeholder needs and requirements definition. This activity begins by identifying the stakeholders.
- Definition of stakeholder needs.
- Developing of the operational concept and other life cycle concepts.
- Transforming stakeholder needs into stakeholder requirements.
- Analysing stakeholder requirements.
- Managing the stakeholder needs and requirements definition.

System Requirements Definition Process as described by ISO/IEC/IEEE 29148:2018

The purpose of the System Requirements Definition process is to transform the stakeholder, user-oriented view of desired capabilities into a technical view of a solution that meets the operational needs of the user. This process creates a set of measurable system requirements that specify, from the supplier's perspective, what characteristics, attributes, and functional and performance requirements the system is to possess to satisfy stakeholder requirements.

ISO/IEC/IEEE note that, as far as constraints permit, the requirements should not imply any specific implementation.

The System Requirements Definition Process includes the following activities: Preparation, Definition, Analysis, and Management.

2.4 Types of requirements

Requirements vary in intent and in the kinds of properties they represent (ISO/IEC/IEEE, 2018). To assist in identifying relevant requirements and categorizing them into groups for analysis and allocation, the use of a type attribute is applied.

Pohl and Rupp (2015) distinguish three types of requirements:

- **Functional requirement**: It is a requirement concerning a result of behaviour that shall be provided by a function of the system. Functional requirements define the functionality of the system under development. Usually, these requirements are divided into functional requirements, behavioural requirements, and data requirements.
- **Quality requirement (non-functional)**: It is a requirement that pertains to a quality concern that is not covered by functional requirements. Quality requirements define the desired qualities of the system to be developed and often influence the system architecture more than functional requirements, such as performance, availability, dependability, scalability, and portability. Requirements of this type are frequently classified as non-functional requirements.
- **Constraint**: It is a requirement that limits the solution space beyond what is necessary for meeting the given functional requirements and quality requirements. Constraints cannot be influenced by the developers. Requirements of this type can constrain the system itself (e.g., “The system shall be implemented using web services”) or the development process (“The system shall be available on the market no later than the second quarter of 2012”). In contrast to functional and quality requirements, constraints are not implemented, they are adhered to because they merely limit the solution space available during the development process. Sources of constraints could be requirements stemming from industry standards (e.g. ISO, IEC), as well as national and international regulations as developed by respective authorities.

Robertson and Robertson (2013) provide the same categorization for requirements as Pohl and Rupp (2015), see Figure 2. Functional requirements are things the system must do to deliver the required functionality to the use. Non-functional requirements are qualities the system must possess. They “deliver” the functionality by making the product usable and acceptable to the users. Constraints are global issues that shape the requirements and restrict the functionality of the end system.

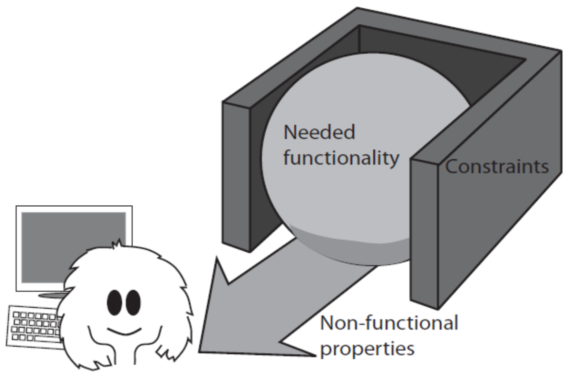

Figure 2: Types of requirements Robertson and Robertson (2013).

According to Adams (2015), functional requirements have the following essential characteristics:

- They define what the system should do.
- They are action oriented.
- They describe tasks or activities.
- They are associated with the transformation of inputs to outputs.

Additionally, Adams (2015) lists the following essential characteristics for non-functional requirements:

- They define a property or quality that the system should have.
- They can be subjective. Non-functional requirements can be viewed, interpreted and evaluated differently by different people.
- They can be relative. The interpretation and importance of a non-functional requirement may vary depending on the system under consideration.
- They can be interacting. One non-functional requirement can impair or benefit the fulfilment of another non-functional requirement.
- They describe how well the systems must operate.
- They are associated with the entire system, not with the individual qualities of the system components.

The ISO/IEC/IEE 29148 International Standard provides the following definitions for functional and non-functional requirements:

- **Functional/Performance requirements**: Functional requirements describe the system, or the system element functions or tasks to be performed by the system. Performance is an attribute of the function. A performance requirement alone is an incomplete requirement. Performance is normally expressed quantitatively. There can be more than one performance requirement associated with a single function, functional requirement, or task.
- **Non-functional requirements**: These requirements include the so-called “ilities”, such as transportability, survivability, flexibility, portability, reusability, reliability, maintainability, and security. There are requirements that describe the qualities of the system and should be identified before initiating the requirements activities. This should be tailored to the system(s) being developed. As appropriate, measures for the quality requirements should be included as well.

Many different requirements classification schemes are used or proposed in the relevant systems/requirements engineering literature and therefore there is no single formal definition for the requirements types. For example, the categorizations by Pohl and Rupp (2015) and Robertson and Robertson (2013) are different to the one provided by the ISO/IEC/IEEE 29148 standard, which identified important types of requirements as: functional/performance, interface, process, quality (non-functional), usability/quality-in-use, and human factors requirements.

2.5 Techniques for eliciting requirements and needs

There are many techniques for conducting requirements and needs elicitation, most of which include interaction with the users and stakeholders (ISO/IEC/IEEE 29148). The following is a brief overview of some of the methods used for eliciting requirements and needs.

2.5.1 State of the art analysis

Domain specific knowledge, such as for the domain of ship evacuation, can be obtained by mapping elements such as the existing systems, procedures, regulations, and environment. The primary role of this knowledge is to support the refinement of requirements to implementable specifications. According to Zave and Jackson (1997), correct specifications, in conjunction with appropriate domain knowledge, imply the satisfaction of the requirements.

State of the art (domain) analysis involves assessing the landscape of related and competing applications to the system being designed. Such an approach can be useful in identifying essential functionality and, perhaps, missing functionality (Laplante, 2018). The evaluation of an existing system can provide valuable information about the extent to which it meets the stakeholder's needs and can identify problems to avoid in the new system. It can also explore the positive aspects of an existing system. The identified useful features can be introduced into the design process of the new system as potential user requirements (Maguire and Bevan, 2002). Domain analysis can also help to identify legacy or reusable components that have to or can be incorporated into the final design.

2.5.2 Workshop

In general, workshops are any formal or informal gatherings of stakeholders to discuss requirements issues (Laplante, 2018). Formal workshops are well-planned and more highly structured meetings than informal workshops.

A workshop, as a group activity, can be very productive in terms of bringing together many stakeholders. During the meeting, the participants can discuss and offer their opinion on a specific subject, and share their knowledge, experience, and expertise. However, group work of any kind has several drawbacks. According to Laplante (2018), a workshop can be difficult to organize and get the stakeholders involved to focus on issues. In addition, problems of openness can occur since people are not always willing to express their opinion in a public forum. Moreover, certain participants can dominate the meeting (and these may not be the most "important" individuals). Such a situation can disappoint and discourage the other attendees to actively participate. There is also the risk of conflict and disagreement.

2.5.3 Focus group

Focus group is a type of group elicitation technique. It is a moderated discussion on a predefined topic involving a small number of participants. The participants are selected based on their relevance with the topic under investigation. Fernandes and Machado (2016) explain that the preparation and conduction of the discussion is similar to those performed in interviews. For example, the moderator prepares a set of questions beforehand and provides feedback during the discussion regarding what is heard. Moreover, they indicate that the application of the technique offers an advantage in terms of the information collected, since a participant can be complemented by another. Hence, the elicited information is enriched and expanded collaboratively.

2.5.4 Questionnaire

A questionnaire is a survey instrument that is composed of a set of questions and is often disseminated to a large group of stakeholders. It can elicit a lot of information in a short amount of time and at a low cost (Pohl and Rupp, 2015). Generally, it is used at the early stages of the elicitation process to quickly define the scope boundaries (Laplante, 2018). When the same questionnaire is used for all persons, it becomes possible to handle statistically the collected answers (Fernandes and Machado, 2016).

A questionnaire can include questions of any type (Laplante, 2018). For example, questions can be closed-ended (e.g., yes/no, or right/wrong) or open-ended to which the participant is free to respond to a level and depth that he/she feels comfortable with. Each type has advantages and disadvantages. Laplante (2018) explains that closed-ended questions provide easier coding for analysis, and help to bound the scope of the system. Open-ended questions allow for more freedom and innovation but can be harder to analyse. They can also result in scope creep, which means the uncontrolled expansion to the project scope without adjustments to time, cost, and resources (PMI, 2017).

Preparing a questionnaire that will be a pertinent and effective source of information is not an easy task. It is time-consuming and requires thorough knowledge and understanding of the domain in question by both stakeholders and requirements engineers (Laplante, 2018; Pohl and Rupp, 2015). Moreover, it is important to follow specific principles so that the questionnaire has the intended effectiveness (Fernandes and Machado, 2016; Pohl and Rupp, 2015). Fernandes and Machado (2016) emphasize that the success of the survey is highly dependent on the way the questionnaire is conceived. As they explain, if the questions are not focused, if they are poorly formulated or if they appear in the wrong order, the answers that will be obtained maybe not only irrelevant but even misleading. Besides, as opposed to interviews, questionnaires do not provide immediate feedback between the surveyor and the surveyed. As a result, it becomes apparent that questions were forgotten or badly formulated only once the questionnaires have been evaluated (Pohl and Rupp, 2015).

2.5.5 Interview

The “opposite” of group elicitation techniques is one-on-one (or small group) interview (Laplante, 2018). This is an obvious and easy-to-use technique to extract system requirements from a stakeholder. In fact, interviews are one of the most popular requirements elicitation techniques (Fernandes and Machado, 2016). The most prominent disadvantage of this technique is that it is very time-consuming (Pohl and Rupp, 2015). According to Laplante (2018), three kinds of interviews can be applied for requirements elicitation: unstructured, structured and semi-structured. Laplante (2018) suggests that, while structured interviews are preferred, the choice of which one to use is very much an opportunistic decision. For example, when the stakeholder’s corporate culture is very informal and trust is high, then unstructured interviews might be preferable. In a stricter, process-oriented organization, structured and semi-structured interviews are probably more desirable.

Unstructured interviews, which are probably the most common type, are conversational in nature (Laplante, 2018). The interviewer asks questions that have not been prepared in advance; questions arise spontaneously in a free-flowing conversation. Unstructured interviews can occur at any time and any place whenever the requirements engineer and customer are together, and the opportunity to capture information this way should never be lost. The technique permits great freedom to the interviewer, but may often result in low-quality results if the interview is not focused and objective (Fernandes and Machado, 2016). Hence, a structured and organized interview is preferable.

Structured interviews are much more formal in nature (Laplante, 2018). They use predetermined questions that have been decided in advance. The main drawback of structured interviews is that some stakeholders may feel uncomfortable with the formality and rigid structure of the conversation and withhold information.

Semi-structured interviews combine the best of structured and unstructured interviews (Laplante, 2018). That is, the requirements engineer prepares some key questions, but then allows for spontaneous unstructured questions to creep in during the interview. The answers of the interviewees may produce new questions that can be discussed immediately. The interviewer may uncover subconscious requirements through clever questions.

Whatever interview technique is used, care must be taken to ensure that all of the right questions are asked (Laplante, 2018). Furthermore, Pohl and Rupp (2015) note that an experienced interviewer individually controls the course of the conversation, completely commits himself to each stakeholder, asks about specific aspects, and thus ensures the completeness of the answers.

2.5.6 Use cases

A use case is a written description of how users will perform tasks on a system (Koelsch, 2016). Modern system design is usually based on use cases (Sage and Rouse, 2009). Use cases are exploited by systems engineers as a tool for documenting and communicating requirements. The use cases outline the required functional performance of the system by producing an observable result for the user. They function as a structured, scenario-based method to develop and represent the behavioural requirements for a system. They can describe the behaviour of even complex systems simply and effectively. Each use case designates a sequence of interactions between one or more users with the system. Typically, a system will have many uses cases, each of which satisfies a need of a user.

Sage and Rouse (2009) suggest that, technically, use cases are not precise requirements. They are a vehicle to discover requirements. The descriptions of the use cases are containers in which the requirements are embedded. Through a use case model, stakeholders can comprehend how the proposed system helps them to fulfil these needs and provides value to them. According to Koelsch (2016), it is possible for use cases to act stand-alone, without shall-statements. Seeing the success of methodologies demonstrates that they can work as a replacement for requirements.

3 PALAEMON Requirement Capture Framework

This section describes the stakeholder-driven process that is employed to elicit functional requirements for the PALAEMON ecosystem. The PALAEMON Requirement Capture Framework will be implemented in two iterations (i.e., V1 and V2). The first version, which is described in this report, includes the detailed functional requirements and high-level use cases that will guide the research work in WP3 – WP6 and drive the integration of the PALAEMON system in WP7 and the execution of pilots in Work Package 8. The second version will be derived by: 1) widening the basis of engaged stakeholders to identify needs that were potentially not covered in the first version, and 2) validating and refining the first version of functional requirements with selected stakeholders and experts from the Consortium.

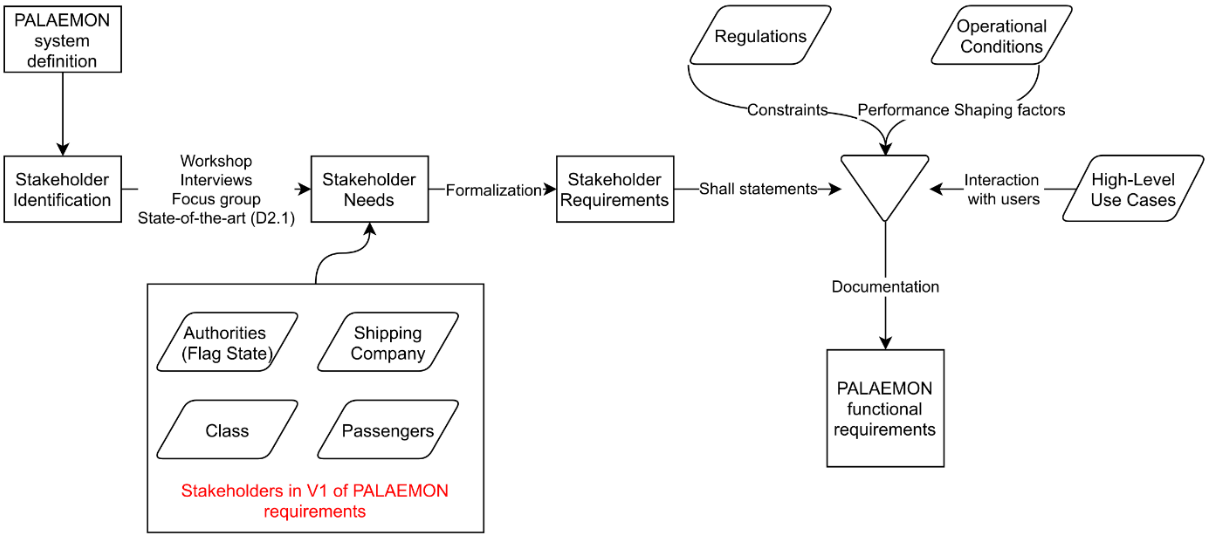

Figure 3: Workflow for the PALAEMON Requirement Capture Framework.

The requirements listed in this report have a direct connection to actual stakeholders' needs and consider the deployment of the PALAEMON ecosystem in real-world conditions. The scope of the requirements covers a wide range of issues, including safety, security/privacy, robustness, and human-machine interactions. The stakeholder needs and functional requirements have been described in relation to the main components of the PALAEMON ecosystem, as described in Section 4 of this report. Figure 3 outlines the workflow used in the PALAEMON Requirement Capture Framework to elicit the current needs of the major stakeholders in maritime evacuation (see Section 5 of this report) and translate them into functional requirements for the main components of PALAEMON. This workflow is based on the recommended practice described in the VOLERE framework (see Section 2).

The first step in the workflow is to define the PALAEMON system, including its boundaries, main components, and functional dependencies (see Section 4). This view was presented to the identified stakeholders that are most relevant to the domain of maritime evacuation. The result of the stakeholder identification process was a list of stakeholders (see Section 5) with the following information documented, which is based on the guidance provided by the VOLERE framework:

- **Stakeholder Class**: Class of stakeholders who share a stake in the project.
- **Stakeholder Role**: The job title, department, or organisation that might indicate a role for this class of stakeholder.

- **Stakeholder Rationale**: Why does this stakeholder need to be involved? Consider benefits and impacts.
- **Classes of Knowledge**: Goals, Business Constraints, Technical Constraints, Functionality, Usability, Performance, Safety, Operational Environment, Security, Regulatory, Maintenance, Design Ideas, Experience in critical scenarios.

The first version of the PALAEMON functional requirements was elicited by engaging representatives from the Flag States, Classification Societies, Shipping Companies, and Passengers. They were involved in the requirements elicitation process by using a combination of tools; an approach that aimed at increasing the efficiency and effectiveness of the process. These tools included structured workshops, focus groups, questionnaires, and semi-structured interviews (see Appendix for more details). In addition, stakeholder needs were also elicited from the domain state-of-the-art analysis that was conducted in the context of Task 2.1 and documented in Deliverable 2.1 (NTUA, 2020).

The identified stakeholder needs were formalized and correlated to the main components of the PALAEMON ecosystem by structured “shall-statements” that resulted in a list of stakeholder requirements. Subsequently, this list was enriched and refined iteratively by considering: 1) design constraints that are required by relevant regulations (see Section 8), and 2) performance shaping factors that are implied by the expected operational conditions of the PALAEMON ecosystem (see Section 7.2). Furthermore, the PALAEMON functional requirements were described by employing a combined/hybrid shall-statement and high-level use case approach, which effectively exploits the advantages of each method (Sage and Rouse, 2009). Functional requirements derived from “shall-statements” provide the precision needed to define the system completely and unambiguously. On the other hand, use cases offer understandability, context, and direct traceability to stakeholder needs, as well as requirements that are based on how the users are expected to interact with the system.

The PALAEMON functional requirements were documented by employing an adapted version of the “snow card” described in the VOLERE framework. For each requirement, the information shown in Table 1 was recorded and a descriptive approach was used that includes why each requirement is necessary and what goals may be achieved. In addition, this type of documentation allows tracing back the requirement to specific stakeholders and facilitates both the validation and revision processes that will be implemented for the second version of the PALAEMON functional requirements. The table was used consistently throughout the requirements elicitation process. When interviewing stakeholders or during the workshop conversations, the card was used to quickly record requirements as they emerged. Later, the component information of the recorded requirements was filled in a computerized version of the card.

Table 1: Functional requirement table, adapted from the "snow card" described in the VOLERE framework.

ID: A unique identification number	**Source**: Stakeholder whose needs are covered by the requirement
Description: A short statement describing the requirement	
Rationale: A short description that justifies the necessity of the requirement and the goals achieved from its implementation	
Dependencies: A list of other functional requirements whose implementation depends on the specific requirement	**Conflicts**: A list of other functional requirements that cannot be implemented if this requirement is satisfied.
Functional Decomposition: A breakdown of the main functional requirement with more specific sub-requirements.	

4 PALAEMON System definition

This section defines the PALAEMON system by stating its goals and describing the functional architecture (sub-systems and functional dependencies) that determines the behaviour of the system, in relation to its intended end-users.

PALAEMON Mission Statement

PALAEMON is a sophisticated maritime evacuation ecosystem for high-capacity passenger ships and Ro-Pax vessels that combines an intelligent ICT infrastructure with a radical re-thinking of mass evacuation systems in the form of PALAEMON (MEVs). The PALAEMON ecosystem provides smart situation-awareness and guidance to the passengers and crew through continuous monitoring and control.

PALAEMON's vision is to improve the effectiveness and safety of the evacuation process for high capacity passenger ships and Ro-Pax vessels, by exploiting advanced ICT technologies and efficiently support the decision-making process of the ship's Master and crew.

PALAEMON will provide supplementary safety from the minimum required by the rules, meaning that PALAEMON's systems and functionalities shall not interfere with existing ship safety systems and operations. PALAEMON will exploit information from existing systems, as well as from the new components to be installed and will provide additional, compared to the current practice, information to support the final decision for evacuation, or not, which will still be taken by the Master. Once the evacuation has been decided as the best course of action, it will be announced via the public address and the general alarm system of the ship manually. No direct automatic communication link between PALAEMON and the current alarm and public address system of the ship is suggested.

PALAEMON operation is categorised in two modes: normal and incident/emergency. The first one corresponds to normal ship operation where some components of the system (such as the localization function) are not active or are monitoring in the background. The transition to the second mode occurs upon the occurrence of an incident, which initiates the activation of all functionalities of the system. Next the focus is on the description of the full operational mode of the system as it deploys all the available functionalities.

The main goal of the PALAEMON system is achieved by:

1) providing **enhanced situation awareness** for the ship's crew and Master.
2) distributing **personalized, evacuation-related information** to the crew and passengers.
3) offering a **safe and effective evacuation system** that is integrated with the PALAEMON ICT infrastructure.
4) **broadcasting evacuation-related information** to other ships and competent authorities.

The PALAEMON system gathers information from smart field devices that will be deployed by the PALAEMON project (e.g. Smart Cameras, Smart Bracelets, AR Glasses, UAV, MEV), sensors (e.g. structural monitoring) and shipboard legacy systems (e.g. smoke detectors, flooding sensors, alarms etc.). This information is processed by the PALAEMON Intelligence Framework that is used to evaluate the developing evacuation and is subsequently displayed on the PALAEMON dashboard, which provides decision support for the Master and the Bridge/Command Team. The PALAEMON dashboard subsequently sends information (e.g., instructions, evacuation-related information, etc.) to the PaMEAS system that distributes it as personalized information to the crew and passengers through PALAEMON field devices, which is a combination of smart bracelets, and AR glasses for crew members. The PALAEMON dashboard also broadcasts evacuation-related information via the VDES communication standard to competent authorities and other ships.

The PALAEMON system consists of the following sub-systems (Figure 4: Functional dependencies among the PALAEMON components.):

- Mass Evacuation Vehicle (MEV).
- Field devices.
- Sensors.
- PALAEMON Intelligence Framework.
- PALAEMON dashboard.
- PaMEAS.

The following is a brief description of each subsystem's functionality.

MEV. The PALAEMON MEV (developed in WP4) is an innovative evacuation craft that aims to replace existing mass evacuation systems and is complemented by other lifesaving appliances (e.g., liferafts). The MEV also includes sensors that interact with the rest of the PALAEMON ecosystem, by transmitting evacuation-related information.

Field devices. The main functionality of the PALAEMON field devices is to generate enhanced situation awareness for the ship's Master and Crew. This is accomplished by gathering visual information on the status of the passenger mustering and the status of the ship (Smart Cameras, Smart Bracelets, AR Glasses, and UAV, developed in Tasks 5.5, 5.1, 5.2, and 5.3 respectively). In addition, the smart bracelets generate the necessary signals and based on them information, such as the exact location of the crew and passengers and their health and mobility status can be obtained. The AR Glasses and smartphones are also used for distributing personalized, evacuation-related information to the passengers and crew (via the PaMEAS system).

Sensors. These devices include the sensors related with the PALAEMON Structural Monitoring (developed in Task 6.1) and Stability Toolkits. PALAEMON will also interface with the shipboard legacy systems (e.g., fire alarms, smoke detectors, flooding sensors, etc.). They are used to gather information regarding the status of the ship and the location of potential hazards (e.g., fire, smoke, etc.).

PALAEMON Intelligence Framework. This sub-system consists of independent services (i.e. Modules) that process the raw information gathered by the sensors and the field devices and feed the new information to the PALAEMON dashboard. These toolkits provide the following information: 1) a visual overview of how the evacuation is progressing on top of the plans and schematics of the ship (Smart Safety System, developed in Task 3.1), 2) an evaluation of the ship's stability (Stability Toolkit, developed in Task 3.2), 3) an evaluation/correlation of the prevailing weather conditions with the ongoing evacuation (Weather Forecasting Toolkit, developed in Task 3.3), 4) an evaluation of the risk of loss of life as a function of ship status and progress of the evacuation (Smart Risk Assessment Platform, developed in Task 3.5), and 5) the smart retrieval of relevant procedures to be followed during the evacuation (Safety Procedures, developed in Task 3.4).

PALAEMON Dashboard. The main functionality of the PALAEMON dashboard is to support the decisions of the Master and Bridge team by providing them with comprehensive and easy-to-use information regarding the progress of the evacuation, which is provided by the PALAEMON Intelligence Framework and the underlying PALAEMON field devices and sensors. The dashboard will include an integrated Decision Support System (PALAEMON DSS, developed in Task 6.4) that will gather information from the PALAEMON ecosystem and provide the ship's Master with recommendations/guidance to support his/her decisions, for example, to evacuate the ship or not and how to proceed with the evacuation most effectively and with minimal risk. The PALAEMON dashboard also provides information regarding the status of the ship and the evacuation process to the VDES module (developed in Task 7.4), which broadcasts this information to the relevant competent authorities and to other ships.

PaMEAS. The main functionality of this sub-system, which is developed in Task 5.4, is to gather real-time information regarding the locations of the crew and passengers during an evacuation (e.g., via the Smart Bracelets), and broadcast personalized evacuation-related information to the Crew Response and Rescue Teams and passengers (e.g., via Smartphones,, Smart Bracelets, and the AR Glasses).

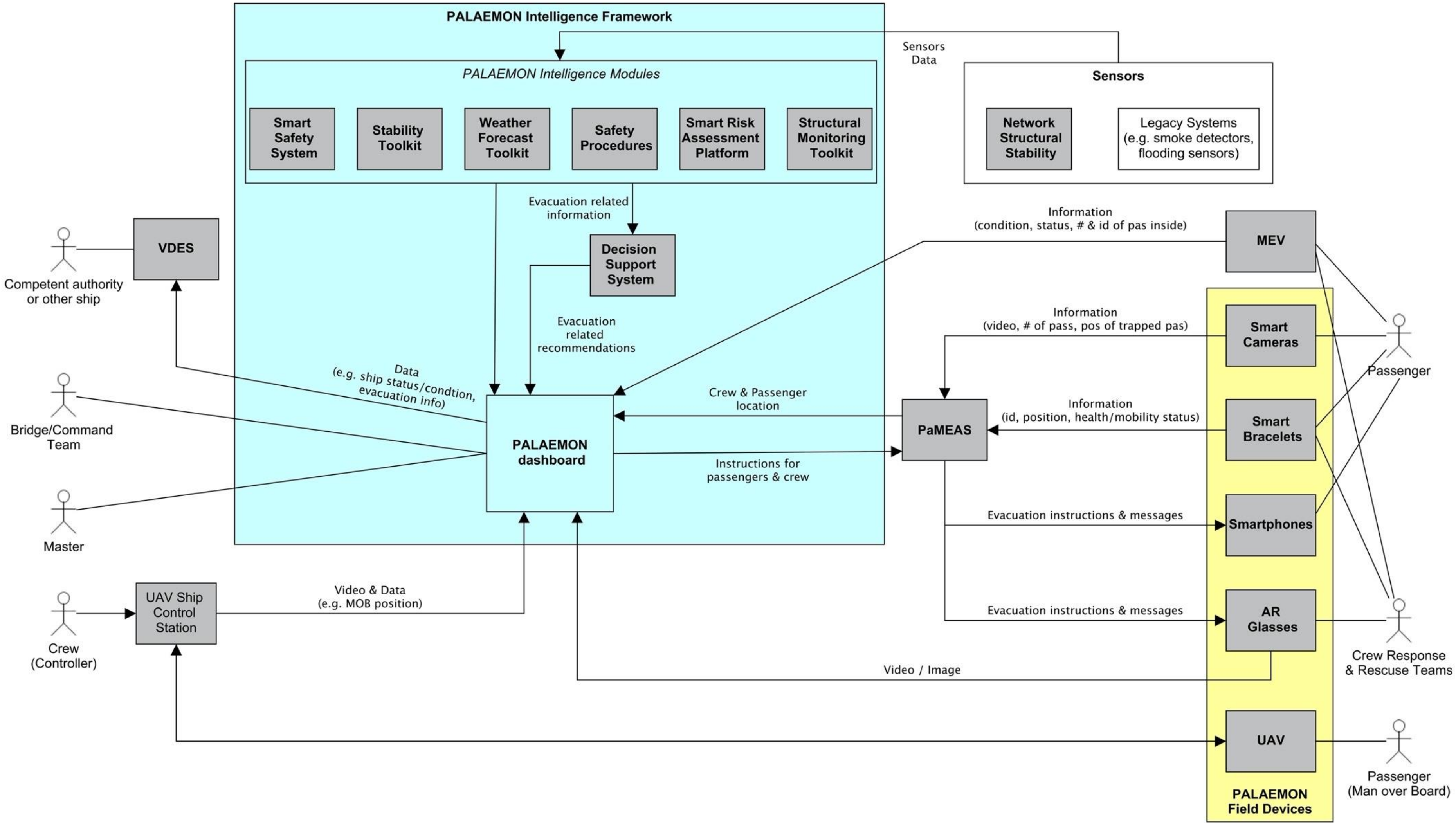

Figure 4: Functional dependencies among the PALAEMON components.

5 Stakeholder identification for maritime evacuation

This section presents the results from the PALAEMON stakeholder identification process that includes the categories of stakeholders that are considered most relevant in the maritime evacuation process. A stakeholder is an individual or organization having a right, share, claim, or interest in a system or in its possession of characteristics that meet their needs and expectations (ISO/IEC 15288). The stakeholders were identified in relation to their vicinity to the operation of the PALAEMON ecosystem and were situated in the following domains (Figure 5): operational work area, the containing business, and the outside world. In addition, the stakeholders were classified in the following classes that share a stake in relation to the PALAEMON ecosystem:

- Maintenance – Service Providers, Developers-manufacturers, and End-users (Operational work area). They directly interact with the system throughout its life cycle, including the design, and operation and maintenance phases.
- Training, and Verification & Certification Providers (The containing business). They ensure that the system fulfils its business and design goals.
- Maritime Authorities, and Industry Standards Bodies (The outside world). They ensure that the operation of the system does not have any adverse impacts to human life, the environment, and property.

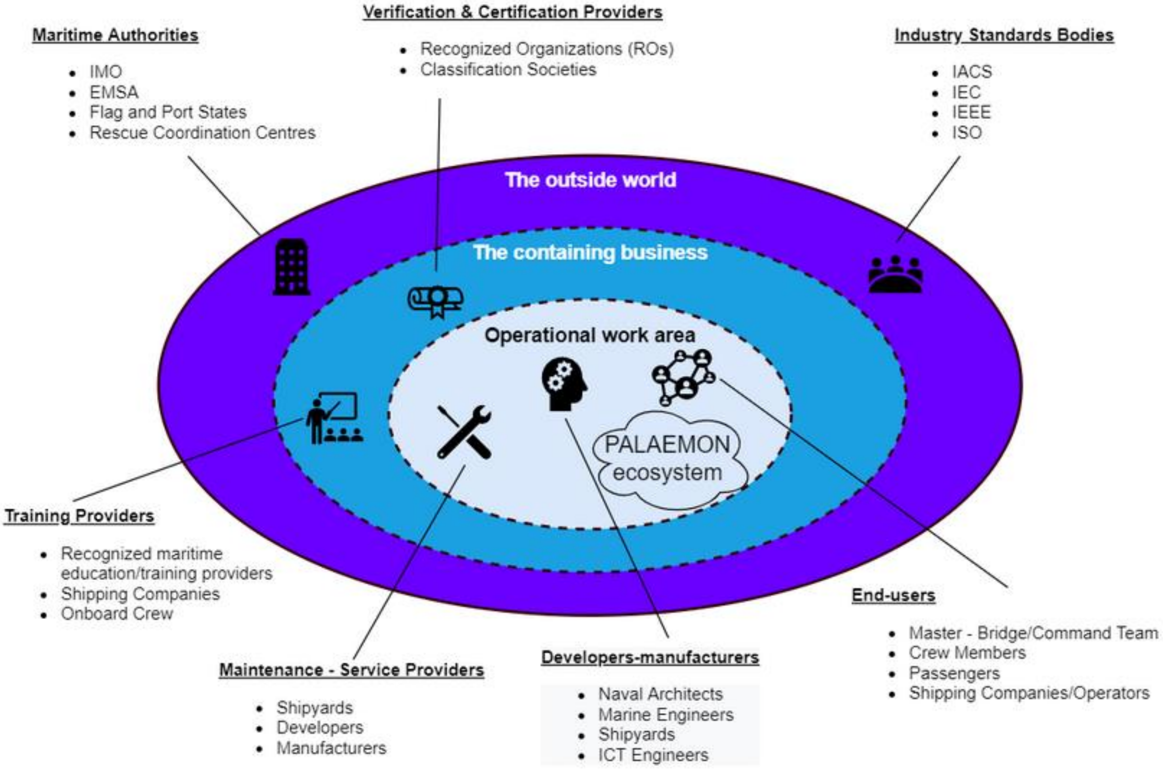

Figure 5: PALAEMON Stakeholder Map, based on the guidance from the VOLERE framework.

The following list describes the identified stakeholders for each domain, the rationale for including them in the requirements elicitation process, and the knowledge they have to offer regarding the PALAEMON ecosystem.

5.1 Operational Work Area

Class	Maintenance and service providers
Role	Shipyards, developers, manufacturers
Rationale	Their prime responsibility is to keep a system well maintained and functional on a regular basis once it has been delivered
Classes of Knowledge	Performance, Operational Environment, Maintenance

Class	Developers-manufacturers
Role	Naval architects, marine engineers, shipyards, ICT engineers
Rationale	They are responsible for the design and construction of the PALAEMON components.
Classes of Knowledge	Technical constraints, Functionality, Performance, Maintenance, Design Ideas

Class	End-Users
Role	Master – Bridge/Command Team
Rationale	The Master and the Bridge/Command Team ought to perform continuous monitoring and assessment of any emergency (including ship abandonment) and respond accordingly. To do that, they must receive as much and accurate real-time information as possible regarding the incident and its evolution by using every available means. Notably, the role of the Master is vital because all the decisions are made from him. Thus, he should be provided with not only suitable information but also with guidance and advice to assist him in his decision-making process.
Classes of Knowledge	Technical Constraints, Functionality, Usability, Operational Environment, Design Ideas, Experience in critical scenarios

Class	End-Users
Role	Crew members
Rationale	Their primary role will be to use/operate the PALAEMON components in case of an emergency. They will also keep the system well maintained and available. During an emergency, the crew members must implement the emergency procedures, and act deliberately, swiftly, and calmly. Some important aspects that affect the crew's performance during an incident are their training, their situation awareness, their adaptability to complex scenarios, the level of information they receive, and the quality of the communication with the Master and the Bridge/Command Team and between them.

Classes of Knowledge	Technical Constraints, Functionality, Usability, Operational Environment, Design Ideas

Class	End-Users
Role	Passengers
Rationale	In case of emergency, the passengers must be guided and assisted in every way to evacuate the ship in an as safe, fast, and convenient manner as possible. Their primary role during ship abandonment is to follow the instructions given by the Master/Command Team and the crew members.
Classes of Knowledge	Usability, Design Ideas

Class	End-Users
Role	Shipping companies/Operators
Rationale	Shipping companies, including cruise ship and passenger ship operators, must maintain safe practices in ship operation and offer a safe environment for passengers and crew members as well. The companies must establish plans and procedures for key shipboard operations concerning the safety of personnel, ship, and protection of the environment. The companies must also identify potential emergency shipboard situations (such as ship abandonment) and establish procedures to respond to them. Shipping companies also include emergency response teams, which comprise technical staff of the company and support the decisions made during emergencies (e.g., can perform calculations).
Classes of Knowledge	Goals, Business Constraints, Functionality, Operational Environment, Maintenance, Design Ideas

5.2 The Containing Business

Class	Training Providers
Role	Recognized maritime education and training providers, shipping companies, shipboard crew (“training” to passengers)
Rationale	Before being assigned to shipboard duties, all crew members must receive appropriate training by recognized maritime education and training providers. Moreover, IMO regulations require seafarers and other personnel working on passenger ships to have specific additional safety and emergency training. Onboard the ship, the seafarers are trained for emergencies through an appropriate training program established by the shipping company. This system of emergency training and education includes procedures and activities developed to familiarize shipboard personnel with the provisions of the onboard safety system/plans. It also includes a program of drills and

	exercises to prepare shipboard personnel to deal with potential shipboard emergencies. Passengers are given a ship-specific safety briefing by means of announcement before or immediately after departure. Information cards, posters or video programs displayed on ship's video displays may be used to supplement the passenger safety briefing. Passengers may also participate in onboard drills and exercises under the supervision of the crew.
Classes of Knowledge	Goals, Operational Environment

Class	Verification & Certification Providers
Role	Recognized Organizations, Classification Societies
Rationale	All shipboard life-saving appliances and arrangements must be verified and approved/certified by the Administration (Flag State) or an approved Recognized Organization (RO). The Administration/RO ensures that the life-saving appliances and arrangements, including ICT components, are evaluated, and tested to ensure that they provide safety standards at least equivalent to the requirements of the applicable mandatory rules and regulations. In general, ROs (i.e. classification societies) verify that the construction of a vessel, its machinery, and its equipment comply with relevant technical and operational standards and carry out surveys to ensure these standards are maintained. Every vessel is built according to the rules of the selected classification society. The equipment provided by the yard and installed onboard is usually type approved by the same classification society facilitating this way the systems verification during newbuilding. Apart from the newbuilding phase, the role of classification society also extends during the lifetime (operation) of the vessel by conducting surveys periodically to ensure compliance with class and international rules and regulations. Additionally, classification societies can also conduct surveys on behalf of the flag state where the vessel is registered, ensuring compliance with the international maritime laws. Administrations also verify continuing compliance with these standards by performing audits and inspections. In other words, Administration/ROs ensure compliance to international regulations.
Classes of Knowledge	Technical Constraints, Safety, Security, Regulatory, Maintenance

5.3 The Outside World

Class	International, Regional, and Governmental Maritime Authorities
Role	IMO, EMSA, Flag and Port states, Rescue Coordination Centres
Rationale	International and regional rules and regulations, as well as national laws, determine and influence what a system may or may not do. Relevant authorities are responsible for the implementation and oversight of these rules and regulations. Maritime authorities include rescue co-ordination centres whose purpose is to coordinate and control search and rescue operations.
Classes of Knowledge	Goals, Regulatory, Performance, Safety

Class	Industry standards bodies
Role	IACS, IEC, IEEE, ISO
Rationale	Existing and future standards can affect the goals of a proposed system. The industry has professional bodies that expect certain standards to be maintained by any product built within the industry or for use by the industry.
Classes of Knowledge	Goals, Performance, Safety, Security

6 Stakeholder needs

This section lists the stakeholder needs that have been identified from the focus group that was conducted on the 14th of August 2019 in the premises of Johanniter Austria, the workshop that was conducted in Athens on 25-26 of November 2019, the users/stakeholder's interviews conducted in the context of Task 2.2, as well as the maritime evacuation state-of-the-art analysis conducted in Deliverable 2.1 (NTUA, 2020). Details about the focus group, workshop and interviews conducted in the context of Task 2.2 are provided in the Appendix.

6.1 PALAEMON system

PALAEMON shall …	Rationale
be able to function in emergency situations and under extreme/adverse conditions	In general, existing ICT systems are not designed for emergency situations. For example, ICT systems will normally crash in case of loss of ventilation / extreme heating.
be able to function along with the existing / legacy systems and receive information (inputs) from them	PALAEMON will not replace the existing / legacy systems, but it will function as a supplement to them, aiming to enhance the current evacuation process. It will also exploit the information already available by them.
have redundancy	To decrease vulnerability and increase the reliability of the PALAEMON components.

PALAEMON shall …	**Rationale**
be powered by an emergency source of electrical power	To enable PALAEMON components to function independently of the availability of the ship's main source of electrical power.
not increase the workload of the crew	To avoid having a negative effect on the situational awareness of the crew.

6.2 Mass Evacuation Vehicle (MEV)

MEV I shall …	**Rationale**
have a modular design with a low cost of production	To keep the cost of the vessel as low as possible and make the design commercially attractive and viable. The available vessels in the market have a non-uniform and unstandardized design. This has a negative impact on various aspects of MEV operation such as crew training.
be reusable	MEV should not be a one-off evacuation platform. The reusability of the MEV has implications in its functionalities as a means of evacuation and as an evacuation training/drills device. The MEV is not expected to act as a tender boat for cruise ships to take passenger on shore.
be equipped with seats for the passengers. The number of seats shall correspond to the passenger capacity of the vessel	MEV should provide enhanced ergonomics in terms of interior design compared to traditional very large capacity lifeboats which are equipped with simple benches for the evacuees.
be launched by a hydraulic mechanism (using hydraulic accumulators)	To use the least space possible for the MEV launching system. A hydraulic system could be more compact than a gravity davit. To be independent of electrical power.
have reduced complexity	The MEV and its components should have a design and implementation of the least possible complexity to facilitate manufacturing and reduce the cost of the vessel.
provide easy access to passengers with mobility issues	The ergonomics of the interior design of the MEV should enable easy access to individuals with mobility issues i.e. elderly people, disabled people, people with wheelchairs, etc.
be easily maintained	MEV's maintenance should not be a complex process. The components of the MEV should be easily retained in a state in which they can perform their intended function.

MEV I shall …	Rationale
be easily inspected	The MEV's design shall facilitate the inspection procedures required by all stakeholders including the relevant authorities (i.e. surveyors, inspectors, etc.).

6.3 Smart Bracelets (SB)

Smart Bracelets shall …	Rationale
replace cruise ship ID cards and provide their functions (access to the ship, cabin door key, onboard charge account, basic passenger information, etc)	To reduce the items a passenger must carry with him/her. To make the bracelet part of the passenger's life on board the ship to convince him to wear it.
transmit basic information for the health condition of the individual (passenger or crewmember)	The Master/Command Team will monitor the health status of passengers and crewmembers during the evacuation process. Thus, they will be able to aid those needed i.e. persons remaining immobilized.
enable localization/tracking of an individual in the water. Bracelet shall function as a beacon	Current search and rescue procedures in man overboard scenarios are based on visual detection of the individual (or of the light coming from the lifejacket lamp) and/or on hearing the lifejacket's whistle.
collect and transmit useful information such as room temperature	Passengers can become moving sensors.

6.4 Augmented Reality Glasses (ARG)

AR Glasses shall …	Rationale
be easy to use, practical and reliable	The AR Glasses should be user-friendly in terms of functionality and wearability. They should not present a challenge and an additional burden for the crew members. They should also be readily available and functional in case of emergency.
provide visual guidance and instructions to the crewmembers for the rescue/evacuation of trapped/incapacitated passengers	To assist the search teams in their task.
display instructions for the crewmembers approved by the Master	During an incident, the crewmembers receive instructions regarding their actions (via VHF communication, general announcement in the public address system, etc.) by the Master/Command Team. These instructions can also be communicated to them with the help of the AR glasses.

AR Glasses shall …	Rationale
be used in low visibility conditions	To be used in case of smoke, low-light, etc.
enable two-way voice communication between the crewmembers and the bridge	To enable the exchanging of information between the bridge and crewmembers.
be able to be used in conjunction with an Emergency Escape Breathing Device (EEBD)	The use of AR glasses must not obstruct the use of EEBD. EEBD is a self-contained compressed air apparatus used as a lifesaving appliance for escaping from a toxic or oxygen-deficient environment (such as an area with smoke, poisonous gases, etc.).
be usable by people wearing glasses	The use of AR glasses must not impair the eyesight of people with glasses.

6.5 Smart Cameras (SM)

Smart Cameras shall …	Rationale
enable identification of passengers assembled in muster stations through face recognition	To automatically identify individuals assembled in the muster stations and count them (considering relevant GDPR provisions). Thus, any missing passenger shall be identified. Search and rescue actions will commence by the crew (search team) if instructed accordingly (by the command team).

6.6 Unmanned Aerial Vehicle (UAV)

UAV shall …	Rationale
be used in Man Overboard (MOB) scenarios	To enable fast scanning of a large area to detect individuals in the water.

6.7 PALAEMON dashboard (Dash)

PALAEMON dashboard shall …	Rationale
assist the Master to decide whether to proceed with the actual evacuation of the ship or not	Decision making in an emergency takes place in a rapidly changing environment and under very pressing and stressful conditions. The system should effectively support the Master in his/her decision-making process to choose the right course of actions to deal with the incident. It will not replace his/her judgement, but it will extend his capabilities.
display all the available information on a single screen and in a plain form	To integrate and simplify all the available information to facilitate and accelerate the decision-making process for the user. In case of emergency, the information provided must be kept to a minimum.
display automatically real-time information regarding the weather	The system should be able to provide to the Master all critical information available from both PALAEMON

PALAEMON dashboard shall …	Rationale
conditions, the stability and structural integrity of the ship, the location of fire or flooding, etc	components and ship legacy systems to support his/her decision making.
display guidance/advice for the Master provided by the company emergency response team	The company emergency team can be a valuable help to the Master during an emergency by providing their knowledge, expertise, experience, etc. and by utilizing the company's available resources/support (internal and external).
enable continuous situation monitoring to the Master	To enhance the situation awareness of the Master and assist him/her in evaluating the emergency situation correctly.
receive inputs from various legacy systems (safety-related)	To provide situational awareness to the Master by collecting safety-critical information (inputs from fire detection system, flooding detection system - bilge level alarms, fire doors, fire dampers, ventilation, etc.).
display the status/availability of lifeboats along with alternatives in case some of them are disabled/inaccessible	The Master/Command Team should be aware of which lifeboats are available and operational to direct the passengers and crew members accordingly.
display the development of the lifeboat launching	The Master/Command Team should be able to monitor the lifeboat launching stage more effectively.
provide automatically contact information about emergency response/search and rescue authorities, port facility authorities, etc	To reduce the workload of the Master/Command Team during the emergency.

6.8 Passenger Mustering and Evacuation Automation System (PaMEAS)

PaMEAS shall …	Rationale
inform the passengers and the crewmembers regarding the emergency situation and its development	The Master/Command Team will be able to communicate more effectively the evacuation plan and relevant/useful information to the passengers and crewmembers. Keeping everybody well informed can also work as a crowd management measure (it supports the mental and psychological state of passengers and crewmembers).
inform the passengers for the stages of the evacuation process and the procedures to be followed on a step by step basis	Passengers need to receive instructions regarding what they must do during the evacuation process.

PaMEAS shall …	**Rationale**
provide the passengers with clear and simple information	Passengers need to receive only crucial information and not to be overwhelmed by it.
be a multi-language application	To provide information to passengers and crewmembers in a language they fully understand.
inform passengers and crew members about alternative muster station and evacuation routes in case the primary muster station and/or evacuation route is disabled/not reachable	The evacuation plan/routes can change due to the incident (e.g. fire) and its evolution. The new evacuation plan/routes need to be communicated effectively to the passengers and crewmembers.
be used for passenger's familiarization with the evacuation process/procedures	To inform passengers about the safety procedures, with special emphasis on evacuation relevant information.

7 High-level use cases

This section explains the operation of the PALAEMON ecosystem, by describing high-level use cases in UML diagrams and the narrative of an indicative operational scenario. Furthermore, the operational conditions that could affect the PALAEMON components' performance and their rationale are presented.

The operational scenario and the functionalities of the PALAEMON components that are described therein may be considered as the long-term (full-scale) vision of PALAEMON, which outlines a fully automated system. Considering that such a scenario is not possible in the short and medium terms, Deliverable 2.4 (Task 2.3) will propose two or three scenarios that can demonstrate the functionality of the PALAEMON system in the context of the pilot demonstrations to be conducted in Work Package 8.

7.1 Operational Scenario

The aim of this sub-section is to provide examples of the utilization of the PALAEMON ecosystem as viewed by its potential end-users: passengers and crew members. Figure 6: Utilization of PALAEMON ecosystem by passengers (end-users). presents the basic functionalities from the perspective of their usage from a passenger while Figure 7 shows the potential capabilities offered to the crew members. In both cases, actions taken while in emergency shall be considered. Subsequently, this sub-section includes a specific example that explains in detail the key elements and functionalities of the PALAEMON ecosystem.

An indicative use case of the PALAEMON ecosystem is provided below by describing what may happen during the evacuation phases of a hypothetical scenario. The scenario presented describes the potential use of the PALAEMON ecosystem after the collision of a passenger ship with another vessel that results in the abandonment of the passenger ship.

Incident occurrence – Initial assessment

During the trip, the passenger ship collides with another vessel, which activates the PALAEMON ecosystem incident mode. Following the collision, the Master and the Bridge/Command Team receive the initial crew reports regarding issues such as the overall condition of the ship, the inflicted damage, and any injuries. A further investigation regarding the extent and severity of the sustained damage is carried out by the dedicated Emergency Response Crew Teams. The position and identity of each crewmember (transmitted by their smart bracelets) are displayed in real time on the PALAEMON real-time smart dashboard (from now on called PALAEMON dashboard). This enables an effective overview and coordination of the emergency response crew teams by the Master and the Bridge/Command Team. One of the first actions of the crew is to launch the available UAV to help identify and assess the inflicted damage to the ship's hull. The UAV transmits in real-time to its control station and the PALAEMON dashboard a video feed of the exterior of the damaged ship area.

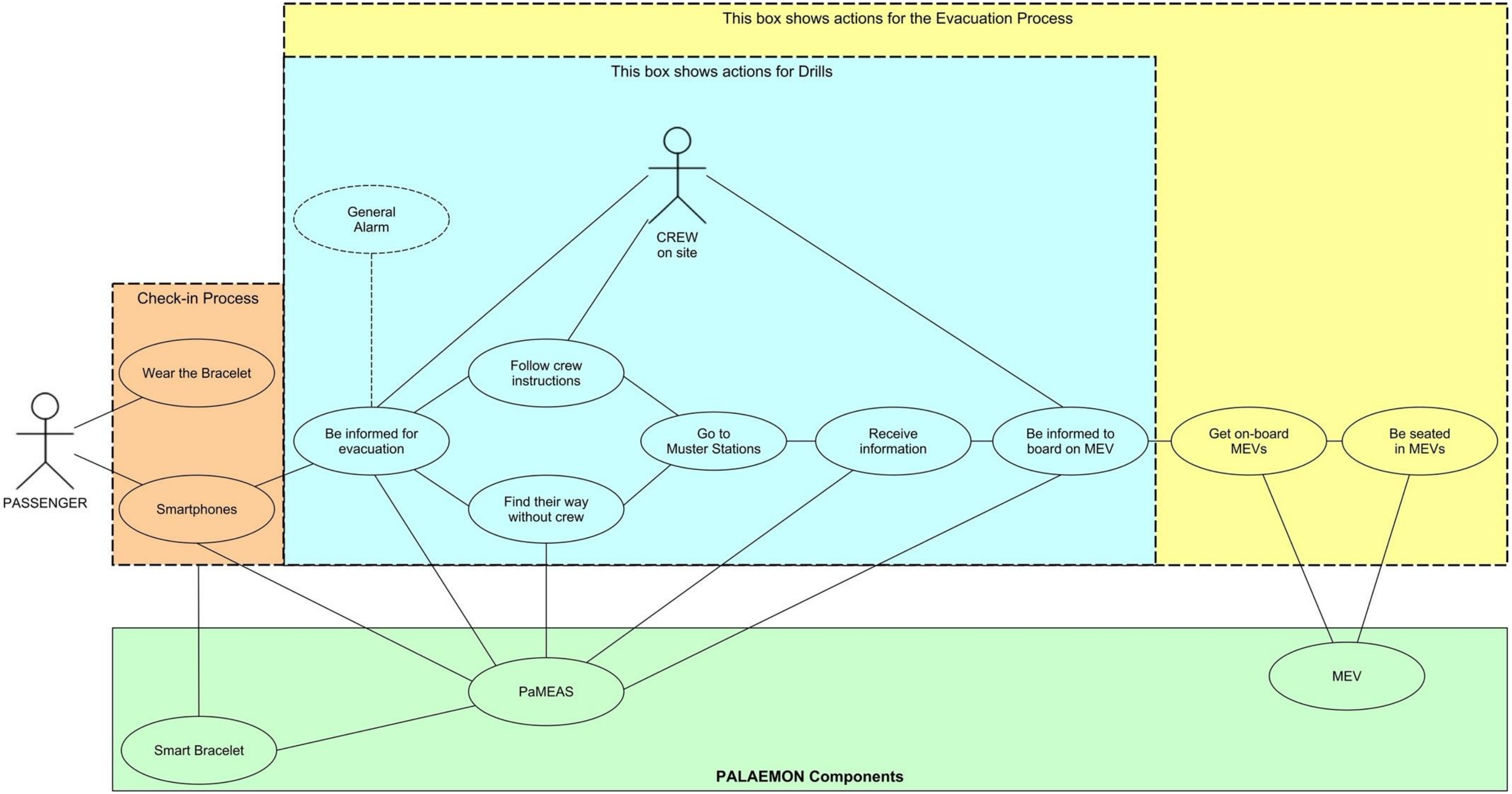

Figure 6: Utilization of PALAEMON ecosystem by passengers (end-users).

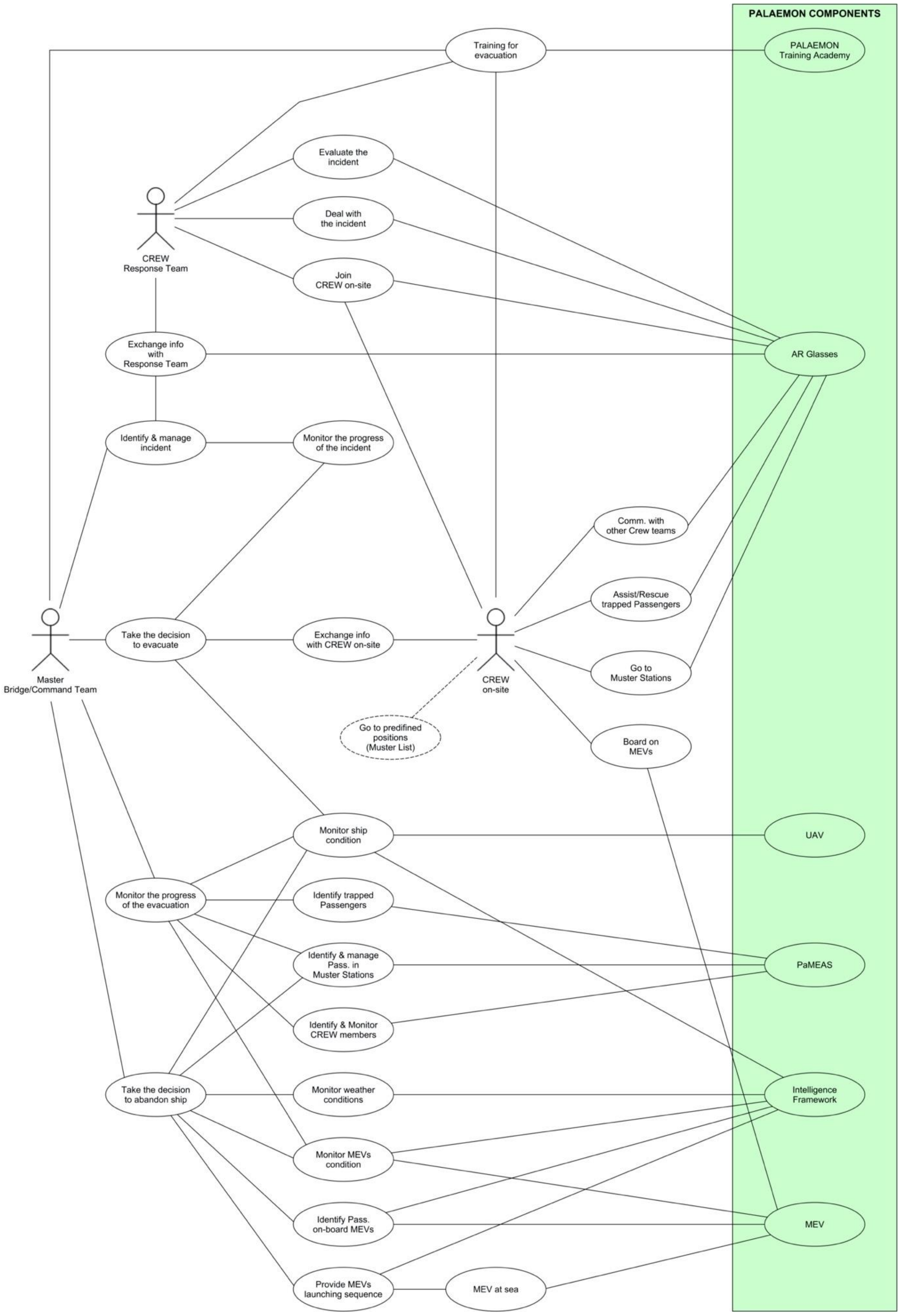

Figure 7: Utilization of PALAEMON ecosystem by onboard crew (end-users).

Meanwhile, the PALAEMON ecosystem is used by the Master and the Bridge/Command Team of the ship to assess, in real-time, the status and condition of the ship by evaluating the incoming information from the PALAEMON components and the ship safety/monitoring systems that are already available onboard. This information is made available through the PALAEMON dashboard, which receives data regarding the intact and damage stability of the ship (PALAEMON stability toolkit), the structural condition of the ship (PALAEMON structural monitoring toolkit), and the weather conditions (PALAEMON weather forecast toolkit). The PALAEMON ecosystem also exploits information from the ship's legacy systems, such as the regarding the presence of fire/smoke in specific spaces(legacy fire/smoke detectors) or regarding the flooding of specific compartments(legacy bilge/flooding sensors).produces the optimal evacuation plan for the moment. This updated evacuation plan is used as the basis for the personalized evacuation path/instructions to be sent to each individual onboard (passenger or crew member).

Sounding the General Alarm

The initial assessment of the sustained damage reveals that the inflicted damage is severe. After consulting the guidance provided by the PALAEMON dashboard, the Master decides to initiate the ship's evacuation process. The dedicated alarm signal is sounded (i.e. General Alarm which consists of 7 short and 1 long blasts), along with the appropriate verbal announcement from the ship's public address system. By exploiting the information provided by the PALAEMON ecosystem and the ship's legacy systems, PALAEMON produces/updates the optimal evacuation plan, which is used as the basis for the personalized evacuation path/instructions to be sent to the passengers and crew members.

Mustering stage

With the initiation of the ship's evacuation process, PaMEAS broadcasts a dedicated alarm signal-message (via the smart bracelets and smartphones) that informs all passengers and crew members that the evacuation process has begun and they need to proceed immediately to their muster stations. Following the alarm message, PaMEAS broadcasts to the passengers and crew members real-time and location-specific information regarding the optimal route they have to follow to reach their muster stations unharmed. These broadcast message also disclose GDPR-related information that allow the PALAEMON ecosystem to start handling sensitive personal information.

With the help of the smart bracelets and smart and/or legacy cameras, the Master and the Bridge/Command Team are in a position to know information in real-time, such as the location, identity, mobility and health status of every passenger and crew member onboard and thus monitor the evolution of the evacuation process through the PALAEMON dashboard.

During this phase, the Master and the Bridge/Command Team may cope with several evacuation related incidents with the help of PALAEMON, as the following indicative examples describe.

Example 1: The Bridge/Command Team receives on the PALAEMON dashboard an alarm regarding two passengers that remain stationary in their room.

According to the personal data (identity and health status) transmitted by their smart bracelets, the passengers are identified as a couple of elderly people, and their health seems to be fine. PALAEMON transmits appropriate navigation instructions (optimal evacuation path) and the personal information of the passengers (e.g., identity, location) to the AR glasses of the closest Search & Rescue Team, after receiving confirmation from the Master and the Bridge/Command team by generating an appropriate alarm message on the PALAEMON dashboard. The Search & Rescue Team proceeds to evacuate the trapped passengers by using their knowledge and skills and consulting the instructions received through their AR glasses. During the rescue process, the Search & Rescue team exchanges information with the Master and the Bridge/Command Team (e.g., receive further instructions, inform about the immobilized passengers, transmit any safety-related information, etc.) by using the verbal two-way communication capability of the AR glasses.

Example 2: One passenger remains stationary in a public corridor.

According to the personal data (identity and health status) transmitted by the smart bracelet, the passenger is identified as a middle-aged woman, and her health status seems to be impaired (she has a low pulse). As in the previous example, PALAEMON transmits the necessary information to the AR glasses of the closest Search & Rescue Team. The Search & Rescue Team proceeds to evacuate the immobilized passenger by consulting the instructions received in their AR glasses and exchanges information with the Master and the Bridge/Command Team. The available personal information (e.g., identity and health status) of the immobilized passenger is also transmitted to the ship's medical personnel to alert them and prepare appropriate response actions.

Example 3: A specific stair is congested with passengers.

The congestion is identified by PALAEMON through the data collected from PaMEAS, which are transmitted by the smart bracelets and the smart cameras. The PALAEMON dashboard generates an appropriate alarm message for the Master and the Bridge/Command Team. Following the Master's permission, a number of crew members are dispatched to assist the respective passengers. They receive the respective instructions through the two-way verbal communication component of their AR glasses and/or their VHF radios.

In the muster stations, the assigned crew members receive the incoming passengers, count them, distribute lifejackets to them, assist them with life-jacket donning, brief them regarding the situation and try to keep them calm. By using the passenger localization/tracking information of PALAEMON (provided by the smart bracelets and the smart cameras), the crew members can know simultaneously the identity and number of passengers having assembled in the muster station. The same information is also available to the Master and Bridge/Command Team through the PALAEMON dashboard. Besides the briefing and instructions provided by the crew members, the passengers in the muster stations also receive relevant information on their smartphones. As the assembly of passengers progresses, the crew members in the muster station, by accessing the PALAEMON localization/tracking information, can know which passengers are still expected to arrive and if there are passengers that have reached another muster station.

During the mustering stage, the life-saving appliances of the ship (MEVs, life rafts, marine evacuation systems, etc.) are being checked and prepared for launching and deployment. The Master and Bridge/Command Team, by exploiting the relevant information provided by the PALAEMON dashboard through the special sensors on the MEVs, can know the availability/operational condition of the MEVs at the initiation of the evacuation and monitor it during the evolution of the process. If a MEV is or becomes unavailable/not operational, the Master and the Bridge/Command Team will know it as early as possible and distribute the passengers to other available means of evacuation.

Embarkation stage

During the embarkation stage, the Master, the Bridge/Command Team and the crew assigned to each MEV can know simultaneously the identity of passengers entering the MEV and their total number by using the passenger localization/tracking information transmitted by the smart bracelets and the MEV's passenger's identification system. All the relevant information is displayed on the PALAEMON dashboard and in the MEV. Thus, the embarkation status of each MEV can be monitored effectively in real-time. This information also helps the Master and the Bridge/Command Team to manage more efficiently the MEV's launching sequence. Moreover, the information on the identity and number of passengers inside each MEV is transmitted by the VDES to the relevant search and rescue authorities and to other ships.

Abandonment – Launching of survival crafts

The Master and the Bridge/Command Team receives through the PALAEMON dashboard real-time information regarding the MEVs' embarkation status (i.e., if all crew members and passengers are onboard). The PALAEMON system provides to the Master the proper launching sequence. Upon approval of the Master, a final VDES signal that contains the latest update on the ship and evacuation process status is transmitted to the relevant search and rescue authorities and to other ships and the Master along with the Bridge/Command Team board the last MEV to abandon ship.

Clearing from the ship and waiting for rescue

After launching, MEVs manoeuvre clear of the ship's side and any floating obstructions. They remain in the vicinity of the vessel to marshal other survival crafts (e.g. life rafts) and tow them away from the ship. The crew of the MEVs also search for survivors in the water. One of the MEVs launches the available UAV to assist with the detection of people who need to be recovered from water, by using its sensors and transmits their location to the MEV.

7.2 Operational Conditions

This sub-section identifies the operational conditions that could affect the PALAEMON components' performance, and therefore shall be considered when specifying use cases and defining functional requirements.

7.2.1 Mass Evacuation Vehicle (MEV)

Parameter	Rationale
Weather conditions Wind speed (usage of ship's anemometer) Sea State (e.g. represented by significant wave height and peak period, or sea force number)	• The safe launching of the MEV can be deteriorated by the wind loads and • The stability, strength, seakeeping, and controllability of the MEV while at sea that could put at risk passenger's survivability.
Ship motions Dynamic motions: (e.g. roll and pitch motions angle, heave and lateral motion): fast motions timescale Development of list angle due to damage / flooding: slow time scale	• Safe launching of MEV can be affected by the relative ship motions. • Launching capability represented by limiting values of trim and heel angles and the height above waterline • Rate of embarkation may be affected.
Embarkation and Position on deck	• Easiness of access and embarkation time. • Affected by the high-risk areas (e.g. fire/smoke can prohibit the boarding to the MEV). • Embarkation areas adequate for special category passengers.
Exposed to fire and strength	• Materials shall be in accordance with the requirements of international regulations.

7.2.2 Smart Bracelets (SB)

Parameter	Rationale
Signal Strength and connection to the system	• Signal shall not be affected by the complex geometry and the ship's environment (presence and materials of decks, bulkheads). • Connection shall be capable for passengers that are located on open decks. • Ability to transmit in congestion (highly density areas).
Operational conditions	• Operation shall be maintained in adverse conditions (high temperature /presence of smoke / humidity / sweat). • Shall be water resistant covering cases for man overboard or for passengers in flooding scenarios.
Readability and level of lighting	• In case and kind of information is provided through the bracelet, this shall be visible in poor visibility

Parameter	Rationale
	conditions due to the presence of smoke and low-light conditions.
Sampling frequency	• Variable frequency sampling depending on the PALAEMON operational mode (e.g. in incident mode a high frequency sampling is needed, less than 5 s). • The system shall know when a bracelet is not carried in passengers' hand (e.g. left in cabin, lost during mustering).
Age of user	• Account for different capabilities when used in normal operation (e.g. payment, door key).

7.2.3 Augmented Reality Glasses (ARG)

Parameter	Rationale
Operation in poor visibility and noise	• Shall be able to operate in the presence of smoke, poor visibility, and lighting conditions, and to adjust the quality of the information shown. • Any audible signal shall be cleared heard in noise conditions.
Operation in fire	• High temperature and flames can affect the information. • Shall safely operate in a spark sensitive environment.
Connectivity	• Quality of signal received can be affected by ship geometry and type of materials used.

7.2.4 Smart Cameras

Parameter	Rationale
Location of cameras	• It shall provide a service as checkpoints; their location onboard will be critical to effectively monitor the required process (e.g. passenger's flow).
Number of recognitions per unit time	• Capability to identify and count multiple passengers within a specific place (e.g. corridor).
Operation in low visibility conditions	• Emergency lighting, presence of smoke.
Operation while ship in motion or heel angle is increasing	• Examine whether results can be disturbed due to the unsteadiness (or progressive list) of camera.
Connection to the emergency source of electrical power system	• Capability the system to be in operation when ship's main power supply system has failed.

7.2.5 UAV

Parameter	Rationale
Weather conditions	• Shall be capable to operate in the averagely weather (defined by mean wind speed wind) conditions. • Shall be capable to identify man overboard in a severe sea state.
Operation in poor visibility	• In some cases of an emergency (e.g. fire with spreading of smoke such as in the case of a balcony fire), the user of the UAV shall be able to handle it safely within a distance that could allow basic information to be seen for the camera. • Dependent on the type of camera available, information provided to the user in the presence of smoke, fog and generally poor visibility conditions could enhance crew's reaction in the case of an emergency (e.g. man overboard
Autonomy time and maximum distance covered	• It shall be defined for a set of motions e.g. turns around ship with a given ship in the steady height.
Area needed for take-off and landing	• A dedicated place onboard shall be arranged for the proper storage.
Readiness to use	• Shall be able to take off immediately when needed to not lose time in an emergency situation.
Autonomy level to be known to PALAEMON System	• It shall be known to the system the remaining operating time until safe landing.

7.2.6 Passenger Mustering and Evacuation Automation System (PaMEAS)

Parameter	Rationale
Capability of performance in the presence of emergency situations (fire, flooding)	• Such emergency situations can impose a risk to the system architecture (hardware, connections, servers, etc).
Loss of main power supply	• Such an event could be probable in an emergency situation, this the system shall be capable of operating from the emergency power supply.
Bandwidth and technical specifications to cover the expected demand in emergency situation	• Coverage, in terms of signal receiving and transmitting, of all areas where passengers and crew may be located. • Demand in terms of data transfer. • AR glasses, smart bracelets, Smart cameras, and smartphones are the main connection systems.

7.2.7 PALAEMON dashboard

Parameter	Rationale
Loss of main power supply	• The system shall be capable of operating from the emergency power supply until safe launching of all MEVs has been performed.
Failure of connection with a sub-system or when a when part of the required information is missing	• The system shall be able to identify and visualize whether the connected sub-systems (e.g. stability toolkit, legacy systems, PaMEAS) are providing the required information as intended or not. • The system shall be capable of identifying the source of the loss signal or missing information. • The system shall be able to evaluate the impact of loss information in the current status and provide alternatives (e.g. by-pass) when one of its components has failed in order to not stop the service. • Manually inserted input shall be permitted.

Passenger and crew status on emergency	• The system shall provide real-time information about:
	  ○ Passenger's status (individual's exact location, direction of movement and health data, % in muster station, % in MEV's.
	  ○ Similarly, for crew.
	  ○ Localisation shall be shown with a prescribed accuracy (e.g. 0.5 m). Status of whether a bracelet is carried by a passenger can be related with health data.
	• Assign a risk level per group/space.

Condition of the status of ship's critical systems on emergency	• The system shall be aware of the real-time status of all critical systems and sub-system that affect ship's survivability.
Ship status in an emergency condition: (e.g. flooding, fire)	• The system shall be able to provide to crew information about ship's status such as real-time prediction of heel and trim angle, real-time estimation of the available time for safe abandonment, Main Vertical Zone status. • The system shall be able to receive and analyse information provided by the stability toolkit, weather forecasting, structural monitoring toolkit, MEV status and other ship's legacy systems (fire/smoke and flooding monitoring systems).
Risk mitigation	• Provide specific instructions for the risk mitigation of selected group or ship's space. • The system shall be able to present to its user how risk level is changed from the proposed actions.

8 Regulatory constraints

This section presents the regulatory constraints, from the relevant regulatory framework, that may result in both functional and non-functional requirements for the PALAEMON ecosystem. The non-functional requirements implied in this section are not part of the functional requirements listed in this report but will serve as a basis for the further development in PALAEMON.

8.1 International Regulations (SOLAS)

The SOLAS Convention specifies minimum standards for the construction, equipment, and operation of ships, compatible with their safety. Certain provisions of SOLAS CHAPTER III (Life-saving appliances and arrangements) have a direct connection with the PALAEMON components and will be detailed below.

Terms such as float-free launching, free-fall launching, inflatable appliance, inflated appliance, launching appliance or arrangement, marine evacuation system, novel life-saving appliance or arrangement, requirements for maintenance, thorough examination, operational testing, overhaul, and repair, are defined in Regulation 3. To avoid confusion, the meaning of the terms used will be those provided by the regulations in force.

8.1.1 Mass Evacuation Vehicle (MEV)

According to Regulation 4, for the approval of the Administration, the novel life-saving appliances (such as the PALAEMON MEV) shall provide safety standards at least equivalent to the requirements of the Code (SOLAS) and shall be evaluated and tested accordingly (MSC .81(70)). The life-saving arrangements shall also be analysed, evaluated, and approved (as per Regulation 38).

- Regulation 7 (Personal life-saving appliances) establishes conditions for equipping the MEV with lifejackets and immersion suits.
- For the operating instructions, Regulation 9 provides that the symbols recommended by the Organization shall be used, according to IMO Resolution A.76(18).
- For the design of the MEV and its launching arrangement, Regulation 11 regarding the sufficient clear deck for muster station in the vicinity of the embarkation zone and Regulation 15 regarding the clearance of the launching stations from the propeller must be considered. The launching arrangement of the MEV shall comply with the provisions of Regulation 16 and unfavourable conditions of trim (10º) and list (20º) should be considered.
- On-board communications and alarm systems - On ships fitted with a MES, a characterisation that could fit the PALAEMON MEV, communication between the embarkation station and the platform or the survival craft shall be ensured (Regulation 6.4.4).

8.1.2 Augmented Reality (AR) glasses, Smart Bracelets, and Smart Cameras

- Their functionality and their use cases will be integrated into the training manual and operational instructions for drills, such as fire drills, rescue drills, and abandonment of the ship.
- Considering that according to Regulation 27, all the passengers onboard shall be counted prior to departure, a cross-check regarding their number with the relevant information collected from the PALAEMON field devices shall be provided.

8.1.3 PALAEMON Intelligence Framework

- The computer-based Decision Support System on the navigational bridge (PALAEMON DSS), will provide the most important information contained in emergency plans, procedures, and checklists and recommended actions to be carried out in foreseeable emergencies, as provided in Regulation 29.
- Muster list and emergencies instructions – As per Regulation 8 and Regulation 37, PaMEAS shall broadcast the muster list and emergency instructions as information customised for the crew members and passengers, specifying the duties assigned to the crew members and the actions to be taken for the crew and passengers when the general alarm is sounded (muster station).
- According to Regulation 19, emergency training and drills shall be considered and appropriate programmes for the familiarizations with the PALAEMON System and drills shall be developed for the crew and passengers, focused on the abandon ship drill, for the maximum exploitation of the system capacities. A training manual shall also be developed, in accordance with Regulation 35, where the characteristics of PALAEMON will be brought to the attention of the crew and passengers.
- The stability toolkit shall observe the provisions of the Code of Intact Stability (MSC 267(85)), Ch 4 - Stability calculations performed by stability instruments.

8.2 Classification Society Rules

Depending on the class of the existing or newbuilding vessel where the PALAEMON components will be installed different rules may apply. Starting from Part 4, Chapter 9 of DNVGL rules for ships (control and monitoring systems) and extending to other rules and standards in this section, consolidation of the most important rules has been conducted and, to some extent, design requirements for the PALAEMON components have been identified.

8.2.1 Approval and certification

Approval and certification of systems depends on their importance, in terms of safety-criticality, which is determined on whether their failure will lead to dangerous safety outcomes. Three system categories are distinguished based on their importance: Non-Important, Important and Essential services and safety functions (Table 2).

Table 2: System categories for approval and certification.

Category	Effects upon failure	System functionality
Non-important	Failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment	Monitoring function for informational/administrative tasks
Important	Failure could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment	Alarm and monitoring functions Control functions which are necessary to maintain the ship in its normal operational and habitable conditions
Essential services and safety functions	Failure could immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment	Control functions for maintaining the vessel's propulsion and steering Safety functions

To answer in which of the above categories PALAEMON belongs in, we must distinguish its systems in two phases, depending on if evacuation has started, which both belong to the incident/emergency mode:

- **Phase 0:** This phase happens before evacuation has initiated. Information and data are gathered from all the PALAEMON components and the DSS tool results in certain suggestions to the Master. The systems included in Phase 0 of the PALAEMON system can be characterized as important, because their failure could provide misleading information to the Master and consequently to potential loss of human life by, for example, delaying the decision making process of the Master.
- **Phase 1:** This phase kicks-in once the evacuation has been selected as the proper course of action. Several systems and components are activated to optimize and facilitate the evacuation procedure, including both hardware (i.e. MEV, AR glasses, Smart cameras, etc.) and software in the PALAEMON Intelligence Framework. Systems and components belonging in this phase can be considered as safety functions.

Classification of control, monitoring, and safety systems shall be according to the following principles (Figure 8):

- Type approval.
- Certification of control, monitoring and safety systems.
- On-board inspection (visual inspection and functional testing).

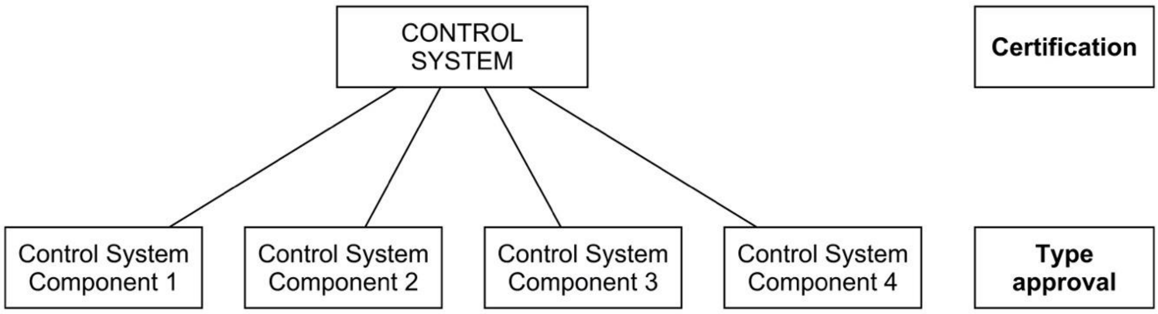

Figure 8: The main classification principles.

An example of the components that shall be type approved are the following:

- Controllers, PLCs.
- I/O cards.
- Operator stations, computers.
- Networks switches, routers, firewalls.

Among the extensive list of the systems that shall be certified the following ones may be of interest for PALAEMON:

- Main alarm system.
- Integrated control and monitoring.
- Safety management systems and Decision Support Systems.

In PALAEMON a certain interface will exist with the current alarm system of the vessel. Consequently, as the same rules describe (see Section 1.4.3, Table 2 of the corresponding rules), any safety management system or decision support system that interface the control, monitoring, and safety system required by the rules (i.e., shipboard legacy systems), is subject to a PC (Product Certificate) type certificate, issued by the classification society of the vessel.

According to DNVGL Class Guideline 0550, Section 3, Paragraph 2.2, a Product Certificate (PC) is a compliance document validated and signed by the issuing organization:

- Identifying the product that the certificate applies to.
- Confirming compliance with the referred requirements.

It is required that:

- The tests and inspections have been performed on the certified product itself or on samples taken from the certified product itself.
- The tests were witnessed by a qualified representative of the organisation issuing the certificate or his authorized representative.

In the same rule the following enlightening guidance note is found:

A safety management system may be a separate system providing an integrated user interface for various safety related systems, e.g. emergency shutdown systems, watertight doors, fire detection etc. The safety management system normally provides a user interface that is supplementary/additional to mandatory user interface required by the rules and regulations.

A decision support system is a system providing manual or automatic support to the operator based on logical functions and algorithms with input from the various control, monitoring and safety systems.

Finally, the same rule clarifies that other control, monitoring, and safety systems may, when found to influence the safety of the ship, require certification.

The PALAEMON system will be a new monitoring and safety system, which will interface with the current alarm and safety system of the vessel and consequently shall be certified by the classification society of the ship. The core behind the PALAEMON system is a Decision Support System and as such shall be handled by the classification society of the vessel.

8.2.2 System design principles

The two main design principles of any system are:

- A single failure in one system cannot spread to another system.
- Redundancy shall be in place for critical components and functions.

Based on the required system availability and according to the DNVGL Offshore rules (DNVGL-OS-D202), four categories of redundancy exist:

Table 3: Level of redundancy and repair time.

Redundancy	Repair time
R0: Continuous availability	None
R1: High availability	45 s
R2: Manual system restoration	10 minutes
R3: Repairable systems	3 hours

PALAEMON is providing additional safety compared to the minimum required. Therefore, high levels of availability for the PALAEMON system are not critical for the operation of the vessel. The PALAEMON system should offer redundancy of either R1 or R2 and the final decision will be also based on technoeconomic parameters. Using the same categorization between the two phases of PALAEMON systems (pre and post evacuation):

- **Phase 0 systems:** The module of PALAEMON that acts as a DSS tool for the evacuation decision should have a lower redundancy (this may be R2) than the modules that will support and optimize the actual evacuation process. The outcome of this phase will be a list of suggestions and the final decision is to be taken by the Master, so high levels of redundancy are not expected for the systems participating in this phase.
- **Phase 1:** On the other hand, the systems that will guide the crew during the evacuation, the monitors that will show the location of passengers in confined areas, etc. shall have an R1 redundancy, as during an evacuation even a few minutes are critical and may result in the loss of human life.

Both single failure and redundancy design principles are very important for PALAEMON, as according to the current architecture of the system, the final integrated system is expected to have a high level of complexity, with many sub-systems and components, both software, in the form of algorithms and visualizations, and hardware, in the form of field devices. Additionally, certain failure detection facilities shall be in place, mainly in the form of self-checks, such as power failures, loop failures, and communication errors.

According to the same rules, a system consists of one or several system elements, which are distinguished in the following categories:

- Automatic control.
- Remote control.
- Alarm.
- Protective safety.
- Indications.
- Planning and reporting.
- Calculation, simulation, and decision support.

Each category is described in detail and the relevant requirements are outlined in the rules. and will not be repeated here. However, because the core of PALAEMON is a decision support tool, it is important to note that output from the calculation, simulation, or decision support modules shall not suppress basic information necessary to allow safe operation of essential and important functions.

8.2.3 Additional Requirements for Computer based systems

DNVGL rules also outline several additional requirements for computer-based systems. As the list is quite extensive, the most important ones and the most relevant to PALAEMON are listed below:

- 1.1.1. System integration shall be carried out by a responsible body, such as yards, manufacturers, or any other competent body.
- 1.4.1. The on-line operation of essential functions shall not depend on the operation of rotating bulk storage devices, such as hard discs. This does not exclude the use of such storage devices for maintenance and back-up purposes.

- 1.4.2. Software and data necessary to ensure satisfactory performance of essential and important functions shall be stored in non-volatile memory.
- 1.6.1. Systems used for control, monitoring, and safety functions shall provide response times compatible with the time constants of the related Equipment Under Control (EUC) – see Table 4.
- 1.6.2. System start-up and system restoration after power failures shall take place with sufficient speed to comply with the maximum unavailable time for the systems concerned, reverting thereafter to a pre-defined state providing an appropriate level of safety.

Table 4: Computer functionalities and response time.

Computer functionality	Response time [s]
Data sampling for automatic control purposes (fast changing parameters)	0.1
Data sampling, indications for analogue remote controls (fast changing parameters)	0.1
Other indications	1.0
Alarm presentations	2.0
Display of fully updated screen views	2.0
Display of fully updated screen views including start of new application	5.0

PALAEMON system consists of many components, field devices, sensors, visualizations and more, which will communicate and exchange data and information. To this end a robust network should be guaranteed for the needs of PALAEMON. A decision that shall be taken during the preliminary design of the system is if PALAEMON will make use of the existing network on board or if a dedicated network will be installed, mainly for the part of wireless data communication. The requirements for an onboard dedicated network are listed below:

- Any network integrating/connecting control and/or monitoring systems shall be single-point failure-tolerant.
- Proper segmentation. A clearly defined system architecture is essential to segment the PALAEMON system, to protect each segment from unnecessary traffic form the rest of the segments. DNVLG Recommended Practice RP-G108 provides guidance on network segmentation, where relevant application rules can be found for:
  - independent functions.
  - system redundancy.
  - separation of systems (e.g. fire detection, navigation, shore connection etc).
- Performance of the network should be continuously monitored, and alarm shall be generated if a malfunction or reduced/degraded capacity occurs.
- Local control of machinery components (i.e. launching of MEV, firefighting) shall be maintained in case of network failure.
- Unauthorized personnel shall not have access to parts of the network not designated for them. For example, in PALAEMON, some parts of the ecosystem will only be accessible for the Master, other for the crew, and other for the passengers. A clear distinction between these parts of the ecosystem should be made at the early stages of the architecture design and sufficient security measures shall be taken.
- The network shall be designed with adequate immunity to withstand possible exposure to electromagnetic interference in relevant areas.

- The control, monitoring, and safety network with its components, connected nodes, communication links (also external interfaces) shall be subject to a failure analysis where all relevant failure scenarios are identified and considered. The analysis may be in the form of, for example, an FMEA and shall specifically focus on the integrity of the different network functions implemented in separate network segments as well as the main network components (switches, routers, etc).
- Wireless communication links may be used in systems as defined by IACS UR E22.

8.2.4 Component design and installation

In this paragraph of the rules all the requirements for the suitability of the equipment to be used in the marine environment are included. These should cover:

- Materials.
- Design and installation.
- Maintenance and checking.
- Marking.
- Standardising.

The environmental parameters given in this paragraph of the rules represent “average adverse” conditions, which will cover most applications on board vessels. Some of the parameters that should be considered for the new technologies developed within PALAEMON are:

- Power supply.
- Pneumatic and hydraulic power supply (if any).
- Temperature.
- Humidity.
- Salt contamination.
- Oil contamination.
- Vibrations.
- Inclination.
- Electromagnetic compatibility.
- Cables materials (special requirements for fibre optics are in place).

For more information for each of the above items the reader is encouraged to refer to the rules at the start of this section.

8.2.5 User interface

The present paragraph is dedicated to the user interface requirements, as PALAEMON will include many new visualizations in several forms (monitors, glasses, signs, alarms, indications, etc) so rules and standards making them as user friendly as possible should be considered during the early design phase.

Location of Visual Display Units (VDUs) and User Input Devices (UIDs)

- Workstations shall be arranged to provide the user with easy access to UIDs, VDUs and other facilities required for the operation.
- The VDUs and UIDs shall be arranged with due consideration of the general availability parameters as shown in Figure 9 and Figure 10.

- Detailed rules are outlined for both VDUs and UIDs, mainly covering the clarity and unambiguity of visualizations and interactions with the user, naming, numbering, tagging.
- The information presented shall be clearly visible to the user and permit readability at a practical distance under the light conditions experienced. This is extremely important for PALAEMON as some of its field devices will have to be operable under low environmental lighting or dark and confined spaces. Requirements for night vision are listed hereinafter.
- Colours should be consistent. Red shall always be preserved to indicate danger, alarm, and emergency only. For more details see Table 5.

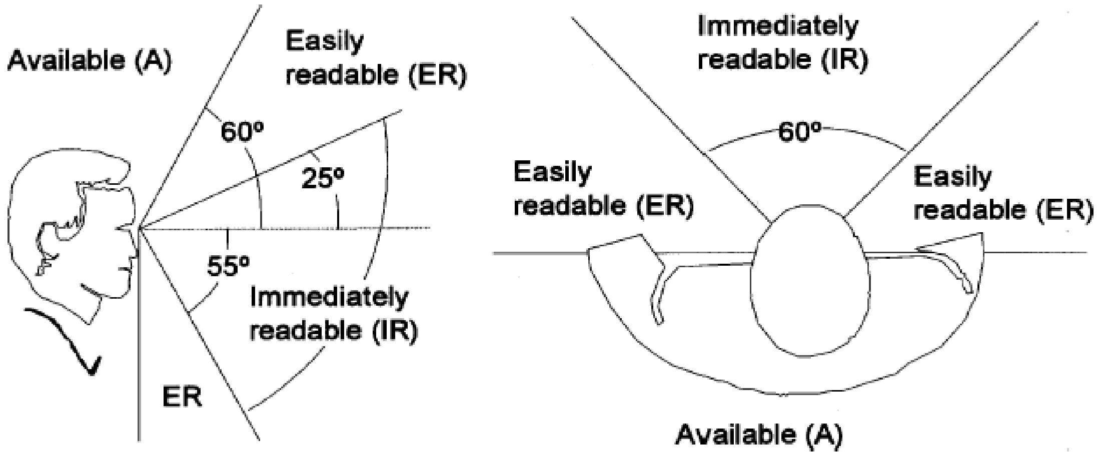

Figure 9: Arrangement of VDUs and UIDs as a function of optical parameter availability for the user.

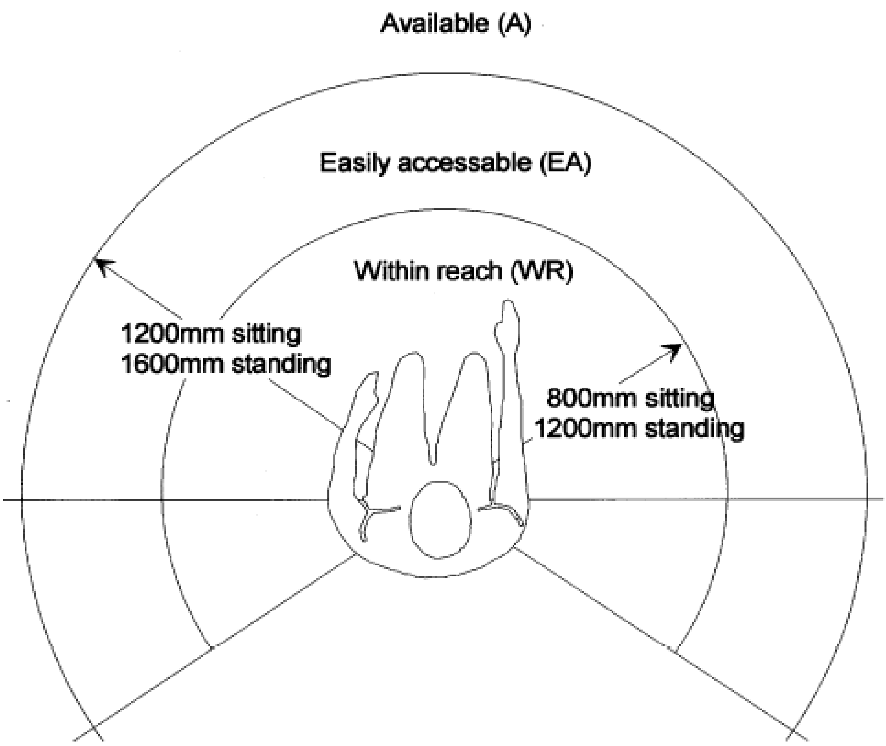

Figure 10: Arrangement of VDUs and UIDs as a function of spatial parameter availability for the user.

Table 5: Colour coding for VDUs and UIDs.

Function	Colour code
Danger, alarm, emergency	Red
Attention, pre-warning, caution, undefined	Yellow
Status of normal, safe situation	Green

Requirements for preservation of night vision

- Warning and alarm indicators shall show no light in normal conditions.
- All UIDs and VDUs shall be fitted with an internal or permanent external light source to ensure that all necessary information is always visible.
- Means shall be provided to avoid light and colour changes during start-up and mode changes, which may affect night vision.
- Illumination: Means shall be provided for adjustment of illumination of all VDUs and UIDs to a level suitable for all applicable light conditions. However, it shall not be possible to adjust down to a level making information belonging to essential and important functions unreadable.
- Adjustments may be arranged using different sets of colours suited for the applicable light conditions.

For PALAEMON, displays that will be carried by the crew and/or passengers shall operate under reduced external light, especially the equipment that will offer guidance under harsh conditions (i.e. smart glasses).

Finally, the human-machine interface has also been standardized with the ISO 11064-5:2008(en) “Ergonomic design of control centres – Part 5: Displays and control”, already being broadly used by developers of software platforms.

9 PALAEMON Functional requirements

This section contains the first version of the functional requirements for the main components of the PALAEMON ecosystem. These functional requirements are described using formalized "shall-statements" that resulted from the elaboration of the identified stakeholder needs, the high-level use cases, and the regulatory constraints in the relevant regulatory framework.

9.1 Mass Evacuation Vehicle-I (MEV-I)[4]

ID: MEV-1	**Source:** Users, Regulations
Description: Shall be able to navigate away from the damaged ship under a variety of conditions.	
Rationale: This requirement ensures that the MEV can safely sail for a certain period and weather conditions to clear away from the ship and navigate to safety.	
Dependencies: MEV-10	**Conflicts:** N/A
Functional Decomposition: MEV-1.1 Shall have ample stability in a seaway and sufficient freeboard when it is fully loaded (number of persons and equipment). MEV-1.2 Shall be capable of maintaining positive stability in an upright position in calm water and fully loaded and holed in any one location below the waterline, assuming no loss of buoyancy material and no other damage. MEV-1.3 Shall have manoeuvrability to sail away from the ship. MEV-1.3.1 Shall have manoeuvrability to safely sail in a swarm of MEVs. MEV-1.3.2 Shall have manoeuvrability to recover people from the sea. MEV-1.4 Shall be self-propelled by an appropriate propulsion system. MEV-1.4.1 Shall be able to operate fully loaded at 6 knots for a period of not less than 24 h. MEV-1.4.2 Shall sail in calm waters with at least 6 knots, when it is fully loaded and with all engine powered auxiliary equipment in operation. MEV-1.4.3 Shall sail in calm waters with at least 2 knots, when towing the largest liferaft carried on the ship and it is fully loaded. MEV-1.5 Shall be resistant to rot, corrosion, seawater, oil, fungal attack, and deterioration due to sunlight. MEV-1.5.1 Shall not be damaged in stowage throughout the air temperature range -30°C to +65°C. MEV-1.5.2 Shall be able to operate throughout the seawater temperature range -1 °C to +30 °C. MEV-1.6 Shall be unsinkable and survive rough weather.	

[4] The requirements for MEV-II will be included in Deliverable 2.3 "Final version of PALAEMON Requirement Capture Framework".

ID: MEV-2	**Source:** Users, Regulations
Description: Shall be capable of sustaining the lives of the embarked persons and providing a safe and habitable environment.	
Rationale: This requirement ensures that the MEV will provide a safe environment for people on-board, following MEV's launching.	
Dependencies: MEV-1	**Conflicts:** N/A
Functional Decomposition: MEV-2.1 Shall protect embarked persons against the natural environment. MEV-2.2 Shall provide appropriate seating for all embarked persons. MEV-2.3 Shall provide provisions and habitability during the anticipated rescue time. MEV-2.4 Shall be designed with seakeeping characteristics to achieve minimum motion sickness. MEV-2.5 Shall have adequate means and measures for fire resistance and protection.	

ID: MEV-3	**Source:** Users, Developers, Regulations
Description: Shall enable safe, easy, and rapid embarkation - disembarkation of persons regardless of their physical condition, age, and mobility, including those needing evacuation by stretcher or other means.	
Rationale: This requirement ensures that the embarkation and disembarkation process of MEV will be conducted in an effective way within the proper time limits, for every person on-board regardless of their condition.	
Dependencies: MEV-13	**Conflicts:** N/A
Functional Decomposition: MEV-3.1 Shall be so arranged that it can be boarded by its full complement of persons in not more than 10 min from the time the instruction to board is given. MEV-3.2 Shall enable safe, easy, and rapid embarkation and disembarkation of elderly people, disabled people, people with wheelchairs and people with mobility or cognitive problems. MEV-3.3 Shall enable safe, easy, and rapid embarkation and disembarkation of families with children. MEV-3.4 Shall enable people carried on stretchers to be brought on-board. MEV-3.5 Shall enable persons and helpless persons in the sea to get on-board.	

MEV-3.6	Shall be designed with an interior arrangement (e.g., minimum area per person) to safely accommodate disabled people and people with special needs.

ID: MEV-4	**Source:** Regulations, Users
Description: Shall be capable of safe and fast launch (loaded with its full complement and equipment) and retrieval by an appropriate launching and retrieval system, under normal operating conditions and under adverse ship and weather conditions.	
Rationale: This requirement ensures the MEV's structural integrity and operational capability during its launching process.	
Dependencies: MEV-8, MEV-9	**Conflicts:** N/A
Functional Decomposition: MEV-4.1 Shall be of sufficient strength to be safely launched into the water when it is fully loaded. MEV-4.2 Shall be of sufficient strength to be launched and towed when the ship is making headway at a speed of at least 5 knots in calm water. MEV-4.3 Shall be capable of being safely launched, when it is fully loaded, under all conditions of trim of at least 10º and list of at least 20º either way. MEV-4.4 Shall enable, when stowed properly and kept in a state of continuous readiness, that no more than two crew members can carry out preparations for embarkation and launching in less than 5 min. MEV-4.5 Shall be of sufficient strength to withstand, when it is fully loaded and with, if applicable, skates or fenders in position, a lateral impact against the ship's side at an impact velocity of at least 3.5 m/s and also a drop into the water from a height of at least 3 m. MEV-4.6 Shall be stowed in such a way to allow for deck space intended for passenger activities, such as leisure and exercise.	

ID: MEV-5	**Source:** Designers
Description: Shall enable the Master and the Command Team of the ship to monitor in real-time its availability, status, and persons on-board throughout the evacuation process.	
Rationale: This requirement enables the continuous monitoring of the MEV's operational capacity during emergencies, which will provide effective decision support to the Crew and the Command Team of the ship.	
Dependencies: Dash-2	**Conflicts:** N/A

Functional Decomposition:

MEV-5.1	Shall transmit information regarding its availability and its readiness to be used prior to the embarkation and launching stage.
MEV-5.2	Shall transmit information regarding its status during the launching stage.
MEV-5.3	Shall transmit real-time data regarding the identity and the number of passengers having boarded the MEV.

ID: MEV-6	**Source:** Users, Developers
Description: Shall provide a means for external communication	
Rationale: This requirement ensures that MEV will have the proper equipment to establish communication with other parties.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: MEV-6.1 Shall enable on-scene communication between ship and MEV, between MEVs, between MEV and other ships. MEV-6.2 Shall enable emergency communication with competent authorities and rescue units.	

ID: MEV-7	**Source:** Users, Developers
Description: Shall be designed to facilitate training and drills.	
Rationale: This requirement ensures that MEV will be utilised for evacuation demonstration, training, and drills.	
Dependencies: PaMEAS-7	**Conflicts:** N/A
Functional Decomposition: MEV-7.1 Shall facilitate the demonstration/familiarization process for passengers. MEV-7.2 Shall enable effective crew training and drills.	

ID: MEV-8	**Source:** Regulations
Description: The launching mechanism shall enable safe and efficient launching and retrieval of MEV-I under normal operating conditions and under the anticipated list or trim for damaged conditions adverse ship and weather conditions.	
Rationale: This requirement ensures the operability and reusability of MEV's launching mechanism.	
Dependencies: MEV-4, MEV-9	**Conflicts:** N/A
Functional Decomposition: MEV-8.1 Shall allow launching and lowering of the MEV-I in maximum load condition. MEV-8.2 Shall enable the MEV-I to be launched against unfavourable conditions of trim of at least 10° and list of at least 20° either way: a) when boarded, as required by SOLAS Regulation III/23, by its full complement of persons; and b) with not more than the required operating crew on board. MEV-8.3 Shall be protected from damage by wash, heavy seas, icing and wind, fire and explosion. MEV-8.4 The launching mechanism shall be remotely operated from the MEV-I for the purpose of launching, and for local operation for launching and retrieval from the operator station on the ship.	

ID: MEV-9	**Source:** Users, Regulations
Description: The launching mechanism shall allow launching and lowering of the fully loaded MEV-I with and without power supply.	
Rationale: This requirement ensures that MEV's launching mechanism will be operational independently from the presence of electrical power.	
Dependencies: MEV-4, MEV-8	**Conflicts:** N/A
Functional Decomposition: MEV-9.1 Shall not depend on any means other than gravity or stored mechanical power which is independent of the ship's power supplies to launch the MEV-In the fully loaded and equipped condition and in the light condition. MEV-9.2 Shall allow retrieval of the MEV-I with the minimum required operating crew using electric power. MEV-9.3 Shall allow retrieval of the lifeboat manually (without electrical power).	

ID: MEV-10	**Source:** Users, Regulations
Description: The inflatables shall provide additional floatability and stability to the MEV-I (when inflated).	
Rationale: This requirement ensures that MEV will have the proper stability to sail safely.	
Dependencies: MEV-1, MEV-12	**Conflicts:** N/A
Functional Decomposition: MEV-10.1 Shall reduce the tendency to capsize expressed by improved roll restoring righting arm and roll damping characteristics. MEV-10.2 Shall provide enhanced floatability in case of damage.	

ID: MEV-11	**Source:** Users, Developers
Description: The inflatables shall be capable of inflating rapidly when MEV-I (fully loaded) reaches the sea surface.	
Rationale: This requirement ensures that the MEV-I inflatables will not delay the launching process.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: MEV-12	**Source:** Developers
Description: The inflatables shall be capable of remaining inflated and withstanding environmental exposure throughout the MEV's stay and movement in the sea and until the rescue operation has been completed.	
Rationale: This requirement ensures that MEV will have the proper stability to sail safe, under extreme conditions.	
Dependencies: MEV-10	**Conflicts:** N/A
Functional Decomposition: MEV-12.1 Shall be damage tolerant and have redundancy. MEV-12.2 Shall be divided into separate compartments, which shall be so arranged that, in the event of any one of the compartments being damaged or failing to inflate, the intact compartments shall be able to fulfil the functions of the inflatable. MEV-12.3 Shall be adequately connected to MEV-I under the exposure of environmental loads when MEV-I is fully loaded.	

ID: MEV-13	**Source:** Users, Regulations
Description: The inflatables shall not impair the embarkation and disembarkation function of the MEV-I.	
Rationale: This requirement ensures that the inflatable devices will not burden the smooth embarkation and disembarkation of passengers and thus increasing the necessary time or requiring more effort from the passengers.	
Dependencies: MEV-3	**Conflicts:** N/A
Functional Decomposition: N/A	

9.2 Smart Bracelets (SB)

ID: SB-1	**Source:** Users
Description: Shall enable localization and tracking of every person on-board the ship (passenger and crew).	
Rationale: This requirement requires that bracelet will be available for every person on-board ship. This requirement ensures that in an emergency the exact location of each passenger will be known to the master/crew to assist the evacuation and mustering procedures	
Dependencies: UAV-2, PaMEAS-2, PaMEAS-4	**Conflicts:** N/A
Functional Decomposition: SB-1.1 Shall transmit real-time signals, subsequently used for the localization of each passenger during evacuation process. SB-1.2 Shall transmit real-time signals, subsequently used for the localization of each crew member during evacuation process. SB-1.3 Shall transmit an alarm in case a person falls form the ship (MOB). SB-1.4 Data shall be used only in case of emergency and will not be shared or distributed to any other parties. SB-1.5 Shall enable counting/identification of passengers in muster stations and inside MEVs. SB-1.6 Shall provide a signal when not carried on passenger’s hand (e.g. left in cabin, lost during mustering, etc.).	

ID: SB-2	**Source:** Users
Description: Shall transmit data wirelessly, under normal and adverse conditions, to a network that covers the entire ship.	
Rationale: This requirement ensures that the network of smart bracelets will operate under extreme conditions and shall not be affected by the complex geometry and the ship's environment (steel structure, presence and materials of decks, bulkheads).	
Dependencies: PaMEAS-9	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: SB-3	**Source:** Users
Description: Shall monitor and provide basic information regarding the health condition (heart rate, temperature, etc.) of every person on-board.	
Rationale: This requirement defines the type of data that the smart bracelets will transmit to the network. The scope is to assist the Master/crew to rank the assistance to be provided by the response team.	
Dependencies: PaMEAS-1, PaMEAS-2, PaMEAS-9	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: SB-4	**Source:** Users
Description: Shall have multiple uses during normal operation of the ship.	
Rationale: Such type of usage will encourage the passengers to wear the bracelet as there will be no need to carry other types of cards for accessing/identification purposes.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: SB-4.1 Shall be used as a multitasking card for identification and access to various areas of the ship. SB-4.1.1 Shall be used from passengers for opening their cabin's doors (e.g. their cabin). SB-4.1.2 Shall be used from passengers as a contactless card for purchasing at the shops on board. SB-4.2 Shall provide data regarding the status of the passengers (on-board or ashore) during a visit on ports.	

9.3 Augmented Reality Glasses (ARG)

ID: ARG-1	**Source:** Developers
Description: Shall provide a "first-person" perspective and enable users to explore the physical environment with simultaneously over imposed digital content.	
Rationale: AR Glasses application assists and provides crewmembers with essential digital information regarding evacuation procedures throughout a realistic environment. AR devices cannot be worn over any type of glasses; however, it is feasible to obtain a prescription insert designed to work seamlessly with the given AR device.	
Dependencies: ARG-04, ARG-03	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: ARG-2	**Source:** Users, Developers
Description: Shall provide real-time visual guidance, instructions, and other relevant information to the crewmembers for the rescue/evacuation of trapped/incapacitated passengers.	
Rationale: This requirement ensures the type of information that will be provided to the crew members by the ARGs.	
Dependencies: N/A	**Conflicts:** N/A

Functional Decomposition:

ARG-2.1 Shall display the location (e.g. cabin number) of the trapped/incapacitated passenger along with other useful information (e.g. name, age, health status, environmental conditions, etc.).

ARG-2.2 Shall display the appropriate path to the trapped/incapacitated passenger from the user's location.

- ARG-2.2.1 When the user points the AR Glasses towards a recognised shape, the 3D plan for that room will be over imposed.
- ARG-2.2.2 Navigation symbols (e.g. arrows) shall guide the user to the location of the trapped/incapacitated passenger.

ARG-2.3 Shall display the optimal path to evacuation (muster or embarkation station) from the user's location.

- ARG-2.3.1 When the user points the AR Headset towards a certain target image, a path will be generated starting from the local GPS position.
- ARG-2.3.2 Navigation symbols (e.g. arrows) shall indicate the exit path and guide the user to the location of the evacuation (muster or embarkation station) from the user's GPS location.
- ARG-2.3.3 The remaining distance to be covered by the user to reach the muster or embarkation station shall be displayed.
- ARG-2.3.4 The exits shall be clearly marked.

ARG-2.4 Shall be able to load and display a 3D map and blueprints of the ship.

ARG-2.5 Shall enable crew members to see mission details (current evacuation plan, crewmembers or passenger's condition, guidance messages from Decision Support System, etc.) but also other team member's information.

ID: ARG-3	**Source:** Users, Developers

Description:

Shall enable real-time communication between the user (crewmember) and the command team.

Rationale:

This requirement ensures that ARG will be utilised as a communication equipment during the evacuation process.

Dependencies: N/A	**Conflicts:** N/A

Functional Decomposition:

ARG-3.1 Shall enable two-way voice communication between the crewmember and the command team.

- ARG-3.1.1 Shall have built-in microphone and earphone(s) for audio communication.

ARG-3.2 Shall enable text communication between the command team and the crewmember.

- ARG-3.2.1 Shall display text messages (e.g. instructions) sent by the command team.

ARG-3.3	Shall store the communication data (e.g. voice, videos, pictures).

ID: ARG-4	**Source:** Developers
Description: Shall be used for training purposes.	
Rationale: This requirement ensures that ARG will be used effectively for training and drills.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: ARG-4.1 Shall be able to add descriptions or instructions to existing ship areas, machinery, equipment, panels, etc. by using an appropriate application (authoring tool). ARG-4.2 Shall be able to add 3D objects and instruments to be used for the creation of AR scenarios by using an appropriate application (authoring tool). ARG-4.3 Shall enable customization of the user interfaces to support the evacuation plan and the crew (team) coordination.	

9.4 Smart Cameras (SM)

ID: SM-1	**Source:** User, Designers
Description: Shall provide information regarding passengers' localization during evacuation.	
Rationale: The aim is to assist Master/crew at monitoring the evacuation and mustering procedure.	
Dependencies: PaMEAS 2	**Conflicts:** N/A
Functional Decomposition: SM-1.1 Shall be used in a multi camera system with overlapped areas to detect and localize persons on-board. SM-1.2 Shall locate autonomously trapped passengers. SM-1.3 Shall enable face recognition during the mustering of passengers. SM-1.3.1 Shall automatically identify passengers in the muster stations and count them. SM-1.4 Shall enable identification of persons facing a difficulty (accident, injury, etc.). SM-1.5 Shall identify persons congestion. SM-1.6 Shall provide updated information to the evacuation plan by recognizing obstacles or objects in the emergency paths (multi-camera approach).	

ID: SM-2	**Source:** Users, Designers
Description: Shall be capable of remaining functionable in different modes of operation, such as low visibility conditions.	
Rationale: This requirement ensures that smart cameras will provide basic functionalities (SM-1) under low-lighting and visibility conditions that are expected to occur in an emergency.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: SM-2.1 Shall operate in low visibility, such as smoke. SM-2.2 Shall operate in low lighting.	

9.5 Unmanned Aerial Vehicle (UAV)

ID: UAV-1	**Source:** Users, Developers
Description: Shall be used to detect external structural damage inflicted on the ship (e.g. due to collision with another vessel, grounding, etc.).	
Rationale: The UAV shall enhance the damage detection capability of the ship.	
Dependencies: Dash-1	**Conflicts:** N/A
Functional Decomposition: UAV-1.1 Shall provide a real-time image/video feed of the damaged ship area.	

ID: UAV - 2	**Source:** Users, Developers
Description: Shall detect individuals in the water.	
Rationale: The UAV enables fast scanning of a large sea area by combining its speed with appropriate search flight paths. For example, this functionality could be used in scenarios such as Man Overboard (MOB) and person recovery by the MEV.	
Dependencies: PaMEAS-4, SB-1	**Conflicts:** N/A
Functional Decomposition: UAV-2.1 Shall be able to assist the user to locate persons in the water, even under the averagely expected sea conditions and in low visibility conditions. UAV-2.2 Shall be able to transmit the position of the persons in the water to the ship.	

ID: UAV-3	**Source:** Developers
Description: Shall be able to conduct (semi-) autonomous flight.	
Rationale: The UAV must be able to safely aviate around the ship by controlling all its subsystems necessary for launch, climb, manoeuvre, cruise, descent, and recovery.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: UAV-3.1 Shall be able to launch/initiate flight (from the deck of the ship and/or from the MEV-I). UAV-3.2 Shall be able to automatically abort a launch if less than optimal conditions exist for launching. UAV-3.3 Shall be able to manoeuvre (change flight path, altitude, heading, etc.). UAV-3.3.1 Shall enable a pilot to manoeuvre the UAV. UAV-3.3.2 Shall be able to manoeuvre autonomously. UAV-3.4 Shall be able to cruise - conduct steady-state (non-accelerating) flight (including holding altitude or maintaining heading). This requirement includes cruise-climb as a type of steady state, non-accelerating flight. UAV-3.5 Shall be able to recover - safely conclude flight operations UAV-3.5.1 Shall be able to land/recover during normal operations (that do not involve dealing with a contingency or anomalous condition). UAV-3.5.2 Just before recovery, shall be able to determine when less than optimal conditions exist for recovering the UAV. If so, the UAV should have the capability to cancel the recovery and try again. UAV-3.6 Shall maintain structural integrity as it flies (airworthiness).	

ID: UAV-4	**Source:** Developers
Description: Shall be able to navigate. Navigating refers to the capability of maintaining navigational control, which involves maintaining knowledge of the current position, the destination, and the four-dimensional path (latitude, longitude, altitude, time) to the destination.	
Rationale: The UAV must be able to identify its current position and determine the next waypoint following the current flight plan. The navigation information is used by the aviate function to fly the UAV along the flight path to the desired destination.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: UAV-4.1 Shall be able to operate in various flight modes – fully autonomous, remotely controlled.	

UAV-4.2	Shall be able to identify the current three-dimensional position (i.e. latitude, longitude, altitude) of the UAV with sufficient accuracy.	
UAV-4.3	Shall be able to determine how to transition to its desired destination.	
UAV-4.4	Shall be able to receive navigation commands through the onboard communication system.	
UAV-4.5	Shall execute the received navigation commands. The navigation functional requirement refers to the physical change in the state necessary to implement the navigation command (moving control surfaces, adjusting speed, etc.). Note: This requirement is performed by another function within the UAV functional architecture i.e. the aviate (manoeuvre) function.	
UAV-4.6	Shall transmit the navigational status to the Sea Control Station (to monitor if the UAV follows the flight plan or a correction is needed).	
UAV-4.7	Shall allow its flight plan to be updated in real-time throughout the mission.	
UAV-4.8	Shall have collision avoidance capabilities	
	UAV-4.8.1	The UAV shall be able to avoid unplanned impact with the surface of the sea/earth.
	UAV-4.8.2	The UAV shall be able to avoid unplanned collision with obstructions (e.g. ships, marine structures, etc.) while transiting.
UAV-4.9	Shall enable weather awareness along the entire route of flight.	

ID: UAV-5	**Source:** Developers
Description: Shall enable UAV flight monitoring control from the Control Station.	
Rationale: The control station shall be capable of manually command the UAV	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition:	

UAV-5.1	Shall enable monitoring of UAV's flight through a suitable human system interface to determine if the UAV follows the intended flight path. This requirement applies regardless of whether the UAV is flying autonomously or is controlled by a pilot.	
UAV-5.2	Shall be able to control effectively and fly the UAV manually during its mission (manual mode).	
UAV-5.3	Shall enable different flight modes for the UAV apart from the manual mode (e.g. automatic flight according to a pre-programmed mission profile, return to home mode, automatic landing, etc.).	
	UAV-5.3.1	Shall be able to produce navigation commands in accordance with the intended flight plan.

ID: UAV-6	**Source:** Developers
Description: Shall enable UAV payload control from the Control Station.	
Rationale: The user of the Control Station should be able to control the sensors of the UAV to focus on the area of interest or on specific details.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: UAV-6.1 Shall control the sensor or sensors carried by the UAV. UAV-6.2 Shall have direct access to or playback of the sensor information received.	

ID: UAV-7	**Source:** Developers
Description: Shall have self-health monitoring (diagnostics) capabilities.	
Rationale: The detection of UAV malfunctions and damages before launching and during flight has a crucial effect on the safe operation of the UAV.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: UAV-7.1 Shall enable pre-flight and post-flight UAV inspection/testing. UAV-7.2 Shall be able to receive real-time telemetry information from the UAV (e.g. fuel state, engine functional parameters, etc.).	

9.6 PALAEMON dashboard (Dash)

ID: Dash-1	**Source:** Users, Developers
Description: Shall display real-time information regarding the progress of the incident, provided by the PALAEMON field devices and the ship's legacy systems.	
Rationale: This requirement defines the data provided to the Master at the time of the incident and prior to the decision to evacuate.	
Dependencies: UAV-1, ARG-1, ARG-3	**Conflicts:** N/A
Functional Decomposition: Dash-1.1 Shall provide data regarding the location of hazards (e.g., fire, flooding etc.). Dash-1.2 Shall provide data regarding the location of the Response Teams.	

ID: Dash-2	**Source:** Developers
Description: Shall display real-time information regarding the progress of the evacuation process, provided by the PALAEMON field devices and the ship's legacy systems.	
Rationale: This requirement defines the information provided to the Master and Command Team during the evacuation process.	
Dependencies: MEV-5, SB-1, UAV-1	**Conflicts:** N/A
Functional Decomposition: Dash-2.1 Shall provide data regarding the condition of the ship after the incident. Dash-2.1.1 Shall provide the weather conditions data. Dash-2.1.2 Shall provide stability data. Dash-2.1.3 Shall provide structural integrity data. Dash-2.2 Shall provide data regarding the progress of evacuation process. Dash-2.2.1 Shall provide passenger and crew members location, speed, and direction of movement. Dash-2.2.2 Shall provide operational condition of MEVs. Dash-2.2.3 Shall provide information about the development of the launching of the MEVs. Dash-2.2.4 Shall provide number of persons at Muster stations. Dash-2.2.5 Shall provide number of persons on-board MEV's.	

ID: Dash-3	**Source:** Regulations
Description: Shall display information contained in emergency plans, procedures, instructions, and checklists.	
Rationale: To centralize all the information needed by the Master and the Bridge/Command Team to perform their tasks, including the applicable provisions of the ship's safety management manual.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: Dash-4	**Source:** Regulations
Description: Shall enable continuous monitoring of the performance of the PALAEMON network, generating an alarm if a malfunction or reduced/degraded capacity occurs.	

Rationale: This requirement ensures that the information provided to support the decisions of the Master and Crew Command Team will be valid and reliable.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: N/A	

9.7 Passenger Mustering and Evacuation Automation System (PaMEAS)

ID: PaMEAS-1	**Source:** Developers
Description: Shall transmit an easily perceivable alarm signal (message) to all passengers and crew members on their smart bracelets and smartphones to notify them about the (mustering) general alarm (supplementary to the ship's dedicated alarm signal and the verbal announcement from the ship's public address system).	
Rationale: This requirement ensures that passengers and crew members receive an additional alert regarding the evacuation process initiation. This will decrease the response time of the passengers and the decision-making process (follow instructions).	
Dependencies: SB-3	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: PaMEAS-2	**Source:** Developers
Description: Shall receive, and report to the ship's Master and Command Team, data regarding passengers and crew members (e.g., location, identity, mobility status, flow, etc.).	
Rationale: This requirement defines the data that will be processed by PaMEAS.	
Dependencies: SB-1, SB-3, SM-1	**Conflicts:** N/A
Functional Decomposition: PaMEAS-2.1 Shall receive data regarding the location, identity and health status of passengers and crew members from the smart bracelets. PaMEAS-2.2 Shall receive data regarding the location, identity, flow, mobility status, etc. from the smart cameras.	

ID: PaMEAS-3	**Source:** Developers
Description: Shall broadcast personalized, evacuation-related information to the crew and passengers.	
Rationale: PaMEAS will transmit personalised information to every person onboard the ship to facilitate the evacuation process.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: PaMEAS-3.1 Shall provide in real-time location-specific navigational instructions to the passengers regarding the route they have to follow to reach the muster stations. PaMEAS-3.1.1 Shall provide clear and simple instructions. PaMEAS-3.1.2 Shall provide instructions, that will be independent from any language. PaMEAS-3.2 Shall transmit messages (instructions/advice) regarding their embarkation to the MEVs. PaMEAS-3.3 Shall identify trapped and stationary/immobilised passengers. PaMEAS-3.4 Shall transmit information to the crew members regarding the evacuation process. PaMEAS-3.4.1 Shall transmit information (location and identity) regarding stationary/immobilised passengers to the Master/Command Team, and (after Master's approval) to the Search and Rescue Team. PaMEAS-3.4.2 Shall enable counting and identification of passengers in muster stations and shall transmit the relevant information to the Master/Command Team. PaMEAS-3.4.3 Shall transmit information regarding the passengers having boarded to the MEVs (passenger identity and total number of boarded passengers).	

ID: PaMEAS-4	**Source:** Users, Developers
Description: Shall assist in MOB incidents.	
Rationale: This requirement defines the PaMEAS operation at a man overboard (MOB) incident.	
Dependencies: SB-1, UAV-2, PaMEAS-9	**Conflicts:** N/A

Functional Decomposition:	
PaMEAS-4.1	Shall be able to detect a person falling from the ship (MOB incident), including id and health status.
PaMEAS-4.2	Shall transmit a signal (alarm) if a person falls from the ship.

ID: PaMEAS-5	**Source:** Users, Developers
Description: Shall receive navigation instructions (evacuation, search and rescue) from the Master and the Command Team of the ship.	
Rationale: PaMEAS must broadcast navigation instructions to the passengers and crew that have been reviewed and confirmed by the ship's Master/Command Team, in order for them to remain in control of the evacuation process.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: PaMEAS-6	**Source:** Users, Developers
Description: Shall be able to operate/remain functional under extreme conditions.	
Rationale: This requirement ensures that PaMEAS will operate under extreme conditions.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: PaMEAS-6.1 Shall have sufficient robustness and redundancy to withstand extreme functional conditions (fire, flooding, smoke, blackout, electromagnetic interference). PaMEAS-6.1.1 The cables, antennas and the network shall be arranged to minimize the effect of a single failure, e.g. by using multiple sensors/transponders with segregated cable routes for each area. PaMEAS-6.1.2 Shall be able to transmit in congestion (highly density areas). PaMEAS-6.2 Shall be able to operate for a period of at least 30 min without the presence of electrical power, after the total loss of ship's main and emergency source of electrical power.	

ID: PaMEAS-7	**Source:** Users
Description: Shall assist passengers during evacuation drills and exercises by transmitting appropriate information to them.	
Rationale: This requirement ensures that PaMEAS will be utilised for evacuation demonstration, training, and drills.	
Dependencies: MEV-7, ARG-4	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: PaMEAS-8	**Source:** Regulations
Description: Shall not impair the performance of the existing legacy systems.	
Rationale: The PALAEMON components will supplement the existing safety systems and will not have a negative effect on their function.	
Dependencies: N/A	**Conflicts:** N/A
Functional Decomposition: N/A	

ID: PaMEAS-9	**Source:** Users
Description: Shall be capable of transmitting and receiving the required information throughout all the accommodation spaces and normal crew working spaces, including open decks.	
Rationale: This requirement ensures the coverage of PaMEAS.	
Dependencies: SB-2, SB-3, PaMEAS-4, ARG-2, ARG-3	**Conflicts:** N/A
Functional Decomposition: PaMEAS-9.1 The characteristics (e.g. bandwidth) of the network that will support PaMEAS operation shall be selected to serve the expected data flow and coverage area. PaMEAS-9.2 Shall be capable of transmitting and receiving the required information to separate groups (e.g. crew teams, passengers in different muster stations), or every passenger onboard at the same time.	

10 Conclusions

This report has presented the results of the requirements elicitation process implemented in the first iteration of the development of the PALAEMON system (V1). The elicitation process was based on the PALAEMON Requirement Capture Framework, which is a methodology that directly connects the actual stakeholders' needs and the deployment of the PALAEMON ecosystem in real-world conditions with the PALAEMON Functional Requirements.

The requirements elicitation process described in this report was based on a comprehensive definition of the boundary of the PALAEMON system, which is encapsulated in the following mission statement.

PALAEMON Mission Statement

PALAEMON is a **sophisticated maritime evacuation ecosystem** for high-capacity passenger ships and Ro-Pax vessels that combines an intelligent ICT infrastructure with a radical re-thinking of mass evacuation systems in the form of PALAEMON (MEVs). The PALAEMON ecosystem provides smart situation-awareness and guidance to the passengers and crew through continuous monitoring and control.

PALAEMON will provide **supplementary safety** from the minimum required by the rules and **additional information to support** the final decision for evacuation, or not, which will still be taken by the Master.

PALAEMON's vision is to **improve the effectiveness and safety of the evacuation process** for high capacity passenger ships and Ro-Pax vessels, by exploiting advanced ICT technologies and efficiently support the decision-making process of the ship's Master and crew.

The scope of the requirements listed in this report covers a wide range of issues, including safety, security/privacy, robustness, and human-machine interactions. In addition, the results have been described in relation to the following main components of the PALAEMON ecosystem:

1) Mass Evacuation Vehicle (MEV).
2) Smart Bracelets (SB).
3) Augmented Reality Glasses (ARG).
4) Smart Cameras (SM).
5) Unmanned Aerial Vehicle (UAV).
6) PALAEMON Dashboard (Dash).
7) Passenger Mustering and Evacuation Automation System (PaMEAS).

A total of forty-three (43) functional requirements were described in formal "shall-statements" for these PALAEMON components. The information used for these requirements included: 1) stakeholder needs – as elicited from the focus group, workshop, and stakeholder interviews, 2) High-level use cases in an indicative operational scenario, and 3) regulatory constraints included in International Regulations (SOLAS) and Classification Society Rules (DNVGL).

The first version of the PALAEMON Functional Requirements (V1) in this report will provide input to the more system-oriented (non-functional) requirements that will be presented in Deliverable 2.6 "PALAEMON Architecture (V1)". The functional requirements for the PALAEMON MEV will also be considered in the design process to be conducted in WP4 and in Deliverable 4.1 "Naval architecture studies, GA and lines of MEV-I". In addition, the high-level use cases and indicative operational scenario described in this report will provide the basis for the work in Deliverable 2.4 “First version of PALAEMON Use Cases Definition & Operational Requirements”.

The second version of the PALAEMON Functional Requirements (V2) will include a refinement of V1, as well as additional functional requirements that may be elicited. Furthermore, V2 will consider the requirements and use cases in relation to higher level of detail for the PALAEMON system (e.g., by considering the system’s sub-components as well). The refinement of V1 will be achieved by validating these requirements with selected stakeholders and experts from the Consortium, through additional stakeholder interviews and workshops, and by taking advantage of the concurrent development process in PALAEMON that will highlight any limitations from a technical point of view. In V2, additional functional requirements may be included by widening the basis of stakeholders to identify needs that were potentially not covered in the first version and engaging them through additional interviews and workshops. In addition, more regulations from which functional requirements may be extracted will be identified and exploited in the elicitation process.

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Appendix

Focus group on needs and requirements of passengers

Method and objective

To identify the requirements and needs of cruise ship passengers regarding safety and evacuation, a focus group was carried out. Thereby especially, the needs of vulnerable groups (elderly, persons with disabilities, children, etc.) as well as major evacuation challenges were discussed. Focus groups are a qualitative data gathering technique. Selected people come together and participate in a planned discussion regarding a topic. The focus group is directed by a moderator, who structures the discussion by his/her questions.

Participants and framework of focus group

The focus group took place on the 14th of August 2019 on the premises of Johanniter Austria. The discussion lasted one and a half hours and was moderated by an employee of the Johanniter Austria Research and Innovation Centre. Four people with different experiences regarding the topic participated in the focus group. The participants had the following characteristics:

- Male participant, approx. 50 years old, paymaster on a cruise ship.
- Male participant, approx. 45 years old, who has done more than 15 cruises.
- Male participant, approx. 40 years old, who was a marketing and sales employee at Costa Concordia.
- Male participant, 37 years old, with practical and scientific knowledge regarding evacuation procedures on land.

Unfortunately, it was not possible to acquire female participants. It was also planned that a senior person, who has attended several cruises, to participate in the focus group. Regrettably, he cancelled shortly before the appointment and it was not possible to find a substitute.

The discussion was recorded and after the discussion the audio file was transcribed. For analysing the data, we used the qualitative, summative content analyses. The objective of the summative content analysis is to reduce the material in such a way that the essential content is preserved. By using more abstract categories, a comprehensive corpus was created (Mayring, 2008). Concerning the interpretation of the results, we would like to stress out that they reflect the opinions and experiences of the participants. The results had not been verified regarding their accuracy.

Results

Development of the cruise ship industry

- One of the fastest growing markets.
- Ship cruises are no longer possible only for well situated people, but also for the broad middle class. Due to the growing capacity of the ships, it is possible to offer cheaper prices, which are affordable for the middle class. Therefore, ship cruises evolved as mass tourism (all-inclusive offers, a huge number of tourists heading to the same spots, cheap offers).
- However, the high number of passengers is associated with huge organisational challenges, e.g. embarking, and disembarking of persons or compliance with safety measures (e.g. muster drill, regular evacuation of passengers, sufficient lifeboats on the ship, etc.).

- Strong increase of Asian passengers. A possible reason for this is the possibility to gamble on ships (which is forbidden in some Asian countries, e.g. China).
- Increasing interest in cruising among the elderly, despite or even because of mobility restrictions. For example, it is very common that on American cruise ships, passengers with reduced mobility use an electric scooter for getting around on the ship. For some travellers, remaining on a cruise ship is cheaper and a more "mobile replacement" for a nursing home.
- There are already offers for supervised cruises e.g. for people with care needs, who have their own nursing staff (expensive).

Identified risk groups

- Elderly persons
- Persons with reduced mobility
- Disabled people
- Sick people
- Drunk people
- Families with children

General needs and requirements of passengers

- Accessibility is the biggest requirement for vulnerable groups.
- In general, older people prefer smaller cruise ships, as the distances which must be covered are shorter. Families with children have similar needs as older people, e.g. limited mobility due to the stroller.

Challenges regarding muster drill

- Heading to mustering station and especially the way back from the mustering station to the elevators (after clearing) can be a challenging situation for some people, as large crowds suddenly move in the same direction (increased incidence of falls, especially for risk groups). That means: The larger the ship, the more chaotic the muster drill.
- The clearing lasts until all passengers have arrived at the mustering station. This can last half an hour up to an hour. People often have to stand in the blazing sun during this period.
- Some people do not take the muster drill seriously and do not attend the exercise. Consequently, the staff must look for these people. Only when all passengers arrive at the muster drill, the exercise is terminated.
- Drunk people do not take the rescue exercise seriously and refuse to participate in it.

Challenges in case of an emergency

- The hallways on the ship are very long and narrow, so that huge pushing and shoving can start, and panic breaks out easily. Panic can cause people not to act rationally or to follow instructions. To implement the evacuation processes, the discipline of the passengers is required. However, in case of panic, this will not be the case.

- In general, passengers with mobility impairments are at risk of not arriving at the meeting point (muster station) on time or being overrun by the crowd.
- Use of elevator: On the one hand, it may be restricted to use the elevators in an emergency, because of the risk of getting stuck in the elevator (e.g. due to power failure). On the other hand, less mobile people cannot get to the muster station without using the elevator or risk falling or getting trampled when using the narrow stairways.
- If passengers do not arrive at the muster station by a certain time, they are being searched for. However, this search goes on as long as the crew is not exposed to danger. Since people are distributed all over the ship, it is a challenge to find missing people.
- Some shipping companies insist that in an emergency, people first must get their lifejacket from the cabin before they get to the muster station. Consequently, passengers must cover long distances, which in turn means that it will take more time to arrive at the muster station. Especially on huge cruise ships, these long distances represent a challenge. Furthermore, evacuation is more difficult, because people are sleepy and have longer reaction times to an emergency.
- Regardless of where passengers are at the time of an alarm, they must go to their muster station, which has been allocated to them (according to the location of their cabin). In practice, however, people will rush to the nearest lifeboat and will not comply with this requirement. The situation is becoming worse if, at the time of the alarm, there are many people in a location (such as a restaurant), because this huge group will head to the nearest collection point. However, lifeboats are intended for a certain number of people and not all people will have space on the boat. People could come into conflict with each other because everyone wants to get on the boat (potential for violence). Once passengers have arrived at the lifeboats it is not possible to forward them to another rescue point.
- At the same time, additional chaos is created, because these people are missing at the assigned muster station and must be searched for.
- If evacuation takes place near the coast, then people will rather swim to the shore and not use the lifeboats or gather at the muster station. As a result, these people are missing at the muster station, causing chaos in the evacuation process.
- As there are separate animation programs for children, many children are away from their parents during the day. In an emergency, it can be expected that parents will first pick up their children from the children's animation area and not head to the cabin to get their lifejacket or gather at the muster station. These create additional distress on the ship.
- In case of an evacuation, orientation on the ship is an aspect, which must be considered. At the beginning of the journey, passengers without cruise ship experience need time to orient themselves on the ship (top - bottom, back - front). Lack of orientation can be therefore also a challenge in an emergency.
- People leave electric scooters on the corridor, which block the already very narrow escape routes.
- Shipping companies inform passengers that in case of an emergency, there are sufficient life-saving appliances for everybody. Except from the lifeboats, as a supplement, there are life rafts (large “suitcases”, which are thrown into the sea and inflate). Access to the life rafts is provided e.g. with a hose system. However, during

bad weather conditions, this rescue operation works only in theory – the life raft offers no safety.

- The entry into the lifeboats is also a critical situation for vulnerable groups because the entry is not barrier-free and can lead to falls. In general cruise ships are not barrier-free. However, accessibility is better on the new ships than on the older ones.
- Dealing with alcoholised persons is problematic, as they could be more difficult to comply with commands or fall more easily.
- Problems with life jacket: Some people do not manage to put on their life lifejackets. Others are in panic and put on the lifejacket already in the corridor and thereby narrow the escape route.
- Providing for the passengers: Once passengers are in the lifeboats they must be cared for. However, emergency rations are very limited and are not sufficient for primary care. Especially, people, who must take their medicine are at risk since they might not have had the possibility to get their medicine from the cabin.
- During the muster drill, people with mobility restrictions get assistance. Also, if a real evacuation takes place the crew will assist people with mobility restrictions and take the time to search for them if they are missing at the muster station.

Suggestions for improvement:

- One suggestion for facilitating the searching process of missing people at the muster station is by using RFID scanners. The payment cards/ID cards of the passengers have already an RFID microchip. It is possible to install RFID scanners at central points (e.g. area at the elevator, deck exit, muster station, etc.). In case of an emergency, these scanners can be activated. When people pass these scanners with their ID card, they are automatically registered. This facilitates the tracking of and finding passengers. The crew would know, where the person was located most recently. Also, if a passenger appears at the “wrong” muster station, he/she would be registered there, and this information would be reported to the assigned muster station. There, the crew would know that the person is safe.
- It was also suggested to use light stripes on the corridors for better orientation.
- The TV should turn itself on and inform about the next escape route. Additionally, the screens in the corridor should be activated and guide passengers to the assigned muster station. These measures would especially help hearing-impaired people.
- In theory, people with disabilities or with assistance needs can be accommodated together on one deck. This would facilitate the evacuation process. In practice, this is not possible, because passengers themselves want to decide in which room category they want to be accommodated.

WP2 Workshop on evacuation

On November 25, 2019 (M6 of the project), NTUA coordinated a workshop on evacuation, which was hosted by ANEK onboard their Ro-Pax Ferry “KRITI II” that was moored at the Port of Piraeus (Greece). The purpose of the workshop was to collect information regarding the ship evacuation process, identify potential problems and areas for improvement of the current systems and procedures, elicit the needs and expectations of the stakeholders (consortium partners and guests), and map realistic use cases.

The workshop included forty-four (44) representatives of stakeholders both within the PALAEMON project consortium and external guests. The participants were requested at the beginning of the workshop to read and sign a consent form that informed them that participation is voluntary and that any participant may withdraw at any time without prejudice. Table 6 lists the stakeholder classes and roles represented in the workshop and Table 7 shows the agenda for the meeting.

Table 6: Stakeholder classes and roles represented in the WP2 workshop on evacuation.

Stakeholder class	Role	Relationship to PALAEMON Consortium
End-users	Master-Bridge Command Team	Internal
End-users	Shipping Companies/Operators	Internal and external
Developers-manufacturers	Naval architects, Marine Engineers, ICT Engineers	Internal
Maritime Authorities	Flag and Port States	External
Training Providers	Recognized maritime education/training providers, Shipping companies, Onboard Crew	Internal and External

Table 7: WP2 Workshop on evacuation agenda.

Monday, 25/11 - PIRAEUS		
Workshop on evacuation		
9:00 – 9.30	Registration – coffee	NTUA/ANEK
9.30 – 10.00	Welcome - Introduction to the PALAEMON project	NTUA
10.00 – 11.00	Evacuation case presentation	Selected stakeholders
11.00 – 11.15	Coffee break	
11.15 – 12.00	Evacuation process questionnaire	NTUA
12.00 – 13.00	Round Table A: Open discussion on evacuation state of the art	All participants
13.00 – 14.00	Lunch break	
14.00 – 14.45	Round Table B: Brainstorming session	All participants
14.45 – 15.30	Mapping realistic use cases	NTUA
15.30 – 16.00	Tour of the ship	ANEK
Closing remarks – Workshop Assessment form		
End of meeting (16.00)		
Early Dinner (18.00)		

During the workshop, the crew from ANEK's ship gave the participants a tour of the ship (focused mainly on the evacuation arrangements and the life-saving appliances) and a brief presentation about the procedures implemented and the equipment used during an evacuation (Figure 11, Figure 12). In addition, ANEK conducted an evacuation drill, with the participation of the workshop participants as observers (Figure 13).

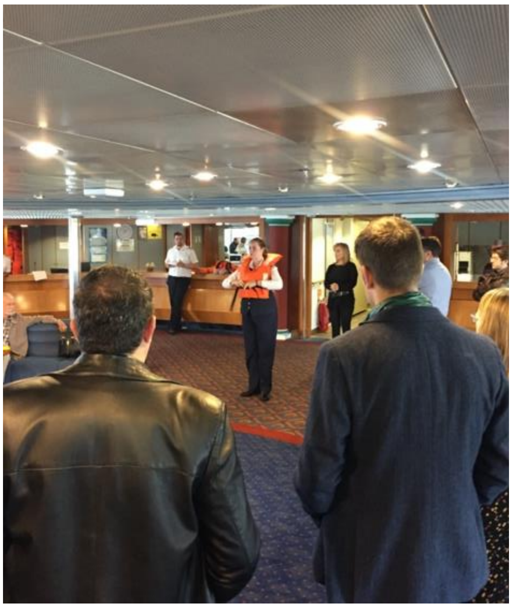

Figure 11: Crew members delivering a "how to wear a lifejacket" session.

Figure 12: ANEK crew member providing information on liferafts.

Figure 13: Launching of a lifeboat.

The tools that were employed to extract information from the participant stakeholders were the following (see also Figure 14):

- **Questionnaire** that was designed to determine the main challenges regarding the maritime evacuation process.
- **Round table discussion and brainstorming session** that aimed at determining key requirements for an evacuation system such as the one being developed in

PALAEMON. The discussion was preceded by a short presentation of the main PALAEMON components and guide questions were used to coordinate the session.

- **Open discussion** that aimed at determining the conditions that the PALAEMON system would be expected to operate. Guide questions were used to coordinate the discussion.

Figure 14: The workshop participants had the opportunity to exchange opinions and ideas and attend interactive presentations.

The following points are the key results and highlights from the workshop.

State of the art on maritime evacuation

- There are considerable differences in the evacuation process between Ferries and RoPax ships. **The evacuation process on Cruise ships is more easily manageable** in terms of passenger localization and mustering.
- **Localization is one of the key aspects of the evacuation process**. Bracelets are considered a very promising idea for localization (incl. in man overboard situations) because they are cheap and fail-proof.
- **GDPR issues are very important for passenger localization** and include questions such as whether the system will be operational only during the emergency phase.
- **Cost is a crucial factor** that affects the adoptability of any kind of innovative evacuation system.
- The main problems with existing evacuation systems include the following: **high complexity**, **frequent failures and malfunctions**, **non-uniform and unstandardized designs** that also have an impact on training that is increasingly system specific.

High-level requirements for the PALAEMON system

- **The MEV-I concept should be more carefully examined** to determine the benefit compared to the existing evacuation systems.
- Important requirements for the MEV should include the following: **high manoeuvrability** (for tendering), **minimum speed** (as per the IMO regulations), **inspectability**, **maintainability**, **easy launching** (preferably with no or minimal energy consumption).
- **Simulation and Virtual Reality (VR)** methods may be very useful in training ship crews for evacuation. Training should also be kept as simple and effective as possible.

- There should be **a more efficient way of transmitting instructions and information** up and down the chain of command, compared to the state of the art that includes the use of walkie talkies and the ship's Public Address (PA) system.
- Communication networks (WiFi, 5G etc.) should be **reliable, redundant, and resilient** to be useful during an emergency evacuation that may include several adverse conditions (e.g., blackout, damage to equipment due to fire etc.).

At the closing of the workshop, the participants were asked to fill-in a questionnaire that was used to assess the effectiveness of the workshop.

The following are the average scores for participant satisfaction on a scale of Very Dissatisfied (1) to Very Satisfied (5).

Table 8: Results of the workshop effectiveness questionnaire.

ID	Description	Score
1.	Overall Satisfaction	3.9
2.	Workshop content	3.9
3.	Possibilities for interaction, exchanging ideas	4.0
4.	Time schedule	3.6
5.	Venue/ Facilities	4.4

Based on the feedback, the **most positive aspects** of the workshop were:

1. The **active participation** of end-users.
2. The **interaction and exchanging of ideas** between experts and end-users.
3. The **evacuation drill** and the venue for understanding the evacuation process.

Based on the feedback, the **main weak points** of the workshop were:

1. **Time management** – not all items in the agenda were covered – and **available time** – the workshop could be a two-day event to cover all aspects.
2. The **conditions** in the venue (lack of sound amplification system, noisy at times, smell of gasoline).
3. Information regarding the PALAMON components could have been distributed to the external stakeholders **prior to the workshop**.
4. The questionnaire was too focused on technical aspects of the evacuation process, **more general questions for passengers** could have been included.
5. Discussions could be split across **more than a single group**, because the open discussion did not involve every participant.

WP2 Stakeholder Interviews

In the context of the work done in Task 2.2, NTUA conducted interviews with selected stakeholders that aimed at eliciting needs and expectations regarding the maritime evacuation process and the PALAEMON ecosystem. The interview followed a semi-structured format, with predefined questions serving as a basis for the discussion. The notes that were taken during the interviews were analysed and the stakeholder needs, and requirements were translated into formal “shall-statements” that were subsequently considered for determining the PALAEMON Functional Requirements.

Table 9 lists the interviews that were conducted and considered for the results provided in this report. It is noted that the interviewees had also attended the WP2 Workshop on evacuation that was organized by NTUA and hosted on ANEK’s ships in the port of Piraeus in November 2019.

Table 9: Information about the WP2 stakeholder interviews.

Date	Stakeholder Class	Role	Name	Place
January 7, 2020	Verification & Certification provider	Principal Surveyor (DNVGL, classification society)	Erikos Mygiakis	DNV GL HELLAS SA headquarters (Piraeus, Greece)
January 10, 2020	End-users	Marine Operations Director, ex-Captain (Celestyal Cruises, Shipping Company/Operator)	Vassilios Gazikas	Celestyal Headquarters (Piraeus, Greece)

The selected interviewees are experts in their respective fields with many years of experience in the maritime domain. For example, Celestyal Cruises is the only home-porting cruise operator in Greece and a preeminent cruise line serving the Greek islands and the Eastern Mediterranean.

The interviewees provided valuable insights and made helpful comments regarding the various PALAEMON components, as well as some proposals for the PALAEMON project in general.

These discussions allowed NTUA to further explore the various aspects of the ship evacuation process and to enhance its knowledge and understanding regarding the passenger ship and cruise ship evacuation.