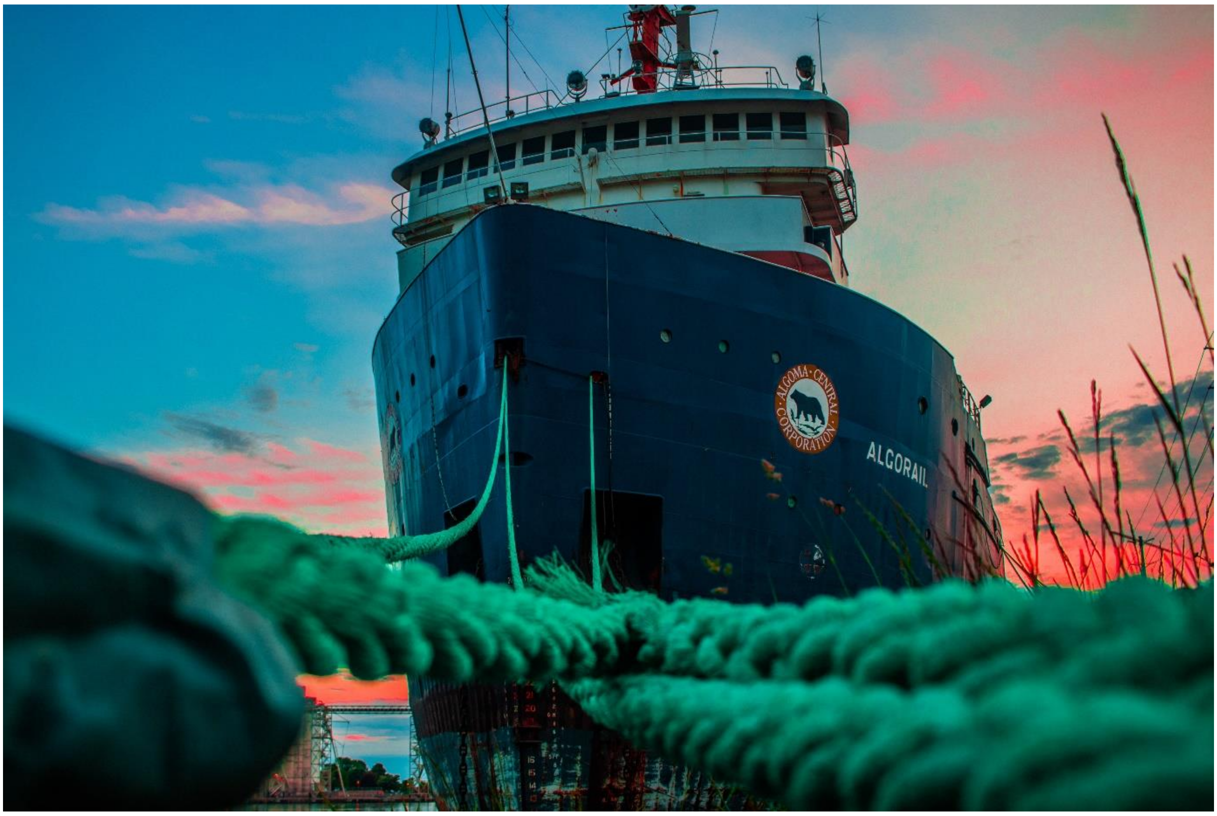
Prepare Ships



Document No: PS_WP1.1

Version: 1.0

Title: Use Cases and Application Scenarios

Date: 2020-01-31

European Global Navigation Satellite Systems Agency

"This project has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No 870239".

Prepare Ships

European Global Navigation Satellite Systems Agency

DOCUMENT STATUS

Authors

Name	Organisation	Review
Luis Sanchez-Heres	RISE	
Johannes Hüffmeier	RISE	

Approval

Name	Organisation	Signature	Date
Mikael Hägg	RISE	MH	2020-01-30

Document History

Version	Date	Status	Reviewer	Description
0.3	2020-01-23			Draft Version
1.0	2020-01-30			Final version

Dissemination level

Short	Type	
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

EU PROJECT NO: 870239

Executive summary

This document formally describes the functionality of the system developed within the Prepare Ships project. To enable the verification and validation of the system, the functionality is described through use cases and application scenarios. The use cases describe the envisioned functions of the system, while the application scenarios describe how those should be of value.

The use cases are presented through a Use-case diagram and number of Use-case narratives as specified by the Use-Case method. Combined, the diagram and narratives capture the functional requirements that will drive the development of the system.

The application scenarios are presented through textual descriptions and simplified graphics. The descriptions capture the general conditions of the scenarios and the expected benefits of the system.

1 Table of contents

1 Introduction

1.1 Purpose

This document formally describes the functionality of the system developed within the Prepare Ships project. To enable the verification and validation of the system, the functionality is described through use cases and application scenarios. The use cases describe the envisioned functions of the system, while the application scenarios describe how those should be able of value.

1.2 Scope

The use cases described in this document capture only functional requirements. Technical and safety requirements will be formulated and described in the next deliverables from Work Package 1.

The application scenarios described in this document capture the general conditions of the scenarios and the expected benefits of the system. The application scenarios are the input for Work Package 6 where the validation tests and methods will be defined.

1.3 Background

The goal of the Prepare Ships project is to dramatically reduce the uncertainty regarding the present and future positions of ships. To achieve that goal, a system that leverages highly accurate global positioning, future position predictions, as well as ship-to-shore and ship-to-ship communication through VDES, is to be developed. Said system is referred to as the **Prepare System (PS)**.

The deployment diagram of the PS's architecture is shown if Figure 1- and Figure 1-2 PS will rely on two kinds of services: GNSS signals and GNSS corrections. Currently, it is envisioned that the GNSS corrections are sent to or negotiated with the PS through VDES, and therefore, the GNSS corrections provider will require a VDES transceiver.

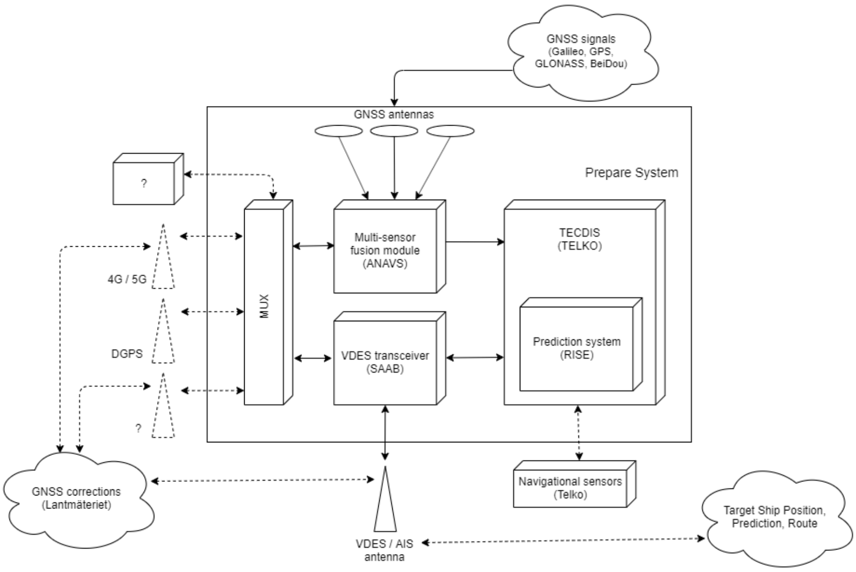


Figure 1-1 Preliminary deployment diagram of the Prepare System's architecture for testing purposes.

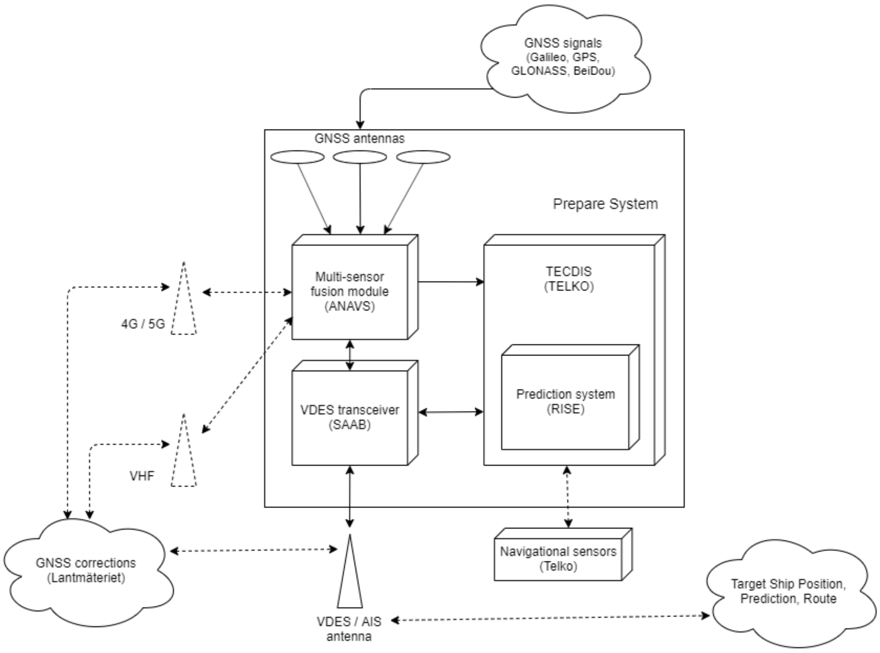


Figure 1-2 Preliminary deployment diagram of the Prepare System's architecture for the final product/ system.

1.4 Document overview

The contents of this document are arranged as follows:

- Section 2 presents the use cases of the PS.
- Section 3 presents the application scenarios of the PS.

European Global Navigation Satellite Systems Agency
HORIZON 2020

1.5 Terminology

Application scenario – A scenario chosen to validate the Prepare System.

Attitude – heading, trim, and list of a Prepared ship with respect to the specified local coordinate system of the Prepare System.

Functional requirements – The functions that the system is required to perform in order fulfil its purpose.

GNSS correction: The position correction parameters (Pseudo Ranges errors, clock errors, ionosphere & troposphere errors, etc.) for all GNSS constellations.

GUI – Graphical User Interface.

Integrity: a system's capacity to provide a threshold of confidence and, in the event of an anomaly in the positioning data, an alarm;

MSF module – Multi-Sensor Fusion module developed by ANAVS within the Prepared Ships project.

MUX – Multiplexer. A physical or digital switchboard.

Navigational Sensors - Navigational sensors imply ship internal sensors and signals from e.g machinery and rudder, automation signals such as steering control and environmental sensors such as wind.

Use case – all the ways a system can be used to accomplish a well specified goal or function that provides value**.**

Use-case diagram – A graphical description of all the use cases of the system, how they interact, and who they benefit.

Use-case narrative – A text or document formally describing a use case.

Prediction system – A software module that predicts future positions and attitudes for the own ship developed by RISE within the Prepared Ships project (see also predicted positions).

Prepare System – The system developed within the Prepare Ships project.

Prepared Ship – A ship with a fully functional Prepare System onboard.

Prepared Target Ship – A Prepared ship within the VDES range of the own ship.

Position – Longitude, latitude, and height of a Prepared ship with respect to a specified geodetic reference system as determined and specified by the Prepare System.

Predicted positions – A subset of the predictions returned by the prediction system. The subset contains the necessary information for displaying the predictions in a TECDIS GUI.

Predictions - The nominal output of the prediction system. The predictions consist of positions and attitudes at different timesteps corresponding to at least a minute in the future with quality/confidence indicators.

Slice - A deliverable unit of work with a scope defined by a fraction or “slice” of the functionality described in a Use-case narrative.

Slice test – A document stating what it means to accomplish a slice through test cases.

Target Ship – Ships in the surrounding that are receiving and sending position and possibly prediction messages from the own ship, e.g. within AIS/ VDES reach..

Test Case – A clearly defined set of inputs and expected outputs for verifying a use case slice or part of it (see use case and slice).

TECDIS – An Electronic Chart Display System developed by TELKO for which added functionality will be developed within the Prepare Ships project.

VDES – VHF Data Exchange System

2 Use cases

The use cases of the PS are presented through a Use-case diagram and number of Use-case narratives as specified by the Use-Case method. Combined, the diagram and narratives capture the functional requirements that will drive the development of the system. The section begins with a brief review of the Use-Case method. Readers familiar with the method can continue to section 2.2.

2.1 Brief review of the Use-Case method

Consider the development of a telecommunication system. One could state that the purpose of such a system is to enable long distance communication. However, this description of the system's purpose is too ambiguous and therefore insufficient for driving the system's development. To resolve the ambiguity, one could state the system's purpose through one or several goals:

Goal: The telecommunication system will enable two persons to send a text message to each other.

If the telecommunication system accomplishes that goal, one could then say that it fulfills its purpose. Likewise, one could also state that the system fulfills its purpose if performs one or several required function, for example:

Required function: send a text message to another person.

Clearly, the goals of a system and its required functions describe the same system attributes from different angles: a required function is defined to accomplish a goal, and a goal is accomplished through a required function.

Goals and required functions are too ambiguous for driving the development of a system as they only describe *what* the system does and not *how* it is done. One possible way of addressing this ambiguity is through use cases. Use cases are all the ways a system can be used to accomplish a well specified goal or function that provides value; they describe the *what*, the *how*, and more.

The Use-Case method is the practice of using use cases for capturing requirements and driving the system's development towards their fulfillment. This method has been used for more than two decades to develop a wide range of products and services, and therefore, several variations of it exist, as it has been developed and modified by different practitioners to meet their development needs. The Use-Case method here presented is one such variation based on the one described by Jacobson et al. 2011.

Overall, the Use-Case method consist of the following steps:

1. **Create a Use-case diagram** – to get an overview of the system and how it provides value through the use cases.
2. **Define Use-case narratives** – to capture the requirements for each of the use cases.
3. **Slice the use cases** – to prioritize development of functionality according to added-value.
4. **Define the slice tests** – to unambiguously state the successful competition of the use case slice.

5. **Analyze the slices** – to determine its impact on the components of the system.
6. **Implement the slices** – to enable the functionality and prepare it for testing.
7. **Verify the slices** – to determine if the slice is ready to be included in a release.

By creating several Use-case narratives and slicing them, the method allows for the prioritization of the use cases and their asynchronous development. One can potentially start slicing a Use-case narrative (step 3) before all the Use-case narratives are created (step 2). One can verify a slice of a use case (step 7) before the test cases of all slices are defined (step 4). The following sections describe the steps in more detail.

2.1.1 Create a Use-case diagram

The first step in the Use-Case method is to create a Use-case diagram, a graphical description of all the use cases of the system, how they interact, and who they benefit. Figure 2-1 Use-Case model for an extremely simple telecommunication system. present a possible Use-case diagram for an extremely simple telecommunication system.

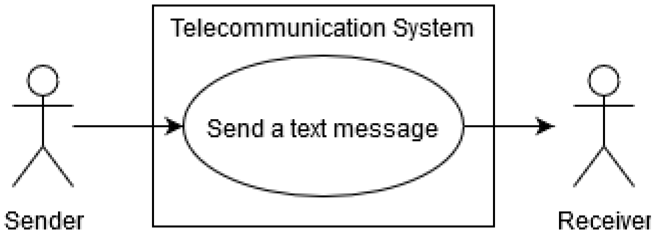


Figure 2-1 Use-Case model for an extremely simple telecommunication system.

The Use-Case diagram above follows the Unified Modelling Language (UML) standard. The system's boundary is represented by the rectangle, use case as an ellipse, the interactions as arrows, and the actors (stakeholders outside the system with whom the system interacts) as stickmen. The direction of the arrows indicates who initiates the interaction.

Systems usually accomplish more than use case, and occasionally, use cases interact with another use cases. Use-Case diagrams can also describe such systems:

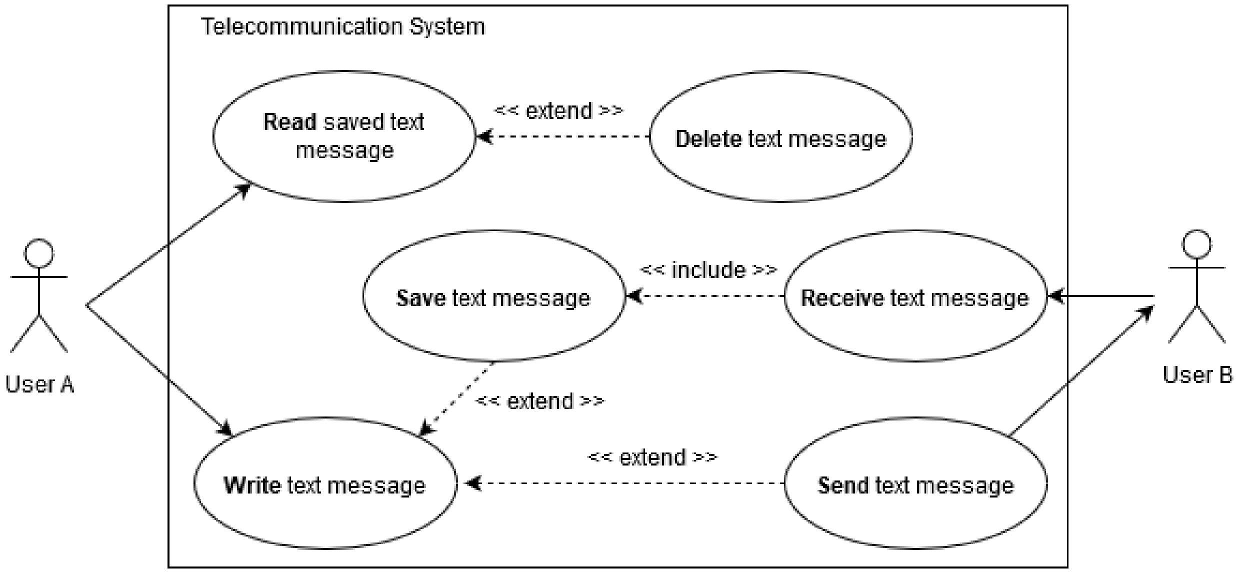


Figure 2-2 Use-Case diagram for the telecommunication system

Here, the dashed arrows indicate two types of relationships between the use cases. First, a dashed arrow with the label <<*include*>> indicates that the use case from which the arrow originates is incomplete without the one pointed out. Above, the “receive text message” use case requires the use case “save text message”. After being received, text messages are saved. Second, a dashed arrow with the label <<*extend*>> indicates that the use cases from which the arrow originate can be used to extend the one pointed out, but It’s not required. Above, User A has the possibility of saving or sending the text message after writing it.

The Use-Case diagram provides an overview of the system. From it, one can understand how it provides value to the user and identify possible gaps. For example, from the diagram above, one can realize that the user cannot delete a message without reading it first or writing and then saving it. Perhaps the system should include a “list all saved messages” use case that is extended by the “delete text message” use case.

The Use-Case diagrams does not describe *how* does the system accomplishes the use cases or exactly what does “accomplishing the use cases” means. That information is captured by the Use-case narrative of each use case.

2.1.2 Create Use-case narratives

The second step in the Use-Case method is creating Use-case narratives for all the use cases presented in the Use-case diagram. Use-Case narratives capture the requirements for each the use cases. Table 2-1 presents the contents of a Use-Case narrative.

Table 2-1 Contents of a Use-Case narrative.

Field	**Description**
Name	The name of the use case.
Brief description	Text describing the goal of the use case.

Pre-conditions	Text describing the required state of the system so that the use case may take place.
Post-conditions	Text describing the required state of the system at the end of the use case.
Basic flow	Text describing the *simplest sequence* of actions that can be performed by the system and actors for accomplishing the goal.
Alternative flows	Text describing *alternative sequences* of actions that can be performed by the system and/or actors for accomplishing the goal.
Special requirements	Text describing non-functional requirements (e.g. safety requirements and standards).

Figure 2-3 Example of a Use-case narrativepresents an example of a Use-case narrative for the use case “read saved text message”.

Use-case narrative – Read saved text message.

Brief description

The use case describes the system’s functionality that enables the user to read a text message that has been saved regardless of whether it is was written by the user itself or received.

Pre-conditions

- The system is displaying the “main menu” window.

Post-conditions

- The text message is displayed on the screen.

Basic flow

1. The user clicks the button on the GUI that reads “saved text messages”.
2. A new window showing a list of all the saved text messages appears on the screen.
3. The user clicks one of the listed text messages.
4. The text message is displayed in a new window along with a button that reads “close”.
5. The user scrolls, if necessary, to read the entire text message.
6. The user and clicks the “close” button.
7. The system closes window and returns to the main menu.

Alternative flows

A0. No saved messages

1. The user clicks the “saved text messages” button on the main menu when there are no saved text messages.
2. A warning message appears informing the user that there are no saved messages with a prompt to close the warning.
3. The user closes the warning.
4. The systems display the main menu window.

A1. Reply to text message

1. The text message is displayed in a new window along with buttons that read “close” and “reply”.
2. The user clicks on the “reply” button and a new window for writing a message is displayed. The receiver field is automatically set to the sender of the read text message.

Special requirements

S0. Text messages must be displayed according to the design specification (e.g. font face, color, size).

S1. Text messages must be censored if they contain foul language.

Figure 2-3 Example of a Use-case narrative for the “read saved text message” use case.

2.1.3 Slice the use cases

A Use-case narrative contains flows: textual descriptions of the actions that can be performed by the system or actor to achieve a goal. The flows are divided into a basic flow and alternative flows. This division enables one to “slice” the use case and prioritize the implementation of its most valuable flows. Each slice is then a deliverable unit of work with a scope defined by one or several of the flows in the Use-case narrative.

In Figure 2-3, the basic flow describes the most valuable flow for the user. The alternative flows describe added functionality that can be implemented after the basic flow. One could therefore slice the use case as follows:

- Slice 1.0: Basic flow and alternative flow A0
- Slice 1.1: Alternative flow A1
- Slice 1.2: Special requirement S0
- Slice 1.3: Special requirement S1

2.1.4 Define the slice tests

A slice test unambiguously states what it is to accomplish a use case slice. Each slice test contains at least one test case that describes a set of test inputs and expected the results. Table 2-2 presents the contents of slice test, while Figure 2-4 Example of a slice test. presents an example of slice test.

Table 2-2 Contents of a test scenario for a slice.

Field	Description
Slice ID	Identification of the slice.
Use-case	The name of the Use-case corresponding to the slice.
Slice contents	Flows and special requirements included in the slice.
Test case 0	Set of inputs, system state, actions and expected results.
Test case 1	…

For example, for the Slice 1.0 described in the previous section

Table 2-3 Example of a test scenario.

Slice Test – Slice 1.0 **Use case:** Read saved text message. **Slice contents:** • Basic flow • Alternative flow A0 **Test case 0:** The system is displaying the main menu window and has 0 (zero) saved text messages. When the user clicks on the button “read saved text messages” a warning with the text “there are no saved messages” appears with a prompt to close the warning. By clicking the prompt, the warning closes and the main menu is displayed by the system again. **Test case 1:** The system is displaying the main menu window and has 1 or more saved text messages. When the user clicks on the button “read saved text messages” a new window displaying a list of the saved text messages appear presenting the name of the author and the subject of the message. **Test case 2:** The system is displaying the list of saved text messages and there is 1 or more saved messages. The user clicks any of the messages and a new window displaying the message’s subject, author, and text appears along with a button that read close. When the close button is clicked the window is closed and the system displays the main menu.

Figure 2-4 Example of a slice test.

2.1.5 Analyze the slices

To meet the requirements stated in a slice, the system will be modified. The purpose of analyzing a slice is to provide a technical guide on how to development the system so that the requirements stated in the slice are met.

2.1.6 Implement the slices

This step refers to the act of implementing the changes to the system defined in the previous step.

2.1.7 Verify the slices

In this step, a slice test is used to verify the implementation of the slice. If the slice is verified as done, the changes are included in the next system release.

2.2 Use Case Diagram of the Prepare System

Figure 2-5 Use Case diagram for the Prepare Systempresents the Use Case diagram for the Prepare System. The diagram shows five types of actors:

- Officer On Watch onboard own ship (OOW): The target user of the Prepare System.
- Prepared target ship: A ship with a fully functional Prepare System that is within the VDES range of the own ship.
- STM target ship: A ship with an ECDIS capable of sending a receiving monitored routes through an AIS message according to the STM's S2SREX specification.
- Multi-GNSS: Multiple constellations of Global Navigation System Satellites (GNSS) sending signals for position fixing.
- Lantmäteriet RTK/PPP: Lantmäteriet's service of RTK and PPP corrections for GNSS signals.

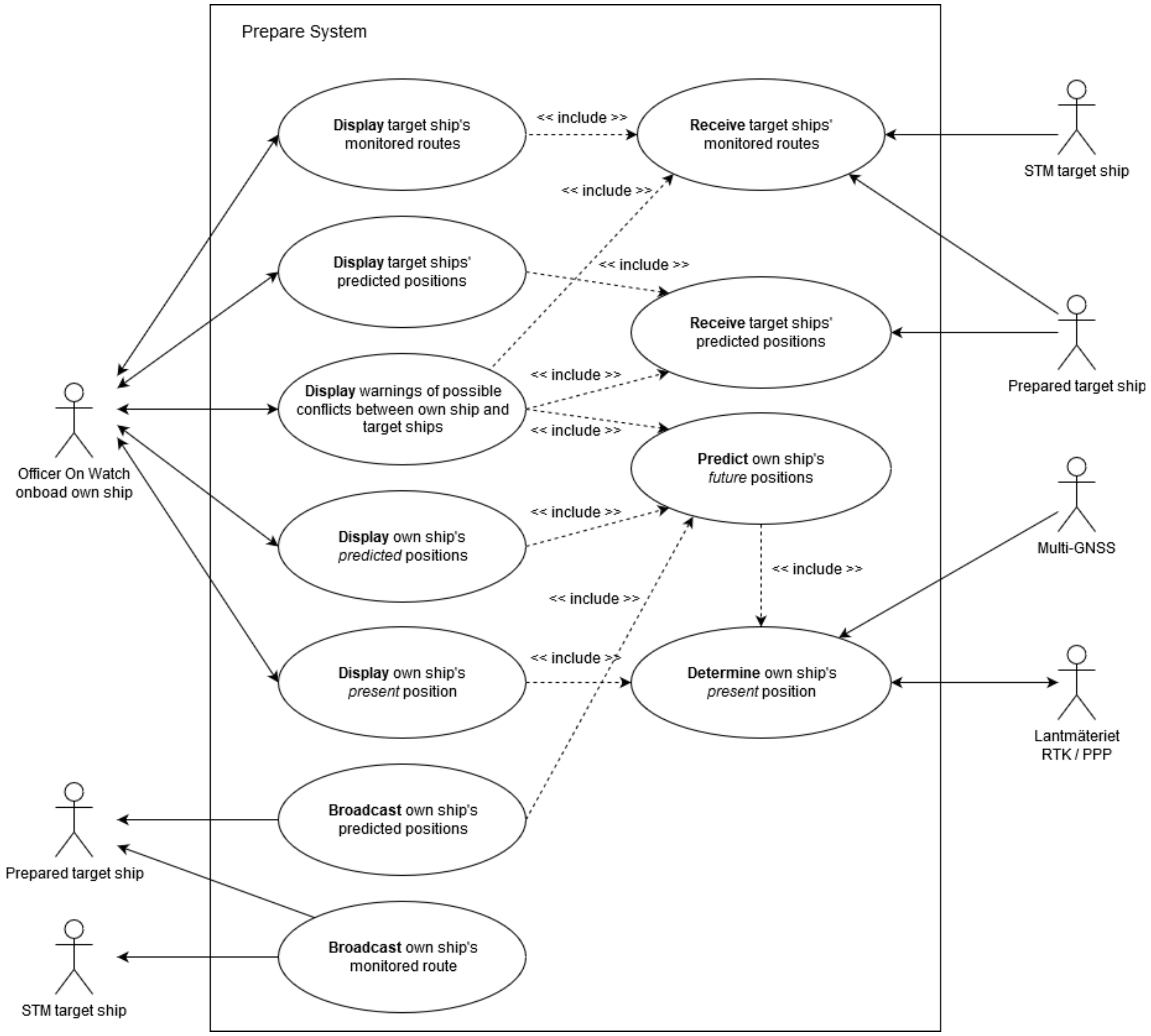


Figure 2-5 Use Case diagram for the Prepare System

As a list, the use cases are:

1. Determine own ship’s present position.
2. Display own ship’s present position.
3. Predict own ship’s future positions.
4. Display own ship’s predicted positions.
5. Broadcast own ship’s monitored route.
6. Receive target ships’ monitored routes.
7. Display target ship’s monitored routes.
8. Broadcast own ship’s predicted positions.
9. Receive target ships’ predicted positions.
10. Display target ships’ predicted positions.
11. Display warnings of possible conflicts between own ships and target ships.

2.3 Use-case narratives

2.3.1 UC1: Determine own ship’s present position

Brief description

This use case describes the ways in which global positioning is carried out by the Prepare System depending on its access to GNSS signals and corrections. The positioning system consists of three GNSS antennas, an ANAVS’s module. From either the VDES communication system or the 4G/5G as the source of GNSS corrections the correction information is received to the ANAVS’s module.

Pre-conditions

- The ANAVS’s module is installed, configured, and operational.

Post-conditions

MSF module continually sends (>10 Hz) the vessel’s:

- **Position** (latitude, longitude, height) of the GNSS antenna in the compound coordinate reference system formed by the 2D geographic reference system WGS84 and the vertical datum “mean sea level”.
- **Attitude** (heading, list, pitch) of the MSF module with respect to its own coordinate system.
- **Accelerations**: The accelerations of the MSF module with respect to its own coordinate system.
- **Accuracy:** A signal indicating the accuracy of the positioning in meters or NULL.
- **Integrity:** A signal indicating whether the MSF module considers to be jammed or unhealthy.

Basic flow

1. The MSF module receives GNSS signals from one or more GNSS constellations.
2. The MSF module checks which kind of corrections are available.

3. The MSF module determines that there are NO corrections available.
4. The MSF module determines it is not being jammed or of being unhealthy.
5. The MSF module calculates the vessel's position using only GNSS signals.
6. The MSF estimate the vessel positions based on sensor fusion with other sources
7. The MSF module sends its output.

Alternative flows

A0. Positioning with only RTK corrections available.

1. The MSF module receives GNSS signals from one or more GNSS constellations
2. The MSF module checks which kind of corrections are available.
3. The MSF module determines that RTK corrections are available.
4. The MSF module establishes a connection with the RTK service.
5. The RTK service sends the RTK corrections.
6. The MSF module calculates the vessel's position using GNSS signals and RTK corrections.
7. The MSF estimate the vessel positions based on sensor fusion with other sources
8. The MSF module sends its output.

A1. Positioning with only PPP corrections available.

1. The MSF module receives GNSS signals from one or more GNSS constellations
2. The MSF module checks which kind of corrections are available.
3. The MSF module determines that PPP corrections are available.
4. The MSF module calculates the vessel's position using GNSS signals and PPP corrections.
5. The MSF module sends its output.

A2. Positioning with only DGNSS corrections available (back-up solution by e.g. MSM).

1. The MSF module receives GNSS signals from one or more GNSS constellations
2. The MSF module checks which kind of corrections are available.
3. The MSF module determines that DGNSS corrections are available.
4. The MSF module calculates the vessel's position using GNSS signals and DGNSS corrections.
5. The MSF module sends its output.

A3. Positioning with a combination of DGNSS, RTK, and PPP corrections available.

1. The MSF module receives GNSS signals from one or more GNSS constellations
2. The MSF module checks which kind of corrections are available.
3. The MSF module determines that multiple corrections are available.
4. The MSF module chooses the correction to use in suitable method based on vessel location: RTK/PPP, RTK, PPP, DGNSS.

5. The MSF module calculates the vessel's position using GNSS signals and chosen correction.
6. The MSF module sends its output.

A4. No GNSS signals available.

1. The MSF module is not receiving a GNSS signal from any GNSS constellation.
2. The MSF module sets the positioning accuracy to NULL.
3. The MSF module sends its output.

A5. The MSF module is being jammed but can recover.

1. The MSF module determines it is being jammed.
2. The MSF module calculates position based on sensor fusion.
3. The MSF module sends its output.

A6. The MSF module is being jammed.

1. The MSF module determines it is being jammed.
2. The MSF module sets the positioning accuracy to NULL.
3. The MSF module sends its output.

Special requirements

None.

2.3.2 UC2: Display own ship's *present* position

Brief description

This use case describes the ways that the TECDIS can display the vessels present position. The present position may be determined by the primary or secondary GNSS positioning system estimated through the Predictor System, or missing.

Pre-conditions

- The MSF module is installed, configured, and operational.
- The TECDIS is installed, configured, and operational.

Post-conditions

- The ships present position is displayed in the TECDIS GUI along an accuracy indicator.

Basic flow

1. The TECDIS receives the output from the MSF module and the positioning accuracy & integrity is *not* NULL.
2. The TECDIS displays the position according to the latest settings.
3. The TECDIS displays an indicator for the accuracy & integrity of the position.

Alternative flows

A0. Contour presentation mode for the present position.

1. The user opens the settings and selects the contour presentation mode.
2. The TECDIS displays the present position as a contour.

A1. Symbol presentation mode for the present position.

1. The user opens the settings and selects the symbol presentation mode.
2. The TECDIS displays the present position as a symbol.

A2. No GNSS positioning available from the MSF module.

1. The TECDIS is not receiving a GNSS derived position from the MSF module (e.g. accuracy with a value of NULL).
2. The TECDIS chooses another GNSS receiver as the source of the positions.
3. The TECDIS raises a warning that must be acknowledged by the user.
4. The TECDIS displays the present position.

A3. No GNSS positioning available and *non-operational* Predictor.

1. The TECDIS is not receiving a GNSS derived position from the MSF module (e.g. accuracy with a value of NULL) or any other GNSS receivers.
2. The TECDIS determines that the Predictor is *not* operational.
3. The TECDIS raises a warning that must be acknowledged by the user.
4. The TECDIS displays the position determined through dead reckoning based on gyro and log or echo-reference.

A4. No GNSS positioning available with *operational* Predictor.

1. The TECDIS is not receiving a GNSS derived position from the MSF module (e.g. accuracy with a value of NULL) or any other GNSS receivers.
2. The TECDIS determines that the Predictor is operational
3. The TECDIS raises a warning that must be acknowledged by the user.
4. The TECDIS displays the last fixed position and the *predicted present* position.

Special requirements

The displayed position complies with the standard IEC 62288 and upcoming S-Mode Guidelines.

2.3.3 UC3: Predict own ship's *future* positions and attitudes

Brief description

Predictions of the own ship's future positions and attitudes are calculated by the prediction system. The predictor system only returns predictions if it deems the input to be sufficient and valid, and the quality of the predictions to be acceptable. Otherwise, the predictor system returns an error message about the validity or sufficiency of the inputs or the quality of the predictions. When the prediction system returns predictions it is considered *operational*.

Pre-conditions

- The MSF module is installed, configured, and operational.
- The TECDIS is installed, configured, and operational.

- The user has switched-on the prediction system.

Post-conditions

- The prediction system returns approved predictions or a message. The approved predictions consist of positions and attitudes at different timesteps corresponding to at least a minute in the future with quality/confidence indicators. The messages may relate to the input data or the quality of the predictions.

Basic flow

1. The prediction system receives the input data.
2. The prediction system deems the input data sufficient and valid.
3. The prediction system deems the quality of its predictions to be acceptable.
4. The prediction system returns the predictions.

Alternative flows

A0. Missing, Invalid and/or insufficient input data.

1. The prediction system receives the input data.
2. The prediction system deems the input data *missing, insufficient and/or invalid.*
3. The prediction system returns an error message related to the input data.

A1. Prediction deemed to be of unacceptable quality.

1. The prediction system receives the input data.
2. The prediction system deems the input data to be sufficient and valid.
3. The prediction system deems the quality of its predictions to be unacceptable.
4. The prediction system returns a warning message communicating that the predictions are of unacceptable quality.

Special requirements

None.

2.3.4 UC4: Display own ship's *predicted* positions

Brief description

The own ship's predicted positions are displayed in the TECDIS GUI if the predictor system is operational (i.e. returns predicted positions and attitudes and NOT a warning or error message). If the prediction system is not operational, the TECDIS informs the user through a warning and error message

Pre-conditions

- The MSF module is installed, configured, and operational.
- The TECDIS is installed, configured, and operational.
- The prediction system is installed and configured.

Post-conditions

- The prediction and its uncertainty is displayed on the TECDIS according to the user's settings.

Basic flow

1. The user switches-on the prediction system.
2. The TECDIS passes all the necessary input data to the prediction system.
3. The prediction system is operational.
4. The predictions and their quality are displayed in the TECDIS GUI according to the latest settings.

Alternative flows

A0. The prediction system returns an error message related to the input data.

1. The user switches-on the prediction system.
2. The TECDIS passes all the necessary input data to the prediction system.
3. The prediction system returns an error message regarding the sufficiency or validity of the input.
4. The TECDIS displays an error message that must be acknowledged by the user.
5. The prediction system is switched-off automatically.
6. No predictions are displayed in the TECDIS GUI.

A1. The prediction system returns a warning message related to the quality of the predictions.

1. The user switches-on the prediction system.
2. The TECDIS passes all the necessary input data to the prediction system.
3. The prediction system returns a warning message regarding the unacceptable quality of the predictions.
4. The TECDIS displays a that must be acknowledged by the user (e.g. "Predictions are not yet operational - learning incomplete").
5. The prediction system improves the prediction in the background.
6. No predictions are displayed in the TECDIS GUI.
7. The prediction system deems the predictions to be of acceptable quality.
8. The prediction system returns a warning message regarding the acceptable quality of the predictions.
9. The TECDIS displays a warning message that must acknowledged by the user (e.g. "Predictions are now operational – learning COMPLETED").
10. The predictions and their quality are displayed in the TECDIS GUI according to the latest settings.

A2. Contour presentation mode for the predicted positions.

1. The user opens the settings and selects the contour presentation mode.
2. The user selects the desired prediction time.
3. The user selects the number of contours.
4. The TECDIS displays the predicted positions as contours.

A3. Swept area presentation mode for the predicted positions.

1. The user opens the settings and selects the swept area presentation mode.

2. The user selects the desired prediction time.
3. The TECDIS displays the present positions a swept area.

Special requirements

The methods for presentation of ship predictions described in IEC 62288 are not sufficient for the presentation of the Prepared System predictions. Therefore, the display of the predictions will follow best practices used in the industry.

2.3.5 UC5: Broadcast own ship's predicted positions

Brief description

When the prediction system is switched-on and operational the predicted positions are broadcasted through VDES.

Pre-conditions

- The TECDIS is installed, configured, and operational.
- The MSF module is installed, configured, and operational.
- The VDES transceiver is installed, configured, and operational.
- The prediction system is installed, configured, and operational.
- The user has switched-on the prediction system and the predictions are displayed in the TECDIS GUI.

Post-conditions

- The VDES transceiver broadcasts a data package containing the predicted positions of the own ship.

Basic flow

1. The TECDIS sends the predictions to the VDES transceiver.
2. The VDES transceiver broadcasts the predictions.

Alternative flows

A0. The user does not want to broadcast predicted positions.

1. The user selects the settings of the prediction systems.
2. The user chooses NOT to broadcast the predictions.

Special requirements

None.

2.3.6 UC6: Receive target ships' monitored routes

Brief description

Monitored routes of prepared or STM target ships are received by the VDES transceiver in the form of an AIS message 8.

Pre-conditions

- The VDES transceiver is installed, configured, and operational.

Post-conditions

- The VDES transceiver sends a data structure containing the monitored route of a target ship.

Basic flow

1. A prepared or STM target ship within AIS range is broadcasting its predicted positions.
2. The VDES transceiver receives the broadcast.
3. The VDES transceiver sends a data package containing the monitored route of the target ship.

Alternative flows

A0. No prepared target ship broadcasting monitored route within range.

1. The VDES does not receive a broadcast.
2. The VDES transceiver does not send anything.

Special requirements

None.

2.3.7 UC7: Display target ships' monitored routes

Brief description

The TECDIS GUI displays the monitored received from prepared or STM target ships within AIS range.

Pre-conditions

- The TECDIS is installed, configured, and operational.
- The VDES transceiver is installed, configured, and operational.

Post-conditions

- The monitored routes are displayed on the TECDIS GUI according to the user's settings.

Basic flow

1. The TECDIS receives a data package containing the monitored routes of the target ship from the VDES transceiver.
2. The monitored routes are displayed in the TECDIS GUI according to the user's settings.

Alternative flows

A0. The TECDIS stops receiving monitored routes from a certain vessel.

1. The TECDIS monitors the age of the monitored routes.
2. Monitored routes older that a defined value are removed from the display.

Special requirements

- The displayed monitored routes comply with the standard IEC 62288.

2.3.8 UC8: Broadcast own ship's monitored route

Brief description

If the user chooses to, the monitored route is broadcasted.

Pre-conditions

- The TECDIS is installed, configured, and operational.

Post-conditions

- The VDES transceiver sends an AIS message containing the monitored route of the own ship.

Basic flow

1. The user chooses or inputs a route to be monitored in the TECDIS.
2. The TECDIS determines that there is not saved default choice regarding broadcasting of monitored routes.
3. The user chooses to broadcast the monitored route.
4. The user chooses the number of waypoints ahead to choose.
5. The TECDIS asks if that choice should be the default one.
6. The user chooses “yes”.
7. The TECDIS saves that choice in the settings.
8. The TECDIS sends the next waypoints to the VDES transceiver.
9. The VDES transceiver broadcasts the waypoints as AIS messages.
10. Broadcasting continues until the route is completed or another route is chosen.

Alternative flows

A0. The user does not want to broadcast the monitored route.

1. The user chooses or inputs a route to be monitored in the TECDIS.
2. The TECDIS determines that there is not saved default choice regarding broadcasting of monitored routes.
3. The TECDIS asks the user if he or she wants to broadcast it.
4. The user chooses NOT to broadcast the monitored route.
5. The TECDIS asks if that choice should be the default one.
6. The user chooses “yes”.
7. The TECDIS saves that choice in the settings.

A1. The user has already chosen a default choice regarding broadcasting of monitored routes.

1. The user chooses or inputs a route to be monitored in the TECDIS.
2. The TECDIS determines that there is saved default choice regarding broadcasting of monitored routes.
3. The TECDIS proceeds according to the chosen default choice.

A2. The user wants to change the default choice regarding broadcasting of monitored routes.

1. The user goes into the setting menu and modifies the default choice.

Special requirements

None.

2.3.9 UC9: Receive target ships' predicted positions

Brief description

Predicted positions of prepared target ships are received by the VDES transceiver in the form of a VDES message.

Pre-conditions

- The VDES transceiver is installed, configured, and operational.

Post-conditions

- The VDES transceiver sends a data structure containing the predicted positions of a target ship.

Basic flow

1. A prepared target ship within VDES range is broadcasting its predicted positions.
2. The VDES transceiver receives the broadcast.
3. The VDES transceiver sends a data package containing the predicted positions of the target ship.

Alternative flows

A0. No prepared target ship broadcasting predicted positions within range.

1. The VDES does not receive a broadcast.
2. The VDES transceiver does not send anything.

Special requirements

None.

2.3.10 UC10: Display target ships' predicted positions

Brief description

The TECDIS GUI displays the predicted positions received from prepared target ships within range.

Pre-conditions

- The TECDIS is installed, configured, and operational.
- The VDES transceiver is installed, configured, and operational.

Post-conditions

- The predictions are displayed on the TECDIS GUI according to the user's settings.

Basic flow

1. The TECDIS receives a data package containing the predicted positions of the target ship from the VDES transceiver.
2. The predictions are displayed in the TECDIS GUI according to the user's settings. If the prediction corresponds to a vessel whose prediction is already displayed, the old prediction is removed and the new one displayed.

Alternative flows

A0. The TECDIS stops receiving predictions from a certain vessel.

1. The TECDIS monitors the age of the predictions.
2. Predictions older that a defined value are removed from the display.

Special requirements

The methods for presentation of ship predictions described in IEC 62288 are not sufficient for the presentation of the Prepared System predictions. Therefore, the display of the predictions will follow best practices used in the industry

2.3.11 UC11: Display warnings of possible conflicts between own ship and Prepared ships

Brief description

The TECDIS uses the predicted position and monitored route, as well as the received monitored routes and/or predicted positions from target ships to predict conflicts within a defined time horizon.

Pre-conditions

- The TECDIS is installed, configured, and operational.
- The VDES transceiver is installed, configured, and operational.
- The prediction system is installed, configured, and operational.
- The VDES transceiver is receiving a monitored route and predicted positions from a prepared target ship.

Post-conditions

- The targets ship(s) and area involved in the potential conflict are highlighted in the TECDIS GUI.

Basic flow

1. The TECDIS detects a potential conflict (e.g. potential collision if the own ship and target ship follow their monitored routes or if either ship's predictions come to pass).
2. The target ships and area involved in the potential conflict are highlighted in the TECDIS GUI.
3. The user or target ship(s) change course or modify the monitored route.

4. The TECDIS detects that the previously predicted conflict is no longer a threat and removes the highlighting.

Alternative flows

None.

Special requirements

None.

3 Application Scenarios

The application scenarios describe the expected impact that the use cases are expected when applied in the shipping industry with the purpose to increase safety, security, efficiency and reduce environmental impact. These application scenarios will be defined in more detail by the requirement specification and when planning the demonstration and testing. While certain of these scenarios will be demonstrated and validated, others will be only partially covered by simulations, etc.

3.1 Background

Ship accident frequencies have been reduced during the last decades [1]. While technical development and decision support by implementation of AIS and ECIDS have reduced the incidents connected to groundings, due to better awareness of the ship's own position, the collisions as an event type in shipping has remained as a contributor to serious shipping accidents. [1]

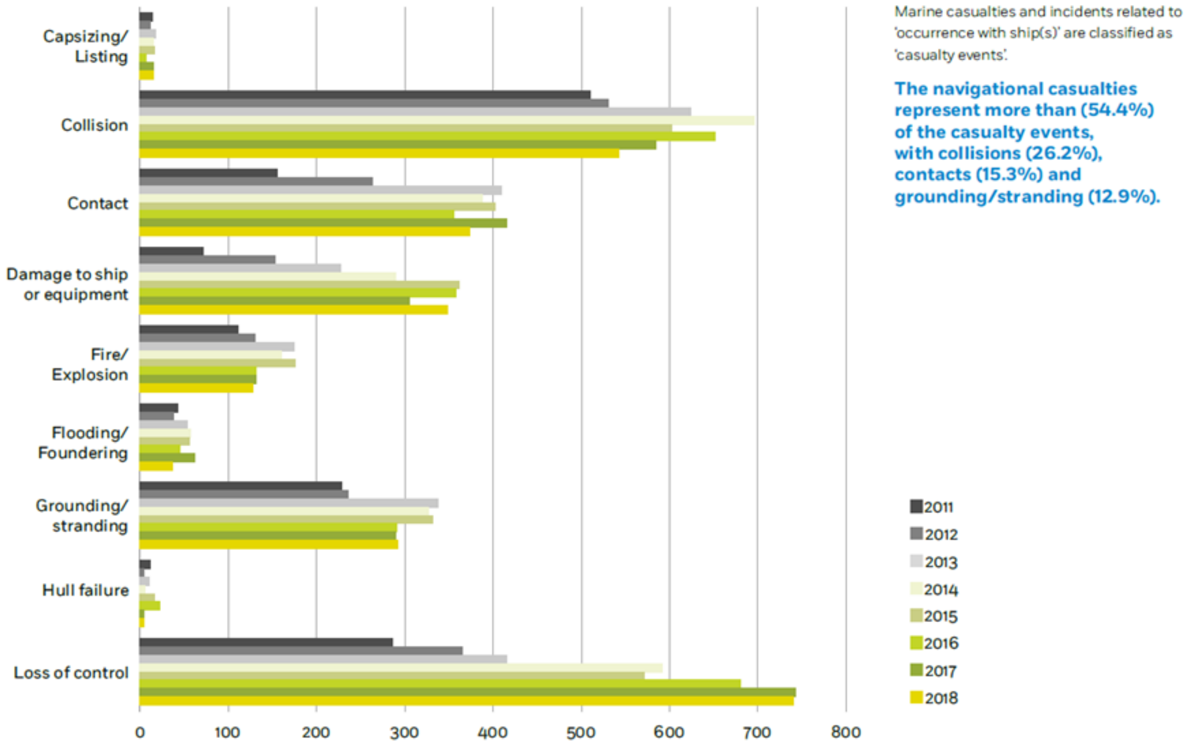


Figure 6: Marine casualties and incidents by event type [2]

Loss of control and Collisions are the two dominating categories of accidents in EMSA's statistics. Human actions split into safety awareness, planning and coordination, lack of knowledge, inadequate work methods and lack of knowledge are some of the most important causal contributions to accidents in EMSA's database. By sharing the

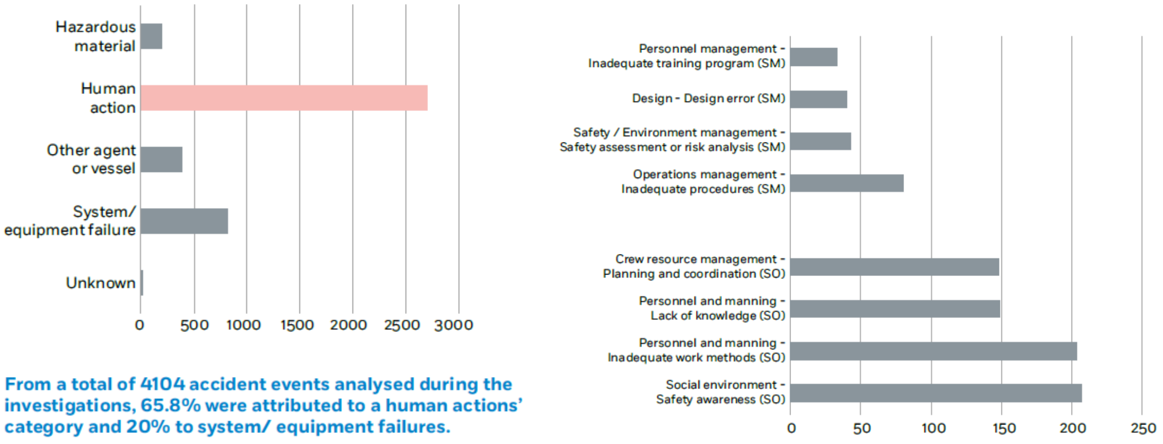


Figure 7: Contributing causes to accidents in EMSAs summary report for 2018 [2]

Situational awareness means having a good perception of your surroundings at all times, comprehending what's happening around you and predicting how this will affect your ship. Several studies have reported that the loss of situational awareness as a significant factor in incidents and accidents that are associated with human performance [3] [4] and [5]. Another study show that [6] situational awareness has significant contributing factors in incidents such as 'inadequate design', 'planning failure', 'communication failure', ' distracting elements' and 'insufficient training'.

Locations that the vessels are in, when experiencing near-misses are often in restricted waters, narrow passages, etc. [2] [7]. Providing dynamic predictions is therefore seen as essential in these waters, where most of the testing will be performed.

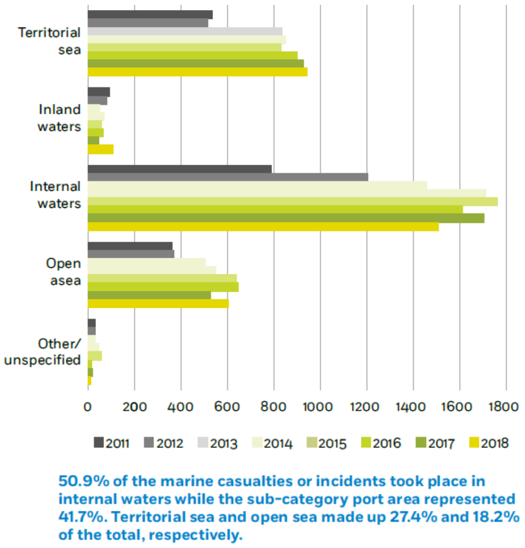


Figure 8: Location on where shipping accidents occur in Europe [2]

Growing awareness of maritime shipping regarding the lack of positional integrity of GNSS and AIS/VDES communication is the main driving force for this application scenario.

Spoofing of GPS positions as well as manipulation of AIS messages is one of the challenges when it comes to shipping security. GPS spoofing involves ships' receivers being tricked with counterfeit satellite automatic identification signals generated to gain control of a navigation system. This can take the vessel off course or show it in a different location. Typically, ship-owners do not publish spoofing attacks. Publicly available information/ confirmed cases have nevertheless increased. Some of these are listed below:

"The shipping industry has been aware of the threat of GPS spoofing for years, but one incident in 2017 pushed the issue higher up the global news agenda. In June of that year, at least 20 vessels in the Black Sea, in the vicinity of Novorossiysk Commercial Sea Port, reported that their automatic identification system (AIS) traces erroneously showed their position as Gelendzhik Airport, around 32km inland." [2]

"GPS equipment unable to obtain GPS signal intermittently since nearing coast of Novorossiysk, Russia. Now displays HDOP 0.8 accuracy within 100m, but given location is actually 25 nautical miles off; GPS display…" [3]

"Six attacks on merchant ships named by Marad attributed to Iran" [3]

"Analysis of AIS data by Lloyd's List Intelligence shows for the first time that Stena Impero fitted the pattern for a spoofing attack when it was seized by the Islamic Revolutionary Guard Corps on July 19" [4]

The IMO (International Maritime Organization) has put requirements on incorporation of cyber risk management into ship safety protocols and procedures. Therefore, the ship-owners will have to find measures and protection against as a matter of regulatory compliance ensuring navigational security.

Differential positioning methods in combination navigation message authentication and secure VDES communication channels will increase integrity for maritime positioning and navigation.

Making use of encryption of AIS data/ authenticated messages for predictors and position information via VDES is seen as a central application scenario for safe navigation. By going back to the typical ship behaviour based on the predictor, the spoofing can be detected to a reasonable extend. The support by correction data when close to shore can give additional indication on integrity of the real position and prediction.

Environmental impact of shipping has been discussed for a long time [12]. New national [13] and international regulations, roadmaps and guidelines (e.g. IMO regulations on energy efficiency (2013) and GHG reduction (2018) to at least 50% by 2050 compared to 2008, EU) have been established.

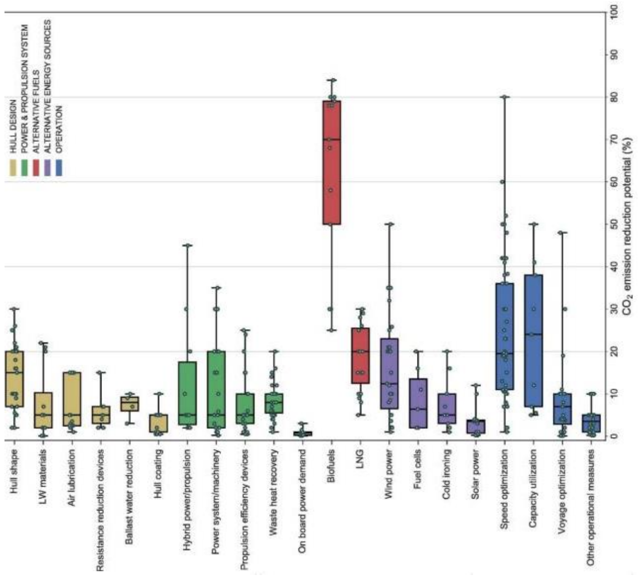


Figure 9: Emission reduction potential [Source: MFAME, Performance of energy efficiency technologies for ships, November 2018]

Much of the research in the field of reduced emissions from shipping have pointed out operational measures (voyage execution) and decision supports as one of the potentially most cost-efficient ways to reduce emissions.

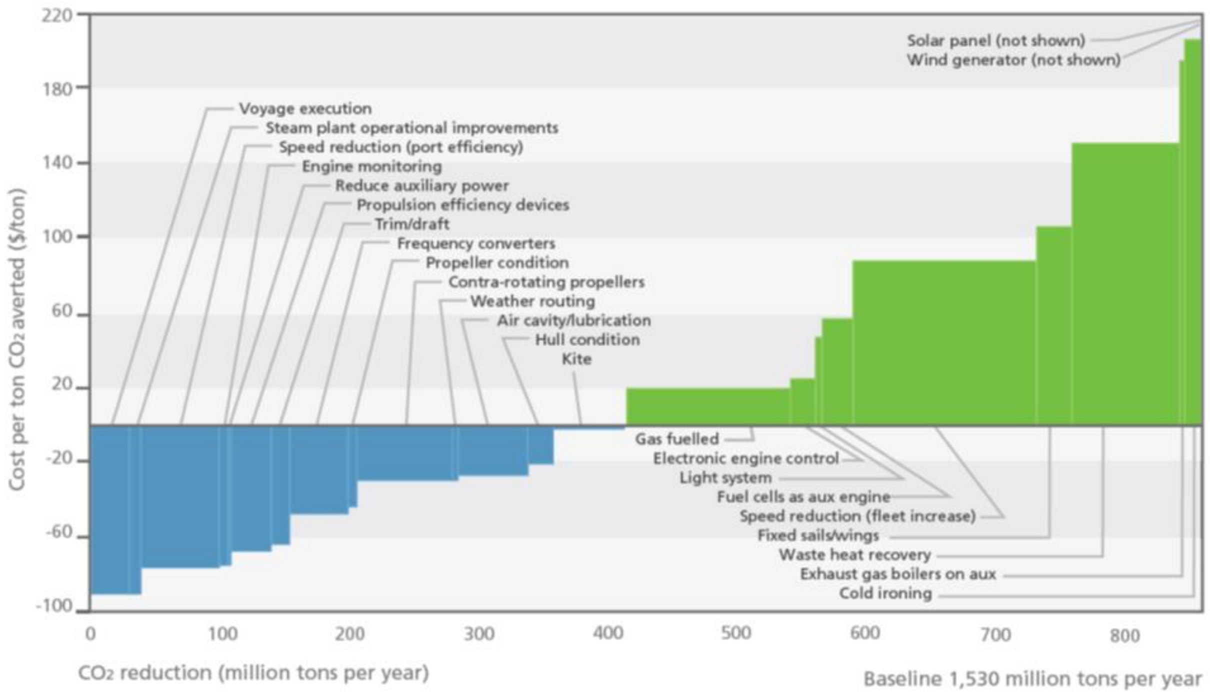


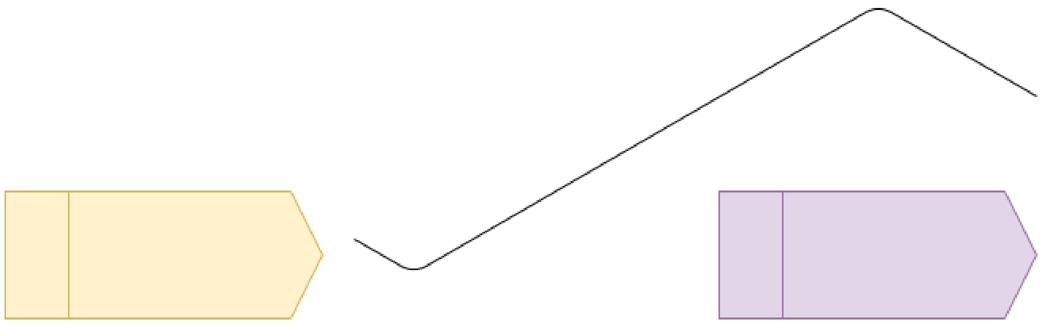
Figure 10: Indicative marginal CO2 abatement costs for 2030 (source: DNV, 2010)

3.2 AS1: Increased Situational Awareness for Collision Avoidance

All the following scenarios are very site and vessel specific with respect to how challenging they are experienced by the crew. Also, effects of workload of the crews, different weather and light conditions have a direct impact. Therefore, these conditions will be varied during the test and validation.

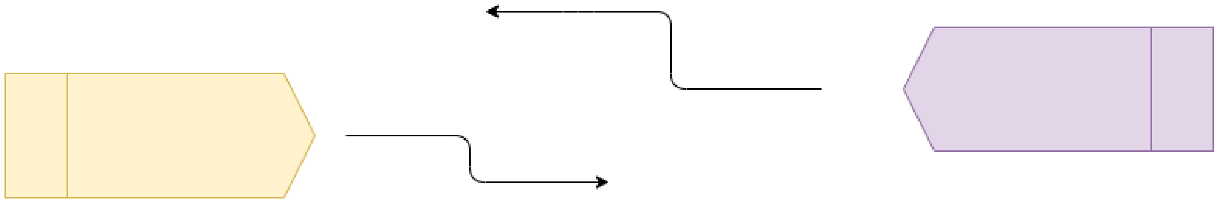
3.2.1 Overtaking situation

Scenario ID	AS1:1
Name	Collision Avoidance in overtaking situation
Description	Two vessels overtaking in restricted fairway
Expected Action	Exchange of predictor messages to avoid collisions and close quarter situations



3.2.2 Meeting situation

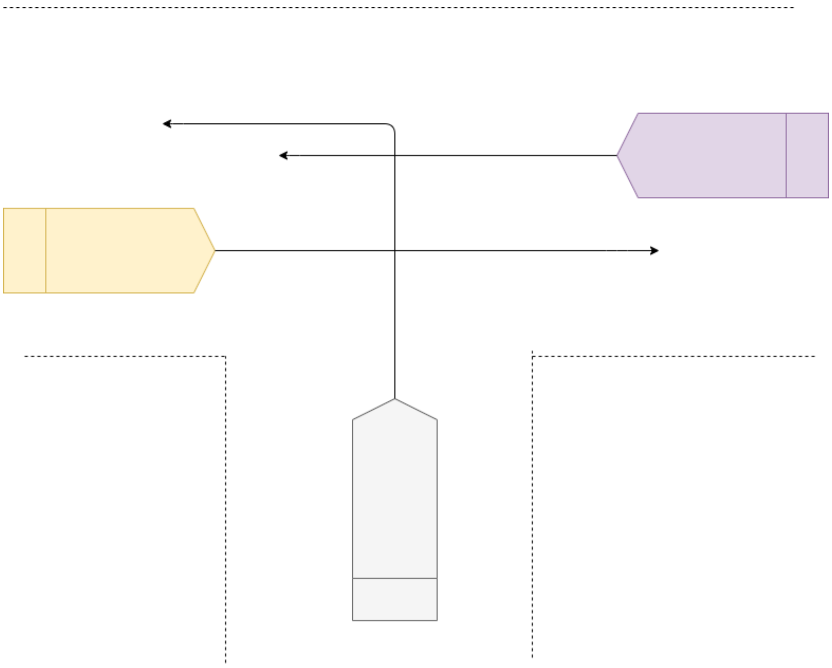
Scenario ID	AS1:2
Name	Collision Avoidance in Meeting situation
Description	Two vessels meeting in restricted fairway
Expected Action	Exchange of predictor messages to avoid head-on collisions and close quarter situations.



3.2.3 COLREG situation in narrow fairways with certainty on routes

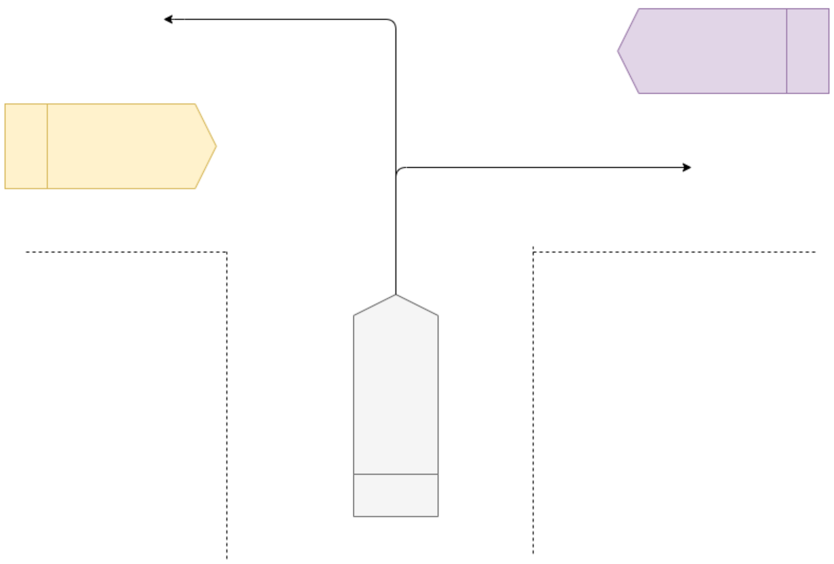
Scenario ID	AS1:3
Name	Collision Avoidance in Meeting situation

Description	Three vessels meeting in restricted fairway with sent out intended routes/ voyage plans
Expected Action	Exchange of predictor messages to allow for safe and efficient passages between vessels.



3.2.4 COLREG situation with high uncertainty of other's route

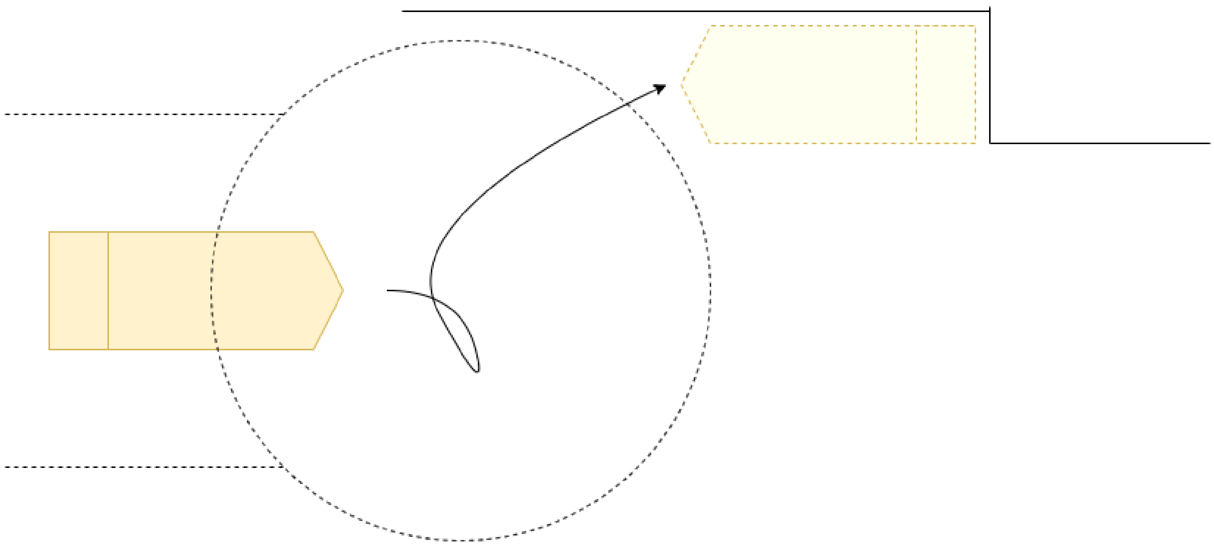
Scenario ID	AS1:4
Name	Collision Avoidance in Meeting situation
Description	Three vessels meeting in restricted fairway with high uncertainty of intended routes
Expected Action	Exchange of predictor messages to allow for safe and efficient passages between vessels.



3.3 AS2: Port, Fairway and Open-water Manoeuvring

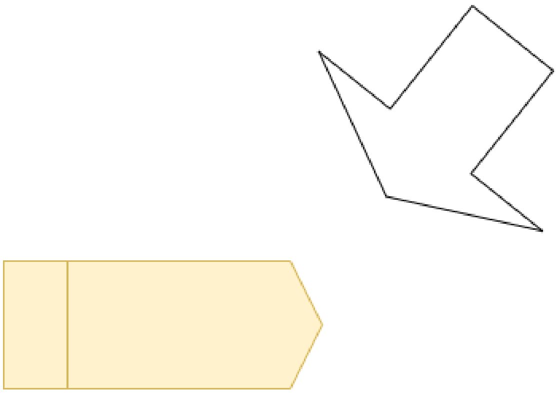
3.3.1 Maneuvering to / from quat

Scenario ID	AS2:1
Name	Maneuvering to/ from quay
Description	Safe and more energy efficient maneuvering to and from quay
Expected Action	Presentation of predictor in ECDIS to allow for safe and efficient maneuvering to quay.



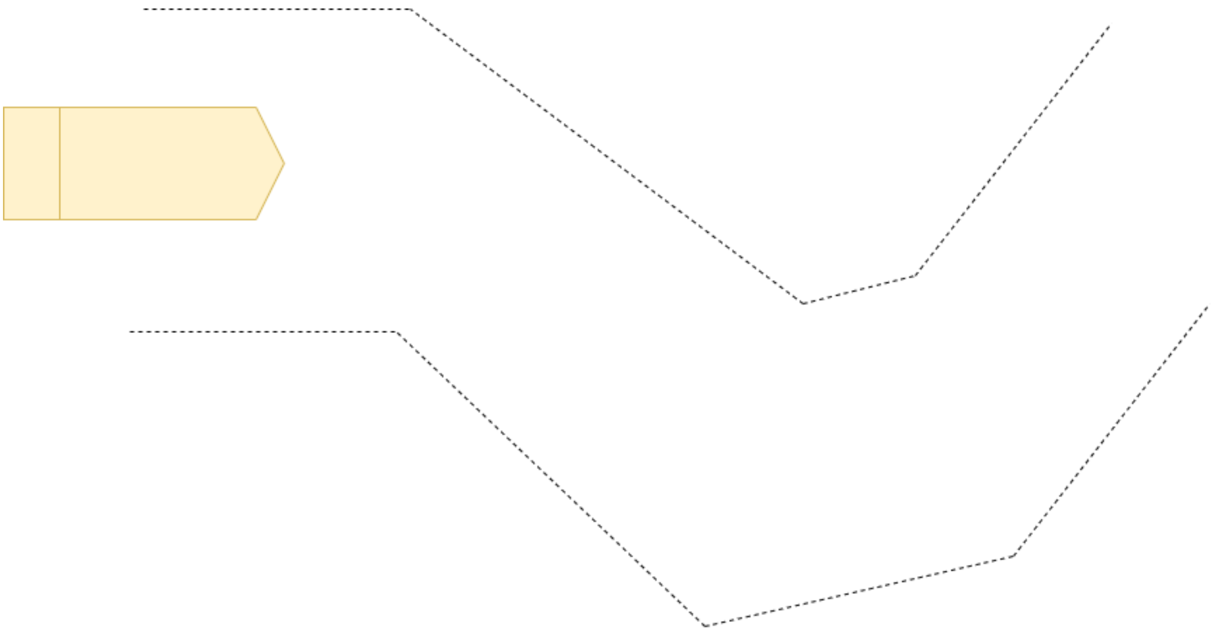
3.3.2 Navigation in adverse weather

Scenario ID	AS2:2
Name	Navigation in adverse weather
Description	Safe and more energy efficient navigation in adverse weather conditions in unrestricted waters
Expected Action	Presentation of predictor in ECDIS to allow for safe and efficient navigation indicating near time vessel motions and movements with high position integrity



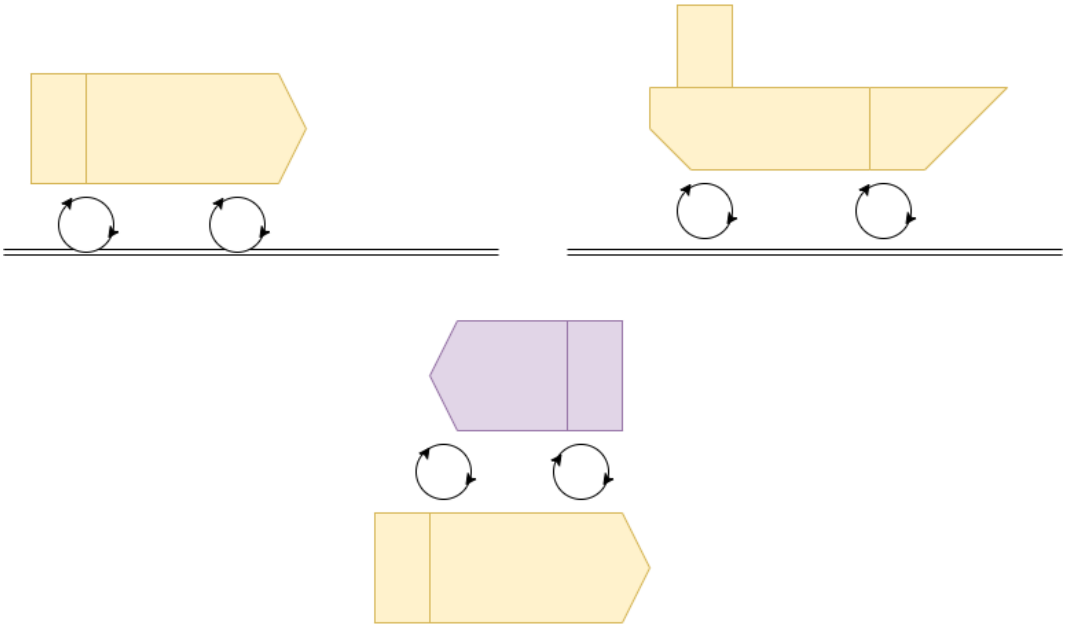
3.3.3 Navigation in fairways

Scenario ID	AS2:3
Name	Navigation in fairways
Description	Safe and more energy efficient navigation in congested waters
Expected Action	Presentation of predictor in ECDIS to allow for safe and efficient passages of congested fairways.



3.3.4 Navigation with hydrodynamic effects

Scenario ID	AS2:4
Name	Navigation with ship-ship interaction, channel effects or shallow water
Description	Safe and more energy efficient navigation in situation where the ship is affected by bathymetry or other vessels
Expected Action	Presentation of predictor in ECDIS to allow for safe and efficient passages.



3.4 AS3: Improved Information Provided to the VTS

There is the possibility seen by VTS operators to get support through decision support tools to help identifying collision and grounding "candidates" as early as possible. Earlier studies have shown that time to groundings, but especially time to collisions evolve very quickly [7].

Scenario ID	AS3:1
Name	Improved Information Provided to the VTS
Description	Improved Information Provided to the local VTS by providing the predictor information in the above described scenarios from AS1
Expected Action	Industry standard derived for communicating predictor information.

3.5 AS4: Enabler of Increased Automation

Automation is a societal trend impacting also the shipping industry. Automation applied in a safe manner is not a radical change but an incremental development.

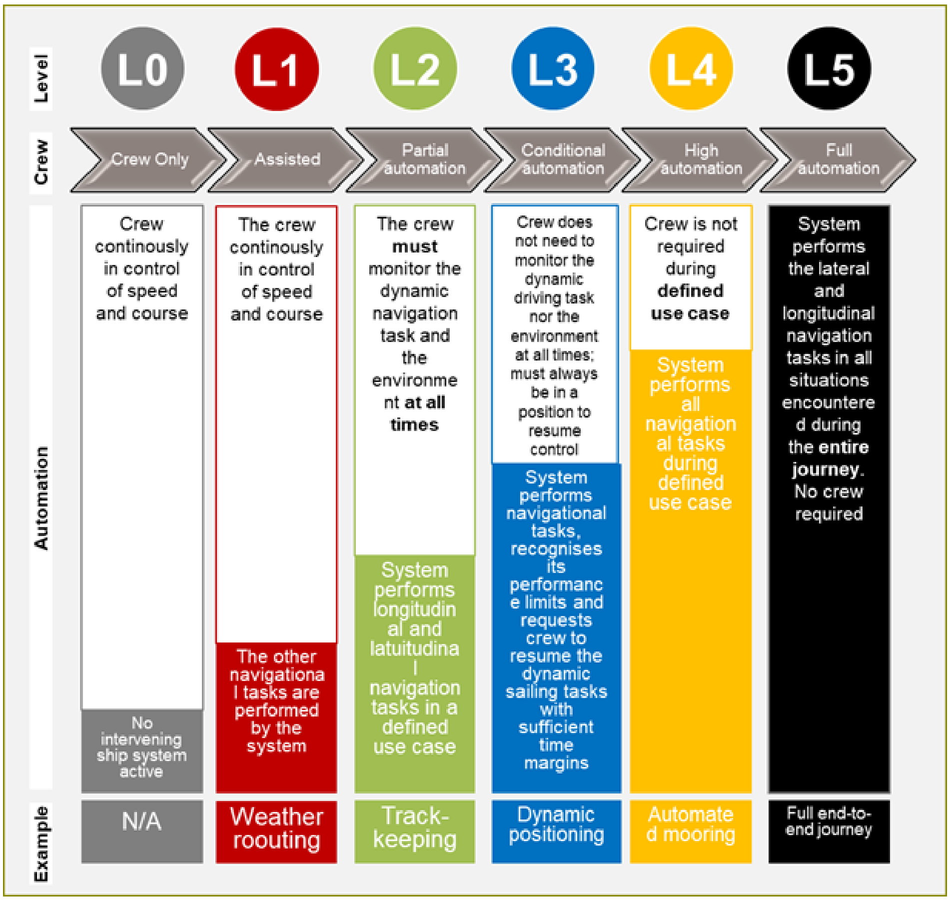


Figure 11: Different Levels of Automation Towards Autonomous Navigation

The development of automation foreseen by the industry implies new generation decision support systems where situational awareness systems are one of the first enablers, as shown in the figure below. The Prepare Ships solutions are an important contribution making further automation of navigation feasible while ensuring safety and security requirements implied on the affected safety critical systems including integrity of accurate positions, prediction of future positions and exchange of such predicted positions indicating intentions. By establishing e.g. the relevant standards for communication of critical information, the increased automation will be made feasible.

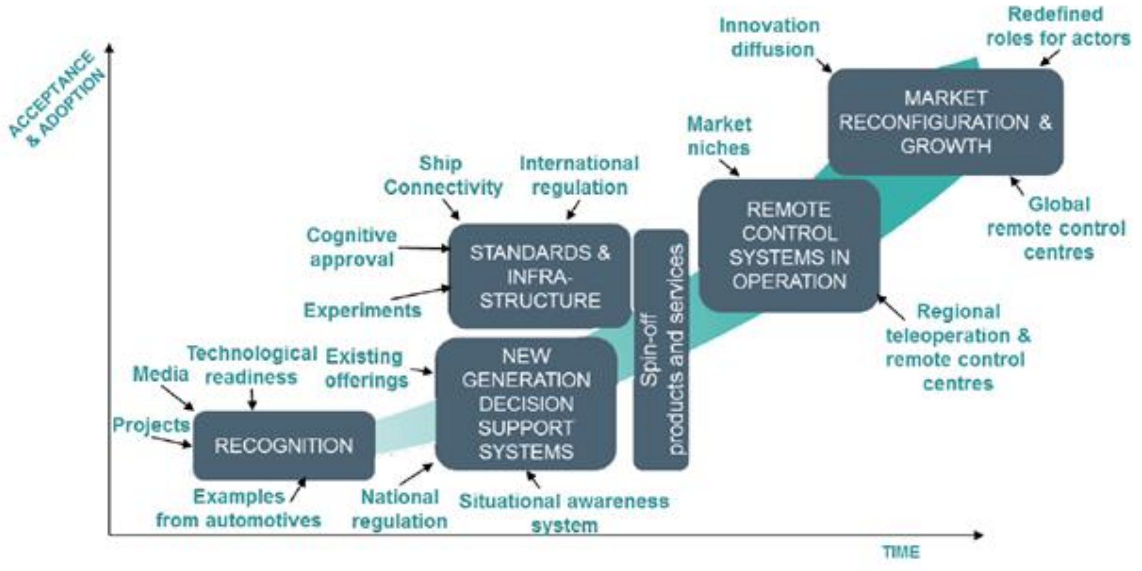


Figure 12: Acceptance and Adoption versus Time in the roadmap towards more autonomous shipping. [6]

Scenario ID	AS4:1
Name	Enabler increased automation
Description	Interaction with other industry players to get ensure that required feedback is given from individual vessels in conflicting COLREG situations to enable automation of certain navigation function.
Expected Action	Industry standard derived for communicating predictor information.

4 References

Jacobson, I. et al. (2011). Use-Case 2.0 – The Guide to Succeeding with Use Cases. Ivar Jacobson International.

International Electrotechnical Commission. (2014). IEC 62288:2014 Maritime navigation and radiocommunication equipment and systems - Presentation of navigation-related information on shipborne navigational displays - General requirements, methods of testing and required test results. International Electrotechnical Commission

Allianz Global Corporate & Specialty. (2018). Safety and Shipping Review 2018. Munich: Allianz Global Corporate & Specialty.

Bockmann, M. W. (den 08 08 2019). *Iran spoofing ship GPS signals, warns US*. (Lloyds List Maritime Intelligence) Hämtat från https://lloydslist.maritimeintelligence.informa.com/LL1128704/Iran-spoofing-ship-GPS-signals-warns-US den 27 01 2020

Bockmann, M. W. (den 16 08 2019). *Seized UK tanker likely 'spoofed' by Iran*. (Lloyds List Maritime Intelligence) Hämtat från https://lloydslist.maritimeintelligence.informa.com/LL1128820/Seized-UK-tanker-likely-spoofed-by-Iran den 27 01 2020

EMSA. (2019). *Annual Overview of Marine Casualties and Incidents.* Lisbon: European Maritime Safety Agency.

Endsley, M. R. (1995). A taxonomy of situation awareness errors. i *Fuller, R., Johnston, N., McDonald, N. (Eds.), Human Factors in Aviation Operations.* (ss. 287-292). Aldershot: Ashgate Publishing Limited.

Energimyndigheten. (2017). *Sjöfartens omställning till fossilfrihet.* Eskilstuna: Energimyndigheten.

Entec UK Ltd. (2002). *Quantification of emissions from ships associated with ship movements between ports in the European Community.* Northwich,: Entec UK Ltd.

ForeSea. (2019). *PM from reference group meeting ForeSea.* Göteborg: SvenskSjöfart & RISE.

Goward, D. (den 07 11 2017). *Mass GPS Spoofing Attack in Black Sea?* (Maritime Executive) Hämtat från https://maritime-executive.com/editorials/mass-gps-spoofing-attack-in-black-sea den 27 01 2020

Grech, M., Horberry, T., & Smith, A. (2002). Human error in maritime operations: analyses of accident reports using the leximancer tool. i *Proc. Human Factors Ergonom. Soc. Ann. Meet.* (ss. 1718–1721).

Hüffmeier, J., & Wilske, E. (2008). *Decision Support Tools for VTS Operators, BaSSy SSPA Report 4005 3946-1 - rev1.* Göteborg: SSPA Sweden AB.

Jones, D., & Endsley, M. (1996). Sources of situation awareness errors in aviation. i *Aviation Space and Environmental Medicine 67* (ss. 507-512). PubMed.

Lo, C. (den 15 04 2019). *GPS spoofing: what's the risk for ship navigation*. (Ship-Technology.com) Hämtat från https://www.ship-technology.com/features/ship-navigation-risks/ den 27 01 2020

Rolls-Royce. (2016). *Remote and Autonomous ships - The Next Step.* London: Rolls-Royce.

Sandhåland, H., Oltedal, H., & Eid, J. (2015). Situation awareness in bridge operations – A study of collisions between attendant vessels and offshore facilities in the North Sea. i *Safety Science 79* (ss. 277–285). Elsevier.

Prepare Ships

RISE Research Institutes of Sweden ◦ SAAB Transponder Tech ◦
Telko ◦ ANAVS ◦ Lantmäteriet

www.prepare-ships.eu

European
Global Navigation
Satellite Systems
Agency

PrePare Ships – Ship Application Use Cases and Application Scenarios