European Maritime Safety Agency

CMOROC
Final Report

Identification of Competences for MASS Operators in Remote Operation Centres

V 3.6

Date: 26.10.2023

EMSA

About this study:

This report was commissioned by the European Maritime Safety Agency (EMSA) under framework contract 2022/EMSA/OP/24/2021

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Recommended citation:

European Maritime Safety Agency (2023): CMOROC Identification of Competences for MASS Operators in Remote Operation Centres, EMSA, Lisbon

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Abstract

The emergence of Maritime Autonomous Surface Ships (MASS) in the near future brings forth not only technical challenges but also new human-related considerations. As MASS technology advances, the implementation of Remote Operation Centres (ROC) will become a key aspect of monitoring and controlling these unmanned vessels.

There are still numerous uncertainties regarding future ROCs. How are such ROCs designed? What tasks are performed in the ROC? Which tasks on board the MASS? Which operators will perform these tasks? What competences and training will be required?

This study thoroughly examines these aspects with a specific focus on three types of vessels: short sea feeder ship, bulk carrier and RoPax ferry. This examination produces in a detailed description of future ROCs, required roles, operational processes, and detailed operator curricula. Thereby, this study aims to provide insights into the future of MASS and ROCs, shedding light on the necessary infrastructure, operational procedures, and human factors required to effectively manage and operate autonomous maritime systems. The findings contribute to the ongoing discussion surrounding the development and implementation of MASS, facilitating the transition towards a safer and more efficient maritime industry.

Executive Summary

Based on the technological progress in recent years (especially in the field of automation, sensor technology, digitalisation, data communication and decision-making algorithms), the introduction of Maritime Autonomous Surface Ships (MASS) is becoming increasingly realistic. But even if an increasing number of functions are taken over or supported by automation, the human operator retains an important role. For example, the operators are monitoring and supervising the automation, and will intervene in the event of malfunctions and emergencies by taking appropriate countermeasures. In the future, the role of the human operators will pivot from being the advice controllers of the systems to being supervisor of the systems. It can be assumed that there will be shore-based Remote Operation Centres (ROCs) from which the MASS can be monitored and controlled. An emerging important issue in this regard is what tasks the MASS operators in these ROCs will be required to perform. Such a change in the function of the operators means that the MASS operators will need to acquire different competences and will have to be trained in line with the requirements of the upcoming tasks.

This study is intended to identify and describe competences for MASS ROC operators. The expected outcome may provide input to the EU Member States and the European Commission, and possibly the IMO, about regulatory purposes, as well as a potential contribution to shape and develop future standards of competence for MASS ROC operators and, consequently, relevant education, training and certification requirements.

The primary focus of the study lies in investigating tasks, functions and required competences of future MASS Operators in several scenarios for two different configurations:
1) Remotely controlled ship with seafarers on board: the ship is controlled and operated from another location; seafarers are available on board to take control and to operate the shipboard systems and functions.
2) Remotely controlled ship without seafarers on board: the ship is controlled and operated from another location; there are no seafarers on board.

This report is subdivided into three parts:
Part I: Part I describes the essential fundamentals of the study. This includes the methodology applied in the study, a definition of the degrees of autonomy on which the study is based, and a description of the reference group that the project team involved in the development of the results through interviews, workshops and observations on various ships.
Three different MASS types and operational scenarios are considered in the study: short sea feeder (ship type A) in short sea trade, RoPax ferry (ship type B) on a one-hour-passage, and bulk carrier (ship type C) on long haul trade. These are specified in technical detail in the underlying study. For each of these ship types, the processes that are carried out for the operation of these ships have been derived. In this regard, importance has been attached to a

holistic approach including voyage planning & documentation, cargo operations, navigation, engineering operations & maintenance, emergency handling as well as management and support processes.

All processes were analysed in more detail and specified in the form of so-called DCoS models. These models describe the tasks to be performed by operators in a future ROC in detail including resources, information and stakeholders required. The processes and tasks form the basis for Part II.

Part II: In Part II of this report, the primary focus shifts towards exploring and understanding the essential competences required for the effective functioning of a future ROC (Remote Operation Centre). This section is comprised of three crucial components: the design of a generic MASS ROC model, the processes within the ROC, and a comprehensive MASS ROC operators' competence catalogue.

The second part starts by providing a detailed specification of the structural organization that a future ROC may adopt. This structural ROC organization is meticulously designed based on a thorough analysis of the processes and tasks that the ROC will be responsible for. By identifying these core functions, the study aims to establish a solid foundation for the smooth operation of the ROC.
One of the key aspects of this structural organization lies in the allocation of specific tasks to different roles within the ROC. Each role is defined with clear-cut tasks, duties, and responsibilities, ensuring a well-defined distribution of workload and accountability. This organizational structure serves as the backbone for the efficient functioning of the ROC.

Building upon this knowledge of the ROC's structural organization and its designated tasks, the subsequent step involves the derivation of the essential competences required for the personnel operating within the ROC. This process involves a meticulous examination of the skills, knowledge, and abilities that individuals must possess to execute their roles effectively. The curriculum development process involves defining competences, which are presented in tables that serve as a structured framework. These tables draw inspiration from the competence tables used in the Seafarers' Training, Certification and Watchkeeping (STCW) Code, which, in addition to specify the seafarers' minimum standards of competence, have been widely recognized in the maritime industry for documenting competences.

The resulting competence catalogue serves as a comprehensive repository of the identified MASS ROC operators' competences. By understanding the specific skills and capabilities required for each role, the document lays the groundwork for developing targeted training programs and assessments.

In conclusion, Part II of this report may serve as a fundamental exploration into the MASS ROC operators' competences necessary for future ROC. By starting with the structural organization of the ROC, identifying essential processes, and deriving competences, the document sets the stage for the effective functioning of the ROC handling its tasks and responsibilities with precision and proficiency.

Part III: In Part III of this report, the focus shifts towards describing the curricula for MASS ROC operators. This chapter delves into the process of curriculum development and outlines the essential steps to create effective training programs for MASS ROC operators.

The starting point of this process lies in defining the qualification objectives, which act as the foundation upon which the entire curriculum will be built. To build up the competences outlined in the qualification objectives, three perspectives are considered during the curriculum development process: learning outcomes, format of assessments, and teaching and learning activities.

To develop a comprehensive curriculum, four general competence dimensions are considered as the basis for qualification objectives: professional-scientific requirements, structural requirements, strategic requirements of institutions and systemic requirements. Following the definition of the competence dimensions, the curriculum distinguishes between two main proposed qualification programs: "MASS ROC Operators Basic Training" and "MASS ROC Operators Advanced Training".

The basic training targets navigators, engineers, and system administrators on the operational level. It equips them with the fundamental skills and knowledge required to function as competent MASS ROC operators. The advanced training is designed for senior navigators and senior engineers operating at the management level. It builds upon the basic training course and includes additional specialized knowledge and leadership skills necessary for handling complex operational scenarios.

For the “MASS ROC Operator Basic Program”, a certificate of competence as a watch officer at operational level according to the STCW Convention is considered a required prerequisite, and the “MASS ROC Operator Advanced Program” requires a certificate at management level according to the STCW Convention. As part of the study, it was determined that the qualifications according to the STCW Convention are fully necessary (with very few exceptions) in order to be able to monitor a MASS as an operator and intervene in the control system.

Both proposed training programs, the basic program and the advanced program, require a duration of 15 weeks. In addition, in-service trainings should be completed, which would take 15 weeks for the basic program and 8 weeks for the advanced program.

In the final chapter of Part III, the report presents the competence-based curricula for MASS ROC operators. The module catalogues determine each module in the training programs. The learning outcomes for each module are defined, and the competences required are considered and explained in detail in the competence tables. The module descriptions determine the module-related exercises and simulator trainings needed. The framework for each module is noted. The module descriptions end with the definition of the individual courses, the workload in hours, the formats for teaching and learning, and the examination formats.

These curricula are presented as proposals and are intended to serve as a framework for further discussion. Due to the evolving nature of the field, detailed specifications are limited, and the document acknowledges that the current knowledge about the future demands might not be sufficient to provide final guidelines.

In conclusion, Part III of the report provides valuable insights into the development of competence-based curricula for MASS ROC operators. By defining qualification objectives, differentiating between basic and advanced training, and utilizing competence tables, educators can create effective training programs. The proposed curricula serve as starting point for further discussions and improvements as the field of MASS operations continues to evolve.

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List of Abbreviations

AFS	Automatic Facility Services (in port, offshore)
AIS	Automatic Identification System
ADR	Accord Dangereux Routier (European regulations concerning the international transport of dangerous goods by road)
AOC	Autonomous Onboard Controller
ARC	Autonomous Remote Controller
AtoN	Aids to Navigation
C/L	Competence Level
CMO	Competences of MASS Operators
COLREG	International Regulations for Preventing Collisions at Sea
CPP	Controllable Pitch Propeller
DCoS	Distributed Cooperative Human-Machine System
EMSA	European Maritime Safety Agency
Eng	Engineer
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organisation
KUP	Knowledge, understanding and proficiency (as column 2 in STCW Code)
LSS	Local Sensor System
MASS	Maritime Autonomous Surface Ship
MET	Maritime Education and Training
MOU	Memorandum Of Understanding
MSC	Maritime Safety Committee (IMO)
OOW	Officer Of the Watch
MRS	Mandatory Ship Reporting System
MSI	Maritime Safety Information
POD	Port of Discharge / Destination
POL	Port of Loading
PP	Passage Plan
PRS	Planned Response Service
RACI	R = Responsibility; A = Accountability; C = Consulted; I = Informed
ROC	Remote Operation Centre
OOW	Officer of the Watch
OPERATOR	Remote Operation Centre Operator
STCW	International Convention on Standards, of Training, Certification and Watchkeeping for Seafarers
UKC	Under Keel Clearance
VHF	Very High Frequency
VTS	Vessel Traffic Service

1. Project Fundamentals

1.1 Definitions and Terminology

In order to have a standardized and consistent terminology, the terms used are defined in a glossary. The glossary can be found in **Appendix A**.
This glossary is built predominantly on five sources which have had a considerable impact on the vocabulary used to discuss, frame and design Maritime Autonomous Surface Ships (MASS) and associated infrastructures, such as Remote Operation Centres (ROC), in recent years. The sources comprise:

- DNV GL AS Maritime. Study of the risks and regulatory issues of specific cases of MASS – Part 1 (DNV, 2020).
- DNV GL AS Maritime. Study of the risks and regulatory issues of specific cases of MASS – Part 2 (DNV, 2020).
- International Organisation for Standardisation. Ships and marine technology – vocabulary related to autonomous ships systems (ISO, 2022).
- DNV GL AS Maritime. Certification scheme for Remote Operation Centre operator (DNV, 2021).
- DNV GL AS Maritime. Specific MASS concepts and risk evaluation technique proposed for testing the RBAT – Third Report (DNV, 2021).

1.2 Degrees of Autonomy

Against the backdrop of increasing automation in the shipping sector, the International Maritime Organisation (IMO) identified four degrees of autonomy in 2018 (International Maritime Organisation, 2018). These four definitions served to set the terminological framework for a large-scale regulatory scoping exercise on Maritime Autonomous Surface Ships (MASS). The review and analysis of relevant maritime safety treaties was concluded in 2021 (International Maritime Organisation, 2021), yet, the definitions of the four degrees of autonomy have become a foundation for research and debates by academics and practitioners in the domain of autonomous maritime systems (Rødseth, Lien Wennersberg, & Nordahl, 2022; Saha, 2021). The four degrees of autonomy have been defined as follows:

- **Degree one**: crewed ships with automated processes and decision support.
- **Degree two**: remotely controlled ships with seafarers on board.
- **Degree three**: remotely controlled ships without seafarers on board.
- **Degree four**: fully autonomous ships.

In 2022, the International Organisation for Standardisation (ISO) published a technical specification on “ships and marine technology – vocabulary related to autonomous ship systems” (ISO, 2022). The ISO Norm suggests a “human-automation classification of operational envelope sub-domains". It differentiates between the level of human control on a process (C) and the degree of automation itself (A):

- **C0** is where automation handles the system control task and where a human is not needed at all.
- **C1** is where the human has responsibilities for some parts of the system control task and the automation has responsibility for others.
- **C2** is where the human has the full responsibility for the system control task, and where automation is only assisting or offering advice to the human. An example of C2 is sailing on open sea where automation may be able to handle simple encounters with other ships, while human assistance is required for more complex situations, such as when a traffic situation gets very complex and collision avoiding regulations need further interpretation (e.g big fishing fleets combined with high traffic).
- **A0** is where automation is not able to control the process alone and always requires human attention.
- **A1** is the degree where automation can handle some parts of the process but not all.
- **A2** is where automation can control all aspects of the process and does not need human assistance. An example of A1 is the same as in the previous paragraph.

These definitions can be plotted into the following matrix:

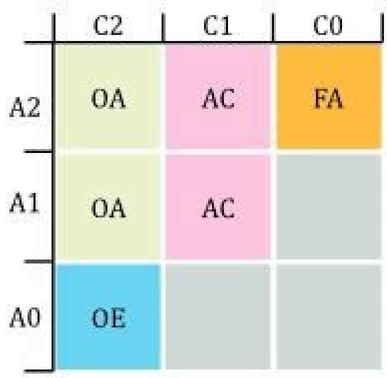

Figure 1: Relationship of automation and control degrees according to ISO/TS 23860:2022(E).

The lower three squares are left blank intentionally. According to the ISO Norm in question “the automation capabilities should be at a high enough degree to correspond to the human control degree. If not, the system is not safe to use” (ISO, 2022).

In the "Study of the risks and regulatory issues of specific cases of MASS (2020)" a proposal from the MSC was used (MSC 100/5/6). The study was based on the combinations A2-B0 and A3-B1. To discuss the requirements for Remote Operators of MASS, this approach seems much more practical than the previous definitions. In the case of "with crew on board", however, it is assumed (A3-B1) that the MASS drives fully autonomously and that only "human supervision" would be necessary. In the case of "no crew on board" it is assumed (A2-B0), that a takeover of direct control functions from an ROC are needed. But for deriving competence requirements for operators, this approach is still very rough.

Table 1: Levels of autonomy and control (source: proposal MSC 100/5/6)

			No qualified operators on board but qualified operators available at a remote location	Qualified operators on board
Levels of autonomy	**A0**	**Manual** Manual operations and control of ship systems and functions, including basic individual system level automation for simple tasks and functions.	X	A0-B1
	A1	**Delegated** Permission is required for the execution of functions, decisions and actions; the operator can override the system at any stage	A1-B0	A1-B1
	A2	**Supervised** The qualified operator is always informed of all decisions taken by the system. Permission of the qualified operator is not required for the ship system to execute functions, decisions and actions; the qualified operator can override the system at any stage.	A2-B0	A2-B1
	A3	**Autonomous** The qualified operator is informed by the system in case of emergency or when ship systems are outside of defined parameters. Permission of the qualified operator is not required for the ship system to execute functions, decisions and actions; the qualified operator can override the ship system when outside of defined parameters. Provided the boundaries of the ship system are not exceeded, “human control” becomes “human supervision”.	A3-B0	A3-B1

A more practicable approach to the characteristic of automation is developed in the project AUTOSHIP (Rødseth, Lien Wennersberg, & Nordahl, 2022). [2] This approach considers that the degree of automation or autonomy for the subsystems may vary, and that different response times are necessary for the subsystem to safely perform the assigned actions.

This is expressed with the value T_{DL}, i.e. the **response deadline**, which is the minimum response time required so that processes and functions can be carried out safely. As an example, the response deadline for an alarm about engine temperatures developing into a critical value can be 20 minutes, but an alarm on a suddenly apparent banking effect and interaction of the ship with the seabed needs a response deadline of less than one minute.

On the other hand, there is the degree of human control. The value T_{MR} represents the **maximum response time** in which an operator must reach the control station, gain situational awareness and be ready to perform the required actions. In the example before, an engineer can rise from his resting place and walk to the location of alarm (on board or in the ROC). But in case of a banking effect the navigator (in case the automated systems are not able to solve the situation) must be available within a response time which is equal to or less than the response deadline of the subsystem.

In Table 2 the authors propose possible degrees of automation and human control. In practice, it can be expected that the levels will be very individual for each subsystem and that the boundary between the levels will be more fluid.

Table 2: Degrees of automation and human control in MASS (Roedseth, et al., 2022)

Degree	Of automation	Of human control
0	Low ($T_{DL} = 0$)	None ($T_{MR} = \infty$)
1	Partial ($T_{DL} > 0$)	Available ($T_{MR} >\sim 20min$)
2	Constrained ($T_{DL} > t$)	Discontinuous ($T_{MR} >\sim 1min$)
3	Full ($T_{DL} = \infty$)	Continuous ($T_{MR} \sim 0$)

The degrees of automation and human control are related to each other by the authors and presented as combined degrees of control (C_m) and automation (DA_n). The characteristic of autonomy resulting from the combinations is defined as:

FA – full autonomy (no operator at control position, automation can operate all required tasks)

AC – autonomous control (the operator is not present close to the control station, but is alerted and back in sufficient time)

OA – operator assisted (the operator is close to the control station, leaving the control position is on own judgement)

OE – operator exclusive (operator permanently at control station)

The combinations are shown in the left-hand side of Figure 2. The authors derive a simplified representation in which they assume only two characteristic cases (*AC* and *OA*) instead of four. The reason is that *FA - full autonomy* is equivalent to the case of a very long absence of the operator at *AC - autonomous control*. The combination *OA - operator assisted* involves the situation of *OE - operator exclusive* is because the discontinuous presence changes to the state of continuous presence.

[2] The following explanations to this approach are also noted in our report “The drafting of a study on the definition and organisation of a Remote Operation Centre (ROC) with a view to its Certification (March 2023)” for the FPS Federal Public Service Mobility and Transport – DG Shipping in Belgium, drafted by the same author as this report.

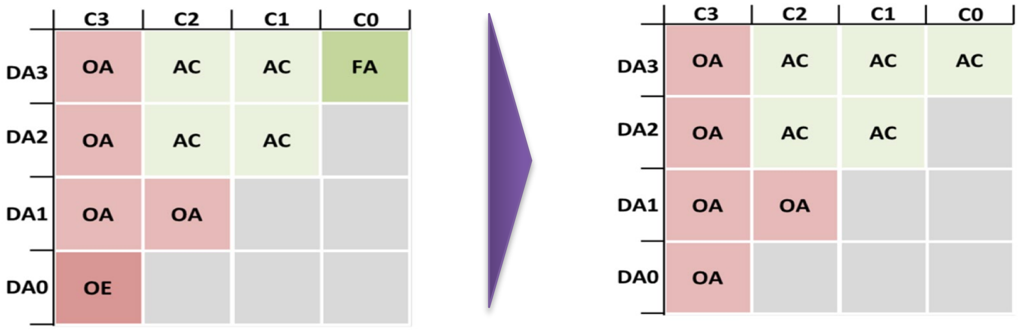

Figure 2: Possible combined degrees of control [C] and automation [DA] (Roedseth, et al., 2022)

The different systems and subsystems will have different degrees of autonomy. Thus, the degrees of automation and human control are to be assigned to the individual systems. This is necessary at least for the safety-relevant systems. Safety-relevant can be the availability of certain systems, but also critical traffic situations or critical behaviour of the ship. It is essential that the response deadlines of safety-relevant systems are defined and that the maximum response time of the operators in the organization of the ROC is ensured.

In order to derive competences from the use cases, a determination of the degree of automation and control is an important basis. From discussions with reference groups and experts from science and practice in ship management, it must be assumed that a MASS cannot be clearly assigned to one of the degrees of autonomy. A MASS will have different subsystems that will have different degrees of automation and autonomy. Depending on the level of innovation, this can vary greatly, and there will be a smooth transition from low levels to higher levels driven by innovation processes. The approach to the necessary reaction times seems very realistic and must be defined for each use case at the level of the degrees achieved per subsystem.

This study is based on the following assumptions:

a) For the different subsystems of a MASS (e.g., control systems for navigation or propulsion or machinery) there will be different degrees of automation.
b) A key driver is the progress in innovation. The technical status of the subsystems is assumed to be the same on board as in the ROC.
c) The MASS is assumed to drive in both cases (with or without crew) in the same degree of automation and control regarding to the different technical subsystems.
d) Both, in the case of "crew on board" and in the case of "no crew on board", the degree of control will depend on the automation level of the different subsystem and the scenario for the MASS.

1.3 Reference Groups

To gather input from daily operations to model the MASS ROC and retrieve expertise in the field of MASS, relevant industry & research partners were identified, and reference groups were established:

- For the **educational and training perspective** the contact with maritime universities organised in the IAMU (International Association of Maritime Universities) has been initiated. The European universities of IAMU took part in a peer review of the outcomes of this study (see member list).
- For the different types of ships considered in this study, relevant contacts in the maritime industry were identified as **maritime industry, ship operators** and its relevant associations. Scandlines, Jebsen Shipping Partners, Schulte Group and Harren Bulker were involved as partners for interviews & travels for observations on board.
- For the **technical and organizational aspects**, the working team “Operators” in the program “Autonomous Maritime Systems”, which was established in April 2018 was involved. The program is driven by the DGON Deutsche Gesellschaft für Ortung und Navigation e.V. (German Institute of Navigation). The members are from administrative bodies (e.g., BSH, German Maritime Centre), research institutes (e.g., DLR, Fraunhofer), traffic services (e.g., pilots organisation, traffic traffic systems) and the manufacturing industry (as Raytheon, Atlas Electronics, Wärtsilä).

With this reference group, interviews, workshops and observation of activities were organized. **Appendix G** addresses details about the interviews, workshops and observations including statements and findings made which may have important consequences on the design of a MASS ROC are addressed.

2. State of the Art

The State of the Art is provided in **Appendix B**. Here, previous studies, practical examples from the maritime sector as well as from other domains are described in detail and important statements and findings for the following aspects are derived:

(1) Principal elements of MASS and MASS ROC (Category C1)
(2) Technical requirements on MASS ROC (Category C2)
(3) Requirements on human interaction in MASS ROC (Category C3)
(4) Legal requirements on MASS ROC (Category C4)

3. Reference Ship Types and Operational Envelopes

3.1 Fundamental Ship Types

In the present study, three different types of ships are considered:

- **Ship Type A**: Dry Cargo Ship (Short Sea Feeder): container feeder with requirements of cargo monitoring in port and limited cargo care at sea.
- **Ship Type B**: RoPax Ferry: short route domestic passenger ferry with high safety requirements due to presence of passengers (i.e., crowd control, evacuation, POB recovery).
- **Ship Type C**: Dry Cargo Ship (Long Haul Bulker): bulk carrier with requirements of long voyages, specific cargo care and cargo hold preparation.

These ships are used as reference case studies. Of course, the technology and operating of a MASS will be not the same as such conventional ships. But the use cases are the fundamental platform to derive the expected requirements, tasks and need of competences and capabilities.

The operational envelope of the discussed MASS use cases contains …

a. … the definition of the MASS system and its use case,
b. … the geographic area of operations, including traffic systems and traffic density,
c. … the description of the environmental conditions,
d. … the description of operations with the stages of the voyage which shall be executed,
e. … the system conditions which mean the level of automation and autonomy,
f. … the functions (processes) for the required operations, and
g. … the division of responsibilities between humans and automation.

The use cases are explained below with reference to points (a.) to (d.). The point (g) is discussed regarding specific requirements to qualification of operators.

The automation levels (e.) are discussed in section 1.3. The processes and functions (f.) are discussed in the later sections and in general.

3.2 Operational Envelope of Ship Type A – Short Sea Feeder Ship

<u>MASS system and its use case</u>

The reference ship is a container feeder ship which operates between Germany and Norway. In general, it should be mentioned that the MASS will not have the same design as today's ships. The designs will be adapted to the innovations to be able to drive autonomously. A comparable MASS vessel is estimated to have similar lines as the Regional ECO Feeder [3]. The particulars are assumed by the project team to be close to the reference ship.

Figure 3: Container Feeder as reference ship and as assumed MASS.

The size of the vessels is assumed to be nearly the same. The cargo capacity will be less due to the additional technologies and innovative propulsion systems on board which will need more space for tanks, automation, batteries, or additional equipment. Also, a modular design of technical devices will take up more space. The speed depends on the economic requirements and the propulsion concept. For this purpose, it is assumed with two CPP and two thrusters for best manoeuvrability. The draught shall allow for destinations with less water depth.

The particulars of the reference vessel and the MASS are listed in the table.

[3] Odense Maritime Technologies: Green Ship Of The Future, 2016

Table 3: Particulars of feeder vessels

Ship particulars	Conventional Feeder	MASS Feeder
Deadweight	11.846 t	tbc
Gross Tonnage	9.996 t	> 6.000 t
Capacity:	960 TEU	850 TEU
Speed max.:	18,5 kn	9 (15) kn
Length:	139,1 m	150 m
Breadth:	22,6 m	25 m
Draft:	8,80 m	6.5 m
Engine	Diesel (combustion engine) 9600 kW	Generators on alternative fuels Electric propulsion
Propulsion	1 Propeller CPP 1 Bowthruster	2 Propeller CPP 1 Bowthruster 1 Sternthruster

The basic application is the transport of dry cargo. Cargo is issued by containers (standardised cargo). A MASS feeder vessel operating in short sea traffic has strong requirements concerning the planning and loading / discharging of containers. Although containers are a standardised cargo, many influences must be considered, such as dangerous goods, container types and ship stability and strength. The interface between MASS/ROC and the container terminal is to design accordingly.

Despite the expectedly relatively short passages, a propulsion by a combustion-electric engine is assumed. The configuration can be generators on bio-fuels or fuel cells, combined with electric motors. The MASS can be equipped with batteries for shorter passages or for use in coastal waters. The accumulators are charged in port, but charging must also be possible at sea. This will require sufficient storage capacity and additional generator sets on bio-fuel. The MASS is propelled by one or two (redundancy) CPP (controllable pitch propeller) and has electric bow and stern thrusters for better manoeuvrability. Equipped in this way, manoeuvring from a remote-controlled position is also possible in stronger winds and currents, or in more challenging manoeuvring situations.

The speed of the MASS is set at 9 to 12 kn to keep the consumption of energy low. As maximum speed, 15 kn should be possible to be able to meet also harsh weather conditions.

Area of operations

The MASS is assumed to operate on standard routes and serve the same berths. The sample voyage is from Bremerhaven (Germany) to different (three) ports in western Norway.

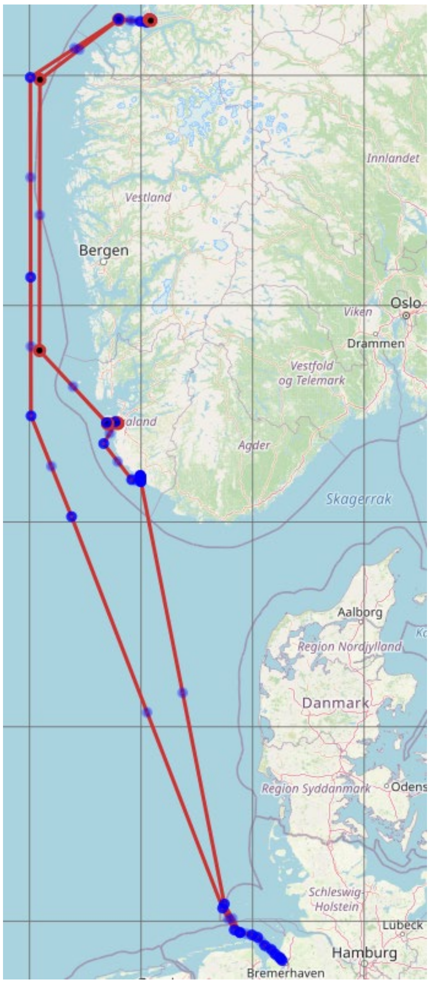

Figure 4: Feeder vessel reference voyage

The total distance is about 1250 nm.

One round trip is 7 days (168 hours), with approximately
- 48 hours port stay
- 6 hours manoeuvring
- 14 hours pilotage
- 100 hours sea passage

Such a voyage covers different navigational requirements such as:
- Ports equipped with different technical and organizational infrastructures
  - A larger port with high traffic load and an infrastructure for MASS in Germany
  - Several smaller ports with less infrastructure and small traffic in Norway
- Restricted waters with different challenges
  - Pilotage in the German Wadden Sea with strong tides and currents
  - Pilotage in narrow and constraint waters in the Norwegian archipelagos
  - Shallow waters in coastal areas
  - Many offshore structures in the sea area
- Dense traffic area
  - Sea passages through areas with high traffic density
  - Crossing traffic to be expected due to crossing shipping lanes, fishing vessels, offshore constriction supplies.
  - Area with environmental challenges concerning wind, waves, and visibility.

Environmental conditions

The MASS will operate in the North Sea. The environmental conditions in this area are very challenging and variable:
- High wind speeds can prevail at short notice from different directions;
- Strong tidal currents are recorded along the coasts;
- The swell is characterized by a short and steep wave;
- Visibility can be very restricted;

A ship of the assumed size is quite a small ship at sea. The weather and environmental conditions need to be observed very carefully, changes predicted by forecasts must be considered in an early stage of a passage. With the expected small speed of the MASS it can require some time to reach sheltered waters.

Trips across the open North Sea require sufficient motorization. The wind and sea conditions in the planned region can change significantly in the short term, in addition to strong tidal currents. The MASS must be able to steam against stronger currents and against swells. The speed reserves must be large enough to be able to minimize strong drifts and associated drift-angles.

Stages of a voyage

The stages of the above-mentioned short sea voyages are:
- Prepare the ship for departure, make it seaworthy and ready to leave;
- Departure, leaving the berth, casting off all connections;
- Manoeuvre the ship to the fairway;
- Pilotage out of the port, through fairways and rivers, passing of locks;
- Sea passage to the approach area of the port of destination, all through coastal waters;
- Anchoring or positioning for waiting or if required;
- Pilotage through fairways and rivers into the port of destination;
- Manoeuvre the ship to the berth;
- Arrival in the port of destination, connect the ship to shore, all systems to port operations.

In case of “no crew on board” the interface for the ROC is to take over a MASS at a berth, prepare for the passage to the port of destination, and to sail the MASS to the berth in this port. In case of “crew on board” the operators on the MASS will take over the same tasks and responsibilities as in the ROC.

The stages are explained in more detail in the chapter with the process descriptions.

Processes and specific competences required by the ship type

The major specifics for operators in comparison to the other use cases in this study are:

The operators have to:

- manage voyages with different ports;
- be available for sea passages up to 48 hours;
- control MASS in direct control (immediate reaction is possible) with much less time as in monitoring mode (longer reaction times), depending on the sea area and length of manoeuvring and pilotage;
- interact with pilots if required;
- manage standardized cargo (containers) with standardized interfaces in ports;
- operate electric powered propulsion systems with combustion generators and use of future bio-fuels;
- manoeuvre without tugs in different locations and environmental situations;
- be familiar with regional systems.

Overall, it can be stated that there is no fundamental difference in competence requirements to other ship types. The requirements from new control and communication technologies and associated procedures are basically the same for all types of ships, varying only in their depth of application.

Special requirements can be seen in new and low-maintenance propulsion systems.

3.3 Operational Envelope of Ship Type B – RoPax Ferry

MASS system and its use case

The reference ship is a RoPax ferry which is operated between Puttgarden (Germany) and Roedby Havn (Denmark). The future MASS-ferry will not have the same design as ferries of today. The shipping company on the reference line ordered a new “zero emission”-ferry with a full-electric propulsion [4].

Figure 5: RoPax Ferry as reference ship and as assumed MASS

The future MASS-ferry will not have the same design as ferries of today. For example, the shipping company on the reference line ordered a new “zero emission”-ferry with a full-electric propulsion. A MASS is assumed to be close to such a design. The new vessel will have nearly the same dimensions because of the dimensions of the berthing facilities in the ports. The propulsion concept is based on current experiences and laid out as a full electrical system without generators. All batteries will be charged in the port. The capacity of the MASS is smaller than the former ship, and the speed is lower.

[4] Source: https://www.scandlines.de/uber-uns/unsere-fahren-und-hafen/

Table 4: Particulars of RoPax ferries

Ship Particulars	Conventional RoPax Ferry	MASS RoPax Ferry
Deadweight	ca 9.400 t	tbd
Capacity:	1.200 Pax, 364 cars (625m for trucks, 118m for trains)	140 Pax, 66 freight units (trucks) (equals the previous capacity in meters)
Speed max.:	18.5 kn	10 kn
Length:	142,0 m	147,4 m
Breadth:	25,4 m	25,4 m
Draft:	5,8 m	5,3 m
Engine	4 Generators + Electric Energy Storage	4 Full Electric Engines, Energy Storage
Propulsion	4 Azimuth Thruster 4 x 3.000 kW	4 Azimuth Thruster 4 x 3.000 kW

A specific challenge of a ferry is the transportation of passengers. In this project a differentiation is necessary between the MASS crew to sail the MASS and the service crew hosting the passengers. From the operational perspective the technical equipment for hoteling is an additional requirement.

<u>Area of operations</u>

The exemplary line is crossing the Fehmarn Belt between Germany and Denmark. The total distance from berth to berth is about 10 nm. The manoeuvring at each port is only a short distance of about 0.5 nm.

The duration of a passage is less than 1 hour. The MASS will need probably 1 hours due to a probable reduction of maximum voyage speed. Due to the schedules, the berthing operations are required nearly all day and every day.

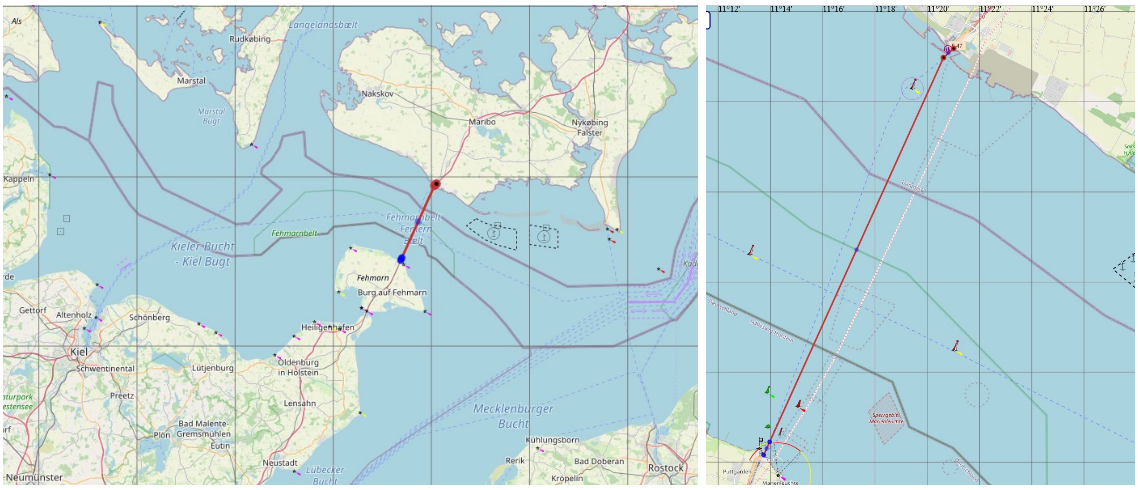

Figure 6: RoPax ferry reference voyages

Such a voyage covers different navigational requirements such as:

> Ports equipped with standardised and optimised technical and organisational infrastructures
- The berths can be designed according to the MASS dimensions
- Supporting navigational aids can be designed to the local requirements

> Restricted waters are very short
- Pilotage just needed when entering or leaving the port
- Pilotage and berthing is one process

> Dense traffic area
- Sea passages by crossing a major shipping lane
- Crossing traffic is permanent

Environmental conditions

The MASS will operate in the Baltic Sea. The environmental conditions in this area are challenging and variable:

> High wind speeds can prevail at short notice from different directions;
> Visibility can be very restricted;
> Currents and waves are not a huge challenge.

The wind and sea conditions in the planned region can change significantly in the short term. The MASS must be also able to enter a port under restricted conditions.

Stages of a voyage

The stages of the above-mentioned ferry passage are:

> Prepare the ship for departure, make it seaworthy and ready to leave;
> Departure, leaving the berth, casting off all connections;
> Manoeuvre and pilot the ship to the open sea;
> Sea passage to the port of destination, all through coastal waters;
> Positioning for waiting;
> Pilotage and manoeuvre the ship to the berth;
> Arrival in the port of destination, connect the ship to shore, all systems to port operations.

In case of “no crew on board” the ROC has the MASS under control permanently. The operators in the ROC prepare the MASS for the passage and sail the MASS to the berth in this port. In case of “crew on board” the operators on board of the MASS will take over tasks and responsibilities on demand.

Processes and specific competences required by the ship type

The major specifics for operators in comparison to the other use cases in this study are:

The operators have to:

- manage voyages with the same (two) permanent ports;
- be available for sea passages of up to 1 hour;
- control MASS in direct control (immediate reaction is possible) with much more time as in monitoring mode (longer reaction times);
- manage semi-standardized cargo (vehicles) with a standardized interface to the terminal;
- manage passengers’ embarkation and disembarkation and stay on board, together with a service crew;
- operate electric powered propulsion systems only, with charging in port;
- manoeuvre very fast without assistance in different environmental situations;
- be familiar with local systems.

Overall, it can be stated that there is no fundamental difference in competence requirements to other ship types. The requirements from new control and communication technologies and associated procedures are basically the same for all types of ships, varying only in their depth of application.

A real special requirement is the handling of passengers in all phases of the voyage.

3.4 Operational Envelope of Ship Type C – Bulk Carrier

MASS system and its use case

The reference ship is a bulk carrier in international trade and operated on long distances. The routes can be very different, as well as the type and properties of the cargo. Typically, a bulk carrier voyage has a leg in ballast to the port of loading, and then a leg loaded with cargo to the port of destination. The ship will proceed after discharging in ballast to a new port of loading again.

Figure 7: Bulk carrier as conventional reference ship and MASS

A bulk carrier operating as a MASS will be completely different designed as a conventional ship. The propulsion system for long-haul distances is assumed to be a combination of engines powered by bio-fuels, probably supported by wind systems (e.g., wing sails, Flettner rotors). Electric energy is generated by solar panels and small wind turbines [5]. Specific challenges for such MASS are the preparation of cargo holds (cleaning) and the bulk cargo operations.

Table 5: Particulars of bulk carriers

Ship particulars	Conventional Bulk Carrier	MASS Bulk Carrier
Deadweight	37.452 t	75.000 t
Capacity:	*5 holds, 4 cranes*	6 - 7 holds, no cranes
Speed max.:	13 kn	12 – 14 kn
Length:	187.0 m	200 m
Breadth:	32,2 m	40 m
Draft:	10,4 m	13.5 m
Engine	*Diesel Engine* 7600 kW	2 bio-fuel engines plus wind system; about 10,000 kW Power generation by solar panels and wind turbines
Propulsion	1 fixed propeller	2 fixed propeller or azimuth drives; Adjustable fixed sails or Flettner rotors

<u>Area of operations</u>

The sample voyage is from Rotterdam (Netherlands) in ballast to Klaipeda (Lithuania) as port of loading. From Klaipeda the vessel sails to Pointe-Noire (Republic of the Congo) with a cargo of grain.

[5] Stena Bulk press release: InfinityMAX concept vessel design, 08.03.2021

The total distance from Klaipeda to Pointe-Noire is about 6100 nm.

The voyage takes about 38 days, with approximately

> 3 days port stay for loading
> 8 hours manoeuvring
> 6 hours pilotage
> 21 days sea passage
> 7 days at anchorage
> 6 days discharging

Figure 8: Bulk carrier voyage

Such a voyage covers different navigational requirements such as:

> Ports equipped with different technical and organizational infrastructures
- Ports with good infrastructure for MASS
- Ports without any infrastructure for MASS

> Restricted waters with different challenges
- Pilotage in narrow areas in the Baltic Sea (pilot required)
- Pilotage in estuaries and rivers without reliable bathymetric surveys
- Pilotage in coastal waters with extreme currents

> Coastal and ocean areas
- Sea passages through areas with high traffic density (Baltic Sea, North Sea, Channel)
- Passing areas with fleets of fishing boats with low equipment standards
- Ocean passage with possible heavy weather situations (strong winds, high waves)
- Drifting or anchoring for waiting
- Higher security requirements may arise in specific areas

<u>Environmental conditions</u>

The MASS can operate worldwide. The environmental conditions depend on the area of operation and can vary. Most critical challenges are:

> Strong winds on ocean and coastal passages;
> High waves on ocean passages;
> Restrictions by deep draught.

The weather and environmental conditions need to be observed very carefully, changes predicted by forecasts must be considered in an early stage of a passage. With the small expected speed of the MASS, it can need time to reach sheltered waters.

<u>Stages of a voyage</u>

The stages of the above-mentioned long-distance voyages are:

> Prepare the ship for departure, make it seaworthy and ready to leave;
> Departure, leaving the berth, casting off;
> Manoeuvre the ship to the fairway;
> Pilotage out of the port, through fairways and rivers, passing of locks;
> Sea passage to the approach of the port of destination, through coastal waters and open sea;

> Anchoring or drifting for waiting;
> Preparation of the ship for loading (if not in ballast condition);
> Pilotage through fairways and rivers into the port of destination;
> Manoeuvre the ship to the berth;
> Arrival in the port of destination, connect the ship to shore, all systems to port operations.

In case of “no crew on board” the interface for the ROC is to take over a MASS at a berth, prepare for the passage to the port of destination, and to sail the MASS to the berth in this port. In case of “crew on board” the operators on the MASS will take over the same tasks and responsibilities as in the ROC.

Processes and specific competences required by the ship type

The major specifics for operators in comparison to the other use cases in this study are:

The operators have to:
- manage voyages mostly with different ports;
- be available for sea passages for several days;
- control MASS mostly in monitoring mode (longer reaction times) with less time in direct control (immediate reaction is possible), depending on the sea area and length of manoeuvring and pilotage;
- manage non-standardized cargo (bulk, break bulk, neo break bulk) with not standardised interfaces in ports;
- operate combustion engines with use of future bio-fuels;
- operate supporting wind energy systems and solar systems for power generation:
- manoeuvre with pilots and using tugs in different locations and environmental situations;
- be familiar with worldwide systems.

Overall, it can be stated that there is no fundamental difference in competence requirements to other ship types, only a few ship type specific requirements. The requirements from new control and communication technologies, and associated procedures are essentially the same for all types of ships, varying only in their depth of application.

Special requirements can be seen in new and low-maintenance propulsion systems. Additionally, the requirements of bulk cargoes are specific. They often need more preparation by the crew (cleaning of cargo holds) and special care (according to IMDG or Int. Grain Code). The deck crew is assumed to be needed on board.

4. Generic Operational System

4.1 MASS Operational System

A standard operational system was defined to develop the requirements for operators of a MASS. The system is in accordance with ISO/TS 23860:2022 Ships and marine technology - Vocabulary related to autonomous ship systems.

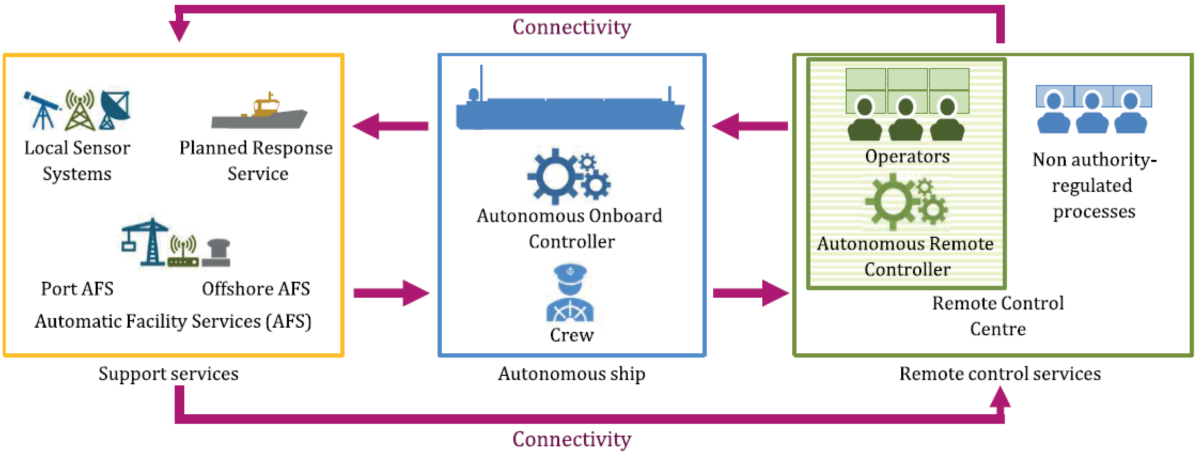

Figure 9: Autonomous Ship System according to ISO/TS 23860:2022

The Autonomous Ship System is the same for all MASS, the differences are in the number of interfaces, used technologies and intensity of necessary communication. The system is projected to standard operations:

- **Port stay** – the voyage is planned, the MASS is prepared, equipped with provisions and bunkers/power, and loaded by cargo or passengers
- **Berthing** – the MASS is ready to go and leaves the berth. Manoeuvring is usually required during this stage.
- **Pilotage** – the MASS has to pass enclosed or narrow waters, following the pilot's advice may be compulsory.
- **Sea passage**- the MASS is sailing through coastal waters and the open sea to the approach area of the port of destination.
- The same stages will be followed in reverse at the POD, including pilotage, berthing and port stay.

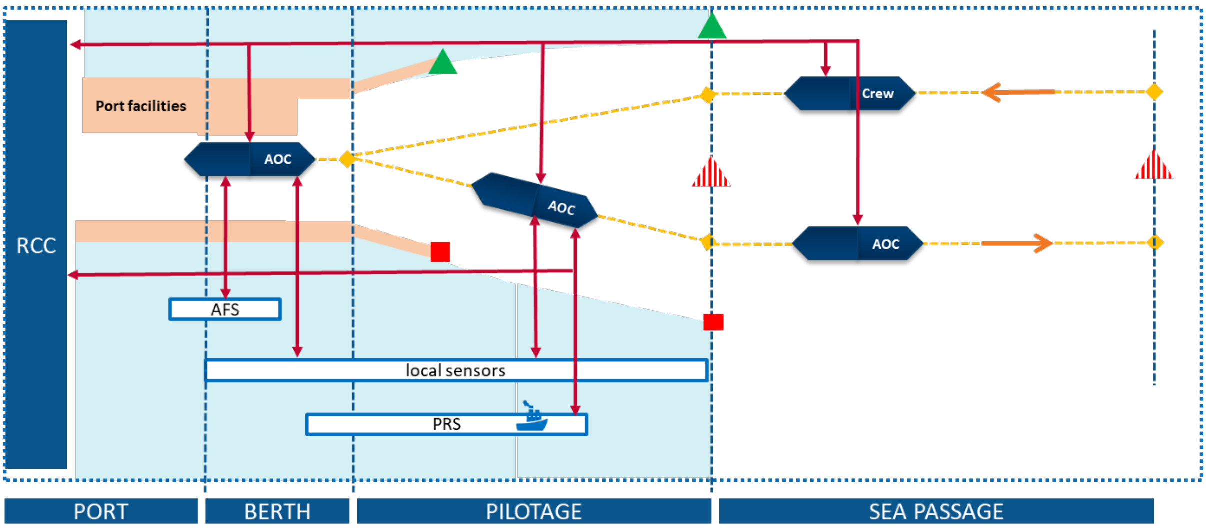

Figure 10: MASS system

In this system the MASS is controlled by an AOC (Autonomous Onboard Controller)[6] and (if on board) a crew.

Interfaces and communication lines to the ROC (Remote Operation Centre) are controlled by Operators and/or ARC's (Autonomous Remote Controllers).

In addition, interfaces and communication lines to support systems are to be considered. These are links to LSS (Local Sensor Systems), AFS (Automatic Facility Services) located in the port or offshore, and PRS Planned Response Services). All analysed ship types will need the same support services.

Table 6: Use of interfaces to automatic systems by the ship types

Systems	**Feeder MASS A**	**Ferry MASS B**	**Bulker MASS C**
LSS Local Sensor Systems			
At the berth:			
Visual systems (video data)	X	X	X
Distance measuring systems	X	X	X
Precise positioning systems	X	X	X
Positioning supporting systems	X	X	X
Environmental measuring systems	X	X	X
...			
At pilotage and sea passage			
Radar improvement systems	X	X	X
Local electronic charts	X	X	X
Positioning accuracy supporting systems	X	X	X
Virtual AtoN	X	X	X
AIS systems	X	X	X
Traffic density and risk indicating systems	X	X	X
….			
AFS Automatic Facility Services in Port and Offshore			
At the berth			
Mooring connecting systems	X	X	X
Gangway operation systems	X	X	X
Power & Fuel supply systems	X	X	X
Other shore connections	X	X	X
Persons-on-board control system	X	X	X
Automatic towing			X
At the berth – cargo related			
PAX data capture and control system		X	
Vehicle data capture and control system		X	
Ramp (RoRo) operations		X	
Container data system	X		
Shore container crane interface system	X		
Shore bulk loading/discharging systems			X
…			
PRS Planned Response Services			
Tug assistance in critical situations	X	X	X
Evacuation systems		X	
….			

Also, the wider context of the Autonomous Ship System is to be considered. The wider context is covering additional interfaces to operators, services and ships. They are not all automated, and actions might be required in order to get in contact with such services.

[6] ISO/TS 23860:2022: Automation onboard the ship is used to control one or more of a ship system's processes or equipment, under certain conditions, without human assistance

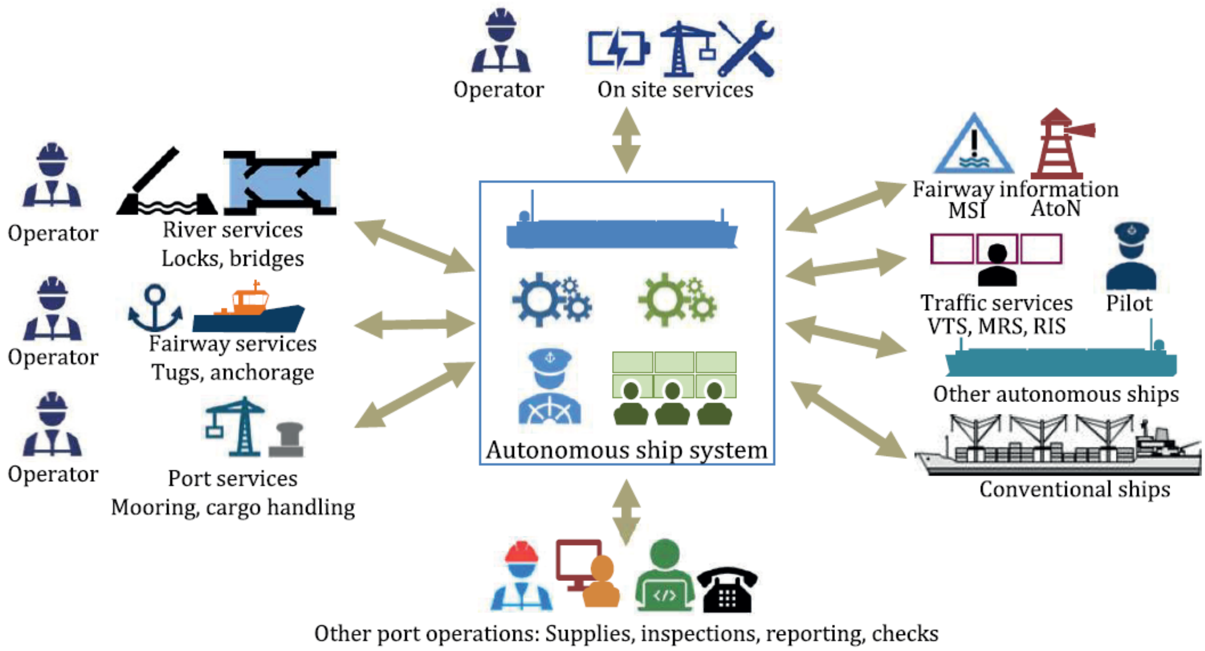

Figure 11: Autonomous Ship System in wider context according to ISO/TS 23860:2022.

In the use cases of the sample ships, such interfaces and communication requirements can be identified for each ship type.

Table 7: Interfaces in the wider context used by the ship types

Interfaces to …	**Feeder MASS A**	**Ferry MASS B**	**Bulker MASS C**
Operators of port and fairway infrastructure			
Lock operators	X	(X)	X
Bridge operators	X	(X)	X
….			
Operators of fairway services			
Tug operators	X	(X)	X
Dredger operators	X	X	X
Anchorage control	X	X	X
…			
Operators of quay and on-site operations			
Mooring operators	X	X	X
Technical supply service operators (electric power, water, fuel, …)	X	X	X
Maintenance service operators	X	X	X
Inspectors and auditors	X	X	X
Operational supply service operators (spares, provisions, …)	X	X	X
Waste and garbage	X	X	X
Security officers	X	X	X
...			
Operators of loading and discharging			
Booking offices	X	X	X
Passenger control operators		X	
Crane operators	X		X
Cargo planning operators	X	X	X
...			
Operators of information systems			
MSI Maritime Safety Information	X	X	X

Interfaces to …	Feeder MASS A	Ferry MASS B	Bulker MASS C
Weather forecasting	X	X	X
…			
Operators of traffic services			
Pilots	(X)		X
Traffic service operators (VTS)	X	X	X
…			
Other Ships			
Conventional ships	X	X	X
Autonomous ships	X	X	X
Leisure boats, small boats without AIS	X	X	X
…			

From this perspective, the operational system and envelope must be determined as one system. The specific deviations in the requirements can be considered in the further holistic approach.

4.2 Generic Process Map

By analysing the routes shown and deriving the entire process that the ship under consideration must go through to navigate this route, we were able to derive a generic process map. For this study, it was important to have a general overview of all processes, showing the overall workflow for the different types of vessels. To derive these processes, we systematically analysed example routes.

To be able to derive all required competences, a systematic and holistic approach is required. For that, a generic process map is developed, based on the analysed operational envelopes and systems of the three ship types as explained above. This generic process map is shown in Figure 12. The focus is on the high-level processes that will be broken down into smaller tasks at a later stage of the study. We reviewed and validated these processes in a workshop with the DGON working group on 12.07.2022 and 07.02.2023.

The process map follows the systematics of a process-oriented design of organisations. Using such an approach, all activities and functions of an organisation like a MASS/ROC organisation will be covered.

Three types of high-level processes are considered:

Core processes

The core processes are focused on the operations and how a service to others (e.g. customers) is provided. By using processes with a sequence of “start/input -> activity -> end/output” all tasks can be identified. The core processes on the high level covers all processes which are necessary to operate a MASS. The core processes are:

1. Voyage Planning & Control
2. Cargo Operations (including Pax)
3. Navigation
4. Engineering Operations
5. Maintenance
6. Malfunctions & Emergencies

Management processes

Every organisation needs management. For the operation of a MASS, management processes are also required. For this project the focus is on processes with direct relation to the operational core processes. Management processes as strategy development, controlling. and company communication are not considered. The management processes determined for the purpose of derivation of competences for MASS operators are:

M1 Organisation of a MASS system
M2 Management of a MASS operating system
M3 Risk Management (for all operational and organisational risks)
M4 Quality Management (aiming for high system reliability and continuous improvement)

Support processes

Each organisational system needs supporting processes. The focus of the support processes is mainly to provide the best resources needed by the system. For the MASS system, four major supporting processes are considered, which are identified as important in keeping the core processes running.

- S1 Providing Human Resources
- S2 Considering all Legal Aspects (for the entire MASS system)
- S3 Providing the Automation Systems (all automation systems needed by a MASS)
- S4 Considering Economic Aspects (to ensure an economic operation)

Based on the definition of the core, management, and support processes, a process map is developed. Each of the processes will be broken down into a structured definition in the next chapter. The needed competences of the MASS system operators will be derived from these perspectives.

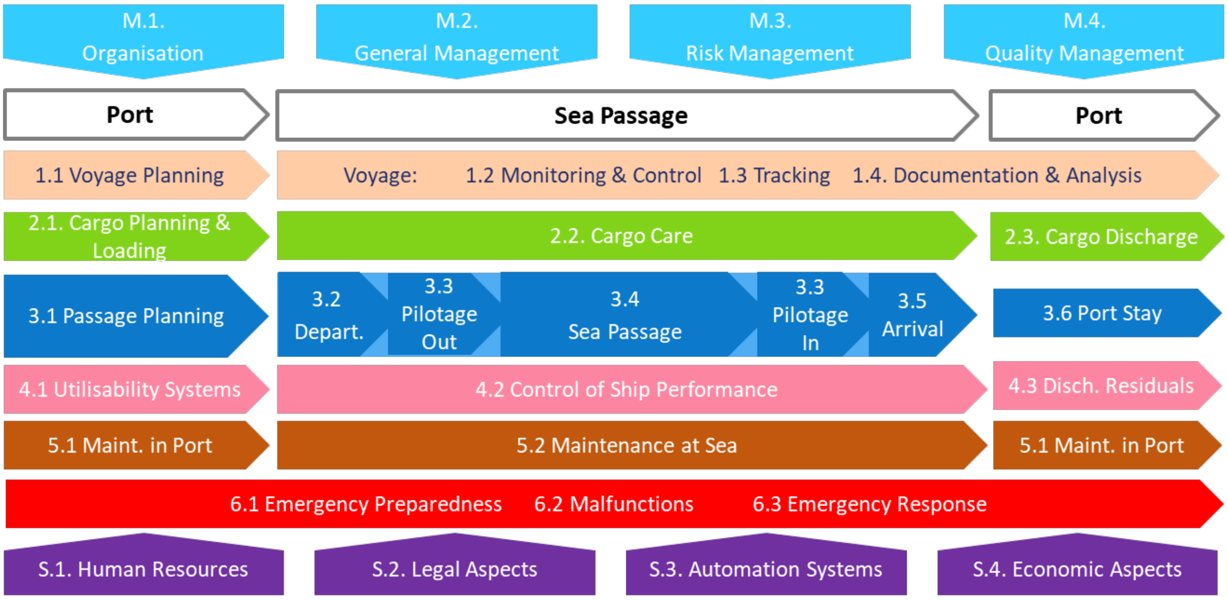

Figure 12: Generic Process Map (Th. Jung, HSB, 2022)

4.3 Analysis of Work Processes on Board

To validate the processes, data acquisitions were carried out on ships that correspond to the three sample cases of this study. The aim of the recordings was to check the processes for completeness, to collect their interfaces, and to classify them in terms of time.
The questionnaire included the following points:

Step 1:
Validate the processes and the tasks which were prepared as a proposal.
Make a list of all processes and tasks which happens on a voyage.

Step 2:
For each process, the following was to be determined:

- Can the process occur at any time, or can it only be carried out at certain times?
- Is the process or task time-critical? Is a reaction necessary immediately or within an hour?
- With whom is the process communicated (interfaces)?

For each process, its parameters have been recorded:

- What is the trigger and input of the process?
- What equipment or resources are needed?

> What are the most important information and data?
> What is the result and output of the process?

For each process, it was determined in which degree of automation and control it could be carried out (in current perspective)

> In autonomous control mode?
> In combination operator and automation?
> Only by an operator?

For each process or task, it has been determined in which mode they can be performed:

> In Monitoring mode?
> In strategic control mode?
> In tactical control mode?
> In direct control mode?

Each process or task was assigned the operator with the corresponding competence level.

The data were collected in a data base for analysing purposes. Also, the data was collected for all three ship types.

The RoPax ferry (ship type B, cf. section 3.3) was visited by a student in navigational sciences who served for several months as cadet on that ship. The shipping company supported the student, so she was able to stay on board for several days in October 2022 to carry out interviews and investigations in all departments. The outcome was used for her bachelor thesis as well. The aim of the bachelor thesis was to investigate the process on board of a RoPax ferry and to analyse them systematically to use them as a basis to develop processes for MASS.

The outcomes of the investigation were discussed by the project team with the fleet captain in an interview format.

A navigational officer (certified in accordance with Section A-II/1 of the STCW Code) mustered on a bulk carrier (ship type C, cf. section 3.4) for a voyage from Europe to West Africa in October/November 2022. The shipping company supported him that he was taken on as an additional crewmember without any additional obligations on the vessel. He was able to investigate all processes in all departments of the ship and carry out many interviews with the crewmembers. His aim was the same: to investigate the process on board of a bulk carrier and to analyse them systematically in order to use as a basis to develop processes for MASS. He also wrote a bachelor thesis on this topic.

The outcomes of the investigation were discussed later by the project team with the ship manager in an interview format.

Unfortunately, the type A, short sea feeder ship, was not available as planned in December 2022. Nevertheless, the definition of the processes and tasks, and answering of the questions, were done in cooperation with an experienced navigational officer who served on such a feeder vessel. The technical perspectives were also discussed with the technical director of the shipping company.

All shipping companies were very interested and supported the data investigation. Further details about the interviews and persons involved can be found in **Appendix G**. The outcomes of the investigations were collected in a big data base and were used by the project team as a basis of process models and derivation of required competences.

4.4 Additional Tasks Based on Expected Technical MASS Functions

In the previous section, there has been an emphasis on the processes which have a basis in today's vessel operation, and which will be quite similar on future vessels. However, increases in automation will lead to additional processes and challenges for future operators in the ROC that need to be considered when defining future competences. These will be based on future functions of MASS, with particular regard to autonomous and shore-based control.

In the following section, the expected functions of a MASS are defined. These functions provide a basic framework for autonomous or semi-autonomous ship operations as well as shore-based control. Deriving these functions allows for the definition of new tasks and competences for the operators in the ROC. These functions are subject to some uncertainty as they are still being researched. Therefore, we remain at a high level of abstraction to describe future MASS functions. At this level, most literature sources agree, and we accordingly assume that these functions will be present on future MASS (possibly in different technical manifestations). This high level of abstraction is sufficient for our purposes as the functions operate on a general, overarching level, making them applicable to various ship designs and operational purposes. To specify the functions, an internal workshop was held within the project consortium. This workshop included information provided by analysing the state-of-the-art (see **Appendix B**) and the reference groups (see **Appendix G**).

The technical functions are listed in the following table. As mentioned above, the scope of functions may differ depending on the level of automation of the MASS. The consequences for the additional tasks and upcoming challenges are then derived below the table.

Table 8: Expected technical functions for MASS

Function	Description
Sensor system and MASS situational awareness (MASS SA)	MASS situational awareness refers to the ability of the MASS to understand and interpret its environment and context in order to make decisions and perform actions that are appropriate to the current situation. An example of a function that contributes to MASS situational awareness is environmental awareness. The MASS must be able to sense its environment using sensors such as cameras, radar systems, or sonars and process this information to obtain an accurate picture of its surroundings. Another important point of MASS situational awareness is that the MASS must know the limitations of its own autonomy and be able to assess whether human action is required to achieve a safe state.
Automated navigation system and associated interpretation of SA information and decision making	One of the essential functions of a MASS is navigation, which is used to route the vessel safely and efficiently. Depending on the level of automation of the MASS, routes can be planned and adjusted based on environmental influences. In addition, the detection and avoidance of obstacles to avoid possible collisions are part of the navigation. The navigation is constantly updated by data from SA & Assessment of the MASS to find a track with minimum risk and high efficiency.
Automated Control System	The autonomous control system sends commands (e.g., executing steering commands by interpreting navigation data) to the physical actuators of the MASS. It includes also (depending on the degree of automation) adjusting the ship's speed and direction as well as control of the various systems on board, such as the power supply or cargo.
Autonomous Communication System	A ship operating autonomously or semi-autonomously must be able to communicate with other ships, the port and other relevant stakeholders to ensure cooperation and coordination. For this, the ship needs a reliable and effective communication infrastructure. The communication function of the MASS includes the ability to exchange data and information with other vessels, the port and other relevant stakeholders. The communication function also includes the ability to process and interpret the received data and information to support decision making and navigation of the vessel.
Autonomous Emergency Response System	The MASS is equipped with automatic emergency response systems that are capable of responding quickly to emergencies such as fire, leakage, or machinery failure to protect the vessel and the surrounding area.

For the specified functions, the MASS requires advanced sensors, which can monitor the state of the vessel, weather conditions, sea conditions, and other relevant parameters to ensure safe and efficient vessel operation. Depending on the type of vessel, the cargo and/or passengers on board are also monitored by the sensor system.

The functions of a MASS enable partial or complete automation of ship control, which also influences the tasks of the operators in the ROC. While in conventional ship control systems the operators usually give control instructions and make decisions manually, when operating a MASS they must be able to monitor the automation and intervene in the processes if necessary. Therefore, new tasks, which focus on the monitoring and control of the automated functions, can be derived from the functions of a MASS. The exact scope of the tasks also depends on the degree of automation. The tasks are listed and described as follows.

Monitoring sensor data

The operators must be able to monitor and interpret the sensor data of the MASS. This requires technical knowledge of the sensors and an ability to assess the reliability of the sensor (Can I trust the sensor in certain weather conditions? How much deviation does the sensor data have? etc.) and includes evaluation of sensor data for consistency and correctness. Already today, the operator must monitor and evaluate a large amount of data. As the number of sensors will increase rapidly, the amount of data that the operator will have to monitor will also increase significantly. It is not advisable to pass this amount of information elements directly to the operator without a pre-processing, as this will lead to an information overload. Information overload refers to the state of being overwhelmed by an excessive amount of information, which can lead to difficulties in processing, organizing, and using the information effectively. Consequently, a ROC operator might not be able to effectively control and monitor a MASS, which can lead to errors, poor oversight and decision-making. To mitigate the effects of information overload, human factors engineering principles can be applied to optimize ROC design, display layout and information presentation. This may for instance include appropriate aggregation of information. A ROC operator must have the ability to interpret the aggregated information appropriately and to understand the interdependencies between different elements of information to identify and interpret errors or critical situations correctly (e. g., when dealing with subsequent errors.). Although information overload is not a new problem, it might be exacerbated by the increased number of sensors in MASS.

Monitoring the automation

The operators must know the exact objectives of the automation and be able to understand and evaluate the actions at an abstract level. Based on this knowledge, the operators must monitor the automation and check whether the automation goals are being met and intervene if necessary. To be able to do so, operators must have a proper situational awareness, which means operators must have a clear understanding of the automation' current state and be able to anticipate changes and potential problems. They need to be able to assess the situation and make appropriate decisions quickly and accurately. Like information overload, this challenge must be met by applying human factors engineering principles during the design phase of new human machine interfaces such as Ecological Interface Design and to provide an overview about the state of the automation as well as its decisions made. In this context, the term 'explainable AI' is often used. Explainable AI refers to the ability of an automatic or AI system to provide clear and transparent explanations for its decision-making processes. Regarding human factors engineering in the ROC, explainable AI is important because it allows operators to understand why an AI system is making a particular decision or recommendation. This can help to improve the overall effectiveness and efficiency of control room operations, as well as reduce the risk of errors and accidents caused by misunderstandings or misinterpretations of AI outputs. It also allows the operator to better understand the AI, including its limitations (under what conditions can the AI perform optimally? When does automation reach its limits e.g., in difficult traffic or weather situations?).

Adjust parameters of automation

Due to external influences, it could be that the goals of the ship operation change (e.g. new port of destination). The operators must be able to change parameters in the automation so that the MASS can operate safely and efficiently. From a human factors' perspective, the operator must not only have good situational awareness, as described above, but also have appropriate interaction controls on the user interface to adjust the parameters. It is often important to assess the impact of parameter changes. To do so, there should be an understanding of the mutual influences of different parameters and the operator should be able to evaluate consequences of parameter changes. Systems that simulate changes (e.g. in the form of digital twins) might be helpful in a future ROC.

Taking over control

In some cases, the operator in the ROC must take over control of the MASS in ROC. This can occur for a variety of reasons, including if the autonomous system encounters a situation it cannot handle (e.g., due to environmental influences) or if the human operator needs to intervene for safety reasons. This requires a clearly defined procedure that regulates the handover/takeover. One of the challenges here will be that the operators need to adapt quickly to the situation and the vessel involved. To do this, they need to get into the loop quickly. The literature suggests new user interface concepts such as the Quickly Getting into the Loop Display (QGILD) (Porathe 2022).

Communication

The operators must communicate with each stakeholder who can be related to the current mission (e.g., with the coastguards in case of preventing any occurrences, or the VTS). Furthermore, the operator needs to take over the communication of the MASS, when they intervene in the automation procedures. One significant challenge in this regard is miscommunication. Miscommunication can occur due to several reasons, such as language barriers, technical issues, or lack of clarity in instructions. Miscommunications can lead to confusion, delays, and even accidents, which can have severe consequences. Communication is therefore an important issue when it comes to training of future operators in ROCs. It is to be expected that new communication concepts with high integration of human and machine communication will be developed in the future for which requirements about competences are difficult to predict.

The analysis of the expected MASS functions revealed that operators should have the competence to evaluate the autonomy and must be aware of its limitations. The tasks describe the basic interaction with the functions of the MASS and are an integral part of the tasks described in the DCoS models (cf. section 5 and appendix C). With the help of these tasks, specific competences of the operators can be derived.

5. Generic MASS ROC Models

5.1 DCoS Modelling

For the definition of the generic MASS ROC models, we followed a **human-centred design approach**. This means that the human operators in the ROC and on board are at the centre of the ROC design. In this way, human capabilities and limitations are considered right from the beginning. Human factors can be designed into the technical systems in order to support human strength and alleviate human limitations.

Moreover, we conceive the ROC as a socio-technical system or **Distributed Cooperative Human-Machine System (DCoS)** (see Figure 13). A DCoS consists of tasks (e.g., monitor traffic, recognize deviations from prescribed/predicted paths, understand MASS problems, solve potential collisions), human agents (ROC operators, seafarers), machine agents (e.g., MASS, assistance systems eventually with artificial intelligence functions) and resources (e.g., communication infrastructure). In a DCoS, tasks are allocated to agents who perform these by using resources. During cooperative task performance the agents interact and communicate to inform and support each other and to potentially adapt to a dynamically changing task allocation, e.g., in emergency cases. The expected workload of the operator during the different operational scenarios will be considered in the determination of the possibility to monitor several vessels temporarily or permanently by one operator. We also describe the consequences when operators actively interact with a vessel or its surroundings (communication relay) and when they exercise remote control.

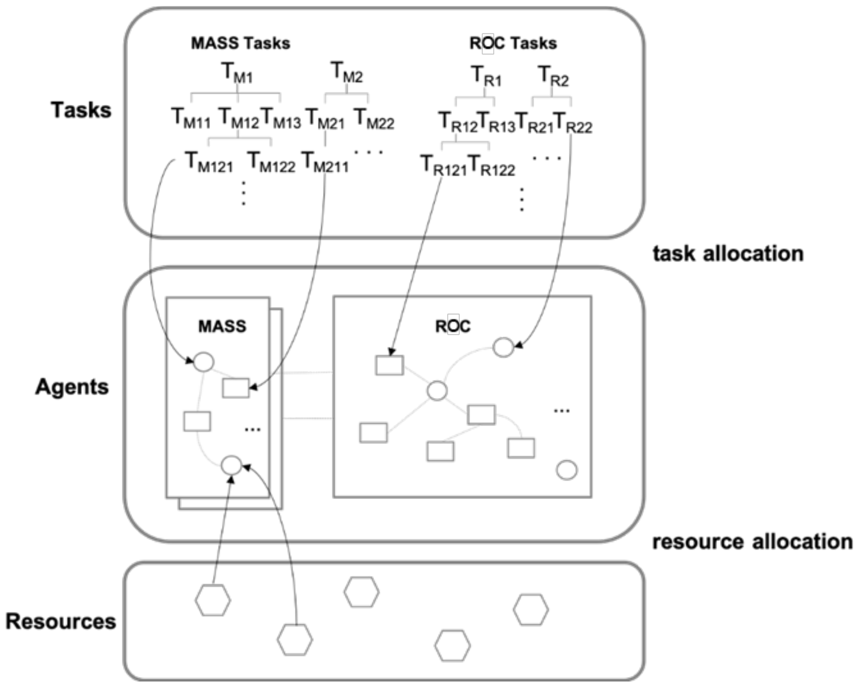

Figure 13: Distributed Cooperative Human-Machine System (DCoS) - Modelling Language.

The DCoS design perspective has the advantage of the elements of the ROC not being designed individually but as a whole, taking all interdependencies into account. It is the overall distributed system (consisting of MASS, seafarers on-board (if any), ROC operators and ROC assistance systems) that must perform the tasks cooperatively to guarantee safety at any time.

In this study, the focus is on the *functional* (in contrast to the *physical* design) design of the ROC. Thus, with regard to the human element, a great attention will be paid on the *cognitive* levels: Which information and which level of understanding is needed to efficiently and safely perform the allocated tasks and to keep the workload at an adequate level in all circumstances? Anthropometrical and physical levels are for later stages of the design, e.g., when the specific user interfaces are designed (not part of this study). This also implies that the level of detail of the functions must be sufficient to enable the identification of required capacities of operating personal. However, it is not intended to achieve a level of detail appropriate for any technical implementation of MASS or MASS ROC.

To address the requirements presented in the study, we slightly adapted the DCOS modelling *(*Figure 14). This affected the following core concepts:

- In the present use case, it is necessary to distinguish between the external agents (e.g., employees in the port who assist with docking or with whom communication takes place for certain tasks) and the internal agents. The latter take over the control of the MASS and take responsibility for safe operation. These are the operators in the ROC or on board of a MASS. The external agents are located on the left side of the diagram. We distinguish here whether the external agents are actively involved in the execution of the task (solid line) or whether only communication with the external agents is required (dashed line). In addition, the type of task execution is declared by the green letter. These are based on the ISO/TC 23860:2022 standard for MASS ROC and are the following:
  - **M - monitoring** (operations which monitor a situation but do not take any action to influence necessary processes)
  - **D - direct control** (operations to control a specific function or parameter)
  - **S - strategic control** (operations to issue fleet-wide instructions that implement and, if appropriate, define specific functions to be used by automatic decision-making units
  - **T - tactical control** (operations to influence the conclusions made by automatic decision-making units of the autonomous ship for a particular purpose)
- In the workshops with the reference groups, it was noticed that many tasks are repetitive or identical for the different vessel types at the present level of abstraction. For this reason, we label the tasks with the letters F (ferry), C (short sea cargo) and B (bulker). If a task is not applicable for a certain ship type, this will be shown in the diagram. Special considerations for the different ship types are also described in detail in the text in the following sections.
- The type of resources & information is framed differently: Required information is circled with a solid line (e.g., the information about the status of the ship) and required hardware resources are circled with a dashed line (e.g., radar). This distinction is important because it can lead to different competences. One piece of information must be made available to the operator within the MASS ROC or on board of the MASS. In addition to hardware resources, the operator may need knowledge of how they function. This comes into play especially when sensor values or unforeseen system failures need to be estimated.

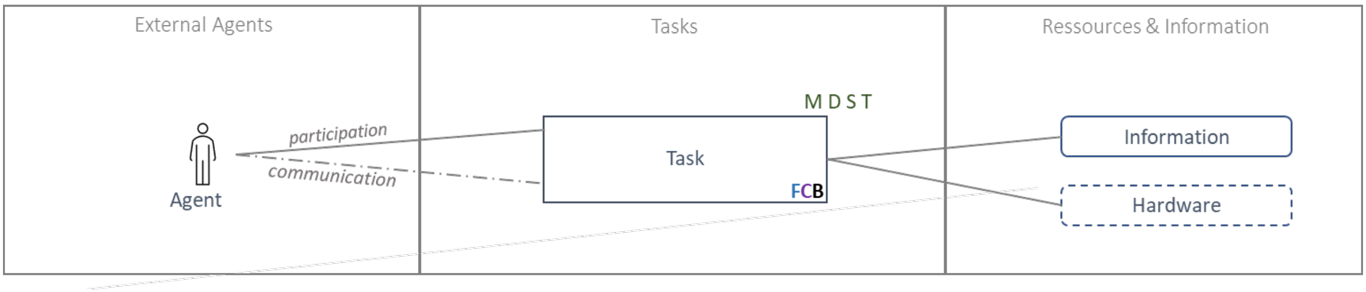

Figure 14: Adapted DCoS Modeling.

With this type of modelling, we have further broken down and analysed in detail all the main processes that we identified in step 0. These are described in more detail in the following sections. They are divided into *Voyage Planning& Control, Cargo Operations, Navigation, Engineering Operations, Maintenance* and *Malfunctions & Emergencies.*

All DCoS models can be found in **Appendix C**. In the following sections, the tasks within the core processes voyage planning, cargo operations, navigation, Engineering operations, maintenance, malfunctions & emergencies as well as management & support processes are roughly described. For each part, the main findings that will have an impact on a possible design of an ROC in the future and thus directly influence the required competences of an operator are addressed in detail.

The DCoS models were created in internal workshops where the processes were broken down into tasks. In these workshops, the internal project group considered the results of the interviews, workshops, and observations with the reference group as well as the results of the state of the art (including studies such as RBAT) and the internal expertise of the Bremen University of Applied Sciences. It was important that the level of detail was chosen to be in line with the need for the derivation of competences. In many cases, tasks can be broken down even further. This was deliberately not done because it would not have provided new insights for deriving competences, and also because there are uncertainties about how particular tasks will be performed on MASS in the future (the technology will significantly change and so will the detailed procedure of some tasks). Therefore, the DCOS models do not claim to be complete, but correspond to a level of detail that was essential for deriving the competences of future operators.

5.2 Voyage Planning & Control

Voyage planning describes two main processes: The planning of the voyage before it starts, and the voyage documentation and control (see Figure 15).

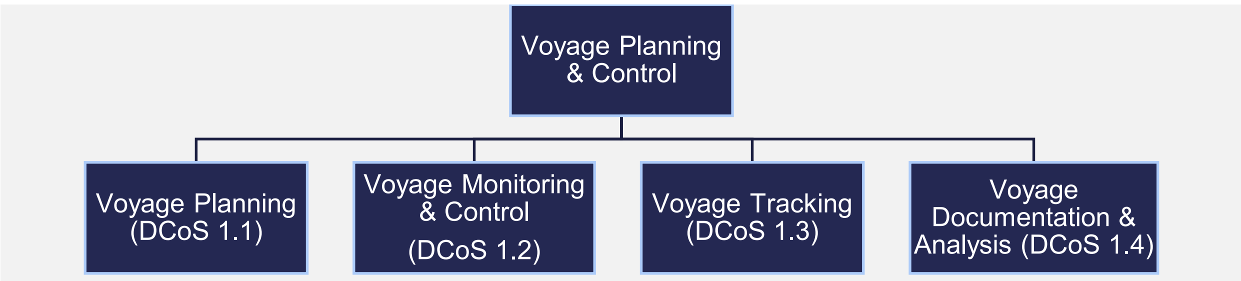

Figure 15: Process Overview for Voyage Planning & Control.

Voyage planning and control is an overarching process composed of 4 processes:

Voyage Planning (DCoS 1.1):
The planning of the voyage before the voyage starts includes planning the operation of port stays and schedules, considering port information, terminal requirements, stevedores or lash gang operations, and the arrangement of required automatic port facilities. The term “voyage planning” in this context has not the meaning as used in STCW Code, the focus is on the specific technical and operational requirements of a MASS system. Such a task can usually be performed in a day shift. Voyage planning is to be differentiated from passage planning, as passage planning refers to the planning of navigation on a ship, which includes the passage from berth to berth.

Voyage Monitoring & Control (DCoS 1.2):
During the entire voyage, all systems and technical components must be monitored to ensure correct functioning of the automation and thus of the MASS as it was described in section 4.4 in more detail.

Voyage Tracking (DCoS 1.3):
Besides monitoring the technical components, also the passage and compliance to the schedule has to be monitored. Thus, in Voyage Tracking, an operator has to observe for deviations in voyage parameters, the required performance indicators, and manage changes in operating the voyage.

Voyage Documentation & Analysis (DCoS 1.4):
Voyage Documentation and Analysis includes continuous collection and gathering of voyage related data and information, analysing this data and maintaining the electronic logbook with status and performance data for all operational issues as navigation and deck, propulsion and machinery, safety and security as well as MASS status and performance. The documentation of voyage data is also used to gain insights that will help optimise future voyages and operations as well as ensure the economic and safe use of the vessels.

The ship types of this study requests all the tasks in voyage planning and control. Only the frequency and the scope will differ.
A MASS in short sea traffic will be used on fixed route. The voyages can be planned once, later they are only adapted to the circumstances.
A ferry will have less effort in planning the trips as they operate on very short distances and visit very few ports. The journeys of a bulk carrier are significantly longer and can have changing ports and passages. The parameters to be considered, such as the technical capabilities of ports, the availability of pilots for a MASS or available navigational aids, may have broader requirements.
The tasks in monitoring, controlling, and tracking of all types of MASS are the same, the differences lie in the scope. The evaluation of voyage data as well as its documentation are necessary for all types of ships. The differentiation

is more driven by the data structures and computer technologies used. To summarise it can be said that the process of Voyage Planning & Control is to apply for all types of ships, only in different scopes and frequencies.

5.3 Cargo Operations

The cargo operations involve cargo planning and loading, cargo care at sea, and cargo discharging (see Figure 16).

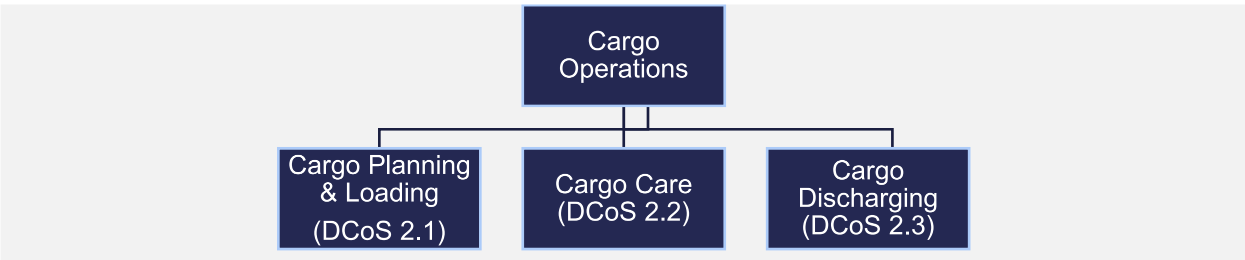

Figure 16: Process Overview for Cargo Operations.

Cargo is understood here not only as material cargo (e.g., containers in the case of short sea cargo and solid bulk shipped by bulk carrier), but also includes passengers in the case of the ferry. The presence of passengers makes the ferry a special case and the handling of passengers requires special attention.

Cargo Planning (DCoS 2.1) involves preparing and potential adjustment of the stowage plan, the planning of the ballasting and the check for stability, draught and trim.

In the case of container vessels, the loading plans are prepared by stowage centres and only need to be checked by the operators. An exceptional case is special cargoes such as dangerous goods, for which the responsibility for planning lies with the ship's management.

During the workshops and interviews with the reference group, it became clear that a lot of tasks could be automated in this process. In particular, the last part—ballasting the ship—is less relevant since modern ships are taking over a large part of the work here thanks to a modern design and new systems. Especially in the case of the ferry, it is no longer a problem if the loading (e.g., with cars) is not planned with the highest precision or if these plans are not followed exactly during loading.

Cargo Loading (DCoS 2.2) does involve controlling and operating the loading of cargo, containers, and vehicles, as well as ensuring safety and security e.g., ensure safety of cargo operation systems, ensure security for (ISPS tasks) and securing the cargo. In the specific case of the ferry, an additional task has to be performed. This is the monitoring of embarkation of passengers (DCoS 2.1.3).

During Sea Passage, the **Cargo Care (DCoS 2.3)** is relevant. This includes for instance monitoring and control of temperatures, ventilation systems, convenience of the passengers, as well as checking the status of cargo securing.

The **Cargo Discharging (DCoS 2.4)** resembles the cargo loading. In this process, the operator has to monitor and control safe and secure discharge of cargo and the disembarking of passengers. For this, the operator has to operate or monitor safe operation of the gangway, the ramps & doors, the hatch covers, and take care of the ballasting of the ship.

Apart from cargo planning, cargo operations take place twenty-four hours a day. Therefore, in a future ROC, cargo operations will have to be carried out in shifts. The operators in the ROC and the terminal[7] will handle the tasks listed above. It is assumed that the terminal will provide a service for planning, loading, and unloading the MASS. Nonetheless, the ROC will be responsible for ensuring that the vessel is correctly loaded and stable. As a lot can be automated, two main tasks remain for the operator: to monitor the safe execution of cargo loading, cargo care and cargo discharging and intervene in case of malfunctions or errors. Thus, the task might mainly consist of monitoring in the future.

The cargo operation processes have the greatest differences between the types of ships in this study. Therefore, the interfaces of the individual systems must be defined and the delimitation of the operators of a MASS must be

[7] The term „terminal“ as used in this study is summarising all possible port operations. A further detailed differentiation as in “stevedores”, “port captain”, “linesman” etc. seems not to be opportune because the automated services will be different from today and from port to port.

determined accordingly. There are no comprehensive definitions for these interfaces yet, they will develop with the innovations in the individual areas. The question of the distribution of responsibility in the port stay and during cargo operations cannot be answered comprehensively at this point.

For the MASS in short sea traffic, the transport of containers was assumed. The ports can be very different, the port technologies of a large container terminal are different than in a smaller port. The loading of containers can be planned completely by the land organization. The loading as well as the unloading of the containers will be operated by the terminal, as well as the lashing (if it is still necessary). Security, safety and occupational health can be monitored by appropriate service companies. However, the status of the MASS in the port must continue to be tracked and monitored by the ROC to be able to take over its control at any time. If there is a crew on board, they will have to take over a port watch. Overall, the cargo "container" is most suitable for automation since there is a high degree of standardization.

The ferry is significantly different, as it has rolling cargo and passengers. The planning of the loading can be done on land and controlled from there. The embarking of passengers can be taken over by the terminal, as well as the loading of vehicles. The care of the passengers is to be taken over by a special service crew. The operators as well as the crew on board considered in this study are not entrusted with the care of the passengers. As with the container feeder, the ROC must be able to monitor the status of the ferry during its stay in port and take over the ship at any time. The short layover times will also require an appropriate watch in the port. The delimitation of responsibilities and taking control in an emergency are topics that need to be addressed outside of this study. Regarding cargo and passenger operations, it should be noted that the processes can be carried out by the terminal, and the requirements for the operators can be aligned with the operational condition of the ship.

A bulk carrier has different loading and unloading requirements. The technologies used in the port depend directly on the type and quantity of cargo. For this type of vessel, it can be assumed that the cargo operations are also fully planned and controlled from by a ship planner ashore. Also, on this type of vessel, the operators in the ROC, and the crew that may be on board must monitor the status of the ship and keep it in an operational condition. As with the other types of ships, this applies to all the ship's own systems, such as equipment for cargo operations, ventilation, safety devices, mooring in the port, propulsion and auxiliary systems.

To summarise, all three types of vessels must be kept in operational condition by the ROC and possibly by the support of the crew on board. The cargo operations can be taken over by the terminals according to the specific requirements of the cargo types.

5.4 Navigation

Navigation is divided into the processes Leaving Port, Pilotage Outbound (confined waters), Sea Passage (open sea), Pilotage Inbound (confined waters), Arrival Port, and Port Stay. These processes are the same for each ship type and differ mainly in the ship's system or equipment and the degree of automation.

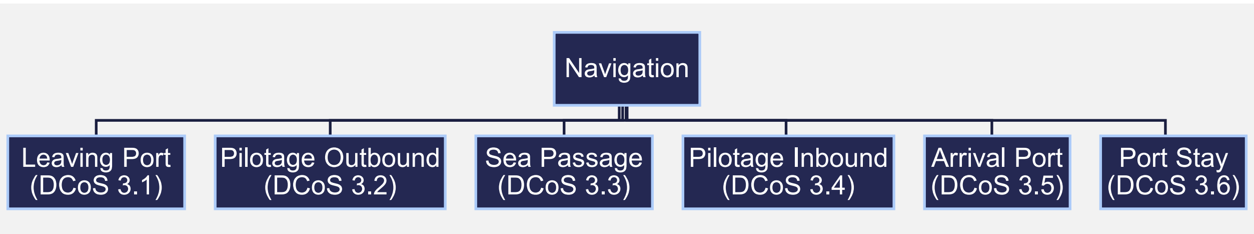

Figure 17: Process Overview for Navigation.

Leaving Port (DCoS 3.1) involves Passage Planning (DCoS 3.1.1) and De-Berthing (DCoS 3.1.2).

Passage Planning (DCoS 3.1.1) comprises tasks that have to be performed before leaving the port. This includes for instance planning and checking the passage plan (waypoints and speed), updating navigation systems and considering weather forecasts and environmental conditions for the vessels passage ahead. Automated navigational services on the passage must be considered.

After this, **De-Berthing** (DCoS 3.1.2) takes place. De-Berthing includes various checks (people on board, connections to port, ship status, watertight integrity etc.) and preparations (determine & arrange port facilities, release ship). It can be assumed that most of these checks can be conducted by automation in the future, and the operator contributes by monitoring the correct functioning. The main task of the operator during de-berthing will be the manoeuvring of the vessel to the fairway, for which the operator requires some information and knowledge (about the environment, the ship status, the passage plan, traffic information and background knowledge about the functioning and usage of navigational equipment).

The de-berthing process will be nearly identical for all ship types. Only within the tasks that are part of this process (see DCoS 3.1), there will be distinctions: E.g., different ship types may have various types of propulsion and rudders. This in turn will affect the manoeuvrability of the ship and will require the operator to gain experience in the ship type concerned over time. It was therefore noted in all interviews and workshops with the reference group that it makes sense for an operator to control and monitor sister vessels. However, a mental rapid switch between two ships technically very different can, otherwise, require a lot of cognitive effort and lead to errors and misjudgements.

Furthermore, the interview and travel with the ferry operator revealed that in some cases, limits are deliberately exploited during de-berthing manoeuvres (e.g., scraping along fenders, because it is already foreseeable that the wind will exert a force on the ship when it leaves a protected area. Otherwise, it is not possible to counter-steer in such a way that a point ahead of the ship can be passed without damage). A camera image on the ship bridge is currently used for this purpose, as well as the haptic feedback on the bridge. Such aspects must be considered for the design of the ROC as well as the automation of the MASS.

Pilotage Outbound (DCoS 3.2) as well as **Pilotage Inbound (DCoS 3.4)** describe manoeuvring the vessel in confined waters. External Agents with whom the operator has to communicate in this process are the Vessel Traffic Information Service (VTS) and other ships. The tasks in this process involve several checks (e.g. position, water depth, under keel clearance (UKC), weather, current and tide, bathymetry), communication with other ships and the VTS, and controlling the ship (course, speed) to follow the planned voyage and avoid collisions in confined waters.

In confined waters, there are sometimes hydrodynamic interactions or other circumstances that affect navigation (e.g., a changing and low UKC due to shifting sandbars). In the interviews with the reference group, it was emphasised that many navigators use the haptic feedback from the vessel to assess the situation. This is based on many years of experience. For the ROC design, it is important to see how many sensors and information need to be correlated in order for the operator to have good situational awareness even though he/she is physically distant from the vessel.

The **Sea Passage** (DCoS 3.3) describes navigation at open sea. This involves determining and checking the ship position, monitoring weather and environment, and monitoring ship status. Furthermore, the operator has to control course and speed of the vessel, apply COLREGs and avoid collisions. For the latter task, the operator might have to communicate with other vessels.

The workshops and interviews revealed that the sea passage is the part of the navigation that requires the least attention from a potential navigator in the control room. The highest cognitive effort within the tasks of this process lies in communication. Here, miscommunications and misunderstandings between two ships occur frequently. This can be additionally complicated in a possible mixed traffic (autonomous ships, non-autonomous ships). Thus, a particular focus for the competences of the MASS ROC operators should lie on training appropriate and target-oriented communication with different traffic participants.

The process **Arrival Port** (DCoS 3.5) comprises **Anchoring** (DCoS 3.5.1) (e.g., in case the vessel has to wait in a specific area for the berth to be available) and **Berthing** (DCoS 3.5.2).

Anchoring might happen not only in the case of waiting, but also to take shelter or to other operational reasons. In this study, anchoring is summarised in this process for all cases.

The berthing of the vessel is quite similar to the de-berthing. The main tasks are manoeuvring the ship to berth, fastening the ship, and connecting power, water, fuel etc.

For the task *manoeuvre ship to berth*, the interviews and workshops revealed that the bridge personnel use visual signals (in particular optical overlays of these) in order to be able to determine the current position more accurately. For this purpose, suitable substitute options would have to be provided in the MASS ROC. As the operators are no longer on board of the ship, the information will have to be presented in an appropriate and efficient way in a future control room in order to build up situational awareness adequately. It is important to note that this probably cannot be replaced by visual feedback only but may need to be supplemented by haptic & acoustic feedback in order not to cognitively overload the operators.

The last process in navigation is the **port stay** (DCoS 3.6). This includes mainly safety and security aspects. Thus, the operator has to maintain security and safety watch, control persons on board as well as the state of berth connections.

The requirements of the different ship types concerning the navigation processes can be stated as the same. The main differences are found in the scope of the activities to be carried out.

Each of the ships must plan its passages. This planning is less complex for the ferry than for a feeder ship with a journey duration of one week in short sea traffic. The bulk carrier has in addition ocean passages to consider. The support of advice from pilots is very dependent on the requirements of the areas and local regulations. Weather routing will be more important on longer passages, but also on the other ship types it is necessary to control the MASS according to the environmental circumstances. Ferries will tend to require less pilotage advice than bulk carriers, which rarely call at a port. For MASS, it must be assumed that the technology of pilotage support will change, but pilotage advice will continue to be required, especially on feeder vessels and for large overseas vessels.

In terms of navigation and determination of position, the requirements are the same for all three types of ships. All navigation systems will meet the same standards. In complexity, the differences lie more in the progress of innovation than in application.

Collision avoidance is subject to the same rules for all ships, which must be applied accordingly.

Significant differences can be found in manoeuvring behaviour. The propulsion systems will differ significantly. Ferries have propulsion systems that allow them to manoeuvre independently in all environmental conditions. Bulk carriers, on the other hand, are designed for long journeys and will require tugboat support for port manoeuvres. Anchoring manoeuvres depend on local conditions as well as the size of the vessel, manoeuvring behaviour and environmental conditions. These manoeuvres must be able to be carried out by the operators for all types of vessels.

In summary, it should be noted that the processes of navigation can differ significantly but will always fall back on the same basic skills. A differentiation of the requirement from the processes of navigation makes no sense since any MASS can meet similar situations.

5.5 Engineering Operations

Engineering Operations refers to the technical operation of a ship. The technical operation includes all technical installations and equipment of a seagoing vessel. The list is a basic framework which can be broken down into the multitude of individual units:

- Propulsion, consisting of energy storage, engine, propeller system, rudder and thrusters, as well as newer technologies such as wind power (e.g. Flettner rotors, rigid sails),
- Auxiliary equipment such as power generation, pump systems, cooling and heating systems,
- Supporting systems as energy generation by solar cells or wind power,
- Deck operating systems such as anchor windlasses, mooring equipment, cranes, hatch covers, bow, stern and side doors and their opening, closing and securing associated systems,
- Ship safety equipment such as fire detection and extinguishing systems, and rescue systems,
- Automation systems and high and low voltage systems
- Communication systems and data lines between MASS and shore as well as on board and in the ROC
- Autonomous control systems with IT network (hardware and software)
- All hoteling systems for accommodations and passenger areas

The technical operation must be guaranteed to ensure a safe passage to the Port of Destination. All systems and equipment must operate reliably and have a high level of availability.

It is assumed that remote-controlled cargo ships on short sea passages will be equipped with electric propulsion and technologies for power generation. These are characterised by easier operation and lower maintenance. Internal combustion engines are only used to generate electricity. Larger internal combustion engines are much more complex and require more control and maintenance. They are unlikely to have a future in remotely operated shipping. Other technologies to consider are solar panels or wind turbines for power generation, or rigid wind sails for longer distance passages. Innovations are expected in the types of machinery and equipment, as well as in their combination.

The following processes are therefore fundamental in nature and may occur to varying degrees.

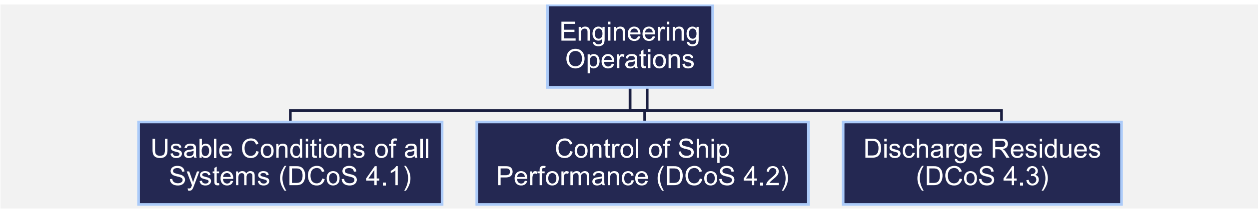

Figure 18: Process Overview for Engineering Operations.

shows an overview of the processes for Engineering operations. This includes ensuring utilisable condition of all systems, controlling ship performance (engine department) as well as discharging residues.

To ensure **usable conditions of all systems** (DCoS 4.1), the operator has to conduct two tasks: bunkering and supply (DCoS 4.1.1) and performing system checks (DCoS 4.1.2). The bunkering and supply involve e.g., connecting and disconnecting electric power, charging batteries, bunkering of fuels, gas, lubrication etc., loading spare parts and replenishment of provisions, consumables. The system checks comprise of preparation and checks of the propulsion system, the auxiliary system, and the automation system.

The second process in Engineering operations is **control of ship performance** (DCoS 4.2). This includes control of auxiliary and machinery systems (DCoS 4.2.1), control of propulsion systems (DCoS 4.2.2) control of performance (DCoS 4.2.3) (e.g., monitoring of indicators for performance, efficiency and consumption) and hoteling (DCoS 4.2.4) (e.g., providing related services for passengers such as air conditioning).

The third process is **discharging residues** (DCoS 4.3). This includes discharge of garbage and sewage, as well as discharge of oily residues, residues of noxious liquid substances and solid harmful substances.

While discharging mostly takes place in port, the controlling of the ship performance takes place during the whole sea passage.

The interviews and workshops revealed that Engineering operations can be carried out well in an ROC ashore. However, one special feature should be considered: In some cases, technicians intuitively pay attention to noises made by the machines. A change in sound can be the first indication that a machine is no longer running properly. For this purpose, it would be beneficial to have a crew on board, who can pay attention to noise, visual signs, etc. on site. In case the ship is only controlled by the ROC (without crew on board) there must be an adequate replacement for this.

Compared to conventional ship systems, the engine control station is expected to merge with the bridge equipment. In addition to navigational data, an operator will also receive data and information from the engine and other technical equipment.

It is expected that an operator will also take over the alarm management of the engine. For more in-depth problem solving, operators with appropriate competences will need to take over these tasks. The scope and capabilities will depend heavily on the type and size of the machinery and will need to be defined individually for each ROC as part of the concept of operations.

Special attention must also be paid to the task of monitoring the automation itself. This task does not yet exist in the complexity that can be expected in a future ROC. In order to derive the exact tasks of an operator in this area, the functionality of the automation must be known. A first version of this at a high level of abstraction is given in section 4.3.

As previously described, the requirements of the different types of ships differ considerably in terms of their propulsion technology and auxiliary machinery and equipment.

The technologies of MASS's future propulsion systems are developing rapidly. Ferries and ships on short sea distances can be equipped with electric drives. On longer passages, other types of propulsion and energy systems can be expected. All three types of ships require supply and disposal in the ports, which must be monitored by operators. The port authorities will take over the operational tasks on site, and if a crew is on board, they can monitor such activities on site.

On the passage, all systems on all types of ships must be monitored. This can be done by operators in remote mode. A crew on board is necessary where individual systems cannot yet be operated in autonomous mode. They can also carry out fault analysis on board and take appropriate measures to maintain the operation of the ship. It does not make sense to differentiate between ship types. The technologies used on board are crucial.

5.6 Maintenance

A challenge for seagoing vessels such as short sea cargo and bulk carriers is their complex machinery and long periods at sea without the possibility of shore-based support. The maintenance process must be subdivided into maintenance in port and maintenance at sea.

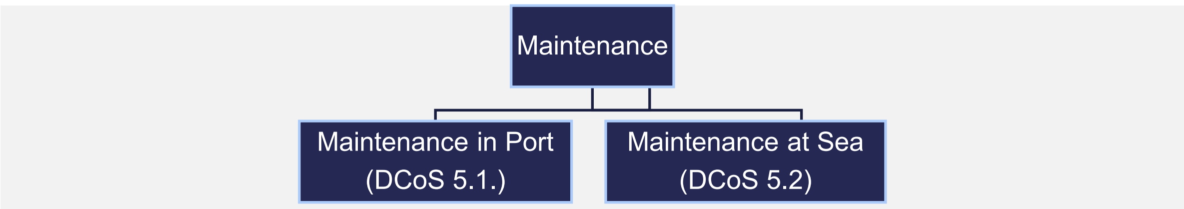

Figure 19: Process Overview for Maintenance.

Maintenance in Port (DCoS 5.1) includes Maintenance Planning (DCoS 5.1.1) (e.g. condition monitoring/planning maintenance, inspection of ship structures, inspection of all equipment (planned, condition based) and planning, starting and check of work orders), and overhauling and repairing the vessel in port (DCoS 5.1.2). It can be assumed that the planning and monitoring of maintenance will be controlled in ship management departments as the condition of a vessel, and therefore the maintenance costs, are of great interest to the ship manager. The ship management departments will also take over the planning and provision of spare parts. However, a ship manager's interest is that a ship fulfils its mission at sea and stays in port for as short a time as possible. So, there will be a certain amount of maintenance at sea.

Maintenance at Sea (DCoS 5.2) involves the inspection of all equipment (planned, preventive, predictive) (engine area, nautical equipment, etc.) as well as repairing and maintaining the equipment during sea passage. The maintenance at sea must be carried by personnel who are on board. In the interviews with the reference group (focus on container ships, bulkers) it was said that continuous maintenance by personnel onboard is favoured for cost reasons. Involvement of external companies for the tasks of this process and maintenance in port would cause higher costs and is therefore not preferred. On the other side the experience from other industries (e.g. IT companies) is that maintenance is more and more outsourced to specialized service providers. This fact is also to consider for future MASS systems with higher technical complexity which will be an important additional interface for ROC operators.

Maintenance tasks that can be transferred from a vessel to a ROC will focus on inspections that can be carried out remotely. This requires the transmission of data (temperatures, vibrations, flow, etc.) or video signals. Software updates can also be performed remotely. As already mentioned, the cost of maintenance will also depend to a large extent on the innovative development of low-maintenance technical equipment.

In the future, battery powered electric motors could lead to lower maintenance requirements than is still the case with today's predominant diesel engines. However, it is not yet foreseeable how/when the full transition from diesel engines to battery powered electric motors will take place.

The maintenance processes must be implemented for all ship types, but they depend on the technical development as well as possible sensor technology for the individual systems:

> Maintenance planning will change towards condition-based maintenance.
> Inspections will increasingly be carried out remotely.
> Necessary ongoing technical maintenance on-board will have to be reduced.

> Repairs must be scheduled by the ROC in suitable time windows.

Special riding crews will be on board for the implementation of maintenance on board. If a crew is on board, they will be able to take over inspections and parts of the technical maintenance. The task of the operators will be to carry out remote inspections, to detect deviations from setpoints and to interpret them, as well as to operate automate maintenance. Operational maintenance work on a MASS is to be controlled by the ROC operators in coordination with the operation of the MASS.

The processes of maintenance do not differ according to the ship types, they are technology driven. Only the time slots for maintenances will be different. A ferry will have very short time in port, but riding crews for maintenance can board and leave the MASS in each port stay quite easily. On short-sea relations the maintenance is to be planned according to the schedule. The time in port for feeder ships will not be very long, maintenance must take place on sea passages, too. The vessels on long-haul passages will need a permanent crew to take over most of the maintenance. Port stays will be longer than for the other ship types but will not be sufficient for all maintenance tasks. The operators of the MASS are not part of the maintenance crews, they just plan and control the tasks. The crew on board, in the parameters of this study, can support the operators in the ROC. However, they should not be distracted by doing maintenance.

5.7 Malfunctions and Emergencies

Risk assessment and contingency planning are already mostly carried out by the shore-based organisation. However, the implementation on the vessels or MASS must be done by the crew or respectively by the ROC operators.

Thus, Malfunctions & Emergencies involve not only the response to emergencies and malfunctions to take countermeasures but also the emergency preparedness (see Figure 20).

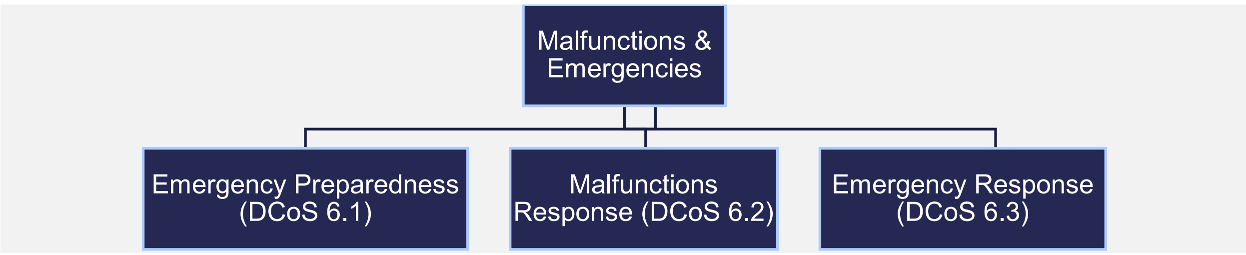

Figure 20: Process Overview for Malfunctions & Emergencies.

Emergency Preparedness (DCoS 6.1) includes performing risk assessments (operational, navigational, occupational, technical, ...), setting up and establishing of contingency plans as well as training and drill participation of the crew and the ROC. The contingency plans have to cover the entire MASS system, that means the MASS itself, but also the data connectivity and the operation of the ROC.

The **response to malfunctions & emergencies** (DCoS 6.2, DCoS 6.3) describes the reaction to alarms e.g., taking appropriate countermeasures in case of a blackout. The response and control of malfunctions and emergencies will require additional capacity, both in terms of manpower and skills. For this reason, it can be assumed that emergency response teams with experts will be set up in the ROC in such cases. Such emergency response teams will need a separate emergency control station for monitoring the conditions on board of the MASS and to take the direct control. In the ROC the operations of other MASS in normal condition shall not be influenced by distraction or additional workload.

Malfunctions and emergencies will differ according to the specific MASS and ship type. The necessary contingency plans are an outcome of risk assessments and will be MASS-specific. The processes in this study can only be determined in general. Malfunctions and emergencies might cover the cases in Table 9 but are not restricted only to these:

Table 9: Exemplary malfunctions and emergency cases

Malfunctions	Emergencies
> blackout > steering gear failure > loss of engine > loss of propulsion > spills (SOPEP) > failure of sensors and automation devices > failure of remote-control system > extreme weather > SAR support (if possible)	> loss of data connectivity > cyber attack > collision > grounding > structural damage > water ingress/flooding > fire in holds/engine/auxiliary/accommodation > emergency towing/pushing > evacuation > person overboard > medical emergencies > helicopter operations in emergencies

To react fast in case of emergencies and malfunctions, the MASS operators always have to keep an overview of the condition of the vessel. This includes not only information about the status of navigation (course, speed, heading, etc.), but also information about maintenance work (e.g., on engines), alarms in different areas of the ship, information concerning the safety of passengers, and information about the status of all technical equipment on board (e.g., ventilation systems in cargo holds or galley areas).

Such an overview would also need to be maintained by an ROC ashore. Especially concerning alarms, shore-based support may be needed. If an alarm occurs in a situation where a difficult navigation manoeuvre is being performed (e.g., berthing), an emerging alarm must be taken over by a second person. This person evaluates the alarm and decides whether a person on site must pass on further information about the situation. For example, in the case of a fire alarm, the cause can be identified, the extent can be assessed, and relevant information can be passed on that is needed to initiate the appropriate countermeasures.

In the case of serious incidents, in the ROC an emergency response team (ERT) may need to take over the management of the emergency. Depending on the type of incident, this can be composed of operators and experts in different qualifications. The persons who take on these functions must have an appropriate experience and demonstrate the highest level of competence. Internet applications can support the teams, e.g., for collecting information and data which can be shared also with external partners such as SAR units, salvage organizations or VTS.

The interviews, workshops and observations within the reference groups revealed that handling malfunctions and emergencies is an enormously important aspect.

Malfunctions covers situations that are not emergencies but can become emergencies. Malfunctions generally massively restrict the operation of a MASS and must be solved immediately. The hazards that can arise from a malfunction are very dependent on the circumstances, such as traffic situations, navigational hazards, environmental conditions, and complexity of the incident. For each type of ship in this study, the malfunctions are essential threats. A differentiation according to ship type cannot be implemented in the processes. The handling of such incidents must be ensured by appropriate and MASS-specific emergency plans.

The distinction between malfunction and emergency is not clearly defined. It is up to the operators to decide when an emergency exists or when there is a risk of an emergency situation arising. According to the contingency plans, operators must act immediately. If a crew is on board, they can significantly support the operators in the ROC. The crew on board can more easily assess the situation, operate safety equipment, take care of the people on board, and control and deploy control measures more easily. Handling emergencies from an ROC is only possible to a limited extent, where automated systems such as for firefighting can be used. Even an assessment of structural damage or water ingress will be problematic for an ROC, as the situation can be complex. Minimising hazards, for example from fire or water ingress, can be achieved by new structural designs of MASS in future, supported by adapted sensors and safety devices.

As previously shown, the processes of handling emergencies must be defined on a ship-specific basis. Based on the requirements, fundamental similarities and differences between the types of ships examined can be identified as follows:

For all MASS, faults and failures of the automation technology and autonomy are very critical. In this situation, operators must be able to keep the MASS under control. The MASS can also put itself into a sleep mode (stop drive, emergency anchors, etc.), for which an ROC must be able to override. If there is a crew on board, they can provide support, but will need all the skills of an operator too.

Significant dangers come from cargoes. Containers carry dangerous goods, vehicles on ferries pose great dangers (batteries, cargo), and bulk cargo has a wide variety of properties. The contingency plans must be designed accordingly.

At this point, it is worth noting the challenge that exists for people on board MASS. In the event of an emergency, they must be mustered and moved to safe areas. In extreme cases, they must be evacuated. It can be assumed that a crew trained in ship safety must be on board if other persons such as riding crews, service crews, or passengers are on board. The crew on board will be able to take control of passengers and other people on board. The operators in the ROC will keep the MASS under control as long as possible, but a transition to the responsibility of the crew on board is expected sooner or later.

The strictest requirements are for ferries that carry a larger number of people. Appropriate evacuation systems will be necessary and must be able to be operated and deployed. Rapid support by auxiliary ships is conceivable, but for ferries on longer journeys, this is only conceivable with a time delay.

The designs of MASS, which are conceived as larger seagoing vessels, are still unknown. Regarding the handling of emergencies, appropriate safety equipment, facilities for boarding, an unmanned MASS and helicopter areas will be necessary, which can be operated and deployed by operators in the ROC and crews on board.

6. MASS ROC Roles and Structural Organisation

6.1 Operational Model

This study assumes two scenarios:

1) Remotely controlled ship **with** seafarers on board: the ship is controlled and operated from another location; seafarers are available on board to take control and to operate the shipboard systems and functions.

2) Remotely controlled ship **without** seafarers on board: the ship is controlled and operated from another location; there are no seafarers on board.

The scope of consideration includes the nautical-technical ship management, i.e. navigational and technical officers. Ratings are not covered.

Scenario 1: MASS with crew on board

In this scenario, the MASS is monitored and controlled from an ROC. The crew on board only takes control when necessary. This scenario does not specify in which situation which control functions are taken over by the crew and to what extent. Different individual scenarios are conceivable:

> If the remote control fails, the crew can take over on board.
> In the event of failure of individual functions of the MASS, the crew can take them over on board.
> In situations with higher demands, such as when the ship docks or casts off, the crew can take direct control.
> The crew can take complete control and the ROC is in stand-by in the background.
> Part of the passage (departure, pilotage, arrival) is carried out by a crew on board, the ROC accompanies these phases in stand-by. For the sea passage, the crew may leave the MASS and the ROC takes over the controls.
> Only parts of the MASS system can be operated remotely, specific systems still require manual operations and control on board.
> … further scenarios are conceivable.

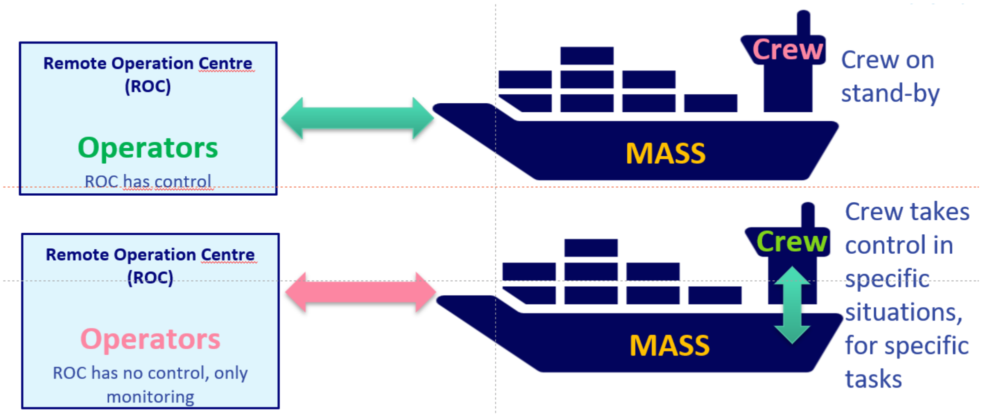

Figure 21: Constellations of remote control with seafarers on board.

Due to the many possibilities of task distributions between crew and operators in the ROC, assumptions are made for this study:

> The operators in the ROC control and operate the MASS on the entire passage.
> The crew only takes over in certain cases, for example the direct control mode or in case of system problems.
> The ROC-MASS data and communication connection remains in place (except in the event of failures).
> The human-machine interfaces of the equipment on board corresponds to the human-machine interfaces in the ROC.
> The degrees of automation and degrees of human control (see Chapter 1.3) shall be adequately defined for control by the ROC and by the crew on board.
> The ROC is completely responsible for MASS operations in remote control mode.
> If the crew takes over the control and operation of the MASS, then the crew takes the responsibility for the MASS completely or for parts of the system.

> Operators in the ROC need all the competences to control a MASS.
> The crew on board needs competences to take over the MASS systems and operate them in stand-alone mode. They will need the same competences about the MASS-system as the operators in the ROC.

In terms of the necessary competences, the requirements must be in accordance with the tasks and responsibilities. Since an ROC basically takes over complete control and operation of the MASS, it can be assumed that the same competence requirements of operating a MASS without a crew on board are also necessary for operators. Operators can receive additional support in their tasks from a crew on board, which is helpful but does not reduce competence requirements. Also, the crew must be able to understand the entire MASS system and operate, analyse, and evaluate it. In case they have to take over full responsibility for the MASS, they must be able to handle the same tasks as in the ROC. Their advantage is that they have personal situational awareness of the on-board situation, and do not have to rely on remote sensory systems.

Scenario 2: MASS without crew on board

In this scenario, the MASS is controlled completely and only by the ROC. In the context of this study, the competences of the operators are understood in such a way that the operators of a MASS are able to take over all the tasks that a ship operation entails in order to sail a MASS from port A to port B.

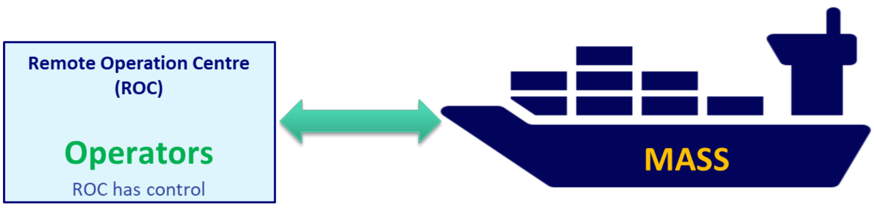

Figure 22: Constellations of remote control without seafarers on board.

Ship types

The operational model in this study is designed for seagoing ships. A specific MASS code by IMO is to be expected for such MASS types.

In the structures of the ROC design derived below, each of the ships under consideration can be controlled and operated. The differences lie in the necessary number of individual workstations, as well as the capacity requirements for operators. It has not yet been defined for which ship sizes competence requirements are imposed. The operational model proposed in this report does not set the limits as in the STCW Convention. The recommendation of the project team and after consultation of the reference groups is to set the limit to a length of 30 meters for all operators. The use of units such as “gross tonnage” or “kW” are not found to give realistic limitations. For example, new propulsion technologies such as wind power will not be covered. Additionally, one unit is proposed which can be used for all MASS operators. The proposal is based on the assumption that ships with a length of 30m and more are operated in international voyages and will have a considerable size. For MASS below the limit of 30 meters, reduced requirements can be imposed. Smaller MASS are more likely to be expected in coastal waters, and the requirements can be coordinated and implemented by the local authorities.

Of course, the length of 30m is a proposal. It should be discussed thoroughly which ship size of MASS will need qualified operators.

6.2 Deriving a Structural ROC Design

The results described in this report (in particular insights from the state-of-the-art and the DCoS models) have an influence on how an ROC should optimally be designed by its structure and which roles are involved in such a control centre.

The following chapter describes in detail how the structural ROC design is derived. In this context, structural design explains a generic model which determines the fundamental organization (e.g., division of tasks among roles, etc.)

However, specific and concrete visualization suggestions as, for example, with user interfaces will not be provided by this model. To derive the structural ROC design, 5 steps were carried out. These are shown in Figure 23.The steps are described in detail in the upcoming subsections.

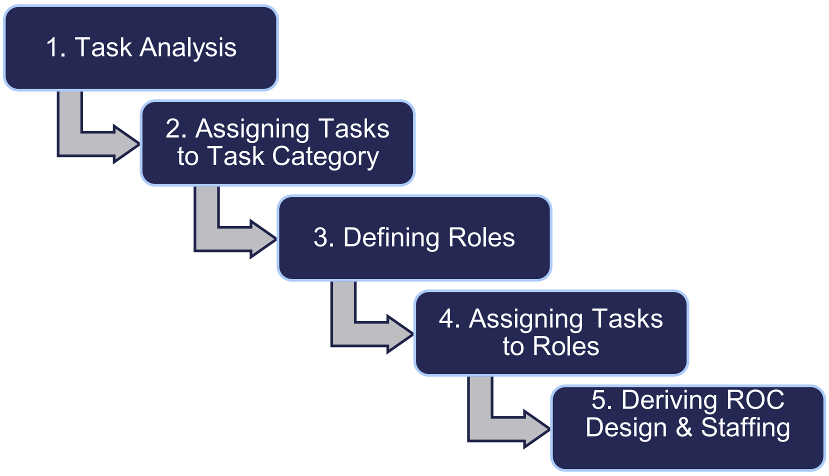

Figure 23: 5-Step Process to derive ROC Design Concept.

6.2.1 Task Analysis

To design an ROC, it is essential to first define all tasks to be performed in the ROC using a task analysis. A task analysis is a key step in gaining a deeper understanding of who communicates with whom, what resources are needed, and what the workflows in a process look like. Based on the task analysis, a categorisation of the tasks can be made, which allows conclusions about the mental workload of the operators. On this basis, the tasks can finally be distributed to the individual roles within the ROC and can be used to define concrete competences for the operators.

Within the scope of this study, a task analysis was carried out based on the core processes defined in Chapter 4. The results of the task analysis are described in Chapter 5.

6.2.2 Assigning Tasks to Task Categories

In the second step, the tasks have been assigned to different categories based on the ISO/TS 23860:2022. These categories include monitoring, direct control, strategic control, and tactical control. They are marked by the letters M, D, S or T on top of the task boxes in the DCoS Models (see **Appendix C**).

These types of tasks are particularly relevant when it comes to the design of the ROC (Remote Operation Centre). They place different demands on operators and how they are processed. Some require special concentration and a focus on individual elements, which excludes parallel execution with tasks that require an overview. The type of task, therefore, has a significant influence on what can be done in parallel, how it is processed, and who can be assigned to it.

Next, the task types will be defined in more detail, with a special regard to the human factors, engineering perspective, and the influence the type has onto the assignment to different roles.

Strategic Control

Strategic Control refers to operations to issue fleet-wide instructions that implement and, if appropriate, define specific functions to be used by automatic decision-making units. Making such decisions and instructions requires planning and organisation. It must be ensured that decisions and adjustments made are in line with the overall goals. This may require analysing historical data to make predictions and decisions for optimisation. Strategic control requires a high degree of focus and concentration on the task at hand. Examples for strategic control are anticipatory long-term decisions and specifications such as adhering to a certain speed under certain conditions in order to save fuel.

Tactical control
Tactical control refers to operations to influence the conclusions made by automatic decision-making units of the autonomous ship for a particular purpose. In terms of the nature of the task, tactical control is very similar to strategic control in that it involves planning and organisation. While strategic control is long-term, tactical decisions are short to medium term, such as weather routing or speed decisions in relation to ETA.

Direct Control
Direct Control refers to the ability of operators to directly interact with and manipulate and control remote systems, parameters, and processes. This can include activities such as manoeuvring the ship in challenging situations (e.g., in berthing/de-berthing or for handling malfunctions and emergencies), controlling the automation (e.g., adjusting parameters and states), and controlling ship components (e.g., remotely operating the anchor).
This type of task usually requires concentration and focus on individual elements, performing an action, and assessing reactions to make adjustments based on feedback received from the system.

Monitoring
Monitoring refers to the process of observing and evaluating the performance of a control system or process by a human operator or team. The purpose of monitoring is to detect and respond to any deviations or anomalies from normal operations in order to maintain the safe and efficient functioning of the system.
In a control room setting, monitoring involves the continuous observation of various sources of information, such as displays, alarms, and control panels. The operator or team responsible for monitoring must be able to quickly identify and interpret the information presented, make decisions based on that information, and take appropriate actions to ensure that the system will remain within safe operating limits.
Effective monitoring in control rooms requires not only the ability to process information quickly and accurately, but also a comprehensive understanding of the system being monitored, as well as the potential risks and consequences of deviations from normal operations.
Monitoring involves observing and assessing different values at regular intervals and having an overview of the situation.

Basically, strategic control, tactical control, and direct control all require a high degree of concentration on the task at hand. This has an influence on the allocation of tasks to different roles in the ROC: e.g., in the ROC there must be roles who perform individual direct control tasks (e.g. a berthing manoeuvre), while other roles keep track of information about the fleet (e.g. monitoring the status of cargo). Simultaneous performance by one person is not viable, as the workload does not allow the person to concentrate on, for instance, a steering task (direct control) and monitor further values from other vessels at the same time.
Classifying these tasks into such categories accordingly facilitates the definition of roles and allocation of tasks to these individual roles in the ROC. This will be described in the upcoming chapters.

6.2.3 Defining Roles

The third step is the definition of roles in an ROC. A role is defined by the assigned tasks and the resulting responsibilities as well as the communication and dependencies to other roles. A clear role definition makes it possible to derive the necessary competences for each of these roles.

The roles must be defined in such a way that all identified tasks in the underlying study can be assigned to the roles. This assignment also requires careful consideration of the task categories (M, D, S, T) from the previous step "Assigning Tasks to Task Categories". Some tasks require a high level of concentration and attention, while other tasks are less demanding. It is important that the roles are designed to take into account cognitive abilities and to ensure that each operator is able to perform their tasks effectively. For example, it is not possible for a role to be responsible for berthing a ship while simultaneously monitoring sensor data from other ships.

Another aspect of the role definition is that the assigned tasks fit thematically and are compatible with each other, i.e., operators should be assigned to tasks from a specific area of expertise (for example, engineering skills). This is to prevent an operator from suddenly having to take on tasks that require specialized skills and knowledge they may not possess. An example of the importance of thematic coordination of operators' tasks in the ROC is the division of roles between navigation and engine room. An operator responsible for navigation requires specialized knowledge in navigation, weather forecasting, safety protocols, and communications with other vessels. An operator responsible for the engine room, on the other hand, needs specialized knowledge in mechanical engineering and maintenance.

When deriving the roles the level of responsibility was considered. Here we adopt a similar approach as that used for the levels of responsibility defined in the STCW Code, namely, management level and operational level, for establishing levels of responsibility of ROC MASS operators. In 1995, the STCW Convention was amended by introducing the STCW Code to reflect the changing needs of the shipping industry, and the amendments included the concept of management level and operational level.

The reason for introducing management level and operational level was to differentiate the level of responsibility and authority of the seafarers. The management level is meant for seafarers who have higher levels of responsibility, while the operational level is for seafarers who have more operational duties, such as watchkeeping.

Seafarers who have management-level positions require a higher level of knowledge and skill to manage the ship's operations and to make decisions in critical situations. They also need to have a comprehensive understanding of the shipping industry's regulations, standards, and best practices. On the other hand, seafarers who have operational-level positions focus on carrying out the operational tasks. They need to have a sound understanding of the ship's systems and operations, as well as the safety procedures and emergency responses.

By dividing the competence, training and certification requirements into management and operational levels, the STCW Code ensures that seafarers are required to achieve competence standards through training relevant to their specific roles and responsibilities. This must also be ensured for future roles in upcoming ROCs and MASS. For this reason, the division into management and operational levels is maintained in the definition of roles of MASS ROC operators in this study.

Within the scope of this study, remotely operated ships by operators in a ROC (in configuration with or without crew on board) are considered. Considering the mentioned factors and the task analysis of the individual use cases, the following roles of the personnel in an ROC are suggested ROC (cf. Table 10):

Table 10: Role description for operators

Role	Description
Remote Fleet Supervisor	The '*Remote Fleet Supervisor*' maintains an overview of the remotely controlled vessels and the operators and organizes the workflows in the ROC. The responsibilities associated to this role include supervising and ensuring resource management in the ROC. The' R*emote Fleet Supervisor"* is constantly aware of the current status of all vessels in a fleet and can make decisions in safety-critical situations to ensure the safety of the vessels. This is a management role that requires similar experience to the current role of the Master. However, specific tasks differ in certain areas, which is why the role of *'Remote Fleet Supervisor'* is introduced instead of a Master. The *'Remote Fleet Supervisor'* is, like the Master, a position (or capacity) that requires the qualification as Remote Senior Navigator.
Remote Senior Navigator Management Level	The Remote Senior Navigator on a management level takes over tasks that require direct control such as steering/maneuvering vessels or remotely dropping/heaving the anchor. These tasks belong to the category of direct control and therefore require a high level of concentration, competences and experience. This is a management role.

Remote Navigator Operational Level	The Navigator on an operational level has the task of monitoring the ships, and based on this, detect safety-critical situations and initiate appropriate countermeasures. The Remote Navigator maintains close communication with the Senior Navigator.
Remote Senior Engineer Management Level	The Senior Engineer on a management level has the responsibility to coordinate necessary maintenance tasks of the MASS or to perform failure analysis for technical systems. To perform this task effectively, the Senior Engineer needs a complete overview about the condition of the machinery and the systems of the MASS, and has to monitor the systems constantly. In case of crew on board, the MASS Senior Engineer will give direct orders to an Engineer on board in cases that require human interventions.
Remote Engineer Operational Level	The Engineer on an operational level is responsible to carry out tasks such as bunkering and supply, checking technical systems such as the propulsion system, operating maintenance tasks, operating not automated equipment, or discharge residuals. If no crew is on board, the Engineer takes over the operational monitoring and control,
Remote System Administrator Operational Level	A Remote System Administrator is required to ensure that the MASS system (which is a complex hardware and software network) operates properly and that the integrity of the data and system performance as well as the permanently available communication system is maintained. The Remote System Administrator is responsible for the planning, installation and configuration of the IT infrastructure in the entire ROC-system and ensures maintenance of all data processing systems. In both cases, with or without crew on board, the System Administrator is assumed to be located in the ROC only.

The degree of autonomy with crew on board assumes that a MASS is controlled by an ROC. The crew is on board as a back-up and can take over tasks that are not automated. It can be assumed that there will be no complete crews on board according to today's definition of safe manning. Furthermore, the crew on board is not outlined in this report. In Figure 24 the operational model with crew on board is visualized.

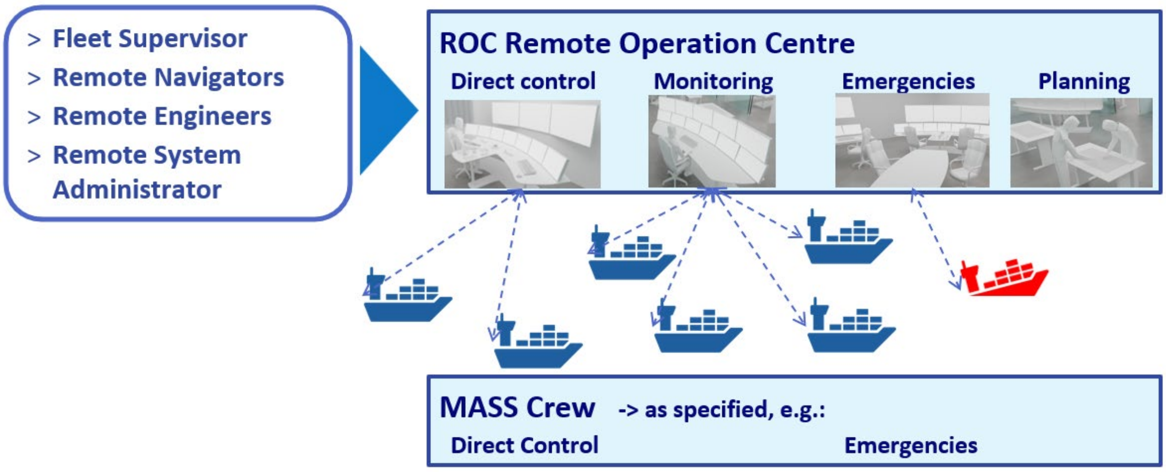

Figure 24: Operational model for MASS with crew on board.

If there is no crew on board, the MASS is completely controlled from the ROC. In this case, the same roles in the ROC will be necessary as in the case of "with crew on board". Figure 25 shows the operational model without crew on board.

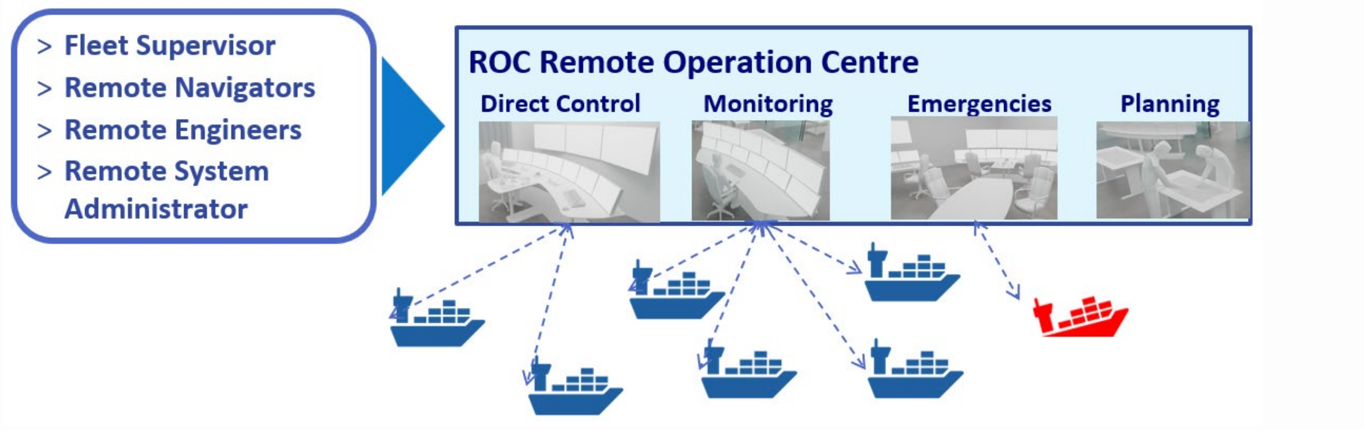

Figure 25: Operational model for MASS without crew on board.

6.2.4 Assigning Tasks to Roles

The previously defined tasks were assigned to different roles in the ROC. For this, we use the so-called RACI matrix. The RACI matrix supports the analysis and assignment of tasks to various roles. RACI is an acronym derived from the four key responsibilities most typically used: *responsible*, *accountable*, *consulted*, and *informed*:

- *Responsible (R):* The person or group who is responsible for carrying out a particular task. They are the ones who will be completing the work and ensuring that it meets the required standards and specifications.
- *Accountable (A):* The person or group who is ultimately accountable for the success or failure of the task. They are responsible for ensuring that the work is completed correctly and on time, and that any issues or problems are addressed appropriately.
- *Consulted (C):* The person or group who may be consulted for input or advice on a particular task. They may have expertise or knowledge that can help inform decisions or improve the quality of the work.
- *Informed (I):* The person or group who needs to be kept informed about the progress of the task. They may not have an active role in the work, but they need to be aware of what is happening and any issues that arise.

By using a RACI matrix, individuals and groups can better understand their roles, duties and responsibilities in the context of a larger process and ensure that tasks are completed efficiently and effectively. In the context of the ROC, this can help to ensure that all aspects of the operation are managed and controlled appropriately, with clear lines of responsibility and accountability.

The following RACI matrices describe the assignment of tasks to different roles and their responsibilities. The numbering refers to the DCoS models.

Table 11: RACI-Matrix for Voyage Planning & Control.

	Fleet Supervisor	Senior Navigator	Navigator	Senior Engineer	Engineer	R. System Administrator	Experts
1. Voyage Planning & Control							
1.1 Voyage Planning	A	R					
1.2 Voyage Monitoring & Control	A	R	R	R	R		
1.2 Voyage Tracking	A	R					
1.4 Voyage Documentation & Analysis	A	R		R		R	

Table 12: RACI-Matrix for Cargo Operations.

	Fleet Supervisor	Senior Navigator	Navigator	Senior Engineer	Engineer	R. System Administrator	Experts
2. Cargo Operations							
2.1.1, 2.3.1 Cargo Planning & Discharging Planning	A	R	C				
2.1.2, 2.3.2 Cargo Loading Operations & Cargo Discharging	A	R	R				
2.2.1 Cargo Care	A	R	R				

Table 13: RACI-Matrix for Navigation.

	Fleet Supervisor	Senior Navigator	Navigator	Senior Engineer	Engineer	R. System Administrator	Experts
3. Navigation							
3.1.1 Passage Planning	A	R	C		R		
3.1.2, 3.5.2 (De-)Berthing	A	R	C				C (Pilot)
3.2, 3.4 Pilotage	A	R	R				C (Pilot)
3.3 Sea Passage	A	R	R				
3.5.1.1, 3.5.1.3 Anchoring	A	R	C				
3.6 Port Stay	A		R				

Table 14: RACI-Matrix for Operations Engineering.

	Fleet Supervisor	Senior Navigator	Navigator	Senior Engineer	Engineer	R. System Administrator	Experts
4. Engineering Operations							
4.1.1 Bunker & Supply	I			A, R	R	C	
4.1.2 System Checks/Preparation	I	I		A, R	R	C	
4.2.1 Auxiliary & Machinery Systems				A, R	R	C	
4.2.2 Propulsion System				A, R	R	C	
4.2.3 Performance	I	I		A, R	R	C	
4.2.4 Hotelling				A, R	R	C	
4.3 Discharge Residues (Management)	I			A, R	R	C	

Table 15: RACI-Matrix for Maintenance.

	Fleet Supervisor	Senior Navigator	Navigator	Senior Engineer	Engineer	R. System Administrator	Experts
5. Maintenance							
5.1.1 Maintenance Planning	A	R		R		R	C
5.1.2 Overhaul & Repair in Port (Management)	A		R		R	R	C
5.1.3 Spare Part Control	A	R		R			C
5.2 Maintenance at Sea (Management)	A	R		R		R	C

Table 16: RACI-Matrix for Malfunctions & Emergencies.

	Fleet Supervisor	Senior Navigator	Navigator	Senior Engineer	Engineer	R. System Administrator	Experts
6. Malfunctions & Emergencies							
6.1 Emergency Preparedness	A	R	C	C	C	C	C
6.2 Malfunction Response	A	R	C	R	C	C	C
6.3 Emergency Response	A	R	C	R	C	C	C

6.2.5 Deriving ROC Design & Staffing

The fifth step is to derive a generic ROC design. In addition to the aspects described previously (Which role performs which task? What information/hardware/resources are needed within the task? Who communicates with whom within the task?), it is important to determine the number of people required per role to ensure that the ROC can operate safely. This differs from case to case and is therefore only shown here as an example of how to proceed in order to derive a safe, secure and efficiently working ROC design. Factors that play an important role are:

- **Schedule**: When and how often occurs demanding manoeuvres, such as berthing or de-berthing, that require a Remote Navigator Management Level to take direct control?
- **Environmental conditions**: How likely is it that a vessel operating autonomously will need to be taken over by a Remote Navigator Management Level because the autonomy can no longer cope with a current traffic and/or weather situation? How demanding is the monitoring of several vessels for a Remote Navigator considering the current environmental situation and the differences between the vessels? This is important because the mental switch between technically differently equipped vessels can lead to misjudgements.
- **Required level of safety**: Ships require rapid intervention in emergency situations to ensure the safety of people on board. Ships operating near the coast or in busy areas also require rapid intervention in emergency situations to prevent damage to vessels, people, or port infrastructure.

These factors will vary from one ROC managed fleet to another. For this reason, there is no one-size-fits-all solution for an ROC, but the exact ROC design must be considered on an individual basis based on the factors described above.

A general organizational structure is shown in Figure 26 and Figure 27. It defines the hierarchy of roles (e.g., the Fleet Supervisor is at the top of the hierarchy), the location (in the ROC or on the MASS), and the possible number of persons per role (per shift) for the exact configuration of a specific ROC (shown in grey below role names).

In case of the MASS with no crew on board, the ROC will be staffed with at least:

- one Remote Senior Navigator as Fleet Supervisor,
- one Remote Senior Navigator (management level),
- one Remote Senior Engineer (management level), and
- one System Administrator (operational level).

In addition, and depending on the required workload, the ROC will be staffed with:

- Remote Navigators (operational level), and
- Remote Engineers (operational level)

In the ROC the roles at the operational level start with a demand of zero, as an operator at the management level is able to take over the tasks of these roles. The minimum total number of persons in an ROC is therefore four. Depending on the concept of operations, more persons may be in each role.

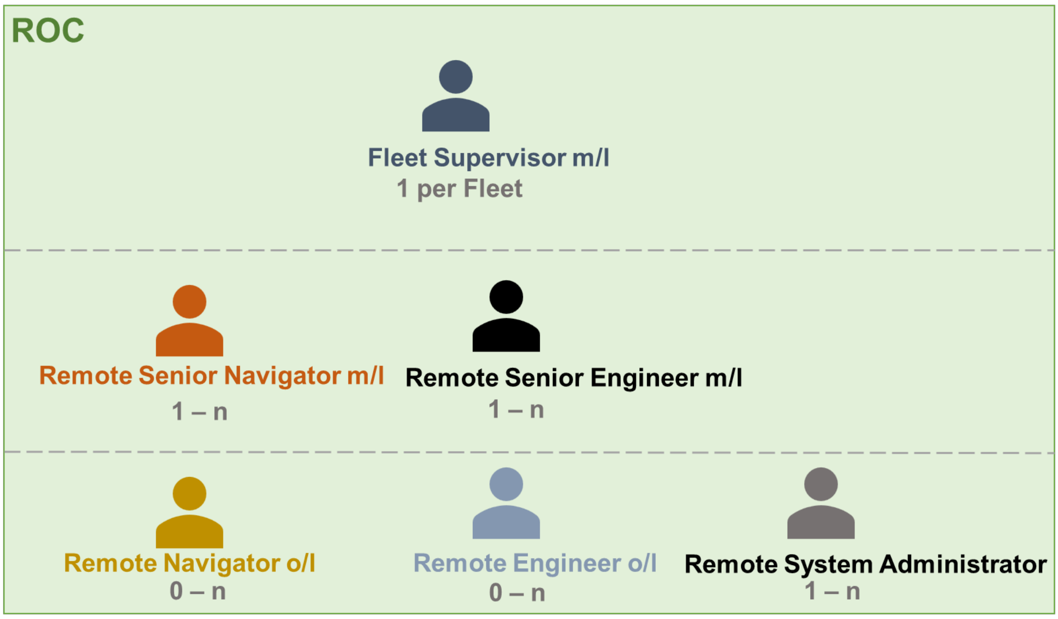

Figure 26: General organizational structure (ROC).

To summarise, the general roles remain the same. The competences are assigned to these roles, but the exact number of persons (staffing) can vary from case to case. The following text illustrates this with examples for different use cases.

Example ROC for use case "Ferry on short passages"

To derive the ROC design, it is important to obtain knowledge about the schedule, the technical equipment of the vessels in the fleet, and the required safety level.

In the following text, we will illustrate the ROC design by presenting an exemplary concept for an ROC managing ferries (similar to the operational envelope of ship type B (RoPax-Ferry) described earlier). The sample fleet consists of four vessels which travel between two ports in close proximity and thus in a short amount of time, carrying passengers and vehicles. The fleet consists of four technically similar vessels, where vessels A and B and vessels C and D are sister vessels. Figure 27 shows a sample schedule. All four vessels are simultaneously involved in berthing and de-berthing manoeuvres to ensure a smooth and efficient ferry operation. Assuming that the berthing and de-berthing manoeuvres are managed as **direct control** tasks by a Remote Senior Navigator, at least four persons are required to perform this task based on this schedule. Should an emergency occur or should a Remote

Senior Navigator suddenly become unavailable due to physical illness, the high safety level on ferries makes it essential to have a Remote Senior Navigator as a replacement. As long as this person is not assisting in direct control, he or she can take over other tasks (see RACI tables).

In **monitoring**, one role can occupy several ships. However, it is useful to entrust one person with sister vessels (see also the results of the interviews and workshops, **Appendix G**). This avoids a considerable mental switch between technically diverse vessels and reduces the likelihood of misjudgements by the operator. For this reason, Figure 28 shows two persons monitoring sister vessels (e.g. during autonomous sea passage or to monitor the condition of the cargo, the stability of the vessel, etc.). In addition, the ROC will include a Remote Fleet Supervisor who will be responsible for the entire fleet, as well as two Remote Senior Engineers who will monitor the technical condition of the vessels. The Remote System Administrator contributes to ensuring the safe operation of the IT systems in the ROC.

	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15	15:30	15:45	16:00
Vessel A	A	A		B	B	B		A	A	A		B	B
Vessel B		A	A	A		B	B	B		A	A	A	
Vessel C	B	B		A	A	A		B	B	B		A	A
Vessel D		B	B	B		A	A	A		B	B	B	

Meaning	Symbol/Color in Table
(De-)Boarding in harbour (A) or (B)	A / B
(De-)Berthing in harbour (A) or (B)	A / B
Sea Passage	

Figure 27: Example Schedule for Fleet of 4 Ferries.

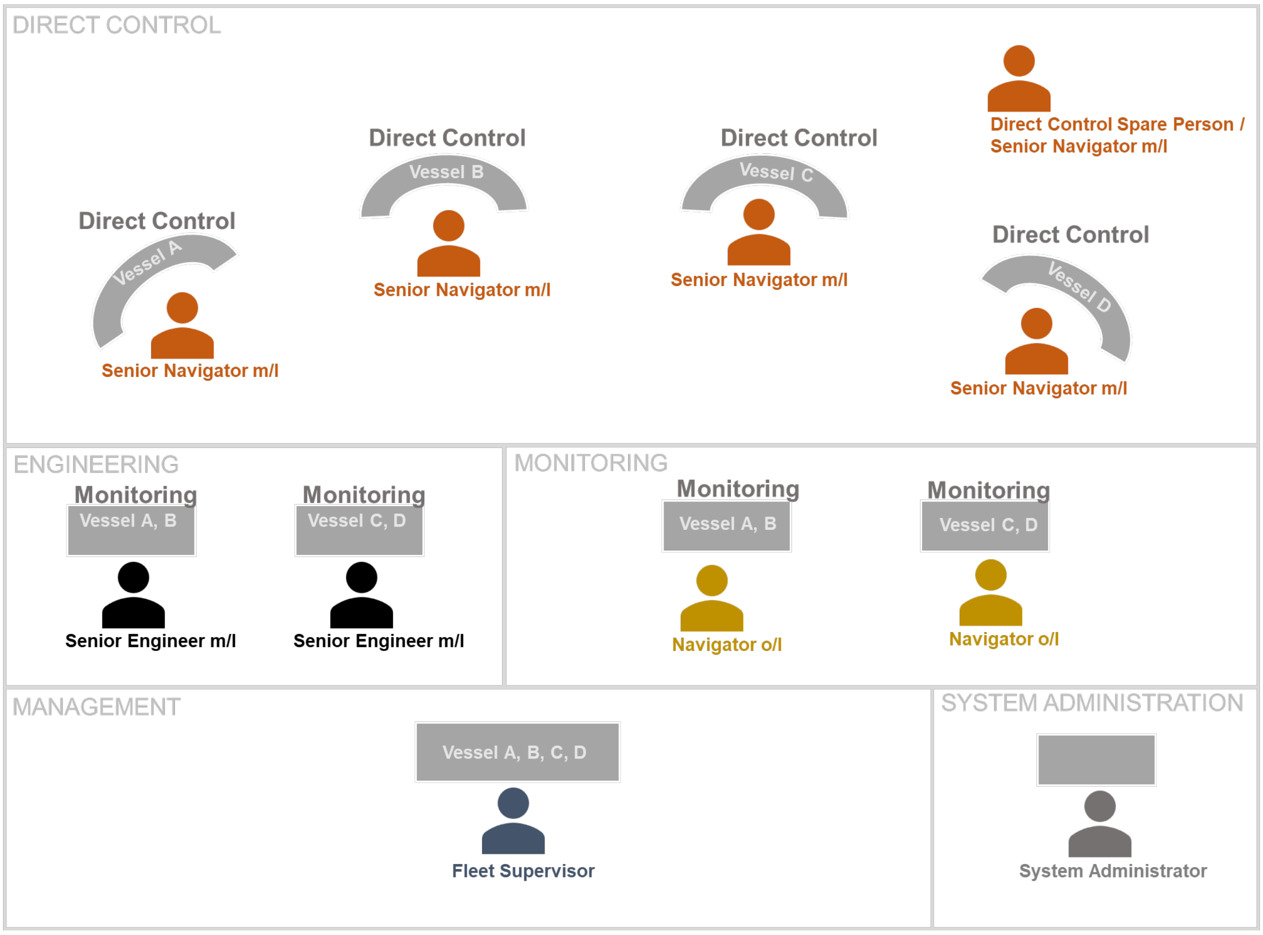

Figure 28: Example ROC Design for “Ferry on short passages”.

ROC for use case "Feeder on short sea passages"

The generic operational scenarios reveal that the feeder and the bulk carrier spend more time at sea than a ferry. There are fewer simultaneous berthing and de-berthing maneuvers. Therefore, the number of persons per role will change: Fewer persons will be needed in direct control and the number of persons in the ROC taking over monitoring will possibly increase. However, one important aspect should be noted: Depending on the type of vessel and the fleet being monitored in an ROC, the number of persons performing the different roles in the ROC might change, but the roles themselves will remain the same, as the tasks will be very identical. This has the advantage that the competences required for the role remain the same and can be handled similarly across vessel types.

In Figure 29 the example of an ROC for a fleet of 6 feeders is shown. The assumption is that not more than two berthing or de-berthing maneuvers are performed simultaneously. For this reason, one person can take direct control. Due to the longer time at sea, the monitoring becomes more complex. For this reason, more persons are assigned here than in the case of the ferry.

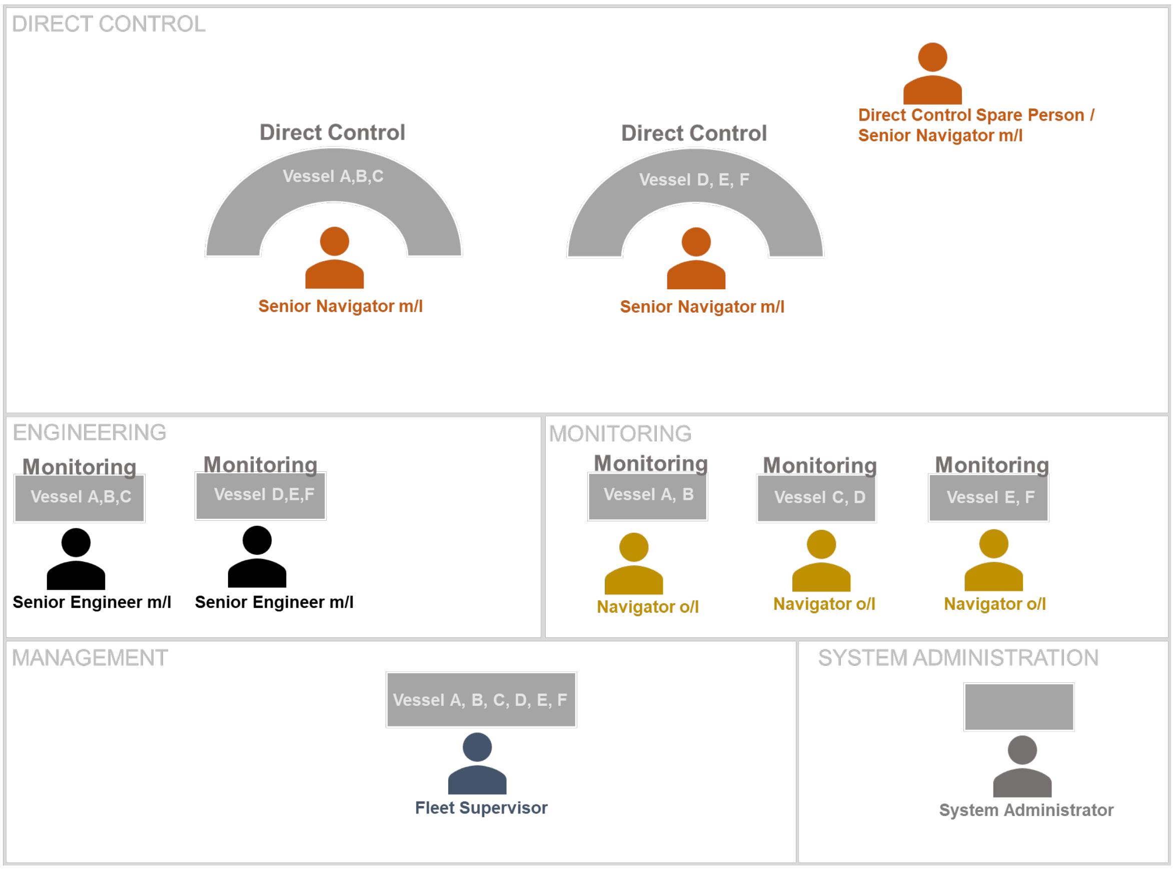

Figure 29: Example ROC Design for Use Case "Feeder on short sea passages".

ROC for use case "bulk carrier on long-haul passages"

For the bulk carrier, the example ROC can look similar to the one for the fleet of 6 feeders shown before. Figure 30 shows an example ROC for 6 bulk carriers that do not perform more than 2 simultaneous berthing or de-berthing maneuvers. Bulk carriers can be technically more complex. For this reason, it is possible that the number of people responsible for monitoring in the engineering area is higher compared to the ferry or the feeder.

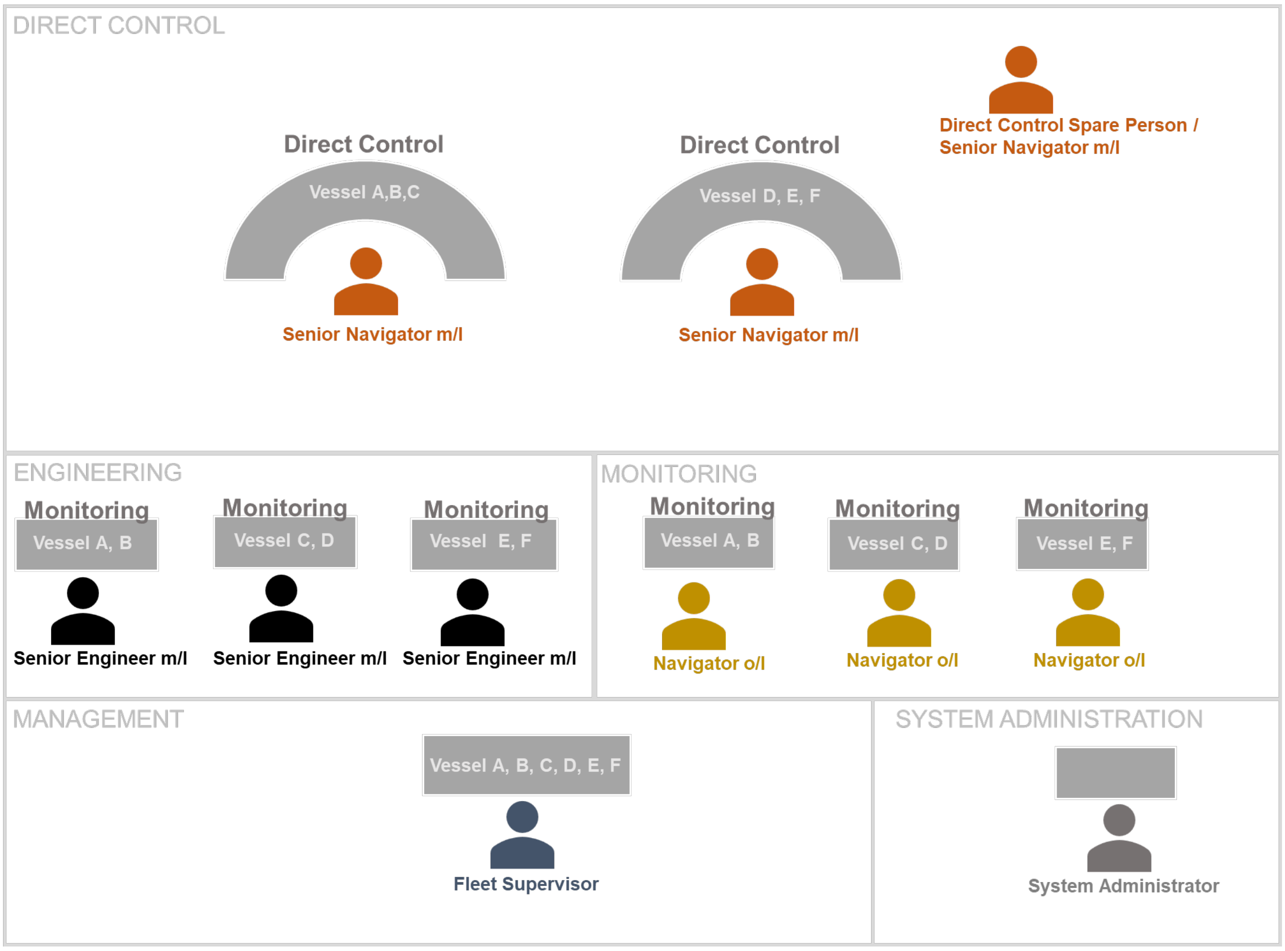

Figure 30: Example ROC Design Use Case "bulk carrier on long-haul passages".

7. ROC Operators Required Competences

7.1 Competence Framework

7.1.1 Standards and Guidelines

In this study, the basic principle of competence orientation is pursued. An essential guideline is the European Standards and Guidelines (ESG) (EHEA European Higher Education Area, 2015), which serves as a common European basis for the development of higher education courses. The description of competence dimensions is based on the European Qualification Framework (QF EHEA) (Danish Ministry of Science, Technology and Innovation, 2005).

The operators of a MASS are controlling a vehicle at sea, which is involved in the international maritime traffic. It is directly connected to maritime safety, as each incident may have an impact to human's life, ships and cargoes, and the marine environment. In the maritime industry, the STCW Code is the mandatory framework for seafarers. Operators ashore will also need seafarer competences. For this reason, the STCW Code is used as a refence for the education and training of MASS operators.

7.1.2 Standards of Competence Specified in the STCW Code

In the previous chapters, the tasks of operators of MASS were analyzed and structured intensively and in detail. The competences defined in the STCW Code were compared with the requirements from the processes and assigned to them.
The allocation of STCW competences is done for each identified process (cf. **Appendix D** - Processes). The analysis of the STCW tables shows that the basic qualification requirements for MASS operators are covered by the STCW Code.

The differentiation between "operational level" and "management level" by STCW is also used in the definition of required competences of MASS operators. The different levels of responsibilities will also be applied to MASS.
The analysis have shown that the requirements for the different operators' tasks can be arranged at different competence levels. On the one hand, a large portion of time will be spent on pure monitoring (as in watchkeeping), but on the other hand, processes will also have to be implemented that require a high level of knowledge and experience (such as maneuvering or problem solving).

In the development of competences for MASS ROC operators, the need for the following qualification fields was identified:

- MASS ROC Navigator (on operational level)
- MASS ROC Senior Navigator (on management level)
- MASS ROC Engineer (on operational level)
- MASS ROC Senior Engineer (on management level)
- MASS ROC System Administrator (on operational level)

The ratings (support level) are not covered by this study.

With these definitions, the existing and proven tables of competence used by the STCW Code to specify the minimum standards of competence are considered. A completely new and differently structured definition of the fields of qualification is not considered as useful. In all expert discussions with the reference groups, it was made clear that the skills to manage a seagoing vessel are also needed to control a MASS. A combination of nautical and technical expertise in one person would be at the expense of deeper knowledge and understanding of the MASS systems. As innovation progresses and systems become more reliable, technical skills may become less demanding in future. But this cannot be assumed for the introduction phase of autonomous shipping, which will last many years.

As far as possible, the assignment of ranks (e.g. Chief Officer, 2nd Engineer, 3rd Officer) to competence levels has been avoided. It is evident that watchkeeping and monitoring tasks will be located at the operational level. The management level is trained for the higher qualification levels, the competences of the operational level are part of it and must be acquired beforehand.

Depending on their personal abilities, it will become clear which navigators and engineers will grow into management positions. For a MASS with crew on board, it can be assumed that a hierarchical and ship-related system will be implemented as is customary today, so that a Master is on board. If there is no crew on board, the management task is taken over by a Fleet Supervisor in the ROC. The person is no longer referred to as a Master, as a Fleet Supervisor can also be responsible for a fleet of several MASS.

Whether there will be a Chief Officer is left open; it will be a senior operator who takes over this rank. In the field of engines and machinery, this study only talks about operation engineers on operational level or senior operation engineers on management level. How the rank of a Chief Engineer is used can still be flexibly defined.

In this study, the Electrotechnical Officer (ETO) competences, as defined in the STCW Code, are consistent with the role of 'ROC System Administrator' as proposed in this study. The STCW Code already requires many competences for the ETO that are stipulated for the operation of a MASS. However, the project team assumes that the system competence for highly networked MASS systems must be further developed, and that the role will change even more into that of a system administrator who keeps a highly complex system in operation. So, it may also be that to operate a MASS-system, the number of system administrators increases while the number of engineers decreases. The role of the system administrator does not necessarily have to be filled by an ETO according to STCW. It is quite conceivable that other pre-qualifications, such as in electronic engineering or computer science, provide an excellent basis. However, to master the specific requirements of a MASS system, it is further proposed to provide additional training. This study continues to pursue the path of providing them as a supplement to the ETO.

7.1.3 Competences

A central role in the competence-oriented consideration is played by the tailor-made formulation of the competences to be acquired. Qualification objectives as well as the learning outcomes of the competence fields should be formulated consistently with the question of what graduates must be able to do at the end of a module. The qualification objectives focus on the central competence fields and carry them out, while the learning outcomes of the subject areas focus on the specific acquisition of competences within the framework of the learning module.

Competences can be formulated at different levels of requirements. Their classification can be carried out via a suitable taxonomy, i.e. a stage model, in the sense that each higher level also includes those abilities defined by the previous levels as prerequisites.

This study uses the common taxonomy according to (Krathwohl & Anderson, 2001) , which is a further development of the taxonomy according to Bloom. The model distinguishes six cognitive process stages: two levels of knowledge (remembering/knowing and understanding) and four levels of ability to deal with knowledge (applying, analyzing, evaluating, extending/creating).

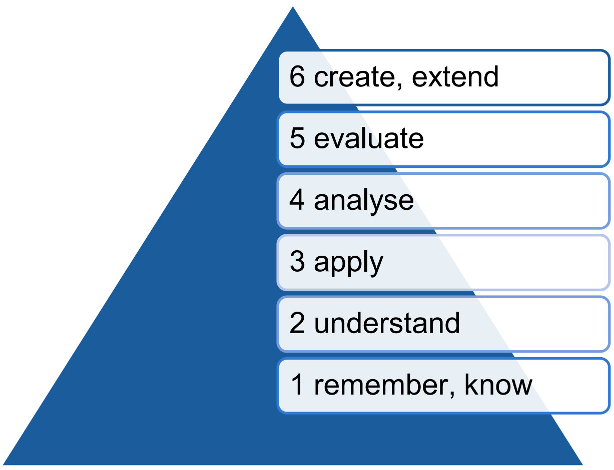

Figure 31: Competence levels according to Anderson/Krathwohl based on Bloom

The affiliation of a competence to a certain requirement level is usually expressed by verbs to express the desired achievement of goals at the end of the learning process; therefore, it is advisable to start a sentence with "After successful completion of the module, the trainees are able to ..." or "After completing the module, the trainees are qualified to ..." etc. The second half of the sentence then contains the specific competence goal in the form "verb + context". Central to an unambiguous result are precise formulations of the competences and the levels to be achieved. For this purpose, it is advisable to form only one sentence per learning outcome, possibly more for clarification.

Table 17: Cognitive dimension and verbs for description

	Levels	Cognitive dimensions	Verbs	Instructional Strategies
6	**create, extend**	Ability to expand or create something based on knowledge, skills and attitudes, as well as new ideas, concepts, points of view, etc. to invent	plan, design, formulate, build, invent, create, compose, generate, derive, modify, develop, produce, devise, make, adapt, arrange, combine, construct, draft, formulate, integrate, manage, organize, prepare, propose, reorder, transform, …	• Formation of a hypotheses, case studies, • problem solving activities, • development plans, simulations, • audio/visuals, multimedia activities, • computer based tutorials, • asynchronous online forums
5	**evaluate**	Ability to weigh alternatives, to make and justify decisions, to find judgments on the value of materials and methods, to make qualitative judgments, to be able to criticize constructively	evaluate, assess, check, determine, maintain, testing, appraise, monitoring, choose, support, relate, defend, judge, grade, compare, contrast, argue, justify, support, convince, select, check, hypothesize, criticise, experiment, detect, differentiate, choose, compare, confirm, diagnosis, judge, measure, prioritise, prove, rank, rate, recommend, research, revise, select, weigh, validate, …	• Case studies, projects, • simulations, • panel discussions, • comparison activities, • audio/visuals, multi-media activities, • computer based tutorials, • asynchronous online forums
4	**analyse**	Ability to classify facts and problems, as well as to break down information into parts in order to deepen understanding and examine relationships	analyse, appraise, test, classify, break down, categorise, monitor, diagram, interpret, criticise, simplify, associate, compare, recognise relationships, organise, deconstruct, attribute, outline, derive, structure, integrate, arrange, calculate, contrast, correlate, differentiate, distinguish, examine, inspect, inventory, solve, verify ...	• Exercises, case studies, critical incidents, • essays, journal critiques, • panel discussions, mapping, • audio/visuals, multimedia activities, • computer based tutorials, • asynchronous online forums
3	**apply**	Ability to transfer information to new situations and make it usable	calculate, predict, apply, solve, use, utilise, demonstrate, determine, model, perform, present, implement, carry out, execute, realize, set up, measure, conduct, modify, operate, practice, establish, state, chart, quantify, visualise, monitor, control, compute, deliver, employ, prepare, sketch, tabulate, adjust, …	• Exercises, drills & practice, • demonstrations, projects, simulations, • sketches, role play, • cooperative learning activities, • field observations, • audio/visuals, multimedia activities, • computer based tutorials, • asynchronous online forums

	Levels	Cognitive dimensions	Verbs	Instructional Strategies
2	**understand**	Ability to recognise and interpret learned facts in order to gain information	explain, paraphrase, restate, give original examples of, summarise, contrast, interpret, discuss, compare, present, translate, illustrate, express, argue, adapt, extrapolate, illuminate, classify, arrange, differentiate, associate, clarify, conclude, draw conclusions, translate, summarise, abstract …	• Didactic questions, • discussion, review, • automated audience • response systems, • multi-media activities, • computer based tutorials, • asynchronous online forums
1	**remember, know**	Ability to remember facts and repeat them	list, describe, recite, outline, define, name, locate, match, quote, recall, identify, label, recognise, remember, state, reproduce, repeat, draft, show, memorise, select, write, sketch …	• Lectures, discussions, • examples, analogies, • audio/visuals, • multi-media activities

7.1.4 Personal and Social Capabilities

As a further competence dimension, personal and social capabilities must be taken into account. Communication and cooperation with other people are also of great importance in highly automated systems. This competence dimension must be seen in the context with the professional competences.

Personal capabilities summarise the ability and willingness to develop oneself and own's capabilities. Motivation and willingness are needed to perform accordingly. The development of specific attitudes and an individual personality are to consider.
In shipping, personal competence becomes more and more important:

> To develop self-management to motivate oneself, as well as the setting and realisation of personal goals.
> To deal with personal stress.
> To foster critical thinking and to develop complex problem-solving.
> The development of ethical awareness and individual values (attitudes) in relation to fellow human beings, things, or goals.
> To develop an awareness of one's own identity, gain an understand of the own role, and to fit into social frameworks and work teams.
> To develop cognitive flexibility to be able to face future challenges in a permanently changing environment.
> To be creative, but also fact-driven in judgements and decision-making

Social capabilities refer to knowledge, skills and abilities related to communication, cooperation and conflicts in intra- and intercultural contexts. They enable people to respond appropriately to the situation in relationships with other human beings.
In shipping, the expectation for high performance is very distinctive. Social skills become more and more important to:

> Gain communicative competence to present fact-related positions and manage problem solving by well formulated and defended arguments in order to ensure successful negotiations with specialists. These include, for example, moderation and presentation skills.
> Cooperate with others, including knowledge and mastery of various methods for managing group collaboration. This includes, among other things, the understanding of organisational structures, role flexibility, the management and support of group developments as well as the formulation and implementation of collective strategies and achieving common goals.
> Be able to face conflicts. The conflicts are to recognise in function and meaning and to be dealt with constructively.
> Develop service orientation.
> Gain emotional intelligence.

The personal and social capabilities are considered in the competence tables for ROC operators.

7.2 Derivation of Competences

7.2.1 Process Descriptions and Competences

All processes are listed and described in **Appendix D**. Each process is presented in the same structure according to the Table 18. For the details, refer to this appendix with detailed description of the processes.

Table 18: Content of process descriptions in Appendix D

Process <no.>	**<process name>**
Scope of application	In which areas the process is used? Differentiations are done for: > Ship type > "with crew on board" and "without crew on board".
Process objectives	What is to achieve by the process as a general objective?
Process operators	Operators who are involved in this process. Assignment to operational or management level. Definition of the location and workstation where the process is mainly operated. Assumption of RACI for the different roles: R=Responsibility, A-Accountability, C-Consulted, I-Informed
Interfaces	Interfaces to other functions.
Event: input	Specific input to process, trigger to start, starting point.
Process description	Brief description of tasks, activities and functionalities.
Resources needed	Needed resources to ensure availability of process, as equipment, systems, interfaces, HMI.
Regulations	Major regulations to be considered in the process.
Event: output	Specific outcomes, results of the process, ending point
Required competences	Required competences, differentiated by the different roles: C/L = competence level STCW = related table MASS = additional competences needed by MASS operators (new table)
Additional comments	Only if required for further explanations.

For each process the required competences are listed in these tables. They are assigned to the roles which will operate the process.

The analysed processes represent the tasks of MASS operators holistically. The analysis showed that the majority of the competences defined in the STCW Convention will continue to be necessary to safely control a MASS remotely or to monitor an autonomous system that takes over this task, and to be able to intervene if necessary.

In this study, the contents of the STCW requirements are not repeated in detail. In the discussion of the processes, their needs are generally addressed, and it is only shown which competences will be needed to be able to control of a MASS.

The STCW Code do not use a taxonomy by using verbs to determine competences. In this study the KUP (knowledge, understanding and proficiency) are transferred into the taxonomy used for this approach. The KUP are interpreted as far as possible and assigned to competence levels to be able to place them in an overall context. As an example, the planning of a passage plan are competences of an officer of the watch at operational level as well as an officer at management level. To differentiate the competence levels, the verb "to plan" is assigned to level "3-apply" for the operational level, but to level "5 - evaluate" for the management level. The authors are aware that further interpretation and coordination is necessary. The assignments to competence levels should be accepted as a recommendation.

Additional required competences for MASS operators are added to each role. They are based on the detailed analysis of the processes and confirmation by the expert groups.

7.2.2 Development of Required Competences

Management Processes

The performance as well as the safety and security of a remote-controlled MASS depends to a large extent on the implementation of higher-level management processes. There will be different interpretations to define which the superordinate management processes are. In this study, we have decided to determine four basic management processes. MASS operators need competences to specify and operate the MASS systems safely and efficient. For that competences are required as:.

M.1 The organisation of MASS in interaction with the ROC
M.2 The general management of MASS systems
M.3 Risk management in all areas of the MASS system
M.4 Management of quality, safety and all other related management systems for a MASS system

Process M.1: Organisation of MASS System
The competence how to organize the operations is a crucial task for ROC operators. In this context, it is not intended that certain forms of organization are suggested. However, it should be kept in mind that the dependencies and interaction between MASS, ROC and shore-based facilities are becoming much more complex. Likewise, the cooperation of people and technical systems is a permanent challenge, and a MASS system will be in permanent development. Processes must be designed, technologies must be adapted, the working environment of operators is subject to constant adaptation.
The tasks of this process are assigned to the navigators and engineers at management level.

The need for competences in the organization of a MASS system exists in all three use cases of this study. Additionally, in all MASS systems, whether with or without crew on board, these competences are required. In general, the operators on management level, especially the navigators and engineers, need such competences. They will be in charge to organise such systems.

Process M.2: General Management of MASS Systems
The requirements for operators concerning the management of MASS systems are very demanding. The operators must understand the highly automated systems and be able to intervene at short notice. This requires a high willingness to work in a team, and the ability to take over and accept tasks in a quick manner. Against the background of the available and sometimes restricted information from technical systems, decisions must be made systematically and implemented quickly. To manage this teamwork with secure and stable processes, a high degree of cooperation and flexibility in accepting work tasks is necessary. An active promotion of a just culture [8] by the management is of great importance.

Furthermore, there are very high demands on the operators in terms of attention and handling of a highly automated system. Situational awareness and thus the competence to recognize and take over complex processes in a short time is of great importance. This competence takes place against a background knowledge of sensor technology and automation, and knowledge of human-machine interfaces. Operators must be able to correctly classify alarms and other information and be able to safely derive measures from them.
Thus, a MASS system requires very good guidance against a background of the special requirements of the remote-control system.

Process M.3: Risk Management
Risk management is a very important task in shipping. MASS systems are highly dependent on technical systems and operate in an environment with high challenges. Risks must be identified and evaluated in all fields of application. Available risk management tools must be known, e.g. as the RBAT tool (cf. RBAT study, DNV GL, 2021). Appropriate

[8] Just Culture: cf. https://skybrary.aero/articles/just-culture

measures to prevent the occurrence must be defined and implemented. For example, risk management is to be applied in navigation, the operation of machines and equipment, in communication and data exchange, in human intervention, or in emergency situations. From this overarching point of view, risk management competences are given great weight. The application of risk management techniques must be mastered. MASS systems will have to be intensively checked for risks, especially in their introductory phase.

Such competences in risk management are required in all three use cases. The requirements apply to all MASS, whether with or without crew on board. Because deep knowledge of a MASS system is required, the process will mostly be assigned to persons with competence as MASS operators. Due to the high level of responsibility and necessary experience, these competences are particularly necessary for navigators and engineers at management level.

Process M.4: Management of Quality and Safety of MASS Systems
Management systems have been established in many fields of application in shipping. In addition to quality management, for example environmental protection, energy consumption, safety aspects and the integration of people must also be managed. Such management systems are standardised, e.g. for quality by ISO 9001:2015 or for environmental protection by ISO 14001. Without such management systems, MASS cannot be operated. The operators must be able to establish, maintain, and optimize appropriate management systems.

A MASS system requires a very high level of safety and security. This can only be achieved if the quality of all technical and organizational systems is at a very high level. The implementation of a MASS related safety system based on a MASS on a similar code as the ISM Code, is needed. Also, for MASS will be important the implementation of climate-friendly technologies. Knowledge of management systems, their objectives, and effectiveness of measures is of great importance. Operators of MASS systems must have understood the systems and be able to apply and implement them optimally.

Competences requirements for management processes by ship types
The competences are required in all three ship types. The organization and implementation for an ROC and MASS-system are required for ferries as well as for ships in short sea or long-haul voyages. To be able to manage complex systems controlling several MASS with locally distributed tasks is a basic competence for each use case. The management of risks and quality are needed in all fields of operations to enhance safety and ensure reliable systems.

Competence requirements for management processes per level of autonomy
In both levels of autonomy, MASS are controlled from the ROC. If a crew is on board and is assigned certain tasks, they must be able to understand, implement and evaluate them in the same way. Thus, operators in the ROC have the same requirements for both levels.
The competences required in the management processes are mainly requirements for the roles at management level to use their knowledge and experience. Basic competences in general management, risk and quality management are required for the roles at operational level too.

Core Processes
The core processes define the core tasks that arise on a voyage of a ship from berth to berth. A total of six core processes were defined, each of which was divided and detailed into further processes:

1 Voyage Planning & Control
2 Cargo Operations
3 Navigation
4 Engineering Operations
5 Maintenance
6 Malfunctions & Emergencies

The tasks to be fulfilled were analysed and structured. Looking at the processes in too much detail was avoided to maintain the overall view.

Core Process 1: Voyage Planning & Control

Process 1.1: Voyage Planning
The operators must have competences that allow them to plan a voyage of a MASS, calling several ports, with its special requirements. Commercial voyage planning is generally carried out by a shipping company. With the use of MASS, however, additional clarifications for the voyage plans will be necessary. For example, it must be clarified whether passages through coastal waters are possible and that ports can be called from a technical point of view. If support systems are to be used on the passages, compatibility and availability must be ensured. This can affect navigational aids as well as automated port facilities.
These tasks must be done at least once for every voyage. Once they have been clarified, they can be used again for next voyages.

Process 1.2: Voyage Monitoring and Control
The voyage monitoring and control are the major tasks of MASS operators. Appropriate use and performance checks of all systems of automation are core competences for operators. These tasks are to be done at the direct control and the monitoring stations.

Process 1.3: Voyage Tracking
The parameters of the voyage can change when the MASS is underway. It is important to take these changes into account quickly and to adapt the schedule accordingly. While in process 1.1, the voyage was planned for the first time, in this process the entire change management is done. Thus, the same information applies to this process as for 1.1 above.

Process 1.4: Voyage Documentation and Analysis
Electronic logbooks must be kept for the MASS system in which all operational data must be recorded and stored. A structured and targeted storage is important to be able to further analyse the data and improve the performance of the MASS system. The maintenance of the data and the care that only correct data is collected is also of great importance. Operators of MASS systems must have a basic competence to be able to classify data and information correctly, and to be able to analyse and evaluate them. This task is reserved for navigators and engineers at management level. The system administrator must be able to technically prepare and provide the data and information.
The digitalisation of processes requires skills to deal with such data. The data shows great potential to make MASS systems more efficient and thus optimise logistics chains and contribute to climate protection.

Competence requirements for planning and control processes by ship types
This process applies to all three use cases. Of course, the design and planning of voyages and schedules for the three use cases differ. Ferries have a timetable with several departures per day, which focus on saving time and efficiency in carrying out manoeuvres. Multi-day timetables are required for the feeder service. Depending on transportation requirements, ports and berths can change, and technical questions have to be clarified again accordingly. Bulk carriers are even more subject to the demand for transport capacity, which results in changing of ports. Every call at a new port must be planned accordingly.
These processes must be done for each ship type. It is more a question of frequency and scope. But the implementation and control of the voyages have the same requirements concerning competences for each ship type.

Competence requirements for planning and control processes per level of autonomy
The tasks remain the same whether a crew is on board or not. The operators in the ROC will perform this task for a MASS, with or without crew on board. Due to the necessary deep understanding of the MASS system, this process is carried out at management level.

Core Process 2: Cargo Operations

The three use cases differ mostly in the processes regarding the cargo operations of the MASS. The processes themselves happens in each use case, but with different characteristics. The interface to the work carried out by the port services can also be very different. To be able to define the processes, the following assumptions were made for the use cases with regard to degrees of automation and interfaces in cargo operation:

Competence requirements for cargo operation processes by ship types

A) Dry Cargo – Container Feeder – Short Sea Traffic
Stowage plans are transmitted by container stowage planning centres. The inspection of the loading as well as the stowage of dangerous goods and other containers with special requirements is the responsibility of the MASS operators, whether on board or in the ROC. The interfaces to the terminal are the container gantry cranes ashore. Whether the terminals are fully automated or operated manually, both are part of the competence requirements. It is assumed that the MASS are designed in such a way that containers are loaded into cell guides and do not have to be secured. The connection of reefer container with the on-board power supply is carried out by terminal personnel or stevedores, as is the cut-off. The closing of all holds and openings is carried out automatically. The verification and control of stability is carried out by the MASS crew or the ROC.
The MASS operators in the ROC and on board must be familiar with all competence requirements of the shipping of containers.

B) Ferry – RoPax – one hour passage
The planning of the vehicles to be loaded is done by the terminal. This includes the check of vehicles with dangerous cargo and the definition of the stowage positions of these vehicles. The vehicles are pre-sorted by the terminal. Loading can be controlled via a traffic light system that indicates the storage space to the vehicles. The vehicles are driven to the MASS by drivers of the port or the passengers themselves. The cargo securing is carried out (if necessary, in the sea area) by terminal personnel.
Passengers get on board via a manlock. The care of the passengers is taken over by separate service personnel, who are specially trained for this purpose.
All entrances such as ramps and gangways can be operated remotely. Security (ISPS) is maintained by a guard service.
The stability is checked by the MASS crew or ROC, depending on the technological standard.
The MASS operators in the ROC and on board must be familiar with all competence requirements of transportation of rolling cargo and passengers.

C) Dry Cargo – Bulk Carrier – long distances
The loading is planned by the ROC, and a crew on board will make double-checks. The monitoring of the loading and unloading operation on board is carried out by the ROC, supported by a port crew. If a MASS crew is available, they will take over the on-board operations in the port. A trimming of the cargo is carried out by the terminal (e.g. by stevedores). In general, remote monitoring is only conceivable for very standardized and suitable cargos under largely constant conditions in regular services.
The ROC plans and monitors the stability, trim. and strength; a crew on board can support or take over this task. Since safety on the sea passage depends directly on correct loading and ballasting, the responsibility for this must be taken by the ROC, supported by the MASS crew if present.
The closure state (closing of all hatches) is assumed automatically. Security in the port is the responsibility of a guard service.
The MASS operators in the ROC and on board must be familiar with all competence requirements of the shipping of bulk cargoes.

Despite the different requirements, the processes themselves are similar. The characteristics of the contents are partly different (depending on the cargo provisions) and are considered in the process descriptions.
Both operators of the MASS in the ROC and on board need to have the competences to handle cargo operations. For cargoes, the competences should be covered by the training and education of MASS operators. Because of the specifics of passenger care and control, additional trainings on these topics should be mandatory for ferry operators.

Process 2.1: Cargo & Embarkation Planning and Preparation

The loading of a MASS must be planned and prepared, and the seaworthiness of the MASS must be ensured. This is an original task of a ship's crew and is to be carried out by the ROC, supported by the possible ship or port crew. With the planning of loading, ballasting, and the resulting stability, a safe sea passage is guaranteed. This applies to all three use cases. Only the requirements of the ship's types are different. The weight of the vehicles means that the ferry requires less compensation by the ballast system than a ship loaded with a heavy cargo (heavy containers, heavy bulk cargo). The competences in assessing ship stability and in taking measures to ensure stability are equal on each ship type. Of course, calculators can do these jobs, but a final evaluation and approval by operators will still be necessary.

The preparation of the MASS for loading cargo depends on the types and requirements of the cargo to be loaded. Standardised containers and rolling cargo require less preparation for loading than bulk cargo. Cleaning cargo holds for bulk cargo is a process that is very difficult to automate and requires a lot of manual effort. For MASS, bulk cargoes probably can only be accepted if the MASS always transports the same types of cargo, or break bulk is shipped with less contamination. Waiting times for cleaning the holds will not be acceptable.

Even if loading can be planned and prepared by terminal services, the responsibility for loading the MASS remains with the operators in the ROC (supported by crew if any). The competence is, according to the responsibility, assigned to the management level.

Process 2.2: Cargo Loading & Persons Embarkation

The loading process in the port can be staffed by the terminals. This interface can vary from port to port. For each of the three use cases, the responsibility lies with the operators of the MASS, whether in the ROC or on board the MASS. Operators are responsible for the MASS at sea and must ensure that the vessel is loaded as planned. While a crew on board can directly monitor and control the loading process, this must be done remotely from an ROC. In this case, close cooperation with the terminal staff must be established and appropriate sensors must be mastered.

Access to the MASS for persons is handled via a gate with identification and a counting device. This is where the terminal staff can give support. On the part of the crew on board or in the ROC, knowledge of the access control functioning is required.

The competences at the monitoring level are located at the operational level; the overall responsibility for loading is assigned to the management level.

Process 2.3: Cargo Care & Persons Control at Sea

Depending on the type of cargo, cargo care at sea will be necessary. The operators must be able to detect hazards to the loads via sensors and initiate appropriate measures to minimise the hazard. For example, temperatures, cargo hold atmosphere, condition of cargo units with dangerous cargo, and cargo securing systems must be observed.

If persons are on board, such as passengers, service staff or riding crews, then an overview of the whereabouts on board must be maintained, and the well-being of the people must be taken care of.

The associated competences are necessary on all use cases. The differentiation lies in the types of cargo and technologies used for load securing and cargo care. While monitoring is assigned to the operational level, the management level requires competences for evaluation and determination of possible measures.

Process 2.4: Cargo Discharging & Persons Disembarking

In principle, the same skills are required for unloading the load as for loading. The process must also be planned, prepared, and carried out.

When leaving the ship, the persons must be identified and counted accordingly. These processes can be supported by the terminal staff and guard services. Observation and control from a distance and remotely, be it on the MASS or from the ROC, must be mastered by the operators.

Competence requirements for cargo operation processes per level of autonomy

As determined in the previous discussion of cargo processes, the cargo and passenger operations will need external support by service providers. The interface between MASS and terminal tasks can be very different. In this study, it is assumed that the MASS operators will get as much assistance from the terminal as possible. In the case that a crew is still on board, it can take over monitoring and control tasks. The question of distribution of responsibilities cannot be answered in this study. The assumption is that the ROC will have the final responsibilities for the shipment and MASS's safety and must give approval to all supporting services, including the MASS crew.

Core Process 3: Navigation

The operators of MASS need the competence to be able to navigate a seagoing vessel. For this the entire process is to consider, from the preparation of a passage, the de-berthing, the outbound pilotage and sea passage to the inbound pilotage and mooring. Also, a ship must be monitored in the port.
The competences are determined in the process descriptions for operational and management level. It is assumed that the operators on operational level will have the competences to prepare, to monitor, and to execute standard operations. The operators on the management level will have more experience and additional competences on higher levels. They will take more accountability and will be able to evaluate and make decisions. This distinction will be found in all navigational processes.

Process 3.1: Navigation when Leaving the Port
Process 3.1.1: Passage Planning
The passage planning can be done at a planning station in the ROC; a crew on board may double-check. In addition to creating a conventional passage plan, the planning needs to cover MASS related topics. For example, the available systems for communication and data transfer are to be consider. Areas may be passed with specific navigational aids which requires specific settings in the MASS systems. All these depends on future technologies which are not established yet.

Process 3.1.2: Departure / De-berthing
The MASS is prepared for departure like a conventional ship. The system check is to be expected as a very systematic procedure which needs more technical background competences.
The connections of the MASS, such as operation of gangways, energy supply facilities, or fixing the MASS at the berth, can be on a higher level of automation than today. A knowledge about such systems and how they are operated is required. This covers the interfaces to automated port facilities too.

Leaving the berth will require competences to manoeuvre a vessel by remote control. The advantage of the crew on board is the direct observation of the manoeuvre, which must be done in the ROC by sensors and displays. But in both cases the MASS is assumed to be able to leave the berth under autonomous control. So the operators in the ROC need the capability to take over the MASS in direct control whenever the situation will require it. The same competences are needed by the operators on board.
The required ship handling competences are needed in all use cases. The frequencies to apply them are different, and the manoeuvring itself depends on the technology of propulsion. The manoeuvring competence is needed for ROC operators in the same way as for the operators on board.

Process 3.2: Navigation on pilotage - outbound
Process 3.3: Navigation on sea passage
Process 3.4: Navigation on pilotage - inbound
The demands for competences of the navigation on pilotage and on sea passage are very similar. In both situations, with or without crew on board, the MASS is assumed to sail in an automatic, nearly autonomous mode. Operators are monitoring the system's performance and are on stand-by for situations which get out of limitations. On pilotage, it is to expect that direct control can happen more often. The pilotage is to be performed in cooperation with local pilots and traffic control systems, depending on the local requirements. The difference for the ROC operators is the dependency on sensors. But the control tasks are the same in both scenarios, also the competences to apply and evaluate the used systems concerning reliability and consistency.
In all the processes, the operators need additional competences in the handling of the highly automated system. Such systems will be established on board of the MASS as well as in the ROC.

Process 3.5: Navigation when entering the port
Process 3.5.1: Anchoring
There should be no waiting times in logistics chains. However, disruptions are to be expected in every system, and unexpected waiting times can occur. If the MASS cannot adhere to a waiting time by adjusting the speed, or if drifting is not an option in the sea area and consumes too much fuel, it will have to anchor. Also in other circumstances, such as waiting for better weather conditions, free access to a port or berth, or due to technical demands, which may force a MASS to anchor.

Assuming that anchoring is an autonomous process, the operators must be on stand-by to take direct control. This applies to the operators on board as well as to those in the ROC. Thus, knowledge of the functionality of the anchor systems is necessary for all operators in order to be able to operate them safely and remotely.
Otherwise, there are the same requirements for competences as on a sea watch in pilotage mode.

Process 3.5.2: Arrival / Berthing
For this process, the statements for process 3.1.2 De-berthing/Departure apply analogously.

Process 3.6: Port Stay
A MASS must also be monitored during the stay in port. All land connections must function safely, including gangways, fixing the MASS to the pier, or supply systems for electricity and fuel. These may also be automated and are to be monitored accordingly. Operators must have the skills to operate these shore connections and ensure safe operation. For automated systems, the operators on board must have the same competences as the operators in the ROC.
Basically, the competences of operators are required in each of the three mentioned use cases. The individual voyages differ essentially in their duration. The frequency of activities thus varies, but the activities themselves are comparable. In the navigation processes listed below, no further differentiation is made between the three use cases. It makes no difference whether the operators take the navigational responsibility on board of a MASS or in the ROC. The major change in comparison to the navigation of a conventional ship is the different interface between operator and vehicle. Additional competences are required to be able to understand the highly automated systems, their limitations, and to control them in best practice. Also, it is a new challenge to rely on technical sensors, to keep the situational awareness and to get quickly into the loop if required.

Competence requirements for navigation processes by ship types
Any ship is to navigate safely by using all available means of navigation. Operators must know all of the applied navigation systems, whether it is a ferry, a feeder vessel, or a bulk carrier. There might be differences in the standards of the technologies used. But it is not possible to differentiate that between the ship types. Ferries may have more equipment to measure distances to the pier or other obstructions. But why should a bulk carrier not have such systems? The processes of navigation are a crucial competence for navigators of any ship or MASS.

Competence requirements for navigation processes per level of autonomy
The navigation process depends on the progress in technology development. The level of autonomy will follow the maturity of the sub-systems used for navigation. A MASS operator must be able to use and to evaluate all available sub-systems in the operation centre or on board. The systems will have the same technologies and standards in the ROC and on board. All operators, whether in ROC or on board, must have the understanding and knowledge about all the used systems.
Most navigational competences are already covered by STCW. They are added according to specific competence demands arising from the operation of a MASS. It must be stated that the required competences are the same in the ROC and on board.

Core Process 4: Engineering Operations

Process 4.1: Utilisable conditions of MASS system
Process 4.1.1: Bunker and supply
The bunkering interfaces of a MASS in the port are not yet known in detail. MASS will need a supply of energy and consumables. The technologies for this and the associated degrees of automation are in development.
For the use case B (Ferry), it is necessary to charge batteries in the port. Corresponding land connections can be automated (robotic). For the use cases A (feeder) and C (bulker), a bunkering of alternative fuels is necessary. Depending on the type of alternative fuel, different systems are conceivable, from the automated rigging of hoses to the replacement of entire fuel cells.

MASS will need competences to master and operate such automated systems. This affects the engineers at the operational and management level. While engineers on board can observe and control the bunker processes on site, direct control and monitoring will be necessary in the ROC. In the latter case, close cooperation with the terminal is necessary, which must take over possible tasks on site.

Process 4.1.2: System checks
Before a MASS can leave the port, an intensive system check must be carried out. This is necessary in all areas. For this reason, navigators, engineers, and system administrators are integrated into it. System checks can be carried out by self-tests of equipment and systems; these results must be released. However, it is to be expected that tests must also be carried out in direct control mode. In addition, they will include settings of systems. The relevant competences are necessary for crews on board as well as for operators in the ROC, and are essential for the safe operation of a MASS. For the system checks and any associated troubleshooting, dealing with digital twins is a necessary prerequisite in order to be able to initiate corrective measures. The tests will not only be carried out by checklist but will also be based on scenarios that must also be mastered.

Process 4.2: Control of MASS performance
Process 4.2.1: Auxiliary and machinery systems
The control of the performance of MASS contributes significantly to economic success. For the operators, the task is to observe all machines and equipment and, if necessary, to make corrections in the settings. This requires in-depth knowledge of the automated systems and their relationships. On the one hand, the operators must master the basics of physics, control engineering, and process data processing. In addition, the functions of sensors, robotics, and automated systems must be known and operated.
The competences are to be expected from engineers and system administrators and are necessary both in the field on board and in the ROC. These competences are also not dependent on one type of ship; they are needed on all of them.

Process 4.2.2: Propulsion System
The same statements apply to propulsion systems as to auxiliary and machinery systems. A differentiation can be made regarding the type of propulsion system. Combustion engines will be operated with alternative fuels, which require specific handling skills. The share of electric drives will increase and must also be controlled. In addition, support systems will be added. On the one hand, it can be solar systems and wind turbines that generate electricity. On the other hand, there will be wind systems that support propulsion. The latter can be rigid sails, Flettner rotors or flexible sails. Given that there will be no propulsion-specific training, engineers must be able to control and operate these new systems remotely. The appropriate knowledge and skills are to be taught. The task will be to monitor these systems remotely and only intervene correctively. This will be necessary both on board and in the ROC.

Process 4.2.3: Performance monitoring
Performance monitoring is crucial for a MASS system. The overall system must be understood, and the engineers and system administrators must be able to assess it in terms of integrity and reliability. Corresponding competences are necessary and are required in the ROC, but also on the MASS, and regardless of the ship type.

Process 4.2.4: Hoteling
Since it can be assumed that a certain number of people will continue to be on board a MASS, their care must also be ensured. For use case B (ferry), this task is more extensive, as passengers and service crew will be on board. A special and separate training for this is not considered necessary, since the requirements for engineers will always be based on the technologies actually used on a ship.
For hoteling, section 4.2.1 on machinery and auxiliary systems can be referred.

Process 4.3: Discharging residues
In accordance with the explanations on bunkering (4.1.1), competences for the operation of automated systems for discharging residues have also been included here. These are supplemented by the competences relevant to meeting environmental requirements in the operation of automated systems.

Competence requirements for operations engineering processes by ship types
As explained and discussed in the previous chapter the differences between the types of MASS are more technology driven. It is not predictable which systems will be used on which ship type in the future. As in other educational

programs, it will be necessary to develop competences in engineering more in general and with focus on specific systems which are expected to be used on MASS.

Competence requirements for operations engineering processes per level of autonomy
The development of autonomous systems and automation solutions in shipping is an ongoing process. It is to expect that new technologies for propulsion and auxiliary systems will be developed in the near future. Climate change and reduction of emissions is the driver for this process.
As discussed in chapter 1.2, the sub-systems for MASS systems will have different level of autonomy. Also, the sub-systems will be part of the entire MASS system, not only the MASS itself or the ROC. A holistic understanding and competences covering all of the sub-system and their use in the MASS system are to consider. To meet the required competences in the future, a more general approach for the development of competences is needed.

Core Process 5: Maintenance

Process 5.1: Maintenance in port
Process 5.1.1: Maintenance planning
The maintenance of a MASS is to be planned carefully. Capacities to carry out corrective maintenance will be available primarily in the port. Essentially, only preventive measures will be able to be carried out at sea.
For planning, a very good knowledge of all systems on board of a MASS and in the ROC is necessary. Due to the complexity of the systems and the tight time windows for maintenance in port, correspondingly detailed planning is necessary. Likewise, maintenance strategies that ensure the availability and reliability, and avoid unnecessary redundancy of systems, must be developed. This requires good knowledge of the application of such strategies.
Due to the automation in all areas of the MASS, these competences must be ensured at all levels by navigators, engineers and system administrators.

Process 5.1.2: Overhaul and repair
Overhauls and repairs are expected to be carried out mainly in port. First and foremost, it is an interface between the operators and the service providers. If the crews are on board, direct communication is possible. However, the integration into the remote-control system must always be observed and managed. Thus, the operators on board must have the same competences as in the ROC. The type of vessel is not to be differentiated.

Process 5.1.3: Spare part control
As part of the maintenance planning, the availability of spare parts is crucial. Demand planning strategies are challenging, the use of digital twins will be helpful. In general, the same explanations as for maintenance planning (5.1.1) must be considered.

Process 5.2: Maintenance at sea
Maintenance at sea will be limited to inspections and minor repairs. This also includes the updating of software. Inspections and updates are to at least be observed remotely, because for actions that can lead to a critical state of the MASS, a direct control is necessary. Due to the reduced number of crew, it will not be possible to have every inspection accompanied by operators, even in the case of crew on board. Thus, the competences of remote inspections and minor repairs carried out by robots will be necessary for operators on board MASS and in the ROC. In case of riding crews on board, the operators must coordinate the maintenance with them and have to ensure the availability of the system. The competences are required for all ship types and concern navigators, engineers, and system administrators.

Competence requirements for maintenance processes by ship types
The required competences are independent of the type of ship, as they affect every type of ship. The parameters for maintenance are availability of maintenance capacities, and that the MASS itself is available for maintenance.
The operators rather have to focus on the performance, availability, and reliability of all subsystems and the MASS-system. Maintenance work is assumed to be done by specialised service providers. On a ferry, this will be easier to implement than on a bulk carrier with longer times at sea. In the latter case, a riding crew is to be expected on board of such a MASS. The operators need the competences about the operational technical systems on board of a MASS and in the ROC. They should be able to take over smaller maintenance tasks and updating of systems. This will be needed on each type of MASS.

Competence requirements for maintenance processes per level of autonomy
The statement above can be taken into consideration concerning the competence requirements by the level of autonomy. It depends on the technical status of sub-systems. All these sub-systems on board and in the ROC must be maintained according to their progress in technical development.

Core Process 6: Malfunctions and Emergencies

Process 6.1: Emergency preparedness
The use of MASS is challenging the emergency organization with new tasks. How the safety devices can be controlled remotely is not yet clear. It can be assumed that new special technologies will be used. A distinction must be made between persons on board and whether they are trained as seafarers or treated as passengers.
In any case, MASS operators must be prepared for emergencies and malfunctions. It is necessary for MASS operators to be able to draw up and apply contingency plans. The operators need appropriate training and drills, which must take place on board. MASS operators in the ROC must also be trained on corresponding scenarios. In all cases, it is a challenge how the MASS communicates with the environment and how measures can be implemented without the support of people on board.
For ferries, the challenge of "passengers and service crew" must be considered. Otherwise, the requirements for the operators are equal for all ship types.

Process 6.2 und 6.3: Malfunctions and emergency response
The response to emergencies and malfunctions must be very fast; the appropriate emergency plans must be applied. The necessary competences for the operators are still under discussion. In this context, the relevant training requirements specified in the STCW Code, such as for firefighting or rescue boats, must be taken into account.
For the use case B (ferry), evacuation measures have to be trained for in particular, and the topic of crowd and crisis management also takes on a new dimension. There are no conclusive proposals on these points in these processes.

Competence requirements for malfunction and emergency processes by ship types
The process concerning emergency preparedness depends on regulations and the implementation of the ISM code in a shipping company. It is to assume that for MASS a similar instrument as the ISM Code must be applied too. The operators in the ROC must be familiarised with these requirements and must be able to apply them. It is a general process for all ship types.
Concerning the emergency response, ferries will have higher requirements because they will have passengers and service crews on board. For the crew on board, the same additional training courses as for passenger ships should be applied.

Competence requirements for malfunction and emergency processes per level of autonomy
Additionally, for emergencies it depends on the safety equipment and how it is already automated. Safety systems are specific sub-systems on a MASS. Operators must have the competences to apply such systems. The higher the degree of automation, the more the operators in the ROC will have to control such equipment. As long the automation is low, operators on board have to apply the safety appliances on board. As already laid down in the STCW Code, the operators on board will need all the relevant safety trainings specified thereby. In general, all operators of MASS need the competences to operate all safety equipment on board of a MASS, remotely or on board.

Support Processes
The support processes serve the core processes. All core processes require support in the same fields of application, which are bundled in the support processes. The competences needed in these support processes do not have to be repeated in every core process. MASS operators must have these competences to be able to implement and operate the core processes efficiently. The support processes listed here have been identified from the analysis as the main ones. This is not intended to be a restriction, but these are considered to be the most important.

- S.1 Providing and developing of human resources for MASS systems
- S.2 Consideration of legal aspects
- S.3 Supporting automation in MASS systems
- S.4 Consideration of economic aspects

Some of the skill requirements listed in these fields can already be found in the STCW tables. The requirements for competences for MASS are further supplemented in the defined processes.

Process S.1: Human resources

The requirements for operators of MASS systems are higher than those for seafarers on conventional ships. Working with a highly automated system requires a high level of concentration and a quick understanding of the situation where rapid intervention is required. Thus, it is necessary to provide MASS operators with competences for dealing with the autonomous systems. This includes topics such as situational awareness, decision making, and workload and stress management. Furthermore, MASS operators must have skills in communication with automated systems or by using them. The different content of technical data information and parallel human communication must be understood and taken into account in the procedures. It can be assumed that in the initial phase of autonomous shipping, there will be people on board. Training for safety on board is therefore essential, especially for the specific equipment on MASS. Such competences are required by operators on board as well as ashore. They have to manage emergency response and have to know how to use the systems and where the limitations are.

Process S.2: Legal aspects

MASS systems will operate within a special legal framework. MASS operators need to know this framework to act and decide accordingly. Operators can intervene in autonomous systems; for this it is necessary to know the corresponding rules. Knowledge is necessary at the operational level; at the management level, the competence must be present in order to analyse the application of the rules.

Process S.3: Automation systems

A MASS System including all control and communication systems is based on a very complex IT network and IT systems. The safe operations of a MASS are based on the fact that these systems are permanently available, have a high level of reliability, and the data is consistent and trustworthy. In principle, these tasks can be performed by a system administrator. However, more experts in IT and communication systems will be necessary. The hardware must be checked regularly, and elements must be replaced during their life cycle. Software of applications and operating systems must be kept up to date. The physical infrastructure must be maintained. Data and information must be stored and made available for data analysis. Cyber security has to be ensured.
Operators of MASS systems must have a basic qualification to be able to support these systems. The use of specialists is to be expected in parallel.

Process S.4: Economic aspects

Finally, economic competence is necessary. Innovations and optimisations in the MASS system will occur permanently. Technical progress must always be reconciled with the safety of a MASS. For this reason, a basic economic qualification makes sense in order to assess business decisions. The operators should be able to assess business issues and to discuss these with experts outside of the MASS system.

Competence requirements for support processes by ship types

The support processes cover general and overall competence requirements. They can be applied to all types of ships; they do not depend on specific ship types.

Competence requirements for support processes per level of autonomy

The support processes cover general and overall competence requirements. They can be applied to all levels of autonomy; they do not depend on a specific level.

7.2.3 STCW Competences for MASS Operators

In the determination of competence requirements, the minimum requirements defined in the STCW Code were compared with the requirements of the processes. It has been shown that the STCW competences already cover a large part of the competence requirements for MASS operators.

As part of this study, the STCW competences were assigned to the individual processes to check their necessity. In the assignment, it had to be determined that the STCW tables do not use clear levels of competences, and that the competences are sometimes not clearly defined:

> the competences are not clearly assigned to the competence level;
> sometimes only keywords are listed, and no verbs are used;
> in some fields of competence there is a great deal of detail, other the fields of competence are only briefly listed.

For these reasons, to maintain clarity and readability, the STCW competences have been partially summarized in the process descriptions or supplemented with verbs. Competency levels have also been assigned. It is clear to the authors that there is room for interpretation in this regard. However, the aim of this study is not to present a complete proposal for the revision of the STCW tables, but to work out the need for MASS operators. For a better understanding, the fields of competence (column 1 of the tables) and their relevance for MASS Operators are explained below.

Table A-II/1 Officers in charge of a navigational watch on ships of 500 gross tonnage or more

Function: Navigation at the operational level	
Column 1	**Need for MASS**
Plan and conduct a passage and determine position	Except for celestial navigation, all competences are required. The competences in navigation are fundamentals to monitor and control navigation of a MASS. The listed navigation equipment will be also used by a MASS. Fundamental meteorological competences are needed anyway.
Maintain a safe navigational watch	The watchkeeping competences are required as well to monitor and control a MASS. The COLREG regulations are essential. Bridge Resource Management is needed for a MASS with crew on board and within an ROC.
Use of radar and ARPA to maintain safety of navigation	Radar is essential for a MASS.
Use of ECDIS to maintain the safety of navigation	ECDIS is essential for a MASS.
Respond to emergencies	The basic knowledge of these competences is fundamental also for MASS.
Respond to a distress signal at sea	MASS can be involved in SAR operations too. It depends on the ability of the MASS to support, which might be different. The basic competences in this field are required, too.
Use the IMO Standard Marine Communication Phrases and use English in written and oral form	It is a crucial competence for MASS too.
Transmit and receive information by visual signalling	A MASS must be able to receive visual signals too.
Manoeuvre the ship	For monitoring and control of a MASS, the basics about manoeuvring are important.

Function: Cargo handling and stowage at the operational level	
Column 1	**Need for MASS**
Monitor the loading, stowage, securing, care during the voyage and the unloading of cargoes	MASS operators need the competences for cargo operations. They will be responsible for the safe carriage. The interfaces to terminal operations are different by ship types and by ports. The fundamentals are important for MASS operators.
Inspect and report defects and damage to cargo spaces, hatch covers and ballast tanks	The MASS operator will be involved in such inspections and needs a basic understanding of ship (MASS) construction.

Function: Controlling the operation of the ship and care for persons on board at the operational level	
Column 1	**Need for MASS**
Ensure compliance with pollution-prevention requirements	Safety and environmental protection issues which are important for the operation of a MASS.
Maintain seaworthiness of the ship	The fundamental knowledge of stability, trim, and strength is crucial for operations of MASS
Prevent, control and fight fires on board	A safety issue which is important for the operation of a MASS.
Operate life-saving appliances	A safety issue which is important for the operation of a MASS, at least as long persons are on board.
Apply medical first aid on board ship	As long as a crew are on board, this competence will be required.
Monitor compliance with legislative requirements	A MASS is involved in international shipping, and the application of legislative requirements is important.
Application of leadership and teamworking skills	Leadership and teamwork are crucial with crew on board and within an ROC.
Contribute to the safety of personnel and ship	As long as crew are on board, it will remain important.

All competences listed in STCW for the “officer in charge of a navigational watch” are required to operate a MASS safely too.
The only exception is celestial navigation. The medical competences and personal safety competences are not needed if no crew and no persons are on board.

Table A-II/2 Masters and chief mates on ships of 500 gross tonnage or more

Function: Navigation at management level	
Column 1	**Need for MASS**
Plan a voyage and conduct navigation	Voyages and passages of MASS must be planned with the same minimum standards according to routing and environmental issues
Determine position and the accuracy of resultant position fix by any means	Except for celestial navigation, all competences are required by MASS too.
Determine and allow for compass errors	A crucial competence for MASS as well. Magnetic compasses may be not on MASS.
Coordinate search and rescue operations	A MASS can be a part of SAR operations, e.g. operators can act as coordinators, although operators are ashore. IAMSAR should be known by MASS operators.
Establish watchkeeping arrangements and procedures	MASS require the same competences. COLREG regulations are crucial.
Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision making	This is a fundamental competence for MASS operators. It must be deepened for MASS regarding the extended navigational equipment.
Maintain the safety of navigation through the use of ECDIS and associated navigation systems to assist command decision making	A crucial competence for MASS.
Forecast weather and oceanographic conditions	A crucial competence for MASS as well.

Respond to navigational emergencies	MASS operators must be able to deal with these emergencies. The procedures will be different, but the basics are the same.
Manoeuvre and handle a ship in all conditions	The manoeuvring of a MASS must be well understood. In direct control mode, a MASS is to be controlled safely. An important competence, also for MASS operators.
Operate remote controls of propulsion plant and engineering systems and services	This is a basic competence for MASS operators who will have more challenges on this topic.

Function: Cargo handling and stowage at the management level	
Column 1	**Need for MASS**
Plan and ensure safe loading, stowage, securing, care during the voyage and unloading of cargoes	The operators of the MASS have to ensure a safe passage and appropriate transportation of cargoes. Not all of these competency contents will meet the requirements directly, such as tankers and tanker operations. But overall, the basics about cargoes are crucial.
Assess reported defects and damage to cargo spaces, hatch covers and ballast tanks and take appropriate action	A basic knowledge about issues in ship construction is an important competence. Bulk carriers are mentioned in this study as a possible use case.
Carriage of dangerous goods	Also, a crucial competence for MASS.

Function: Controlling the operation of the ship and care for persons on board at the management level	
Column 1	**Need for MASS**
Control trim, stability and stress	A crucial competence for MASS.
Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea, security and the protection of the marine environment	Competence required for operations of MASS
Maintain safety and security of the ship's crew and passengers and the operational condition of life-saving, fire-fighting and other safety systems	Competence required for operations of MASS
Develop emergency and damage control plans and handle emergency situations	Competence required for operations of MASS
Use of leadership and managerial skill	Also a crucial competence for MASS.
Organize and manage the provision of medical care on board	As long as persons are on board, this competence is required.

All competences listed in the STCW Code for "masters and chief mates" are required to operate a MASS safely, too. The only exception is celestial navigation and perhaps magnetic compasses.
The medical competences and personal safety competences are not needed if no crew and no persons are on board.

Table A-III/1 Officers in charge of an engineering watch in a manned engine-room or designated duty engineers in a periodically unmanned engine-room

Function: Marine engineering at the operational level	
Column 1	**Need for MASS**
Maintain a safe engineering watch	It is a crucial competence for operators too.
Use English in written and oral form	Needed in international shipping.
Use internal communication systems	As basic competence needed, also for MASS.
Operate main and auxiliary machinery and associated control systems	It is a crucial competence. Several technologies are listed for this competence, marine steam and gas turbines may be obsolete for MASS. But all other systems must be known also by MASS operators.
Operate fuel, lubrication, ballast and other pumping systems and associated control systems	MASS will have piping and pumping systems too. It is a basic competence to be able to operate them.

Function: Electrical, electronic and control engineering at the operational level	
Column 1	**Need for MASS**
Operate electrical, electronic and control systems	These are crucial competences for MASS operators.
Maintenance and repair of electrical and electronic equipment	As basic competences to manage, control, or maintain and repair electric and electronic equipment. Will be more important for MASS systems.

Function: Maintenance and repair at the operational level	
Column 1	**Need for MASS**
Appropriate use of hand tools, machine tools and measuring instruments for fabrication and repair on board	The practical part of this competence will not be so important for MASS operators. But the knowledge of how to do repairs is necessary for the evaluation of maintenance jobs.
Maintenance and repair of shipboard machinery and equipment	The practical part of this competence will be not so important for MASS operators. But the knowledge of how to do repairs is necessary for the evaluation of maintenance jobs.

Function: Controlling the operation of the ship and care for persons on board at the operational level	
Column 1	**Need for MASS**
Ensure compliance with pollution-prevention requirements	Safety and environmental protection issues which are important for the operation of a MASS.
Maintain seaworthiness of the ship	The fundamental knowledge of stability, trim, and strength is crucial for operations of MASS
Prevent, control and fight fires on board	A safety issue which is important for the operation of a MASS.
Operate life-saving appliances	A safety issue which is important for the operation of a MASS, at least as long persons are on board.
Apply medical first aid on board ship	As long as a crew are on board, this competence will be required.
Monitor compliance with legislative requirements	A MASS is involved in international shipping, and the application of legislative requirements is important.
Application of leadership and teamworking skills	Leadership and teamwork are crucial with crew on board and within an ROC.
Contribute to the safety of personnel and ship	As long as crew are on board it will stay important

All competences listed in STCW for "officers in charge of an engineering watch in a manned engine-room or designated duty engineers in a periodically unmanned engine-room" are required to operate a MASS efficiently and safely.
Exceptions might be the competences about marine steam and gas turbines. The practical part of the maintenance competences might be not so important for a MASS Operator. The medical competences and personal safety competences are not needed if no crew and no persons are on board.

7.2.3.1 Table A-III/2 Chief engineer officers and second engineer officers on ships powered by main propulsion machinery of 3,000 kW propulsion power or more

Function: Marine engineering at the management level	
Column 1	**Need for MASS**
Manage the operation of propulsion plant machinery	Competences about diesel engines will stay important, although other fuels will be used the future. Steam and gas turbines are obsolete for MASS.
Plan and schedule operations	Both competences are required by MASS operators too. The theoretical part contains a lot of fundamentals about engineering for propulsion, power generation, and auxiliary systems. The practical part is important for the operation of all technical systems on board of a MASS.
Operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery	
Manage fuel, lubrication and ballast operations	MASS will have piping and pumping systems, too. It is a basic competence to be able to manage the relevant systems.

Function: Electrical, electronic and control engineering at the management level	
Column 1	**Need for MASS**
Manage operation of electrical and electronic control equipment	These are crucial competences for MASS operators.
Manage trouble-shooting, restoration of electrical and electronic control equipment to operating condition	As basic competences to manage, control or maintain and repair electric and electronic equipment. These will be more important for MASS systems.

Function: Maintenance and repair at the management level	
Column 1	**Need for MASS**
Manage safe and effective maintenance and repair procedures	The practical part of this competence will not be so important for MASS operators. But the knowledge of how to manage maintenance and repairs is necessary for MASS operators
Detect and identify the cause of machinery malfunctions and correct faults	These are crucial competences for MASS operators.
Ensure safe working practices	This practical competence will not be so important for MASS operators. But the knowledge about safe working is necessary for the management of all practical jobs on a MASS.

Function: Controlling the operation of the ship and care for persons on board at the management level	
Column 1	**Need for MASS**
Control trim, stability and stress	A crucial competence for MASS.
Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea, security and the protection of the marine environment	Competence required for operations of MASS
Maintain safety and security of the ship's crew and passengers and	Competence required for operations of MASS

the operational condition of life-saving, fire-fighting and other safety systems	
Develop emergency and damage control plans and handle emergency situations	Competence required for operations of MASS
Use leadership and managerial skills	Also a crucial competence for MASS.

Table A-III/6 Electro-Technical Officer

Function: Electrical, electronic and control engineering at the operational level	
Column 1	**Need for MASS**
Monitor the operation of electrical, electronic and control systems	It is a crucial competence for MASS operators too. Contains a lot of required theoretical competences.
Monitor the operation of automatic control systems of propulsion and auxiliary machinery	It is a crucial competence for MASS operators.
Operate generators and distribution systems	It is a crucial competence for MASS operators.
Operate and maintain power systems in excess of 1,000 volts	It is a crucial competence for MASS operators.
Operate computers and computer networks on ships	It is a crucial competence for MASS operators.
Use English in written and oral form	Needed in international shipping.
Use internal communication systems	As basic competence needed, also for MASS.

Function: Maintenance and repair at the operational level	
Column 1	**Need for MASS**
Maintenance and repair of electrical and electronic equipment	As basic competences to manage, control or maintain and repair all electric and electronic equipment. Will be very important for MASS systems.
Maintenance and repair of automation and control systems of main propulsion and auxiliary machinery	
Maintenance and repair of bridge navigation equipment and ship communication systems	
Maintenance and repair of electrical, electronic and control systems of deck machinery and cargo-handling equipment	
Maintenance and repair of control and safety systems of hotel equipment	

Function: Controlling the operation of the ship and care for persons on board at operational level	
Column 1	**Need for MASS**
Ensure compliance with pollution-prevention	Safety and environmental protection issues which are important for the operation of a MASS.

requirements	
Prevent, control and fight fires on board	A safety issue which is important for the operation of a MASS.
Operate life-saving appliances	A safety issue which is important for the operation of a MASS, at least as long persons are on board.
Apply medical first aid on board ship	As long as a crew are on board this competence will be required.
Application of leadership and teamworking skills	Leadership and teamwork are crucial with crew on board and within an ROC.
Contribute to the safety of personnel and ship	As long as crew are on board it will stay important

All competences listed in STCW for "electro-technical officers" are required to operate a MASS efficiently and safely. The practical part of the maintenance competences might not be so important for a MASS Operator. The medical competences and personal safety competences are not needed if no crew and no persons are on board.

Application of STCW Code for MASS operators

The tables of the STCW Code cover the minimum standards. Thus, only basics are addressed for many fields of competence.

In these tables, STCW is geared towards all types of vessels. It does not focus on individual types of ships. Special requirements are dealt with in specific tables, such as for tankers or passenger ships or ships in polar waters.

Since almost all competences from the STCW tables are required for MASS operations, they must continue to be used as a basis. Additional competences for MASS which are necessary are listed in a separate and additional table. This is then the basis for the training of MASS operators.

8. Curriculum Development

8.1 Qualification Objectives

8.1.1 Structure of Competence Objectives

The starting point for the development of a curriculum is the definition of qualification objectives for the training programs. For this purpose, four general competence dimensions are considered.

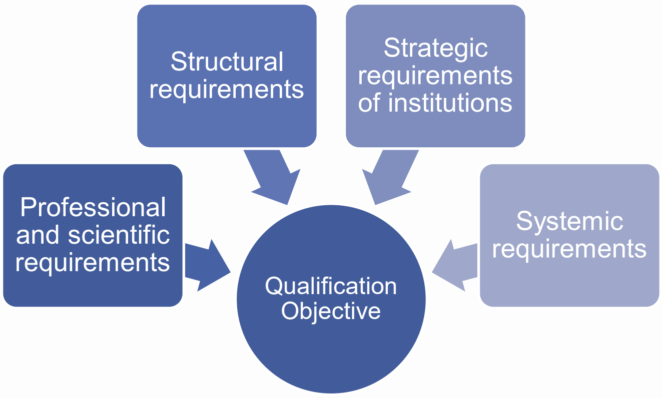

Figure 32: Competence dimensions for qualification objectives

Professional-scientific requirements
The qualification objective should be determined in such a way that it complies with recognized national and international standards. For these curricula, particular attention is paid to the international STCW convention, which sets the minimum standards of competence for seafarers. In addition, it must be ensured that national standards can also be considered in the context of implementation. Within the framework of this study, there is no need to specify a specific graduation. Since operators in ROC's will be subject to national conditions, adaptability must be taken into account here.

Structural requirements
Structurally, the learning outcomes are assigned to four competence dimensions:
> Knowledge and understanding (extension, consolidation, and understanding of knowledge)
> Using, applying, and generating knowledge (applying and transferring knowledge)
> Communication and cooperation
> Reflection of professional identity

As explained in section 7.1.2 qualification programs are needed for the operational and the management level. The framework for required competences are the general qualification objectives which are to be outlined for the operator's basic program on operational level and the senior operators advanced program on management level. The qualification objectives will ensure employability of operators and support the personality development of operators.

Strategic requirements of training institutes
It is necessary for the individual training institutes to be able to implement their respective profile characteristics. So, it is conceivable that the training program is offered as a stand-alone program, or that it is part of a graduate program. The program can be offered by training institutes, vocational schools, academies, or universities. The design of the curriculum with its individual courses must be adaptable according to the objectives and possibilities of the institutions.

Systemic requirements
The qualification objective must be considered systemically in the design of the curriculum. The learning outcomes are to be derived from the qualification objective. The structure of the training program must ensure the achievement

of the qualification objective. This means that the course sequence, the formats of teaching and learning, and the types of examinations are coordinated.

8.1.2 Qualification Objectives "Basic Training of MASS ROC Operators"

The basic training covers the navigators, engineers, and system administrators on operational level.

Competence Dimensions	
	Graduates of the program "MASS ROC Operators Basic Training" …
KNOWLEDGE AND UNDERSTANDING	Extension of knowledge and understanding
	… are familiar with the navigational and technical applications of remote-controlled MASS. … understand the autonomy and automation functionalities of remote-controlled MASS … can differentiate the specific requirements of MASS in comparison to conventional ships. … are familiar with procedures to monitor a single or a fleet of MASS in an ROC.
	Consolidation of knowledge and understanding
	… can explain the technical and operational basics of remote-control with regard to the navigation and technical operation of MASS. … understand the design and interfaces of all systems of remote-controlled MASS.
	Comprehension of knowledge and understanding
	… understand the context of an ROC and a remote-controlled MASS. … understand the roles of the operators and crew on board.

USING, APPLYING AND GENERATING KNOWLEDGE	Applying
	… can monitor a fleet of remote-controlled MASS and can intervene in case of deviation from limitations. … can monitor MASS cargo and mission operations in the port and at sea. … can monitor the entire MASS systems and is able to intervene for appropriate measures in case of deviations from regular operations. … contribute to the safety and security of the MASS at sea and in port, and of the ROC.
	Transferring
	… are able to set operational tasks for remote-control MASS in relation to theoretical fundamentals. … will identify operational potentials to improve MASS systems and address them accordingly. … analyse the state and condition of all MASS systems by systematic approach.

COMMUNICATION AND COOPERATION	… communicate navigational and technical requirements by using MASS related terminology. … act as valuable team member in an ROC or on board of a MASS. … are able to share planning and monitoring tasks in ROC's and on board of a MASS.

REFLECTION OF PROFESSIONAL IDENTITY	… understand their personal role as a MASS operator at operational level. … take their personal responsibility in monitoring of remote-controlled MASS. … can take over operational activities for the remote control of individual and a fleet of MASS. … are able to identify challenges in the operation of MASS and initiate appropriate measures.

8.1.3 Qualification Objectives "Advanced Training of MASS ROC Operators"

The advanced training covers the senior navigators and senior engineers on management level.

Competence Dimensions	
	Graduates of the program "MASS ROC Operators Advanced Training" …
KNOWLEDGE AND UNDERSTANDING	Extension of knowledge and understanding
	… are familiar with all operations of navigation, technology, and equipment of a remote-controlled MASS. … can explain the autonomy and automation functionalities for remote-controlled MASS. … understand the operational limitations of all navigational and technical MASS-systems in the ROC and on board of MASS. … are familiar with all procedures to monitor and control a single or a fleet of MASS in an ROC
	Consolidation of knowledge and understanding
	… can explain the requirements of the navigational and operational remote-control systems. … understand the operational demands of all navigational and technical systems for safe and secure operations.
	Comprehension of knowledge and understanding
	… understand the operational context of all navigational and technical MASS-systems in the ROC and on board of MASS. … understand the interdependencies between automation functionalities for remote-controlled MASS. … can explain the different requirements to the roles of operators and crew on board.

USING, APPLYING AND GENERATING KNOWLEDGE	Applying	
	… can control a single MASS in direct mode under all conditions. … can plan and control cargo and mission operations in the port and at sea. … can analyse and evaluate the entire MASS system and is able to plan and initiate appropriate measures in case of deviations of intended parameters. … maintain and ensure the safety and security of MASS at sea and in port, and of the ROC.	
	Transferring	
	… are able to set technical, procedural, and personnel tasks for remote-control MASS in relation to theoretical fundamentals. … will identify technical, procedural, and personnel potentials to improve MASS systems and initiate implementation of appropriate optimisation. … Analyse and evaluate the state and condition of all MASS systems by systematic approach.	

COMMUNICATION AND COOPERATION	… communicate navigational and technical decisions and directions to all concerned team members in an appropriate and understandable way. … act as a leader of ROC teams and crews on board of a MASS. … are able to coordinate all planning, monitoring and control tasks within the MASS operating team and other parties involved in MASS operations.

REFLECTION OF PROFESSIONAL IDENTITY	… understand their personal role as a MASS operator at management level … take their personal responsibility in monitoring and direct control of MASS … can take over the navigational and technical management of a fleet of MASS … are able to assess the operation of a MASS and make appropriate decisions

8.2 Competence Tables

8.2.1 STCW Tables

The structure for specifying the minimum standards of competence in the STCW Code in tabular form is well known in the maritime industry (cf. Table 19). For that reason, the structure of the STCW competence tables is generally used for the development and documentation of competences.

Table 19: Table for documentation of competences according to STCW Convention

Function: XY Management or operational level:			
Column 1	**Column 2**	**Column 3**	**Column 4**
Competence	Knowledge, understanding, and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Competence on a high level.	Detailed break-down to specific competences	Description of any methods, media, simulators, and equipment needed to demonstrate such competence	Criteria to evaluate achieved competences
…	…	…	…

8.2.2 Competence Tables for MASS Operators

The competences are documented in a structure similar to the STCW tables. They are listed in the competence tables in **Appendix E**. For this study, column 1 in Table 20 is defined as “fields of competence”. In general, the same definitions as in the STCW Code will be used in this column, but they are also extended. In this way, a common basis is achieved with the competences newly defined as learning outcomes for MASS ROC operators. Examples are:

- Plan and conduct a passage of a MASS.
- Monitor and control the navigation of a MASS.
- Apply MASS-related risk management.

In the later developed module descriptions, the “fields of competence” are used as “learning outcomes”.

In column 2 the single identified competences are listed as learning outcomes. They are the competences derived from the process descriptions and extend on the STCW competences.
In a separate column, the competence levels (C/L) are assigned according to the used taxonomy explained before. The cross-reference to the processes, in which the competences are identified, is added in the last column.

A verification of the competences was conducted before transferring them into the competence tables. In several expert meetings and interviews within the reference groups (cf. Appendix G), the competences were discussed, and additional identified requirements were added to the tables.

Table 20: Table for documentation of competences for MASS operators

	Function: XY Management or operational level:		
Column 1	**Column 2**		
Qualification objectives	Competences as learning outcomes. The operator is able ….	C/L	Processes
Qualification on a high level.			
Fields of competence (learning outcomes)	Break-down to specific competences described according to the competence dimensions	Assigned competence level	Number of processes in which the competences had been identified
…	…	…	…

It is proposed to determine five new competence tables:

- MASS 1-1: MASS ROC Navigator (on operational level)
- MASS 1-2: MASS ROC Senior Navigator (on management level)
- MASS 2-1: MASS ROC Engineer (on operational level)
- MASS 2-2: MASS ROC Senior Engineer (on management level)
- MASS 3-1: MASS ROC System Administrator (on operational level)

The tables in **Appendix E (**Competence Tables) represent the required competences for MASS ROC operators on operational and management level.

8.2.3 STCW Qualifications Required for MASS Operators

The analysis of the competences required in the STCW Code shows that they are almost completely required as a basic qualification for MASS operators. Thus, the certificates according to STCW are a prerequisite for the qualification as a MASS operator.
Table 21 lists the Certificates of Competency, which are prerequisites for training as a MASS Operator.

In this context, the system administrator must be considered in a more differentiated way. In the discussions with the expert groups, it was identified that a pre-qualification as an electrotechnical officer according to STCW is not to be considered as mandatory. In addition to the trained ETO, persons with other qualifications can also be very well suited for work as a system administrator. The focus of this role is very much on a functioning IT and communication system. The nautical-technical requirements are covered by navigators and engineers. A maritime education is therefore not necessarily required. The specific competences required can also be demonstrated by persons with education in computer science or electrical engineering. Since these training courses can vary greatly in the individual countries in which ROCs are located, this study does not go into more in-depth detail. The competent body of the national administration must approve the basic education as prerequisite to start a training for a MASS System Administrator.

Furthermore, in the discussions with the expert groups, it was found out that the proposed roles of engineers and senior engineers will continue to be necessary. It is quite conceivable that these functions will be merged with those of navigators and senior navigators. However, this means that the complexity of the tasks and the associated competence requirements are significantly reduced. This in turn depends very much on the innovation and development of future systems. From today's perspective, the future effects of innovations and developments beyond a medium-term horizon cannot be predicted. It can be assumed that the complexity of the systems will require the possibility of intervention by the operator in the medium term. It should also be kept in mind that the role of service providers will continue to evolve. If not all competences can be covered by ROC operators, their role will become much more important. In this case, specific questions and problem solutions will no longer be able to be processed by the operators. The operators will then grow more into a role in which they coordinate the service providers' experts.

Table 21: Compulsory STCW Certificates of Competency for MASS Operators in ROC's

STCW Table	Certificate of Competency	MASS Navigator	MASS Engineer	MASS Senior Navigator	MASS Senior Engineer	MASS System Admin.
A-II/1	Officer in charge of navigational watch (operational level)	**X**				
A-II/2	Master and Chief Mate (management level)		**X**			
A-III/1	Engineer in charge of a watch (operational level)			**X**		
A-III/2	Chief Engineer and Second Engineer (management level)				**X**	
A-III/6	Electro-Technical Officer (operational level)					**(X)**
A-IV/2	GMDSS Radio Operator	**X**		**X**		

In addition to the Certificates of Competency, further Certificates of Proficiency are required for seafarers according to the STCW Convention. These trainings include qualifications that are also important for the operation of MASS. These are primarily safety-related trainings.

As part of this study, it was found that in the medium-term, people on board MASS must be expected. In the degree "MASS with crew on board", this is the crew that can intervene in the control of the MASS. In addition, the other people on board must also be considered, such as maintenance technicians or service crews. These are not part of the "MASS crew" in the sense of this study. However, the safety of these persons on board a MASS must be ensured.

In the curriculum for the MASS operators, the MASS-specific safety equipment and the corresponding procedures are dealt with, so that no separate safety training is necessary. However, it is assumed that the basic skills on the safety conditions on a ship are taught additionally in the STCW-courses. This applies to all aspects of safety and security.

The question of medical care for people on board of a MASS remains open. For these, MASS operators on board (they are seafarers) will continue to need these courses. For MASS operators in ROCs, there will be more a coordinating task in the context of telemedicine, in which medical experts take over possible emergencies on board online.

It is recommended that the respective administration responsible for the ROC determines which additional qualifications MASS Operators need in ROCs as part of the evaluation and approval of the Concepts of Operation (ConOps). A ConOps covers all requirements of a MASS system and determines technical equipment, communication lines, safety and security related procedures as well as staffing with competent people.

In Table 22, the relevant Certificates of Proficiency are listed. For certain types of vessels, such as ferries with passengers on board, additional certificates may be mandatory for MASS operators, too. This is to be determined by the respective administration.

Table 22: Compulsory STCW Certificates of Proficiency for MASS Operators in ROC's

STCW Table	Certificate of Proficiency	MASS Navigator	MASS Engineer	MASS Senior Navigator	MASS Senior Engineer	MASS System Admin.
A-VI/1	Basic Safety Training (1-1,1-2,1-4)	**X**	**X**	**X**	**X**	**X**
A-VI/2	Survival Craft and Rescue Boats other than Fast Rescue Boats	**X**	**X**	**X**	**X**	
A-VI/3	Advanced Fire Fighting	**X**	**X**	**X**	**X**	
A-VI/4	Medical First Aid	**X**	**X**	**X**	**X**	
A-VI/4	Medical Care			**X**		
A-VI/5	Ship Security Officer			**X**		
A-VI/6-1	Security Awareness Training	**X**	**X**	**X**	**X**	**X**
A-VI/6-2	Training for Seafarers with Designated Security Duties	**X**	**X**	**X**	**X**	

8.3 Constructive Alignment

8.3.1 Perspectives of Constructive Alignment

This study is using the approach of constructive alignment, which is well established in the development of educational programs. To develop a curriculum three perspectives and their correlation are to consider (cf. Figure 33).

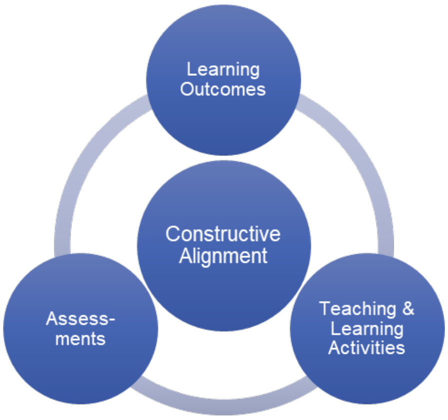

Figure 33: Constructive Alignment

The perspectives can be explained by questions:

> **Learning outcomes:** What students should be able to do after completing of a module?

> **Format of assessments:** Which format of examination is suitable to assess the actual acquisition of competence?

> **Teaching and Learning Activities:** Which format of teaching and learning is suitable to achieve the required competences?

The design of the individual modules in a training program is derived according to this reference.

This approach differs from that of the STCW code. As a result, however, both approaches are comparable. The STCW Code uses a combination of the KUP's in column 2 and the methods and criteria to demonstrate and assess competences in column 3 and 4. In the constructive alignment approach, the competences are defined as learning outcomes. Implicitly, this also covers the criteria for evaluation. The breakdown to evaluation criteria can therefore be dispensed with. The methods for demonstrating competences are covered by the content of the modules in the curriculum and the choice of examination forms.

8.3.2 Learning Outcomes

The learning outcomes are defined in the individual modules of the curriculum. They represent the competences expected to be demonstrated by a MASS ROC operator. The competences are assigned to the competence levels to be achieved. In the development of the curriculum, it is considered that the basics (competence levels 1 and 2) are taught at the beginning of the training program, and at the end of the training the higher competence levels are reached (competence levels 3 to 5).

In the competence tables (**Appendix E**), the general and overall learning outcomes are defined in the first column: "fields of competences". These were assigned to the modules according to the competence dimensions.

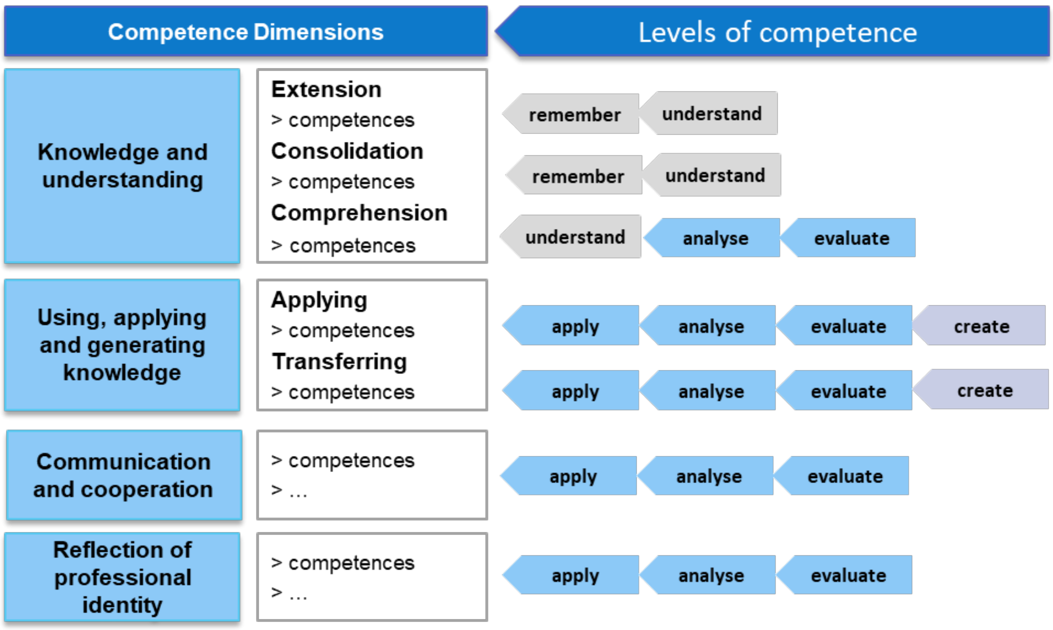

Figure 34: Competence dimensions with required levels of competence

The individual competences in column 2 of the competence tables are assigned to the "fields of competence". These more detailed competences are formulated according to the competency levels. The qualification requirements for MASS Operators are focused on application, analysis, and evaluation. It thus corresponds to a requirement profile at the level of a university of applied sciences degree. The highest competency level, "create, extend", was not used in the assignment. At this (highest) level, the focus is on developing new applications and innovations. For MASS Operator, this requirement does not apply.

Important aspects in the derivation of competences can be summarized:

- For graduation, the level of a university of applied sciences is assumed.
- The focus is on output, not on input, and the verbs used to formulate the competences have been chosen accordingly.
- Learning outcomes must be detectable and verifiable.
- Previous education must be considered as a starting point for the formulation of learning outcomes.
- Learning outcomes must be achievable within a defined time frame.
- In the module descriptions, learning outcomes of higher taxonomy levels are mainly used. These include competences at lower levels of competence. The focus is on what should be achieved at the end of the module.

8.3.3 Assessments

One of the principles of competency-based examinations is that the existence of a competency can only be measured through its application. By reproducing only knowledge, acquired competences can only be checked to a limited extent. It is therefore crucial that an application context is created for examinations in which students can demonstrate their acquired skills. In order to be able to establish an application context, a suitable form of testing must be chosen. In addition, suitable tasks must be developed within the examinations. Table 23 lists forms of examination that are suitable for a competency-oriented examination.

Table 23: Formats of Assessments

Format of assessment	Abbr	Explanation
Written Test	WT	Working on a set of questions to be determined by the examiner and related to the content of the module in question, using the common methods of the subject in a limited time with defined aids and under supervision.
Module Paper	MP	Written discussion of a topic of the module or a related concrete practical professional question, including relevant literature. If appropriate, including an expert discussion based on the written elaboration.
Written Presentation	WP	Independent and in-depth written discussion of a problem related to the context of the module with the inclusion of relevant literature as well as presentation of the work and its results in an oral presentation with corresponding discussion.
Practical Exercises	PE	Demonstrating to solve tasks in practical exercises by using simulators or computer-aided applications. Candidates should demonstrate that specific and practice-relevant situations are mastered.
Project Report	PR	Demonstrating the ability to work in a team and to develop, implement, and present concepts. Candidates should demonstrate that they can define goals and develop interdisciplinary solutions and concepts.
Experimental Research	EX	Includes the preparation, implementation and presentation of practical work or experiments and their documentation as well as the indication, evaluation and critical appraisal of the results obtained in the form of a report or oral presentation.
Development Work	DE	Creation and demonstration of software (as an example), including the associated documentations (such as task, specification, design, source program, test documentation, user notes, and application example).
Oral Examination	OE	Dealing with a complex of questions related to the content of the module in the form of a colloquium. Candidates should demonstrate that they can recognize the context of the examination field and classify special questions in it.
Oral Presentation	OP	Media-supported presentation of theoretical and practical work results in front of an audience. Candidates should demonstrate that they can adequately illustrate a certain set of questions in a given time using presentation and lecture techniques.
Report	R	In a report, the course and the relevant events of a practical phase are described and evaluated; the report may include a brief oral presentation.

Different formats of examination can be used for the different types of competences. These are assigned in their basic suitability in Table 24. It should be kept in mind that the examinations must be designed differently depending on the level of competence. If knowledge is tested in a written exam, this can be done as part of a multiple-choice test. If the test is to be taken at higher competence levels, then “open questions” can be formulated in a written test, which give room for analysis or evaluation. In the upper levels, elaborations (MP, WP) and reports (PR, EX, DE) are recommended.

From the proposed forms of examination, suitable formats of assessment were selected for each module in the module catalogue. The aim is to ensure that as far as possible different examination formats can be used in one module. This allows training institutes to develop their individual curriculum according to their requirements.

Table 24: Suitability of assessment formats to competence levels

Format of assessment	Abbr.	1 remember	2 understand	3 apply	4 analyse	5 evaluate	6 create
Written Test	WT	suitable	suitable	if applicable	Suitable	suitable	rather not
Module Paper	MP	suitable	suitable	if applicable	suitable	suitable	if applicable
Written Presentation	WP	suitable	suitable	if applicable	suitable	suitable	rather not
Practical Exercises	PE	if applicable	if applicable	suitable	suitable	suitable	rather not
Project Report	PR	if applicable	if applicable	suitable	suitable	suitable	suitable
Experimental Research	EX	if applicable	if applicable	suitable	suitable	suitable	if applicable
Development Work	DE	if applicable	if applicable	suitable	if applicable	if applicable	suitable
Oral Examination	OE	suitable	suitable	suitable	suitable	suitable	rather not
Oral Presentation	OP	suitable	suitable	suitable	if applicable	if applicable	rather not
Report	R	suitable	suitable	if applicable	if applicable	if applicable	rather not

8.3.4 Teaching and Learning Activities

Finally, in the development of a curriculum, it must be determined which formats of teaching and learning are to be chosen. The use of appropriate forms of teaching and learning is a crucial element of being able to build-up competences.

The acquisition of competences is to be understood as a process that gradually leads from knowledge-based competences to activity-oriented competences, taking their interrelationships into account. Forms of teaching and learning in which theoretical and technical-practical content are coupled with references to application and practice are particularly suitable. The forms of teaching and learning should therefore not only promote receptive learning but should also enable active and problem-solving discussions of teaching content.

Table 25 lists forms of teaching and learning that support competence-oriented teaching. The formats are strongly geared towards smaller group sizes, which allow intensive communication and cooperation. Thus, the form of seminar teaching is focused on a high level of interactivity between lecturers and students.

Table 25: Forms for competence-oriented teaching and learning

Teaching & Learning Formats	Abbr.	Description
Seminar Style Lecture	SL	**Objective:** Imparting subject-systematic basics and methodological skills; Deepening and intensifying the acquired expertise in application. **Working method:** Interactive lecture and discussion of exemplary usage and practicing methodological knowledge. **Group size:** 12 to 18 students (max. 36)

Seminar	S	**Objective:** Development and discussion of subject-specific issues; Application and implementation as well as critical discussion and interpretation of individual factual issues. **Working method:** Independent work by the students, guided by teachers. **Group size:** 12 to 18 students
Project	P	**Objective:** To work on new questions and problems. Solving a larger task. **Working method:** Independent work by the students, preferably in smaller teams, guided by teachers. **Group size:**12 to 18 students
Simulation	SIM	**Objective:** Use of reflective exercises in respective scenarios by using realistic simulation. Supervision and support by instructors. Learning and applying methods and procedures. **Working methods:** Teamwork, practical exercises, briefings and debriefings, group discussions in collegial consultation form. **Group size:** 3 to 6 students, depending on the exercises.
Module-Related Exercises	MRE	**Objective:** Development of practical and systematic working methods to enable students to work independently on individual problems and to study on their own. Use of computer-aided exercises and application-related devices. **Working method:** Application and in-depth use of technical and methodological knowledge; conducting case studies. **Group size:** 8 to 12 students (depending on available equipment and tasks).

The individual forms of teaching and learning are to be selected according to the desired acquisition of competence in the respective competence level. Thus, simulation is particularly suitable for learning applications. Projects are suitable for the higher levels of competence, in which learned competences can be built up by working on complex issues. Table 26 provides a reference to the suitability of teaching and learning forms for certain levels of competence.

Table 26: Suitability of forms of teaching and learning for competence levels

Teaching & Learning Formats	Abbr	1 remem-ber	2 under-stand	3 apply	4 analyse	5 evaluate	6 create
Seminar Style Lecture	SL	suitable	suitable	if applicable	suitable	suitable	rather not
Seminar	S	suitable	suitable	suitable	suitable	suitable	suitable
Project	P	if applicable	if applicable	suitable	suitable	suitable	suitable
Simulation	SIM	if applicable	if applicable	suitable	suitable	suitable	rather not
Module-Related Exercises	MRE	suitable	suitable	suitable	if applicable	if applicable	rather not

9. Competence-based Curricula for MASS ROC Operators

9.1 Module Descriptions

From all previous considerations and thoughts, the module catalogue documented in **Appendix F** was developed. The module catalogue contains the description of the individual modules that represents the curriculum. The modules were compiled based on the competence tables. In terms of content, competence requirements were brought together into related subject areas. Additionally, the workload of the students was taken into consideration in the order of the content. Some of the modules can be further subdivided thematically, which can also lead to a finer structure of the modules in the design of a training offer. The description of a module is designed to ensure the achievement of qualification objectives. For this study, they will be structured as follows:

Each module description starts with the number, name, and abbreviation of the module.

First, the workload hours are determined.
The total workload represents the total of all hours needed as effort by the students.
The lectures, simulator exercises, and module-related exercises together are the contact hours of a student to the program. In addition, the time for examinations is calculated too.
The time for self-studies refers to the time a student shall have for learning on their own, to study literature and to prepare for the lectures. Example:

Workload total (h):	128h	**Lectures (h):**	64h	**Simulator (h):**	24h
Exercises (h):	12h	**Examination (h)**	4h	**Self-Studies (h):**	16h

The next block explains the scope and frequency of teaching. The assumed number of lectures and exercises are calculated, based on the duration shown as (n h). Additionally, the designated student group who have to visit courses of this module are named. Example:

Scope und frequency of teaching:	16 classes lecture (4h) 3 days simulator training (8h) 3 classes exercises (4h)	All operators at operational level: ▪ Navigators, ▪ Engineers,

The core of the module description are the learning outcomes. Each module is designed so that these learning outcomes can be achieved. The learning outcomes are taken from the first column of the competence tables in **Appendix E**. According to the detailed, defined competences in the competence tables, these “fields of competences” are assigned to the competence levels (marked as (CL x)). The structure is derived according to the qualification objectives explained previously. The number of learning outcomes is reduced intentionally to the “fields of competence”. It is not advisable to put all detailed competences which are required into this table. The module description shall stay focussed and give an overview; details can be found in the competence tables. The learning outcomes are expressed by the phrase “… are expected to be able …”.

Learning outcomes: Upon successful completion of this module, participants are expected to be able to … *(regarding knowledge and understanding (extension, consolidation, and understanding of knowledge))* … Competence 1 (CL x) … Competence 2 (CL y) … *(regarding using, applying, and generating knowledge (applying and transferring knowledge))* … Competence 1 (CL x) … Competence 2 (CL y) … *(regarding communication and cooperation)* … Competence 1 (CL x) …

(regarding reflection of professional identity) … Competence 1 (CL x) *Consider MASS competence tables for details.*

In the next box, the contents of the lecture are listed. This can be understood as a simplified syllabus for the courses of the module. The intention is to give headlines which covers the competences listed in the competence tables. It is intended to keep it flexible due to the innovation and development of MASS shipping in the mid-termed future. To each block of topics, the expected hours for the classes are assumed.

Course content (lecture):	Hours:
Content A ▪ topic x ▪ topic y ▪ topic z	X h

The exercises are explained in the next box. For module-related exercises as well as for the simulator training, some hints are given to the possible content. In the design of the individual syllabi, the content can be developed accordingly and related to the learning outcomes.

Exercise content:	Hours:
Module-related exercises (as examples and suggestion) ▪ e.g. … ▪ e.g. …	x h
Simulator training ▪ … ▪ ….	x h

Some further information is given in the following lines. English is proposed as the language of teaching. This is due to the fact that ROC's will operate in an international context, and English as the business language should be mandatory for the graduates. Additionally, programs with international participation should be possible. All prerequisites which are required to be allowed to take the module are to be determined in the module description too. The program for MASS operators will focus on competences for practical application. To support the learning of the students, adequate equipment is required. For module-related exercises, appropriate workstations with necessary databases and training software are needed to enable realistic exercises. Operators in ROCs depend on working with IT-based workstations, which is crucial to have an adequate learning environment. That is also important for simulators of ROC operations and remote-control of MASS. Further information is given on literature for module preparation, and other important topics.

Language of teaching:	English
Prerequisites:	Qualification according to STCW requirements for navigational officers or engineers on operational level
Teaching facility and equipment:	> For lectures: classroom with audio-visual presentation systems > For module-related exercises: workstations with access to digital twins for exemplary use cases > For simulator training: ROC simulator with planning, monitoring, and direct control stations
Preparation/literature:	Lecture notes will be provided, participants will receive a reading list at the beginning of the course.
Further information:	The module represents a basic course for navigators, engineers, and system administrators operating a MASS.

At the end of the module description, the courses of the module are determined. A module may consist of different courses, depending on the content of the classes or on the required teaching staff. Additionally, the module-related exercises and simulator training are considered in this table. The contact hours are assigned to each course. In the last two columns, the formats for learning and teaching as well as for examination are proposed.

Course title	Teaching staff	Contact hours	Learning and teaching methods	Examination method(s), scope and duration
n.n.n.n course title	Person competent in xyz	n h	Format of teaching and learning	Format of examinations

9.2 Module Catalogue

9.2.1 Modules for “MASS ROC Operator Basic Program”

The "MASS ROC Operator Basic Program" covers the training of operators at operational level and consists of the following modules (cf. Table 27) :

- three modules (1.1.1 – 1.1.3) for all MASS ROC Operators
- three modules (1.2.1 – 1.2.3) for MASS ROC Navigators
- two modules (1.3.1 and 1.3.3) for MASS ROC Engineers
- two modules (1.3.2 and 1.3.3) for MASS ROC System Administrators
- one module (1.4.1) as in-service training for all MASS ROC Operators

Table 27: Modules "MASS ROC Operator Basic Program"

No.	Module	Summarized Learning Outcome	Comp. Level
1.1.1.	MASS Operations 1	to understand the components of a MASS system, to operate them as part of the system, and to interpret the performance	2 - 4
1.1.2.	MASS Safety and Security 1	to be able to contribute to the specific safety and security requirements of a MASS system	3 -4
1.1.3.	MASS Management and Administration 1	to be able to work in a MASS operator team within legal requirements	2 - 3
1.2.1.	MASS Navigation	to plan and conduct a MASS passage and to take the responsibility on navigation	3 - 4
1.2.2.	MASS Navigation Monitoring	to conduct a safe watch and to take the responsibility on monitoring the MASS system	3 - 4
1.2.3.	MASS Cargo and Mission Operations 1	to monitor cargo and mission operations and to maintain seaworthiness of the MASS	3 - 4
1.3.1.	MASS Engineering Operations 1	to operate all technical systems and automation, and to operate remote maintenance	3 - 4
1.3.2.	MASS Automation and Control	to operate automation and autonomy systems, and to operate remote maintenance	3 - 4
1.3.3.	MASS Operations Monitoring	to monitor the operations of a fleet of MASS and to intervene appropriate	3 - 4
1.4.1.	In-Service Training 1	to understand the systems and operations in ROC and on board of a MASS	2 - 3

The first three modules cover topics that are relevant to all operators. In this "Basic Program", they are the entry modules.
Modules 1.2.1 to 1.2.3 contain topics for Navigators. The focus is on the navigation and monitoring of a fleet of MASS. Furthermore, the special features of MASS about cargo and mission operations are covered.
For Engineers, modules 1.3.1 and 1.3.3 are scheduled in parallel. These modules deal with the operating technology and automation of a MASS, as well as the monitoring of a fleet of MASS.
For Systems Administrators, module 1.3.2 is provided instead of module 1.3.1. Its focus is more on automation technology and the necessary computer systems for autonomous shipping. System Administrators as well as Engineers complete module 1.3.3.

Module 1.4.1 covers the in-service training in an ROC and on board a MASS. The in-service training is to be carried out by each candidate. The relevant modules for Navigator, Engineer, and System Administrator are shown in Figure 35.
All modules of the "Basic Program" are mainly at competence level 3 (apply), with a maximum of level 4 (analyzing).

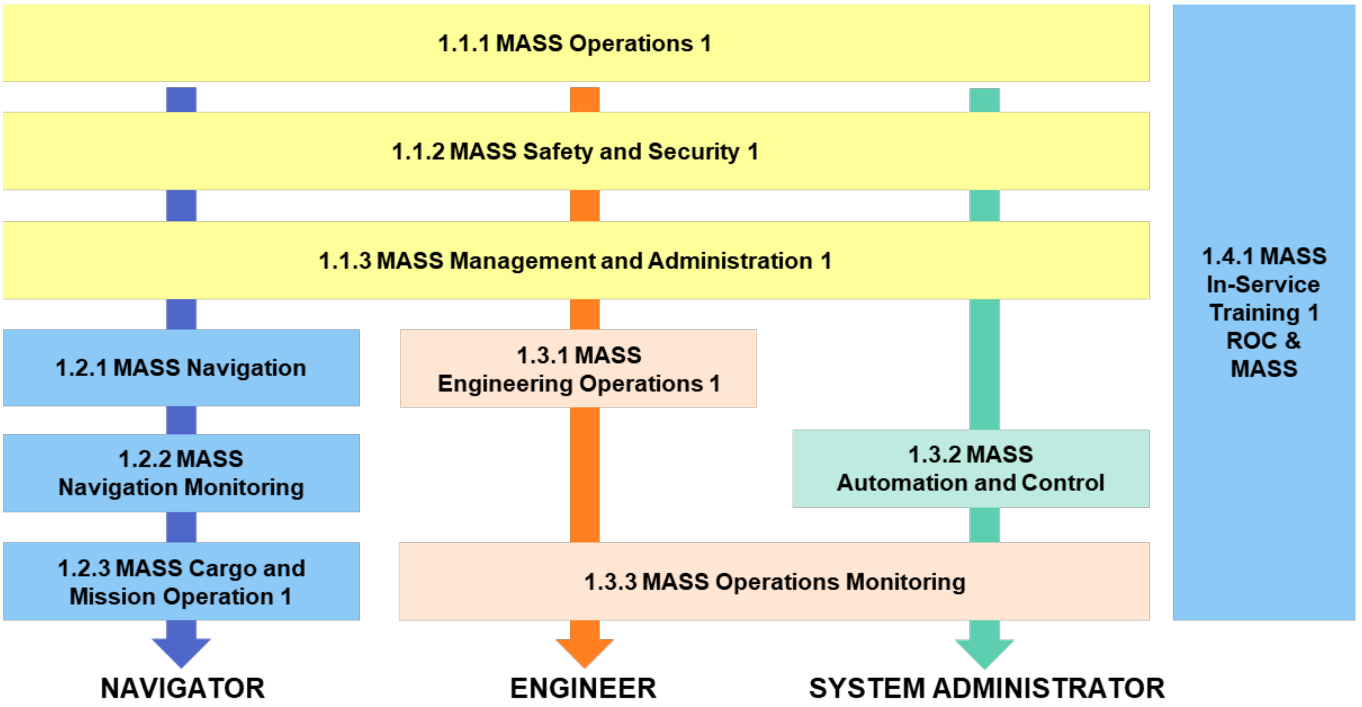

Figure 35: Arrangement of Modules "MASS ROC Operator Basic Program"

The detailed module descriptions as explained in the previous chapter are listed in **Appendix F** (Module Catalogue).

9.2.2 Modules for "MASS ROC Operator Advanced Program"

The "MASS ROC Operator Advanced Program" covers the training of operators at management level and consists of the following modules (cf. Table 28) :

- three modules (2.1.1 – 2.1.3) for all MASS ROC Senior Operators
- three modules (2.2.1 – 2.2.2) for MASS ROC Senior Navigators
- two modules (2.3.1 - 2.3.2) for MASS ROC Senior Engineers
- one module (2.4.1) as in-service training for all MASS ROC Senior Operators

Table 28: Modules "MASS ROC Operator Advanced Program"

No.	Module	Summarized Learning Outcome	Comp. Level
2.1.1.	MASS Operations 2	to manage an entire MASS system und to analyse and optimize its performance	4 - 5
2.1.2.	MASS Safety and Security 2	to develop safety and security systems, and to maintain a safe and secure operation of the entire MASS system	4 - 5
2.1.3.	MASS Management and Administration 2	to develop and improve the entire MASS system and MASS operator teams within legal and economic requirements	4 - 5
2.2.1.	MASS Navigation and Control	to plan and manage MASS voyages and to manoeuvre the MASS in direct control under any condition	4 - 5
2.2.2.	MASS Cargo and Mission Operations 2	to plan, manage, and control cargo and mission operations of the MASS, including control of persons on board and seaworthiness of the MASS	4 - 5
2.3.1.	MASS Engineering Operations 2	to manage all technical systems and automation, and to improve reliability, availability, performance, and resilience of the entire MASS system	4 - 5
2.3.2.	MASS Operations Control	to manage a fleet of MASS and to take direct control of a MASS on demand to apply appropriate measures to keep all systems in proper working conditions	4 - 5
2.4.1.	In-Service Training 2	to evaluate the performance and critical conditions in ROC and on board of a MASS	4 - 5

The first three modules cover topics are relevant to all operators. These modules expand on the modules from the Basic Program with more perspective to the management of MASS systems.
Modules 2.2.1 to 2.2.2 contain topics for Senior Navigators. The focus is on the management of a fleet of MASS and to manoeuvre MASS in direct control if needed. Furthermore, the special features of MASS concerning planning, managing cargo and mission operations are covered.
For Engineers, modules 2.3.1 and 2.3.2 are scheduled in parallel. These modules deal with the management of the operating technology and automation of a MASS, as well as the control of a fleet of MASS.
For Systems Administrators, no further specific program is determined. In case they are specialists from other disciplines, they have sufficient understanding about the specific requirements of MASS systems in the Basic Program. Because they are not involved directly in the navigation of management of MASS, a further program does not seem necessary. But of course, it is possible that they join the "MASS ROC Operator Advanced Program" like the MASS Senior Engineers.

Module 2.4.1 covers the in-service training in an ROC and on board a MASS. The in-service training is to be carried out by each senior operator and focuses on the management of performance and critical conditions. The relevant modules for Senior Navigator and Senior Engineers are shown in Figure 36.
All modules of the "Basic Program" are mainly at competence level 3 (apply), with a maximum of level 4 (analysing).

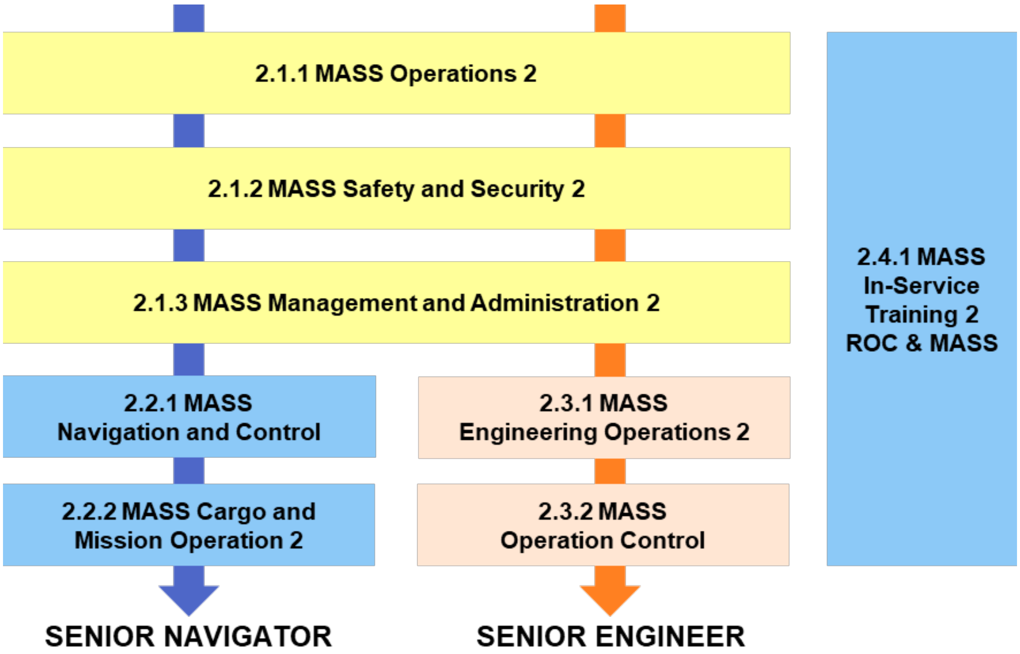

Figure 36: Arrangement of Modules "MASS ROC Operator Advanced Program"

The detailed module descriptions as explained in the previous chapter are listed in **Appendix F** (Module Catalogue).

9.2.3 In-Service Training

Hands-on training is provided for both programs. In all discussions with the expert groups, it is considered essential to gain initial practical experience in an ROC and with a MASS. Qualified operators need the in-service training for reflection of learned theory and to gain a deeper understanding of the complexity and demands of a MASS system.

The in-service trainings are to be arranged flexibly. It is conceivable to arrange them in a block before the beginning or at the end of the training program at a training institute. It should also be possible to divide them up and carry them out parallel to the training program. Seeing that, at the time of this study, there is no sufficient number of ROCs and MASS involved in such programs, there must be an introductory phase. A in-service training must be possible in an ROC as well as with manufacturers of automation systems. It may also be that it is not possible to sail on a MASS, which means that operations in the port or in new construction at a shipyard as well as in maintenance must be possible.

To complete the "MASS ROC Operator Basic Program", the completion of a practical phase as in-service training is planned. For the students is the aim of this first in-service training to gain their first experience in the practical operation of an ROC. They should also be given the opportunity to get to know the technical and operational conditions on board of a MASS. Students should have experienced a MASS at sea and in port to get a practical idea of how it works. If the students are later deployed as a crew on a MASS that is controlled by an ROC, they must have initial practical experience. The contents of the first in-service phase are described in the module catalogue for module 1.4.1.

In-service training is also planned for the "MASS ROC Operator Advanced Program". The same explanations apply to this as to the first in-service training. The 2nd in-service training is designed to gain the first real experience in direct control of a MASS. Under supervision, the transfer from MASS to direct control mode and the operation of remote-controlled manoeuvring is to be trained. Furthermore, safety-critical situations must be simulated and trained in real operation. The contents of the second practical phase are described in the module catalogue for module 2.4.1.

9.3 Workloads

9.3.1 Time Effort Calculation

In the expert meetings within the reference groups, the time needed for MASS ROC operator programs was discussed intensely. When summarising the discussions, the majority of the opinions were:

- The MASS ROC Operator programs are supplementary programs to trainings according to STCW Code. They should not extend the time already invested in the previous fundamental training and education for too long. It must be practicable for interested persons to gain the competences as remote operator in an appropriate time.
- It should be possible for educational institutes to offer the program as a stand-alone training course, as part of a training program, or integrated in a study program.
- The time required should be about 15 weeks. This time frame fits into one semester or one trimester. The required time frame is checked against the content and workload of the proposed modules in the curriculum.
- The focus is not to train specific experts but operators of advanced technologies. Expanding competences in scientific skills should be assigned to bachelor or master programs. The programs for MASS operators can be part of study programs, but this is not a must.
- The time spent should be the same for the basic program and the advanced program.

The bases for the calculation of work efforts are 40 hours per week, which result to 8 hours per day. The total training programs will take 600 hours in 15 weeks. The distribution of work hours is considered for the different types:

- Lectures: objective ca 50% of the total time.
- Simulator training: objective ca 12% - 15% of the total time.
- Exercises (module-related): objective ca 15% of the total time.
- Examinations: objective ca 2% – 3% of the total time.
- Self-studies: objective ca 20% of the total time.

In the first step the time for lectures was assumed by considering the content (compare module descriptions in **Appendix F** Module Catalogue). One lecture is calculated with 4 hours. It should be the responsibility of the training institutes to determine how long one lesson (calculated by one hour) will take; it can be less than 60 minutes to compensate breaks or switching rooms and lecturers.

In the next step, the simulator training times were determined. The expert groups suggested to plan with sufficient time for simulator trainings. In the programs, they assumed 9 to 11 days, each consisting of 8 hours. Of course, it is possible to plan simulator sessions also for half a day, which would result in doubling the days. This will depend on the concepts and capacities of the training institute.
In the module-related exercises, the students will be guided by a lecturer. This time should be used in the training institute. Together with the simulator training, the module-related exercises should cover more than 25% of the total time calculated. Both, simulator training and module-related exercises, are a very important part of in-service training in the competence-oriented training program.
Time for examinations should not be forgotten in the calculations. The calculated time is about 3%. The formats of assessments have been discussed previously. The training institutes have to decide on the format they will use and how long an examination should take. The time is calculated for written examinations. An oral test, a presentation, or a seminar paper will need different time. This is to consider in the individual curricula of the training institutes.
The students need time for self-studies which is calculated as 20%, equalling to about one day per week. This time is required for reading literature, meeting in learning groups, to completing exercises, and preparing for the examinations.

9.3.2 "MASS ROC Operator Basic Program" Workload

In the next tables, the workload, understood as time effort for a student, is calculated. It is based on the desired learning outcomes and the content of the modules. The calculated number of hours per module and activity is a proposal. The training institutes should be able to adjust them according to their specific programs. At the end, the required competences for MASS ROC operators must be achieved.

Table 29: Workload Calculation Basic Program for Navigators

Module No.	Module Name	Lectures [h]	Simulator [h]	Exercises [h]	Examination [h]	Self Studies [h]	Total [h]
	Workload for the MASS Operator Basic Program						
1.1.1.	MASS Operations 1	64	24	12	4	24	**128**
1.1.2.	MASS Safety & Security 1	36	16	8	2	16	**78**
1.1.3.	MASS Management & Admin. 1	40		16	2	16	**74**
	Subtotal all Navigators and Engineers	140	40	36	8	56	**280**
		50.0%	*14.3%*	*12.9%*	*2.9%*	*20.0%*	*100.0%*
1.2.1.	MASS Navigation	56	24	16	4	28	**128**
1.2.2.	MASS Navigation Monitoring	48	24	8	2	16	**98**
1.2.3.	MASS Cargo & Mission Operations 1	40		24	4	26	**94**
	Subtotal Navigators	144	48	48	10	70	**320**
		45.0%	*15.0%*	*15.0%*	*3.1%*	*21.9%*	*100.0%*
	Total Navigators	**284**	**88**	**84**	**18**	**126**	**600**
	Workload in weeks (@40h/week)	*7.1*	*2.2*	*2.1*	*0.5*	*3.2*	***15.0***
		47.3%	*14.7%*	*14.0%*	*3.0%*	*21.0%*	*100.0%*

Table 30: Workload Calculation Basic Program for Engineers and System Administrators

Module No.	Module Name	Lectures [h]	Simulator [h]	Exercises [h]	Examination [h]	Self Studies [h]	Total [h]
	Workload for the MASS Operator Basic Program						
1.1.1.	MASS Operations 1	64	24	12	4	24	**128**
1.1.2.	MASS Safety & Security 1	36	16	8	2	16	**78**
1.1.3.	MASS Management & Admin. 1	40		16	2	16	**74**
	Subtotal all Navigators and Engineers	140	40	36	8	56	**280**
		50.0%	*14.3%*	*12.9%*	*2.9%*	*20.0%*	*100.0%*
1.3.1.	MASS Engineering Operations 1	80	12	24	4	42	**162**
1.3.2.	MASS Automation & Control	80	12	24	4	42	**162**
1.3.3.	MASS Operations Monitoring	64	36	24	4	30	**158**
	Subtotal Engineers	144	48	48	8	72	**320**
	Workload in weeks (@40h/week)	*3.6*	*1.2*	*1.2*	*0.2*	*1.8*	***8.0***
		45.0%	*15.0%*	*15.0%*	*2.5%*	*22.5%*	*100.0%*
	Total Engineers	**284**	**88**	**84**	**16**	**128**	**600**
	Workload in weeks (@40h/week)	*7.1*	*2.2*	*2.1*	*0.4*	*3.2*	***15.0***
		47.3%	*14.7%*	*14.0%*	*2.7%*	*21.3%*	*100.0%*

In Table 30, it is to consider that the module 1.3.1 is dedicated to Engineers and 1.3.2 to System Administrators. They are calculated as parallel modules.

9.3.3 "MASS ROC Operator Advanced Program" Workload

In the next tables the workload for the advanced program is proposed. It was calculated on the same basis as for the basic program but taking the modules of this program into account.

Table 31: Workload Calculation Advanced Program for Senior Navigators

Workload for the MASS Operator Advanced Program						
Module Name	**Lectures [h]**	**Simulator [h]**	**Exercises [h]**	**Examination [h]**	**Self Studies [h]**	**Total [h]**
MASS Operations 2	40	16	16	4	16	**92**
MASS Safety & Security 2	32	16	8	4	10	**70**
MASS Management & Administration 2	68		16	2	32	**118**
all Senior Navigators and Engineers	140	32	40	10	58	**280**
	50.0%	*11.4%*	*14.3%*	*3.6%*	*20.7%*	*100.0%*
MASS Navigation & Control	88	40	16	4	24	**172**
MASS Cargo & Mission Operations 2	80		32	4	32	**148**
Senior Navigators	168	40	48	8	56	**320**
	52.5%	*12.5%*	*15.0%*	*2.5%*	*17.5%*	*100.0%*
Senior Navigators	**308**	**72**	**88**	**18**	**114**	**600**
Workload in weeks (@40h/week)	*7.7*	*1.8*	*2.2*	*0.5*	*2.9*	***15.0***
	51.3%	*12.0%*	*14.7%*	*3.0%*	*19.0%*	*100.0%*

Table 32: Workload Calculation Advanced Program for Senior Engineers

	Workload for the MASS Operator Advanced Program						
Module No.	**Module Name**	**Lectures [h]**	**Simulator [h]**	**Exercises [h]**	**Examination [h]**	**Self Studies [h]**	**Total [h]**
2.1.1.	MASS Operations 2	40	16	16	4	16	**92**
2.1.2.	MASS Safety & Security 2	32	16	8	4	10	**70**
2.1.3.	MASS Management & Administration 2	68		16	2	32	**118**
Subtotal	all Senior Navigators and Engineers	140	32	40	10	58	**280**
		50.0%	*11.4%*	*14.3%*	*3.6%*	*20.7%*	*100.0%*
2.3.1.	MASS Engineering Operations 2	88		32	4	40	**164**
2.3.2.	MASS Operations Control	72	40	16	4	24	**156**
	Subtotal Senior Engineers	160	40	48	8	64	**320**
		50.0%	*12.5%*	*15.0%*	*2.5%*	*20.0%*	*100.0%*
	Total Senior Engineers	**300**	**72**	**88**	**18**	**122**	**600**
	Workload in weeks (@40h/week)	*7.5*	*1.8*	*2.2*	*0.5*	*3.1*	***15.0***
		50.0%	*12.0%*	*14.7%*	*3.0%*	*20.3%*	*100.0%*

9.3.4 In-Service Training Workload

The duration of in-service trainings was discussed in the expert group meetings. It was considered that no experience is available for such in-service trainings. From today's perspective only very few remote operation centres will be available for in-service trainings, but it is to be expected that the number will grow in near future. From the view of experience with in-service training as required by the STCW Convention it was considered that practical experiences with MASS systems are an important part to gain and foster competences before taking over responsibilities as operator in an ROC.

The duration of the first in-service training for the basic program is considered as 15 weeks. The time can be divided in blocks of different duration.
In total, 480 hours (totalling to 12 weeks) should be completed in an ROC, in port with MASS operations, or on board of a MASS. The remaining 120 hours, which are 3 weeks, should be used for self-studies.

The duration of the second in-service training for the advanced program consists of 8 weeks. Because the students in the advanced program will have already practical experience at least from the first in-service training the time is reduced to the mentioned 8 weeks. This time can be divided in blocks of different durations.
In total, 240 hours (totalling to 6 weeks) should be completed in an ROC, in port, or on board of a MASS. It should be possible especially to gain experience in direct control tasks in any operation, and in the training of safety-critical situations. The remaining 80 hours, which are 2 weeks, should be used for self-studies.

9.4 Training Program Sequence and Schedules

9.4.1 Sequence of Training Programs

The training to become a MASS ROC Operator first requires a training in accordance with the STCW Code as a basic qualification.

The "MASS ROC Operator Basic Program" requires a Certificate of Competency at operational level to get started. In the discussion with the expert groups, it was determined that there should be a minimum experience time on a conventional seagoing vessel. This experience time is estimated at 12 months of sailing time as a ship's officer in charge.

If these requirements are met, the students can start with the "MASS ROC Operator Basic Program". After completing the training and practice in the ROC and on board a MASS, graduates can start as an operator in an ROC or on a MASS and take over the monitoring.

To be able to take up the "MASS ROC Operator Advanced Training", a Certificate of Competency at management level must be presented. This means that the required practical time as officer of the watch at sea, and the training program at management level must be completed. If these are available, then the "MASS Operator Advanced Training" can be started directly. After successful completion, the role of a MASS operator at management level can be started, a fleet of MASS can be managed, and a single MASS responsibly controlled in direct control mode.

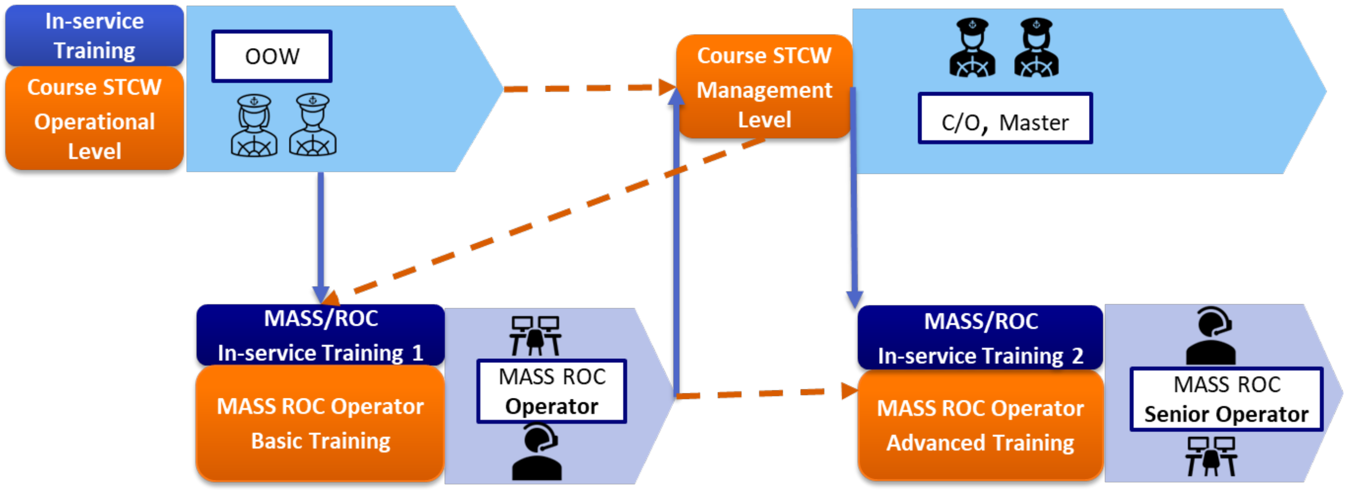

Figure 37: Sequence of the MASS Operator Training Programs

9.4.2 Schedules of Training Programs

The schedules are a proposal and an example how the training programs can be implemented on the timeline. Different arrangements are possible.

The modules for both programs can be scheduled well on the timeline of 15 weeks. The contact hours are on average 30 to 32 hours per week, which are incurred on site at the training institute. Thus, at least 8 hours per week remain for self-studies.

The schedules outlined in the tables below are suggestions on how to arrange each module on the timeline. There is no further in-depth study, as the planning of the modules is individual and many parameters, such as the available capacities of rooms, simulators, or lecturers must be considered.

Table 33: Schedule "MASS ROC Operator Basic Program"

MASS ROC Operators Basic Course - Schedule			**Week**														
No	**Modules for Navigators**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1.1.1.	**MASS Operations 1**	lectures & exercises	■	■	■	■	■	■	■	■							
		simulator training					■	■	■								
1.1.2.	**MASS Safety and Security 1**	lectures & exercises									■	■	■	■	■		
		simulator training														■	■
1.1.3.	**MASS Management and Administration 1**	lectures & exercises	■	■	■	■	■										
1.2.1.	**MASS Navigation**	lectures & exercises	■	■	■	■	■	■	■								
		simulator training								■	■	■					
1.2.2.	**MASS Navigation Monitoring**	lectures & exercises						■	■	■	■	■	■				
		simulator training											■	■	■		
1.2.2.	**MASS Cargo and Mission Operations 1**	lectures & exercises											■	■	■	■	■

MASS ROC Operators Basic Course - Schedule			**Week**														
No	**Modules for Engineers**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1.1.1.	**MASS Operations 1**	lectures & exercises	■	■	■	■	■	■	■	■							
		simulator training					■	■	■								
1.1.2.	**MASS Safety and Security 1**	lectures & exercises									■	■	■	■	■		
		simulator training														■	■
1.1.3.	**MASS Management and Administration 1**	lectures & exercises	■	■	■	■	■										
1.3.1.	**MASS Engineering Operations 1**	lectures & exercises	■	■	■	■	■	■	■	■							
		simulator training								■	■	■					
1.3.3.	**MASS Operations Monitoring**	lectures & exercises									■	■	■	■	■	■	■
		simulator training											■	■	■	■	■

Table 34: Schedule "MASS ROC Operator Advanced Program"

MASS ROC Operators Advanced Course - Schedule			**Week**														
No	**Modules for Senior Navigators**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
2.1.1.	**MASS Operations 2**	lectures & exercises	■	■	■	■	■										
		simulator training						■	■								
2.1.2.	**MASS Safety and Security 2**	lectures & exercises										■	■	■	■		
		simulator training														■	■
2.1.3.	**MASS Management and Administration 2**	lectures & exercises	■	■	■	■	■	■	■	■	■						
2.2.1.	**MASS Navigation and Control**	lectures & exercises	■	■	■	■	■	■	■	■							
		simulator training									■	■	■	■	■		
2.2.2.	**MASS Cargo and Mission Operations 2**	lectures & exercises						■	■	■	■	■	■	■	■	■	■

MASS ROC Operators Advanced Course - Schedule			**Week**														
No	**Modules for Senior Engineers**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
2.1.1.	**MASS Operations 2**	lectures & exercises	■	■	■	■	■										
		simulator training						■	■								
2.1.2.	**MASS Safety and Security 2**	lectures & exercises										■	■	■	■		
		simulator training														■	■
2.1.3.	**MASS Management and Administration 2**	lectures & exercises	■	■	■	■	■	■	■	■	■						
2.3.1.	**MASS Engineering Operations 2**	lectures & exercises	■	■	■	■	■	■	■	■	■	■	■				
2.3.2.	**MASS Operation Control**	lectures & exercises							■	■	■	■	■	■	■	■	■
		simulator training									■	■	■	■	■		

9.5 Use of the Curricula

The curricula developed are to be understood as a holistic proposal. They are a framework that provides a guideline for the further development and specification of education and training programs for MASS ROC operators. The development of needed competence and the curriculum derived from them is based on many assumptions. The technical development and innovations in the automation of MASS is a process whose results cannot be predicted. For this reason, care was taken in the development of the training content to ensure that there is flexibility to be able to adapt to future findings.

Within the framework of this project, it was found that the training of MASS ROC operators is hardly or only selectively considered in most current projects. They mostly refer to individual use cases and reflect a specific application.

The aim of this study is to develop a curriculum that is related to different types of MASS and pursues a holistic approach to content. The view is extended beyond the smaller units of MASS under development. It is necessary to start today to initiate the training for operators to be able to have them in place in a few years' time. The present draft of curricula for the training of MASS ROC operators is intended to serve as a basis for further discussion.

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