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AUTOFLEX

[D5.1] Interface Standard
- Draft standard for KET interface standardisation

Work package	WP5	Realising the modal shift (business models, impacts, standards, and recommendations)
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EXECUTIVE SUMMARY

This deliverable presents a draft standard for the interface between the Situation Awareness System (SAS) and the Autonomous Navigation System (ANS) for autonomous inland waterway vessels developed within the AUTOFLEX project. The work addresses a key challenge for autonomous navigation: Establishing a common and standardized method for exchanging situation awareness information between perception systems and navigation systems. Such standardization is essential to support interoperability, reduce integration costs, and lower barriers for small and medium-sized enterprises entering the emerging market for autonomous inland waterway transport.

The report investigates the research question: What standardized situation awareness information is required to support the perception, interpretation, and decision-making processes of an autonomous inland waterway navigation system? To answer this question, the work builds on established theories of situation awareness, previous European research projects, emerging standards for Maritime Autonomous Surface Ships (MASS), and operational requirements from the European Code for Inland Waterways (CEVNI).

A key outcome of the study is the clear separation of responsibilities between the SAS and the ANS. The SAS is proposed to focus on the detection, classification, and state description of relevant objects and environmental conditions, while the ANS is responsible for traffic-situation assessment, future-state prediction, route execution, and navigation decision-making. This distinction enables a well-defined interface that supports modular system architectures and vendor-independent solutions.

The deliverable adopts Endsley's three-level model of situation awareness as the conceptual foundation. Level 1 covers perception through detection and classification of objects; Level 2 describes object states and relationships; and Level 3 concerns projection and understanding of future traffic situations. The proposed interface standard focuses primarily on Levels 1 and 2, providing the information necessary for the ANS to perform navigation-related analyses and decision-making functions.

The main contribution is a comprehensive conceptual data model expressed through UML class diagrams. The model defines standardized representations for dynamic objects (vessels, convoys, floating constructions, living beings, and floating obstacles), fixed infrastructure and waterway features (bridges, locks, signs, buoys, marks, and geographical objects), environmental conditions, and sound signals. The model is specifically tailored to inland waterway operations and aligns with existing European inland navigation standards and practices.

The report further discusses implementation considerations and future standardization pathways. It also highlights the need for future work on uncertainty representation, sensor accuracy, richer geometric modelling, and integration with route-exchange and maritime information service standards.

Overall, to our knowledge, this deliverable provides the first structured proposal for a standardized SAS–ANS information interface for autonomous inland waterway navigation.

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The proposed model establishes a common foundation for future industrial implementations, interoperability initiatives, and international standardization efforts.

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LIST OF ABBREVIATIONS

Abbreviation	Description
ANS	Autonomous navigation system
ENC	Electronic Navigational Charts
IMU	Inertial Measurement Unit
iENC	Electronic Navigational Charts for Inland Waterways
IWT	Inland Waterway Transport
IWW	Inland Water Ways
MASS	Maritime Autonomous Surface Ships
ROC	Remote Operation Center
SAS	Situation awareness system
VTS	Vessel Traffic Service
	Note that the term *Object* can be used in two different contexts: One as a physical object that is detected by the SAS during sailing. The other is an object as an instance of a class in the UML diagram. For this latter meaning, we use the term *instance*.

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1 INTRODUCTION

1.1 THE AUTOFLEX PROJECT

The AUTOnomous Small and FLEXible vessels – project (AUTOFLEX) is a Horizon Europe funded project that targets expansion of waterway transport into small and underutilized canals. The primary goal is to develop technology and concepts that enables a modal shift from road transport to zero-emission inland waterway transport. The project approaches this problem from several angles. One of them is that of proposing standardized interfaces between the different systems included in an autonomous vessel, that is, situation awareness system, navigation and manoeuvring system, hull and propulsion system, power and energy system, integrated automation system and mooring system. This document focuses on the interface between the situation awareness system (SAS) and the navigation and manoeuvring system (ANS). The scope of this deliverable is to report on the work done in *Task 5.2 Accelerating uptake of autonomy by technical standardisation*. This work is part of work package 5 on realising the modal shift with respect to business models, impacts, standards, and recommendations.

1.2 SCOPE OF THE DELIVERABLE

This deliverable reports on the work to define a standardized interface between a SAS (Situation Awareness System) and the ANS (Autonomous Navigation System) onboard an inland waterway vessel, with the purpose to lower the threshold for small and medium-sized companies to enter the market.

The formal part of the interface standard proposal consists of a data model with the information exchange content between the SAS and ANS. When it comes to the related system behaviours, that is, the functions, this is considered to be part of the ANS, and this is only briefly discussed in this deliverable.

The deliverable also contains informal recommendations to practical implementation of the interface standard including relevant data protocols, and data formats. Since this is a draft standard, any description of hardware standards is not relevant.

The analysis is based on information from WP4, especially the development of the Mission Exchange Model to map the data that needs to be transferred from ROC to ANS, together with a proposed structure (taxonomy) for autonomous navigation barges that is developed in the ReNEW-project. The analysis is also based on results from other EU-projects and standards, as described throughout this document. Further, the main source of this draft standard is the European Code for Inland Waterways, sixth revised edition, 2024, published by CEVNI [20], since this contains detailed descriptions of rules for navigation on European inland waterways, in addition to rules for marking of the inland waterways and also of the vessels themselves.

The proposal in this deliverable was presented at the ISO/TC8/SC26 Smart Shipping plenary meeting on 16th of June 2026.

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1.3 MOTIVATION

Situation awareness is critical for autonomous navigation of MASS, and outputs from the SAS form the basis for the decisions and actions taken by the ANS to ensure safe navigation. [2] emphasis that standardization and integration of sensor information for presentation to and use by the officer on the watch already exist, while standardization of the sensor data for use by the autonomous navigation system onboard a MASS is still missing. In most definitions of situation awareness for MASS, the functionalities of the ANS and the objectives of the SAS are closely related, and the interface between the SAS and the ANS when it comes to which data to exchange, is not clearly defined. The aim of this report is to discuss and define this interface as a starting point for further clarifications.

From the MASS Code [8], we know that the situation awareness system of MASS must ensure *observability*, including detection and classification of the own ship system state, the state of surrounding dynamic objects, the interaction between own ship and these dynamic objects, in addition to detect and classify the environment and also the actual traffic situation. [8] defines situation awareness as:

> *"Situational awareness means the perception of surroundings and environmental elements in different modes of operation, the condition of all relevant systems and events with respect to time and space, the comprehension of their meaning, and the projection of their future status."* [8]

Further, [8] lists the following sub-functions of MASS navigation (either autonomous or remote), based on the mode of operation:

- Voyage planning
- Situation awareness
- Collision and grounding avoidance
- Route execution and monitoring

This means that [8] lists situation awareness as one of the functions to be performed by the ANS. Situation awareness is further described as follows in [8]:

An ANS or system for remote navigation should maintain adequate situation awareness for the purpose of ensuring safe navigation:

- *An ANS or system for remote navigation should continuously monitor all information necessary for safe navigation, based on the OE[1].*
- *An ANS or system for remote navigation should continuously analyse the current situation in order to perceive and process navigational and environmental elements and project or predict future statuses. This should be done whilst considering the operation goals and objectives, the system's capability, and the modes of operation.*
- *An ANS or system for remote navigation should provide a means to make the information obtained and all analysis accessible as necessary.*

Similary, IALA defines situation awareness as follows [29]:

[1] Operational Envelope

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> *Situation awareness refers to the ability to identify, process, and comprehend the critical elements of information about what is happening in the surrounding environment at any given time. It involves being aware of what is happening around you and understanding how that information, events, and your own actions will impact your goals and objectives, both immediately and in the near future.* (from [29])

[3] emphasis that the tasks performed by the ANS when making navigation decisions and taking the correct actions include the usage of information from maritime regulations, collision avoidance predictions, planned long- and short-term routes, and also communications with authorities and surrounding ships.

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2 RELATED WORK

This chapter summarizes some of the various viewpoints of situation awareness that are found in the literature.

2.1 ELEMENTS OF SITUATION AWARENESS

One of the earliest works on formalizing a theoretical model of situation awareness was published in 1995 by Endsley [1]. This paper distinguishes the term situation awareness from situation assessment, where situation awareness describes a *state* of knowledge, while situation assessment describes the *process* of achieving and maintaining situation awareness. Further, situation awareness is defined to cover knowledge only related to the dynamic environment. Another important restriction is that situation awareness is separated from decision making and performance. Further, situation awareness is described by the three hierarchical phases: 1) what is happening (perception) 2) what does it mean (comprehension) and 3) what might happen next (projection). This is further described in Section 2.2 [1] also points on the temporal aspects of situation awareness, in that the status is given for a certain time series, both for historical data and for predictions.

Further, Song et al describes the following elements of situation awareness for MASS [5]:

- Navi-chart: A navigation chart provides both physical entities and virtual features such as fairways, anchorages, and controlled areas. For a MASS, chart data is a critical sensing source, supplying most of the information about the physical and virtual entities needed for situation awareness. However, because the chart encodes this information through symbols and descriptive attributes, it cannot be used directly by the MASS. The system must first transform the chart content into computable objects whose spatial relationships can be derived using spatial-topology methods.
- Regulations: Maritime navigation is governed by several regulatory frameworks, including COLREGs and local rules, for instance for IWT [20], which guide vessel behaviour in different areas. In addition, various services provide recommended routing practices for ship operators, for example, guidance on safe approaches to port areas or transits under bridge spans.
- Human: Humans remain a critical component of the waterborne transport system encompassing not only seafarers and VTS operators but also company managers, port personnel, search-and-rescue staff, and other supporting services.
- Environment: The environment comprises physical factors in the surroundings that influence a vessel's navigational state. Typical elements include wind, waves, and other weather conditions.
    - Geography: Natural features such as islands, rocks, seabed topography, shorelines, and oceanographic conditions (e.g., waves and currents). These elements influence navigation by affecting route planning, track-keeping, and manoeuvring
    - Infrastructure: Human-made structures within the waterborne transport system, including beacons, buoys, berthing facilities, and other navigational or port installations.

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  - Weather: Meteorological conditions that directly impact navigational safety, including visibility (affected by fog, rain, or snow) and wind, which can significantly influence vessel stability and manoeuvring.
- Surrounding ships: It is essential to determine the relationships between own ship and nearby vessels when it comes to the rules in COLREG or in IWT, such as head-on, crossing, or overtaking situations. This is needed in order to identify whether the vessel acts as the give-way or stand-on ship.

2.2 DIFFERENT LEVELS OF SITUATION AWARENESS

According to the MASS Code [8], the SAS is viewed as part of the ANS. One reason for doing this, is that functionalities of these two systems are very closely linked. Detection and classification of objects and describing their states are necessary to be able to predict and classify the actual traffic situation correctly. At the same time, the actual traffic situation may influence how detection and classification of objects need to be done, for instance, which states of the objects are needed to be able to correctly assess the current traffic situation, and also which objects need to be classified. Still, in this work, we separate the SAS from the ANS to be able to propose a standardized interface covering the data requirements by the ANS when it comes to situation awareness. As a starting point, we use the theory on situation awareness by Endsley [1], who presents three phases in achieving situation awareness in dynamic decision making, Figure 1, and also as described in Section 2.1 .

- Level 1: *Perception* of elements in the current situation: The first step is to obtain information of relevant objects in the environment, including information of own vessel, information from the chart and from relevant regulations.
- Level 2: *Comprehension* of the current situation: This level includes understanding the significance of these elements with regards to the current task, this means to understand the current situation based on the input from level 1.
- Level 3: *Projection* of future status: This level includes taking information from level 1 (perception of elements) and level 2 (understanding of the current situation) to predict the actions taken by the objects in the environment.

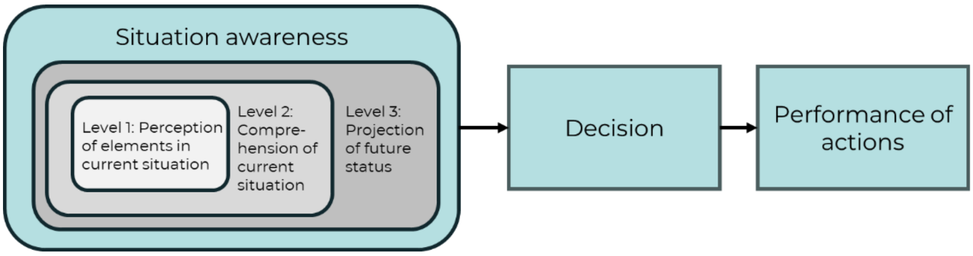

Figure 1 Situation awareness in dynamic decision making (Source: Simplified from [1])

This view on situation awareness is also used in several other works, for instance by Song et al in [3], [4], and [5], and by Sharma et al in [9]. [9] also gives an overview of the information requirement for each level of situation awareness based on interviews with seven pilots regarding their navigation from a pilot boarding place to a berth. For level 1, perception, they list the following:

- Ship status: Position, speed, gyro heading, magnetic heading, and under keel clearance

- Equipment status includes operational status of the following: Navigation system (GPS, ECDIS, Radar, AIS data), Radio system (VHF/MF), Steering system, Communication channels (Portable radios, PA systems), Fire and safety equipment, Signal lights, Deck equipment, and Engine controls
- Route plan: Planned route, distance to waypoints, planned speed for each leg, air draft
- Traffic and obstacles: Location of targets, number of targets, Traffic Separation Scheme (TSS) to be followed, and Vessel Traffic Service (VTS).

2.3 OPERATIONAL SHIP INFORMATION AND STATIC CHART INFORMATION

An important aspect of situation awareness for MASS is the close relationship between own ship operational data and the static properties of the chart. This is further described in [10], where operational data including information about the environment (wind, waves, current) and own ship status is related to the geographical data as ENC data, maritime safety information and statical data about own ship.

In [6], van Baelen et al employ ship domains (SD) and map domains (MD) to illustrate relationships that are relevant within a given navigational situation. A key point is that static chart data serves as an essential input for positioning both own ship and surrounding objects, and for establishing situation understanding. A dynamic map is constructed by combining static information from the digital chart, which forms the base layer, and dynamic information about own ship, other vessels, and additional objects. The dynamic information is overlaid onto the static layer to produce a dynamic situation-awareness map.

Regarding chart data, it is not incorporated directly as raw map content, but rather through the static and dynamic properties of the own vessel and surrounding objects, for example, navigational constraints and regulatory requirements. However, generally, the SAS does not need information about the chart and the chart objects to be able to provide situation awareness information to the ANS.

2.4 RELATIVE POSITIONS AND MOVEMENTS

As mentioned in Section 2.3 , Van Baelen et al in [6] describes for inland water ways navigation how objects, their properties and states can be linked to properties in the map, the regulations and to the various tasks that a ship is set up to perform. An example of this is shown in Figure 2. The geometry of a vessel is represented by a vessel frame. This frame is positioned in the map using the uncertainty zone, SD0 (Ship Domain). This indicates the uncertainty of the position and orientation of own vessel. The SD1 indicates the motion sone of own vessel based on its speed and abilities to change speed and course. This could also include information from environmental sensors, for instance regarding the visibility. SD2 can be given several different semantics, dependent of the use case. One possibility is to define this as the area where the SAS needs to detect and classify objects. This area can for instance have relations to communication information, for instance to AIS positions for ships in this area. The figure also shows MD0, which is a map domain that describes the lane in the canal to be followed by own vessel. The geometry of the ship domains is also dependent of knowledge about the perception systems, that is, their capabilities and uncertainties. To the picture in Figure 2, we can also add geometry–task-relations, that is, the description of the vessel's task, with the corresponding implications for the ANS when taking into account the intensions.

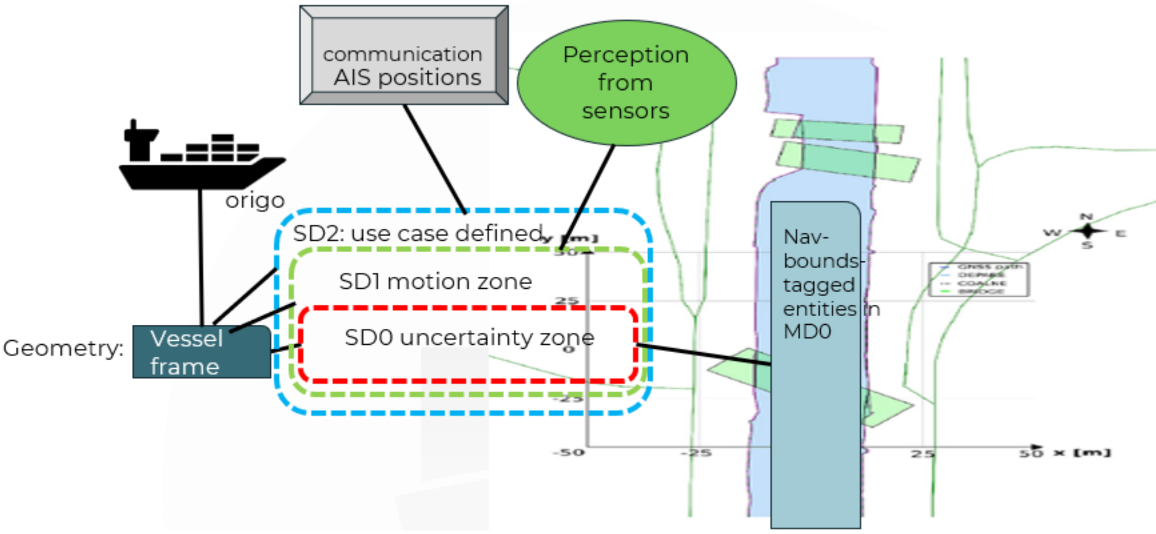

Figure 2 Relationships between objects and states

[31] proposes a way to define the spatial area around a vessel in which all navigation-relevant objects must be detected by the vessel's situation awareness system early enough. The objects must be detected early enough both in time and distance. The purpose is to allow for understanding the situation, making decisions, and taking control actions that ensure safe navigation for MASS under different concepts of operation. This proposal also discusses that different objects need to be detected at different distances, for example a buoy, a fishing boat or a large containership, and also that the difficulty in detecting the different objects is not the same.

2.5 OPERATIONAL DESIGN DOMAIN

A taxonomy for an Operational Design Domain (ODD) for an automated driving system is described in [28]. The ODD represents the operating environment where the automated driving system can perform its tasks safely. The ODD taxonomy is specified to be able to implement the minimum safety requirements for an automated driving system. This standard is developed for cars, but this is also relevant for autonomous ships. The taxonomy consists of three main groups of concepts> The scenery, which is the non-moveable elements of the operating environment (zones, drivable area, junctions, special structures, fixed road structures, temporary road structures), the environmental conditions, which is weather and atmospheric conditions (particulates, illumination, connectivity), and dynamic elements, which is the moveable elements included in the operational domain (traffic and subject vehicle).

The same grouping of objects can be used for MASS as well. ISO has defined the Operational Envelope (OE) as an alternative to the ODD as follows in TS23860: *Conditions and related operator control modes under which an autonomous ship system is designed to operate, including all tolerable events* [38]. This definition is also used by Wennersberg and Nordahl when

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defining the observability and controllability as criteria for safe navigation of autonomous ships [37].

2.6 UNCERTAINTY IN SITUATION AWARENESS

The detection and classification of moveable and fixed objects will come with a given uncertainty, which may have several causes. The ISO standard 25934[2] on *Guidelines for the development of verification procedures for autonomous navigation systems*, describes events and consequences for degradation of situation awareness related to autonomous navigation systems. This gives a hint on which factors can contribute to the uncertainty of the detection and classification of the objects that are reported in the SAS-ANS interface. In this deliverable, we will not go into details regarding how to describe the uncertainty of the situation awareness results.

[2] Committee Draft (2026)

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3 METHODOLOGY

3.1 SITUATION AWARENESS FUNCTIONS

In this report, we adopt Endsley's three-level model of situation awareness (perception, comprehension, projection) as the conceptual foundation [1]. These levels are adapted to define the requirements to situation awareness for safe MASS navigation. At the same time, the model is used to clarify the division of responsibilities between the SAS and the ANS. The *functions* needed to be performed related to situation awareness are as described by the following three levels:

Level 1 - Detect and classify objects: For MASS, this level of situation awareness includes object detection and classification based on different types of sensors. This information is given at a single point in time. It is used for assessment of future trajectories of the objects and for the prediction and classification of the traffic situation. The detection and classification of the objects are separated into:

- An **internal world model** which contains formalized information about detected and classified objects, including own vessel and other detected and classified objects, both fixed and moveable, including surrounding ships, and human-made infrastructure (including beacons, buoys, light signals, marks and signs, bridges and locks. This also includes information about the weather taken from various sensors and sources. In our draft SAS-ANS-interface, we have excluded information about own ship domain from the internal world model.
- An **external world model** which contains formalized information taken from the relevant chart and regulations. For charts, this includes the identification of specific areas that may affect the prediction and classification of the traffic situation. In addition, some parts of the regulations that can be linked to the objects that are detected, need to be identified. In our draft SAS-ANS-interface, building up the external world model is part of the ANS functionality.
- In addition, these two world models can in some cases be combined, for instance to improve the detection and classification of objects. And example is the detection and classification of traffic lights along the inland waterway. These traffic lights are marked in the chart ([21], [22]), and they can also be detected by cameras. The same is valid for instance for buoys, which are both marked in the chart, and can also be detected by camera and sometimes by radar as well. This is also taken as part of the ANS functionality.

Level 2 – Describe object states : For MASS, this level consists of describing the states of the objects that were detected and classified in level 1. This is done to give a more detailed picture of the situation, to formalize this, and then next to provide this to the ANS when deciding on the safe navigation on inland waterways. This information is also given at a certain point in time. This level contains information to make it possible to position the dynamic objects in the chart, and also to map the status of static objects in the chart to the actual data obtained from a sensor, for instance if a traffic light at the entrance of a lock shows red or green light. This means that the SAS interface gives information about the object states, while the mapping to

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the chart is done by the ANS. In the SAS-ANS-interface, the object states are described as values of attributes, that is, as instances of the UML classes.

Level 3 – Predict and classify the traffic situation: For MASS, this level consists of projecting future trajectories for own vessel and other dynamic objects into time series, starting with the current point in time. These predictions will be based on a specific navigation task needed to be performed by the MASS, for instance due to navigation rules or other regulations, in combination with the dynamic traffic situation. It is also dependent on the overall mission that the MASS is performing, for instance sailing on a route in open waters, following the lane in a canal, passing bridges and locks, or manoeuvring in ports. At this level, the correct understanding of the situation is assessed at a set of time stamps. The prediction and classification of the traffic situation is performed as part of the ANS. Information related to these functionalities is therefore not part of the SAS-ANS-interface.

3.2 SITUATION AWARENESS INFORMATION

Based on these three levels of situation awareness, the information gathered from sensors, sensor fusion and other sources as charts and regulations, are structured as shown in Figure 3. The right side of the figure describes how each level in the situation awareness is represented in a structured data model. This means that the left-hand side of the figure lists the functionalities of SAS and ANS, while the right-hand side of the figure lists the relevant data that is produced by each of the functionalities and that is needed by the ANS to perform its navigational tasks.

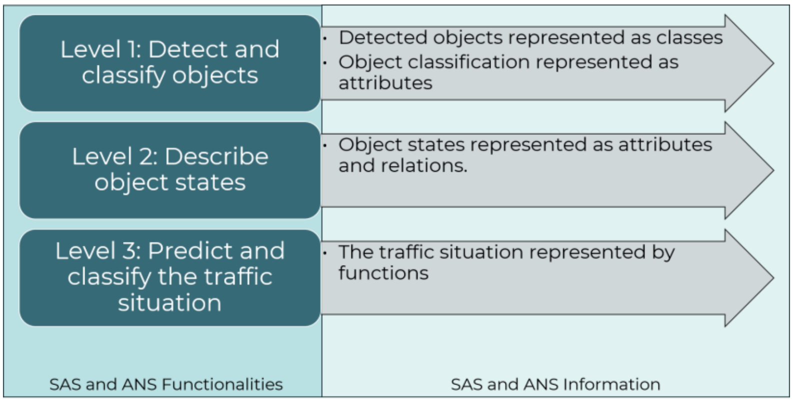

Figure 3 Structuring Situation Awareness information

This is also in line with the functionalities for situation awareness as proposed by the Autoship project in [11], as listed in Table 1.

S11	Situation awareness (Observation)	Relation to SAS Levels
S111	Determine location, verify chart information, AtoN	Level 1, Level 3
S112	Observe weather and sea	Level 1
S113	Determine visibility	Level 1
S114	Detect and classify objects and obstacles	Level 1 and Level 2
S115	Assess own ship and traffic situation	Level 3

Table 1 Functions in situation awareness as described by Autoship (Source: [11])

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3.2.1. LEVEL 1 – DETECTED AND CLASSIFIED OBJECTS

This level defines the information needed to represent objects detected and their classification. This is both for own ship and other objects.

3.2.1.1. SENSORS

Regarding object detection and classification, [18] states that multi-sensor perception is an important part of the SAS. The SAS must gather reliable data about the vessel's surroundings using a wide range of sensors: Digital cameras, GNSS (satellite positioning), active ranging sensors (e.g., radar, lidar), environmental sensors, AIS (Automatic Identification System) and Electronic Navigation Charts (ENC). Further, raw sensor data must be combined into a coherent environmental picture to achieve state estimation. This means that data from multiple sensors must be merged and that noise and inconsistencies must be filtered. The SAS must detect and correctly classify other vessels, buoys, signs and markings, bridges and locks, and other obstacles and hazards. This is critical for safe navigation and collision avoidance.

3.2.2. LEVEL 2 – OBJECT STATES AND RELATIONSHIPS

This level contains information about the state of the objects that were described in level 1. In the interface model, this is defined as attributes on objects and relationships between objects. It is defined at a single point in time. It includes information about own ship and other objects used as a starting point for predicting and classifying the traffic situation in level 3. In this SAS-ANS-interface, the information about each detected object is described in absolute values, not relative to own vessel. This is done to ensure that the ANS has consistent information as basis for its calculations.

While some sensing systems may internally detect and track objects relative to own ship, the SAS-ANS interface standardizes the exchange of object state information in an absolute reference frame. Relative measurements offer several advantages at the sensing and tracking level. Many sensors, such as radar, lidar and cameras, naturally observe targets as range, bearing, relative speed, or relative motion with respect to own ship. Using relative measurements can simplify sensor processing, reduce sensitivity to errors in navigation data, and allow rapid assessment of collision risk, since quantities such as closest point of approach (CPA) and time to closest point of approach (TCPA) are inherently based on relative motion. Relative representations may also be computationally efficient for local tracking functions and can provide robust short-term situational awareness even when the absolute position accuracy of own ship is limited.

The choice of absolute values applies only to the interface definition, not to internal system implementations. A SAS may therefore use either relative or absolute representations internally and perform any necessary transformations before information is exchanged across the interface. Expressing object states in a common absolute reference frame provides an implementation-independent representation of the traffic situation and ensures that all objects are described consistently regardless of sensor type or tracking methodology. It also facilitates the fusion of information from multiple sensors and external data sources, enables a shared traffic picture between cooperating systems, avoids ambiguities related to differing own-ship reference states, and provides a stable basis for prediction, classification, route planning, and situation assessment functions within the ANS. By defining a single reference

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frame for data exchange, the interface supports interoperability while allowing each subsystem to employ the most suitable internal representation for its operational needs.

3.2.2.1. OBSERVATIONS RELATIVE TO SENSORS

The ship dynamics and other time varying properties of detected ships and detected objects are modelled as attributes of the object's class. It is also modelled as a relationship to the sensors onboard own ship that did the observation. This is needed to be able describe the source of information, for instance regarding the position of the sensor onboard own vessel and the settings of for instance the cameras.

3.2.3. LEVEL 3 – ANS FUNCTIONS

The SAS provides the foundational data for path planning, collision and grounding avoidance, manoeuvring decisions, and predictive modelling of future vessel states. Without a trustworthy SAS, autonomous navigation cannot function safely.

Some of the tasks performed by the ANS includes to project future trajectories and to predict and classify the traffic situation. When the traffic situation is classified, the ANS can use information from the SAS to further specify the action to take. Based on a specific task, for instance to follow the lane or to handle a head-on meeting, the ANS can predict the next situation. This can be done for instance by identifying overlaps between own ship domain and the ship domain of the meeting vessel, the distance to the shore side, or the relevant navigational boundaries expressed as a ship domain in the case of a head-on situation.

More generally, an operational zone for a moveable object can be defined, which is dependent on the use case, for instance of the actual traffic situation detected. This is done by the ANS, since the ANS will know more about the capacities of own ship than what is known by the SAS. This means that operational zones are not part of the SAS-ANS interface.

The functional perspective of the ANS will not be further formalized in this draft standard, as it is too immature and has too much uncertainty regarding the way forward to be able to propose standardized functions in the SAS-ANS interface. This means that in the rest of the description, we will focus on the information requirements for level 1 and 2.

3.3 THE ROLE OF THE CHART

Strictly speaking, situation awareness can be performed without knowledge of the chart if the task is restricted to the detection and classification of movable and static objects. However, chart information combined with GNSS positioning, radar data, or other navigation sensors can improve both detection performance and classification accuracy. An example is light signals along waterways, which become significantly easier to detect and classify if the SAS knows from chart information that the vessel is approaching for instance a bridge or a lock.

From an architectural perspective, the chart primarily belongs to the ANS. Navigation decisions require not only knowledge of physical objects but also knowledge of the navigational environment, applicable regulations, and waterway constraints that are found in the chart. By placing chart handling in the ANS, the chart can be maintained together with the rule base and navigation logic used for route planning, traffic rule compliance, and decision support. This enables the ANS to reason directly about traffic separation schemes,

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restricted areas, harbour zones, lock approaches, turning basins, intersections, and other chart-defined operational areas.

Further, the ANS needs the chart to describe the traffic situation in a context-aware manner. In addition to evaluating the positions and movements of vessels and obstacles, the ANS can assess whether vessels are approaching regulated zones, entering harbour areas, navigating within traffic lanes, or approaching special infrastructure such as locks and bridges. Such contextual information is essential for navigation and collision avoidance decisions but is not strictly necessary for the perception task itself.

A challenge associated with relying on chart information is the need for continuously updated charts. Waterway infrastructure and regulations may change over time, and inaccurate or outdated chart data may affect navigation decisions. This issue is particularly relevant for inland waterways, where temporary restrictions, lock closures, construction activities, and changing waterway conditions can occur. Consequently, mechanisms for chart updating and integration with services such as River Information Services (RIS) become important.

In addition to having the chart assigned to the ANS, there are arguments for also allowing the SAS to have access to chart data as supporting information. Chart information can improve object classification by providing prior knowledge about expected objects and structures in the environment. For example, if a sensor detects a stationary target at the location of a charted navigation mark, bridge structure, or light signal, the chart information can increase confidence in the classification. Similarly, chart information may help distinguish between truly fixed objects and slowly drifting objects under normal environmental conditions. In such cases, chart information acts as contextual information supporting perception rather than as a primary source for navigation decisions.

However, chart information should be used with caution within the SAS. Chart positional accuracy may differ from sensor accuracy, particularly in older charts or areas where infrastructure has changed. Consequently, chart information may not always be suitable as a direct reference for precise positioning or object localization. The role of the chart within the SAS should therefore be limited to supporting detection and classification. Sensor observations should remain the primary source for determining the current state of the environment.

Based on these considerations, the proposed architecture assumes that chart ownership resides in the ANS, where chart information is combined with navigation rules, route planning functions, and traffic assessment. However, this should be further assessed in upcoming versions of this proposed standard.

3.4 ACCURACY OF DETECTIONS

According to [18], the biggest challenge for the SAS is to quantify the uncertainty in what the SAS identifies, make sure that it reliably detects all relevant objects, and provide explainable outputs. In addition to this comes the fact that visual sensors will have difficulties working in reduced visibility as for instance during dark nights or in fog or rain. In this draft SAS-ANS-model, we will not include information about the accuracy of the detected information.

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4 DRAFT SAS-ANS INTERFACE STANDARD

4.1 INTRODUCTION

This chapter describes the data content of the SAS-ANS interface as a conceptual model expressed as UML class diagrams. Attributes containing the internal IDs of the objects of each of the classes are not added to the diagrams. This could for instance be added as UUID or just written as a simple ID, but this is omitted here, to be able to hold the data model at a conceptual level.

Descriptions of UML Class diagrams and choices made regarding the modelling are found in Appendix A.

Figure 4 shows a simplified picture of the tasks performed by the SAS and the ANS, and where the SAS-ANS interface fits in.

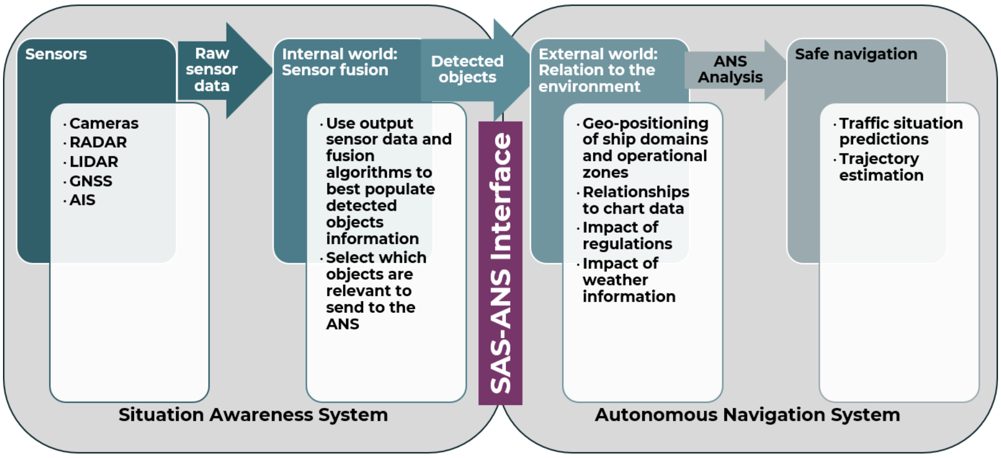

Figure 4 SAS-ANS interface overview

The main part of the interface is divided into the following groups of data:

- Dynamic objects (watercrafts, living beings and other floating objects), Section 4.2
- Scenery (Fixed waterway objects, including geographical objects, signs, buoys and infrastructure), Section 4.3
- Sound signals, Section 4.4
- Environmental conditions, Section 4.5
- Enumerate types, that is, relevant code lists, Section 4.6
- Complex types used for the attributes in the interface model, Section 4.7
- Own ship information is handled outside the interface model, but this is covered in Section 4.8 for completeness.
- Overview of sensor types and positioning data, Section 4.9

In several cases, the basic information is sent from the SAS to the ANS, leaving it to the ANS to do calculations that are needed to do the correct assessment of the situation and to act accordingly. An example is the position of own vessel and other vessels in the fairway, for instance the distance from the boundary of the marked fairway on the starboard bow side,

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the starboard aft side, the port bow side, and the port aft side. The SAS interface provides the position of detected objects and vessels as an area with a list of latitude/longitude-positions, and also the positions of the detected banks. Then, it is up to the ANS to calculate the position of own ship and other moveable objects in the fairway. This approach is chosen, since the ANS will have extra information that are used in the calculations, both charts, more information about bridges, locks and vessels, information about the mission of the vessel, and also the possibility to do more calculations on this information.

Further, information about moveable objects is given in absolute numbers, not relative to own vessel. This is relevant for instance for the course and heading of the objects that are detected.

An overview of the interface model is given in Figure 5.

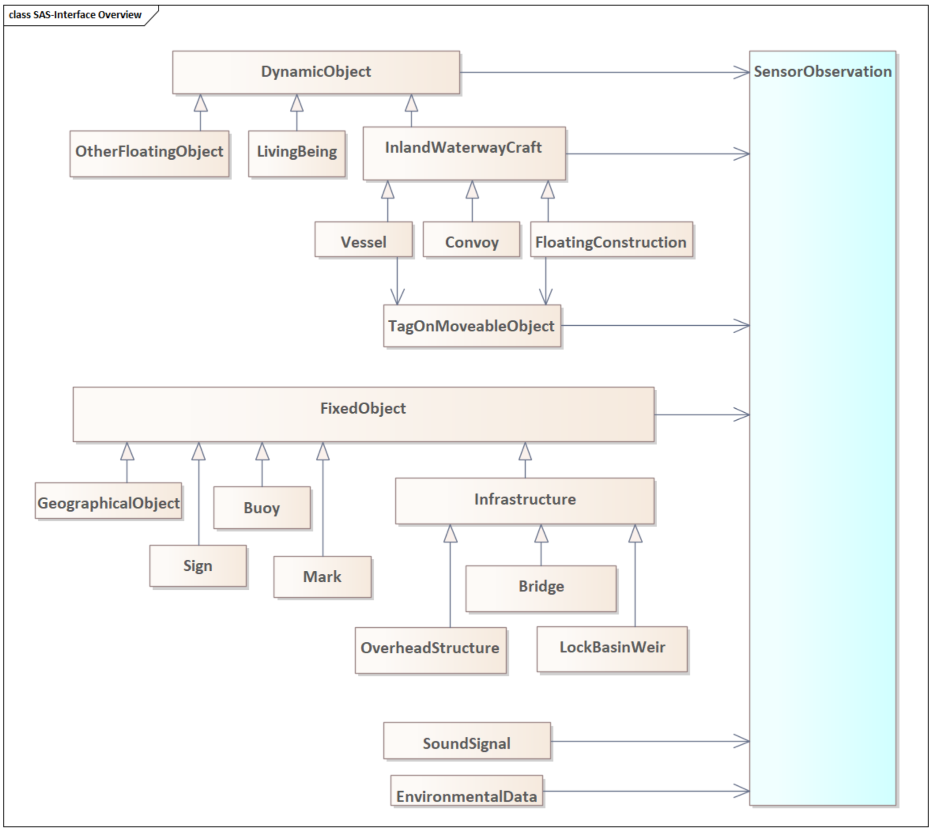

Figure 5 Overview of the data exchange model for the SAS-ANS interface

The following sections describe the data model for the SAS-ANS interface. All attributes are set to optional, since it is impossible to say which properties can be found in each case. In that way, the data model is a maximum model. Also, when it comes to the positioning, a simple approach is used: GM_Point is used to describe a position in a latitude/longitude-system. GM_Point is a GeoMetrical point as defined in the standard *ISO19107 Geographic Information – Spatial schema*. Two or more GM_Points are used to indicate a curve. Three or more GM_Points are used to indicate an area. When further describing this model, the description of areas must be extended, for instance to follow the GML-standard similar to what is used in the S-100 framework. In the following, **Class** names are shown in bold, while *attribute* names are shown in italic.

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4.2 DYNAMIC OBJECTS


Source: Photo by Marianne Hagaseth, © 2026

For inland waterways, dynamic objects that need to be detected and classified, include [20]:

- Watercrafts:
  - Vessels, also including small crafts with no AIS or communication means. For vessels, its signs, boards and flags onboard must be detected separately from the hull and vessel constructions.
  - Floating constructions, which can be
    - floating equipment e.g. dredgers, cranes, pontoons, survey units
    - floating establishment e.g. floating docks, floating restaurants or platforms, construction bases
    - Assembly of floating material
  - Convoys, which can be towed, pushed, or side-by-side-constructions. These are a set of vessels and floating constructions that are moved as one unit, and either pushed or pulled by a motorized vessel.
- Living beings:
  - Persons or animals in the water
- Other floating (and possibly moveable) objects as for instance (see code list **OtherFloatingObjectTypeContentType**)
  - buoys set out for marking of fishing gear or an anchor,
  - logs/timber/wood,
  - debris such as lost containers, and
  - other trash floating in the navigable waters

The data model for dynamic objects is shown in Figure 6.

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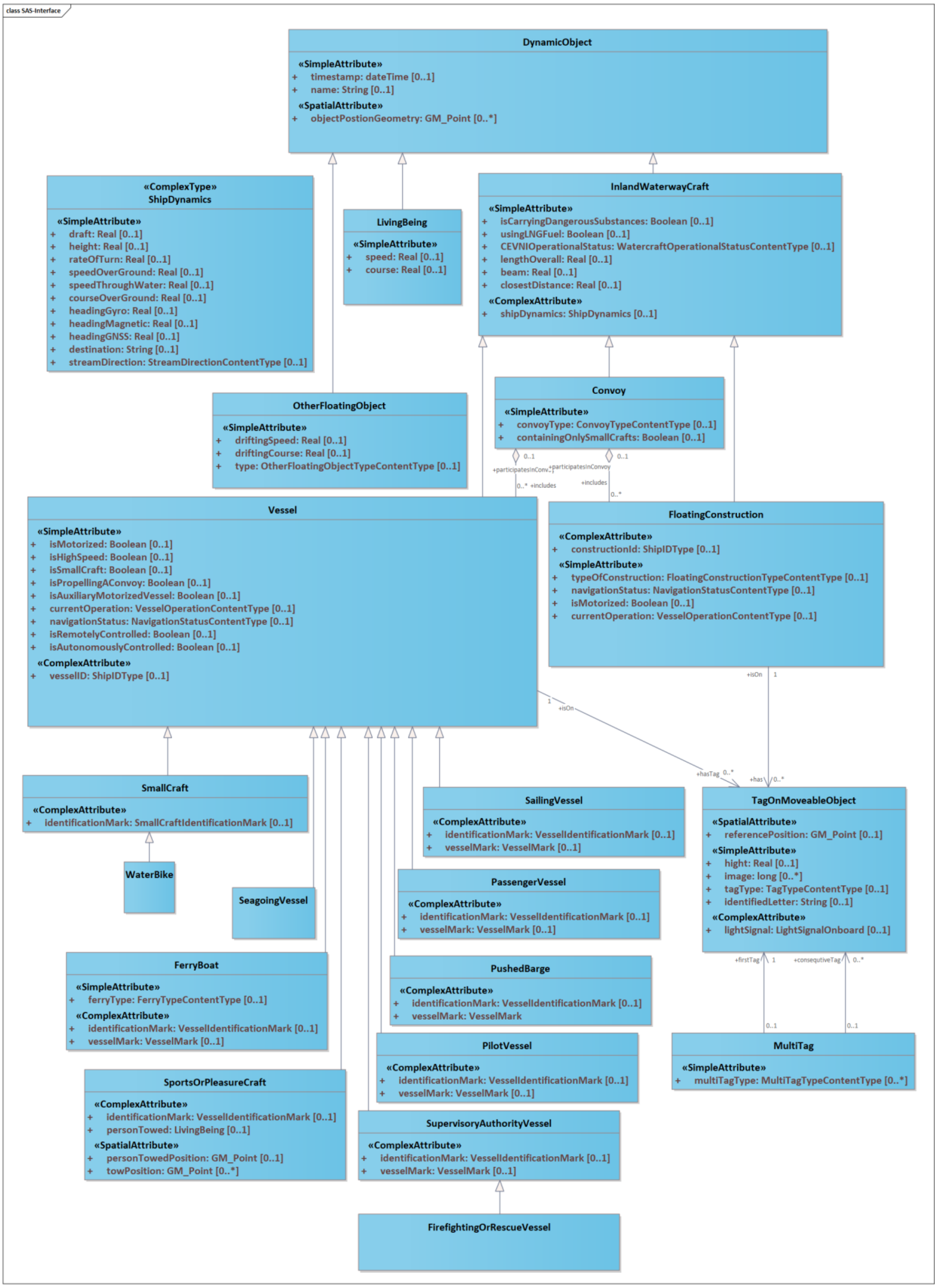

Figure 6 Interface model for dynamic objects

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Dynamic objects are grouped into three categories by specialization: **InlandWaterwayCraft**, **LivingBeing** and **OtherFloatingObject**.

The class **DynamicObject** has the following attributes, which are inherited by all its subclasses:

- *timestamp*: Each measurement from a sensor has a timestamp attached to it saying when the measurement was recorded. This is recorded in **SensorObservation**.*timestamp*. However, the *timestamp* given here, gives the time when the calculation of the position attribute of the **DynamicObject** instance was finalized, possibly based on fusion of information from several sensors.
- *name*: The SAS can assign a name or code for the object detected, for internal use by the ANS.
- *objectPostionGeometry*: This is a list of **GM_Points** that gives the latitude/longitude-position of the dynamic object. This builds on a specific set of **SensorObservation**s, where **SensorObservation**.*timestamp* is the point in time when each of the position observations were made. The *objectPositionGeometry* is a single position (latitude/longitude) for signs, buoys and marks, and a list of two or more positions (latitude/longitude) for infrastructure objects (bridges, lock basins, and weirs).
- *positionObservation:* This is the set of sensor observations that the positioning of the dynamic object is based on.

4.2.1. INLANDWATERWAYCRAFT

The following attributes are added for **InlandWaterwayCraft:**

- *isCarryingDangerousSubstances*: Is true if the craft is carrying dangerous substances. Berthing in case of transport operations involving dangerous substances is described in Article 7.07 in [20]. Information about a vessel carrying dangerous substances is found by detecting markers on the vessel.
- *usingLNGFuel*: Is true if the craft is using LNG as its fuel. Passage through locks are regulated in Arcticle 6.28 in [20], where special rules apply for vessels that are using LNG. Information about a vessel using LNG is found by detecting markers on the vessel.
- *CEVNIOperationalStatus*: This is of type **WatercraftOperationalStatusContentType,** and this contains information about a watercraft's operation as described by the CEVNI code [20] in several of its rules. The values are: Stationary, Under way/proceeding, Stopped and Engaged in fishing. This is a simpler and shorter list than what is provided in the navigational status information in the iAIS messages that conforms with the International Standard for Tracking and Tracing on Inland Waterways [33]. This, more extensive code list, is given in **NavigationalStatusContentType**, and this is relevant only for vessels and floating constructions, not for convoys.
- *lengthOverall*: Length of craft.
- *beam*: Width of craft.
- *closestDistance*: The closest distance from own ship to a detected vessel. This information comes in addition to the information about the current positioning of own vessel and the current positioning of the detected craft.
- *shipDynamics*: This is of type **ShipDynamics** and contains a set of dynamic values for the craft as described in Section 4.7 .

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- *IdentificationMarks*: Every vessel, except small craft and seagoing vessels, shall bear identification marks on its hull or on fixed boards or plates. This information is represented in the complex type **VesselIdentificationMark**. For small crafts, the complex type **SmallCraftIdentificationMark** is used for the relevant identification information.

An **InlandWaterwayCraft** can be of three different categories, represented by three sub-classes: a **Vessel**, a **Convoy** or a **FloatingConstruction**. A **Convoy** consists of one or more **Vessel**s and/or one or more **FloatingConstruction**s, where exactly one of the vessels taking part in the convoy is the vess/el that is propelling the convoy.

4.2.1.1. VESSEL

The specializations of **Vessel**, namely, **SmallCraft**, **WaterBike**, **SeagoingVessel**, **FerryBoat**, **SupervisoryAuthorityVessel**, **PilotVessel**, **PassengerVessel**, **PushedBarge**, **FirefightingOrRescueVessel**, **SailingVessel**, and **SportsOrPleasureCraft** is defined according to the CEVNI Code. These categories are implemented in the data model by adding the respective classes as subclasses or sub-subclasses of **Vessel**. The **Vessel** class contains the following attributes that are inherited by all vessel types:

- *isMotorized*: True, if the vessel is using its engine.
- *isHighSpeed*: True if the vessel is defined as a high-speed vessel according to the CEVNI Code, otherwise false. This excludes small crafts. This needs to be a separate attribute, since vessels of different categories can be defined as high-speed vessels.
- *isSmallCraft*: True if the vessel is defined as a small vessel or craft according to the CEVNI Code, otherwise false. This excludes passenger vessels, ferry-boats, pushed barges, and some types of push/tow/propel vessels. This needs to be an attribute, even if we have a separate class for **SmallCraft**, since also vessels of other categories, can be defined as small crafts.
- *isPropellingAConvoy*: This is true, if the vessel is currently propelling a convoy. Each convoy must have exactly one vessel that is propelling it.
- *isAuxiliaryMotorizedVessel*: A vessel can be an *auxiliary motorized vessel* which means that in the context of a convoy this vessel is a secondary, motorized craft that travels immediately ahead of or alongside a primary convoy (such as a pushed, towed, or side-by-side formation).
- *currentOperation*: This describes the special operation that the vessel is carrying out according to the CEVNI code, and this includes the values Engaged in underwater diving, Engaged in minesweeping, and Carrying out work e.g. surveying, measuring, dredging (**VesselOperationContentType**)
- *vesselID* is the various identifications of the vessel possibly found by AIS messages, or by other means. This includes call sign, IMO number, MMSI number, registration port and country, ENI, ship name, and possible an official name. For this attribute, we use the complex type **ShipIDType**, taken from ISO28005, with additions to fit requirements in the CEVNI code. The ENI is the unique European vessel identification number which can be found in iAIS-messages or read from the hull. For IWT vessels that do not have this number assigned, an official number is assigned to it, and this number can be read from the hull.
- *navigationStatus*: This is the navigational status given by the iAIS-messages as described in [33] and added to the code list **NavigationStatusContentType**.

- *isRemotelyControlled* and *isAutonomouslyControlled*: This is used for MASS to indicate whether the vessel is remotely controlled or autonomously controlled.
- *participatesInConvoy*: This indicates if this vessel is participating in a convoy. The convoy is described by the **Convoy** class.
- *hasTag*: This is a list of tags that are identified on the detected vessel, including for instance flags, lights, pennants, boards, signs, and other day signals as balls, cylinders and cones. This information is according to the attributes in class **TagOnMoveableObject**. This class is further described in Section 4.2.4.

4.2.1.1.1. SMALLCRAFT

SmallCraft has *identificationMark*: The name and owner of a small craft as detected from the vessel's hull (**SmallCraftIdentificationMark**). Water bikes are explicitly mentioned as a type of craft by the CEVNI code (**WaterBike**).

4.2.1.1.2. SEAGOINGVESSEL

The possibility of having seagoing vessels sailing on inland waterways is explicitly mentioned in the CEVNI code. However, this type of vessel (**SeagoingVessel**) does not have any extra attributes, compared to what is inherited from the super-classes.

4.2.1.1.3. FERRYBOAT

FerryBoat has the following attributes in addition to the attributes that are inherited from the super-classes:

- *ferryType*: The type of ferry, which can be a free-running ferry or a cable ferry.
- *identificationMarks*: Vessels that are not small crafts, can have more detailed marks on them to identify them. This is covered by the class **VesselIdentificationMark**. This is typically found by detecting the marks on the hull or other places on the vessel. **VesselIdentificationMark** is shown in Figure 19.
- *vesselMark*: This is information about the maximum draught level and whether a vessel is using LNG as fuel. This information is not relevant for small crafts. This information is described in the class **VesselMark**.

4.2.1.1.4. SAILINGVESSEL, PASSENGERVESSEL, PUSHEDBARGE, PILOTVESSEL AND SUPERVISORYAUTHORITYVESSEL

The classes **SailingVessel**, **PassengerVessel**, **PushedBarge**, **PilotVessel** and **SupervisoryAuthorityVessel** all have the same attributes, in addition to those attributes inherited from the super-classes:

- *vesselMark*: Same as for ferry boats, Section 4.2.1.1.3.
- *identificationMarks*: Same as for ferry boats, Section 4.2.1.1.3.

In addition to this, **SupervisoryAuthorityVessel** also have a sub-class **FirefightingOrRescueVessel**, inheriting all attributes from its super-classes.

4.2.1.2. CONVOY

A convoy consists of one vessel, which is propelling the convoy, and one or more vessels and/or floating constructions. A convoy has the following attributes, according to the CEVNI code:

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- *convoyType*: This describes the type of convoy, which can be Towed, Pushed or Side-by-side, according to **ConvoyTypeContentType**.
- *containingOnlySmallCrafts*: This is true, if the convoy is a collection of only small crafts.

4.2.1.3. FLOATING CONSTRUCTION

Source: Photo by Marianne Hagaseth, © 2026

A floating construction has the following additional attributes as described in the class **FloatingConstruction**, and according to the CEVNI code:

- *constructionId*: Similar to **Vessel**.*vesselID*, as described in Section 4.2.1.1.
- *typeOfConstruction*: According to the CEVNI code, a floating construction can be of three different types, as described in **FloatingConstructionTypeContentType**:
    - Floating Equipment e.g. dredgers, cranes, pontoons, survey units
    - Floating establishment e.g. floating docks, floating restaurants or platforms, construction bases
    - Assembly of floating material
- *navigationStatus*: Same attribute as for **Vessel**, see Section 4.2.1.1, except that for floating constructions only the statuses Under way and Stationary while working are used, according to the CEVNI Code.
- *isMotorized*: Same attribute as for **Vessel**, see Section 4.2.1.1.
- *currentOperation*: Same attribute as for **Vessel**, see Section 4.2.1.1.

4.2.2. LVINGBEING

Persons and animals in the fairway need to be detected by the sensors onboard. For simplicity, the class **LivingBeing** holds the speed and course of such objects, in addition to the inherited timestamp, name and position from **DynamicObject**.

4.2.3. OTHERFLOATINGOBJECT

The **OtherFloatingObject** class is used for other drifting objects in the water that is recognized by the sensors and that may affect the safe navigation of the MASS. This class gives the drifting speed and course, and it also indicates the type of object as listed in **OtherFloatingObjectTypeContentType**: Marking buoy, timber, debris, other trash, fishing gear and canoe.

4.2.4. ONBOARD SIGNS, FLAGS AND OTHER OBJECTS

Signs, flags and other objects onboard are described in the class **TagOnMoveableObject**, with the following attributes:

- *referencePosition*: This is the position onboard the vessel or the floating construction where the tag is detected. It is given by a geographical latitude/longitude-position and can be compared with the **DynamicObject**.*objectPositionGeometry* of the position of the whole vessel or floating construction to make sure that this position is related to the actual hull or construction.
- *hight*: This is the hight of the tag above the waterline.
- *image*: This is the images of the tag that is detected from the sensors.
- *tagType*: This is the type of the tag that is detected onboard, taken from the code list **TagTypeContentType**. **TagTypeContentType** is a list of various types of signs, flags and other objects onboard that are used for various kinds of signalling. These can be e.g. flags, pennants, signs, boards, floating markers attached to the vessel, lights, balls, cylinders, cones or bicones. A set of one or more signs are described by the class **MultiTag**.
  MultiTag: This class was added to handle the case where several tags constitute one signal, as it is important that the SAS can detect and classify a set of signs or lights, not only single observations. This class contains the following attributes:
  - *firstTag*: This is a link to the first tag detected onboard.
  - *consecutiveTag*: This is a link to the rest of the tags detected onboard.
  - *multiTagType*: This is the type of the collection of tags that was detected. The codes in the code list are identifying various types of vessels, convoys, and floating equipment by their set of day and night signals, as listed in **MultiTagTypeContentType**.
- *identifiedLetter*: This contains a letter or text that is identified on the tag.
- *lightSignal*: This is the identified light signals onboard as described in the class **LightSignalOnboard**, with the following attributes:
  - *colour*: The colour of the light (red, white, green, yellow, blue)
  - *intensity*: The intensity of the light (bright, strong, ordinary)
  - *flashingType*: The flashing pattern of the light that is observed (continuous, scintillating, quick scintillating, sending SOS, or being dark)
- *hasTagObservation*: This gives the timestamp for the sensor information, in addition to the relevant sensor information.

Source: Photo by Marianne Hagaseth

Source: Photo by Marianne Hagaseth, © 2026

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4.3 FIXED OBJECTS (SCENARY)

The scenery includes fixed objects that are detected by the sensors, mainly cameras and radars, and possibly by lidars, such as:

- **GeographicalObject:** Geographical objects, e.g. navigable waters and waterways and information about the shorelines and banks.
- **Sign** and **Buoy:** Information about signs, buoys and light signals along the sailing route
- **Infrastructure**: Information about infrastructure as bridges, locks, weirs, aqueducts, and overhead structures and others.

The class **FixedObject** contains the following attributes that are inherited to the sub-classes:

- *waterwayType*: This is the type of waterway that the object is located in, as described by the code list in **IWWTypeContentType** (main, tributary or harbour), and as defined in the CEVNI Code.
- *objectPostionGeometry*: This is a list of **GM_Points** that gives the latitude/longitude-position of the dynamic object. This builds on a specific set of **SensorObservation**s, where **SensorObservation**.*timestamp* is the point in time when each of the position observations were made (*hasPositionObservation*). **Sign**s, **Buoy**s and **Mark**s have a position geometry consisting of one GM_Point. **GeographicalObject**s and **Infrastructure** objects will have a geometry consisting of two **GM_Point**s (a line) or more **GM_Point**s (a curve or an area). More complex shapes are possible according to the GML-standard used by S-100, and this can be added to a final version of this standard. In this draft version of the standard, we describe curves and areas as a list of points.
- *timestamp*: Each measurement from a sensor has a timestamp attached to it saying when the measurement was recorded. This is recorded in **SensorObservation**.*timestamp*. However, this *timestamp* gives the time when the calculation of the position attribute of the **FixedObject** instance was finalized, possibly based on fusion of information from several sensors.
- *image*: This is the image of the fixed object that is detected by the sensors, most often by some cameras.

FixedObject has following direct sub-classes:

- **Sign**
- **GeographicalObject**
- **Buoy**
- **Mark**
- **Infrastructure**, which includes the sub-classes **OverheadStructure**, **Bridge** and **LockBasinWeir**.

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Figure 7 shows the interface model for fixed objects.

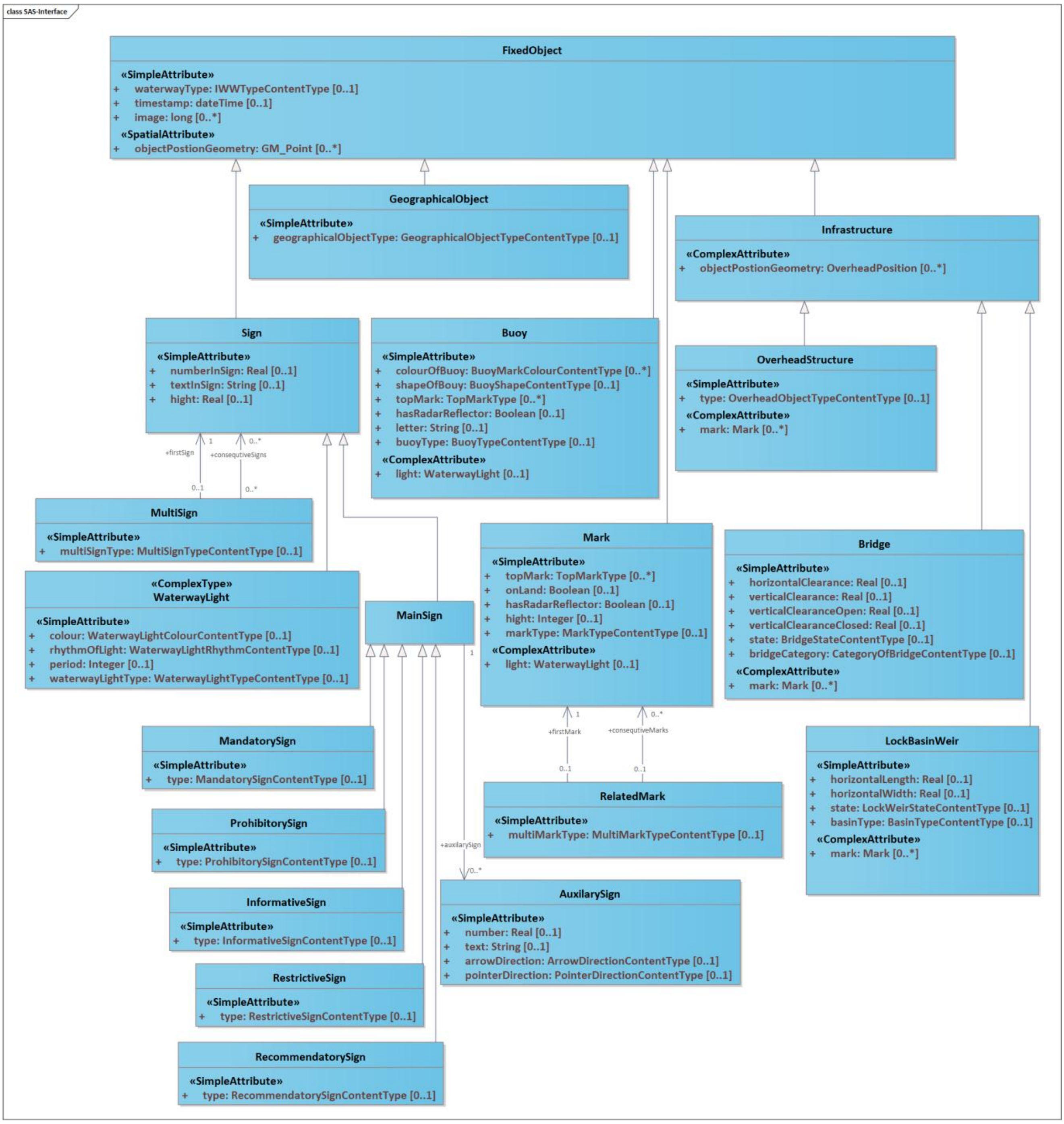

Figure 7 Interface model for fixed objects (scenery)

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4.3.1. SIGNS


Source: Photo by Marianne Hagaseth, © 2026


Source: Photo by Marianne Hagaseth, © 2026

This section describes properties related to waterway signs that are found along the inland waterways and that are described in the CEVNI code [20]. The different types of signs are modelled as specialization of the **Sign** class, namely the **MainSign** class and the **WaterwayLight** class. The **MainSign** class contains signs which are boards with the symbol on it, and with a certain shape. **MainSign** does not contain lights. **WaterwayLight**s are light signals that are used for traffic regulation and navigation. These light signals do not have any boards, just the light. The **MainSign** and the **WaterwayLight** classes inherit the attributes from the **Sign**-class. Some of the **MainSign**s and the **WaterwayLight**s have the same semantics, one expressed with boards, and the other with lights.

The **Sign** class has the following attributes:

- *numberInSign*: Some of the signs contain a number that must be read by the SAS, for instance the speed limit, or the number of meters from the sign that the message on the sign is valid, measured from the sign. This attribute contains the number that is read by the sensors.
- *textInSign*: Similarly, some signs have text in it or an extra sign over or beneath the main sign that gives more details in the form of text. This attribute is used to hold this text.
- *hight*: This is the height in meters of the main part of the sign above water level.

4.3.1.1. MULTISIGN

For several of the signs, both **MainSign**s and **WaterwayLight**s, a set of two or more signs must be read and interpreted together, not as separate signs/lights. Examples are signs used to indicate a distance along the waterway or an area, for instance the waiting area before a bridge or weir. Another example is the traffic lights in front of bridges or locks, which can consist of more than one light. For this, we use the class **MultiSign** to represent the relationship between two or more signs (*firstSign* and *consequtiveSign*). The line or area is defined by the positions of the signs. The class **MultiSign** contains a reference to the first sign in the group of signs, a reference to the consecutive signs in the group of signs, and the type of the group of signs (*multiSignType*) as described by the code list in **MultiSignTypeContent** class.

4.3.1.2. MAINSIGN

The **MainSign** class has the following sub-classes: **MandatorySign**, **ProhibitorySign**, **InformativeSign**, **RestrictiveSign**, and **RecommendatorySign**.

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MainSign inherits the attributes from **Sign** and have the attribute *auxiliarySign* in addition: *auxiliarySign* is of type **AuxilliarySign**, and it contains information about detected signs that are attached to main signs, for instance signs with text that describes more details about the main sign. **AuxilliarySign** has the following attributes:

- *number*: The number that is detected on the auxiliary sign.
- *text*: The text that is detected on the auxiliary sign.
- *arrowDirection*: The direction that the main sign is valid for (left, right, or up) (**ArrowDirectionContentType**)
- *pointerDirection*: The direction that the main sign is valid for (left or right) (**PointerDirectionContentType**)

4.3.1.1. WATERWAYLIGHT

The **WaterwayLight** contains detected light signals along the waterway or in the waterway. Typical light signals are traffic lights in front of bridges and locks to show the status of the these. **WaterwayLight** can be part of a **Mark** or a separate signal. **WaterwayLight** has the following attributes:

- *colour*: The colour of the detected light (green, red, yellow, white) as listed in the enumerated type **WaterwayLightColourContentType** .
- *rhythmOfLight*: This is the rhythm of the light on the buoy or the mark that are detected by the sensors, for instance fixed, occulting, flashing, or rhythmic light with a certain period. If the light is not fixed, but follows a certain rhythm that is not known, the code "Rhythmic light" is used. Also, the sensors can also detect a light that is off, meaning that this attribute is set to "Dark". This code list is described in the type **WaterwayLightRhythmContentType**.
- *period*: This is the period of the rhythm of the lights, in seconds.
- *waterwayLightType*: This is the type of the light when one light can be interpreted separately. This code list is described in **WaterwayLightTypeContentType**. For lights that consists of a set of two or more lights, **MultiSign**.*multiSignType* with the code list in **MultiSignTypeContentType** is used to represent the interpretation of these lights.

4.3.1.2. SUB-CLASSES OF MAINSIGN

The sub-classes of **MainSign** each have a *type* attribute in addition to the attributes inherited from **MainSign**. The *type* attribute has the following code list for each of the classes, respectively:

- **MandatorySign: MandatorySignContentType**
- **ProhibitorySign: ProhibitorySignContentType**
- **InformativeSign: InformativeSignContentType**
- **RestrictiveSign: RestrictiveSignContentType**
- **RecommendatorySign: RecommendatorySignContentType**

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4.3.2. GEOGRAPHICAL OBJECTS


Source: Photo by Marianne Hagaseth, © 2026

An important task for the SAS is to identify geographical objects to be able to give a clear picture of the scenery that can be sent to the ANS for further analysis. The class **GeographicalObject** has the attribute *geographicalObjectType* which indicates the type of the geographical object identified by the SAS. This value is fetched from the code list described in the class **GeographicalObjectTypeContentType**, and this code list contains values as fairway, bunkering area, specific risk area, waterway, port area, loading/unloading zone, shoreline and bank.

4.3.3. BUOYS


Source: Photo by Marianne Hagaseth, © 2026

The class **Buoy** describes buoys that are detected during the voyage. A buoy is always located in the water. They are floating on the water and are anchored to the seabed.

- *colourOfBuoy*: This is the colour of the buoy itself. One buoy can have one or more colours, e.g. stripes of two different colours. When the buoy has several colours, the values are indexed starting from the bottom and upwards. The class **BuoyMarkColourContentType** contains the colours green, red, yellow, blue, white, black indicating which colours can be used for buoys according to the CEVNI Code.
- *shapeOfBuoy*: The buoy can be conical, cylindrical, spherical or a spar, according to the code list in class **BuoyShapeContentType**.
- *topMark*: A buoy can have several top marks, each of them with one or more colours (stripes) and with a certain shape. The top marks are numbered from the bottom to the top, starting with index 1. The topMark is of type **topMarkType**.
  topMarkType: This describes the possible top marks that can be placed on top of a buoy. These top marks have one or more colour(s) (**BuoyMarkColourContentType**) and a certain shape (**MarkShapeContentType**)
- *hasRadarReflector*: Whether the buoy has a radar reflector or not.
- *letter*: Buoys can also have some letters printed on them. For instance, a letter "P" painted in white on the buoys indicates that the fairway is adjacent to a berthing area.

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- *buoyType*: This contains the description of the type of buoy found, according to the CEVNI code, and listed in the enumerated type **BuoyTypeContentType**. Examples of types are buoys to limit the fairway, cardinal buoys, and special buoys.
- *light*: Some buoys and marks have a light attached to it. The information about detected lights is listed in **WaterwayLight**, see Section 4.3.1.1. If no lights are detected, this attribute is empty.

4.3.4. MARKS


Source: Photo by Marianne Hagaseth, © 2026
Source: Photo by Marianne Hagaseth, © 2026

Marks that are detected during the voyage are used for navigation by the vessel. Marks can be located on land or in the water. They are fixed to the ground, both in water and on land. They can also be fixed on an auxiliary craft positioned on the water to draw attention to an obstacle or a danger point. For these marks, the sign is placed on top of a pile. Marks can also be placed on horizontal piles, for instance to mark the distance from the shoreline.

Marks can also be placed on overhead cables or pipelines to identify this when they are crossing the fairway. The attributes that are specific for **Mark**s, are described here:

- *topMark*: A mark can have several marks on top of the pile, each of them with one or more colours (stripes) and with a certain shape. The top marks are numbered from the bottom to the top, starting with index 1. This is similar to the *topMark* attribute for **Buoy**s as described in Section 4.3.3.
- *onLand*: A mark is either placed on land (true) or in the water (false).
- *hasRadarReflector:* whether the buoy has a radar reflector or not.
- *hight*: For some marks, for instance marks on overhead cables, the estimated hight above water level is relevant.
- *markType*: This contains the description of the type of mark found, according to the CEVNI code, and listed in the enumerated type **MarkTypeContentType**. This includes marks to indicate the position of the channel in relation to the banks, marking of cross-overs, marking of danger points, marking of bridge pillars, and overhead cables.
- *light*: A mark may also have a light on top it, with the same characteristics as for lights on a buoy, see Section 4.3.3.

The SAS also needs to detect patterns of marks, where several marks must be understood together, as a whole. Examples of this is alignment marks and cross-over marks. This is handled by the class **RelatedMark**, which contains a reference to the *firstMark*, a reference to the *consecutiveMarks*, in addition to the type of the pattern of marks that are detected (*multiMarkType*), as described in the enumerated type **MultiMarkTypeContentType** (cross-over or alignment).

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4.3.5. INFRASTRUCTURE


Source: Photo by Marianne Hagaseth, © 2025

This section describes the attributes for infrastructure elements that are detected by the sensors onboard. The data model for bridges, locks, and overhead cables is set up based on the manually created classes based on information from the Inland ENC Harmonization group Draft Encoding guide for Inland ENCs, 2024. This is based on work done in WP4, deliverable D4.5 in this project. However, for the SAS, we have only included the attributes that we suppose are the attributes that can be decided by the SAS through its sensors and by doing sensor fusion. The ANS will import this information and use this together with information from the chart to possibly enhance the information about the infrastructure by using other sources than the sensors and sensor fusion, for instance other sources of the status of the bridges, locks and overhead cables. Examples of information that is not included here is the vertical datum of the bridge, information about the accuracy, and information about the location code and the MRN (Maritime Resource Name).

The class **Infrastructure** overrides the attribute *objectPositionGeometry* from **FixedObject**. The attribute *objectPositionGeometry* is of type **OverheadPosition**, which includes both the latitude/longitude position in addition to the free height in meters above water level. *objectPositionGeometry* indicates the position of the cable, the bridge or the entrance of the lock with two or more data points. The free height is not relevant for locks, and it is only relevant for bridges that does not open completely.

4.3.5.1. OVERHEADSTRUCTURE

The **OverheadStructure** has the following attributes:

- *type*: This is the type of the overhead structure, either cable or pipeline. The code list is described in class **OverheadObjectTypeContentType.**
- *mark*: Overhead cables can be marked with for instance several radar reflectors to indicate the free hight under the cable. For this, we use the **Mark** class, but only the attributes *hasRadarReflector*, *hight*, and *markType* are used.

In addition, we have the attribute *objectPositionGeometry* (a list of latitude/longitude and free height) that is inherited from **FixedObject** that describes the positioning and height of the cable or pipeline.

4.3.5.1. BRIDGE

The **Bridge** class has the following attributes:

- *horizontalClearance*: The width of the bridge in meters that is available for safe navigation, as detected by the sensors onboard. This may, or may not, be the same as the total physical width of the object.
- *verticalClearance*: The vertical clearance measured from the plane towards the bridge.
- *verticalClearanceOpen*: The vertical clearance of the bridge in opened condition (e.g. an opened lifting bridge) measured from the plane towards the bridge overhead.
- *verticalClearanceClosed*: The vertical clearance of the bridge in closed condition (e.g. an opened lifting bridge) measured from the plane towards the bridge overhead.
- *state*: The state of the bridge according to **BridgeStateContentType** (open, closed, fixed, is closing, is opening)
- *mark*: This is the list of marks related to a bridge, for instance to show where to pass under the bridge, where the free height is largest, or floats or piles that marks the bridge's piers. Detailed information about these marks, including the position, is described in the class **Mark**, see Section 4.3.4.
- *bridgeCategory*: The category of bridge can be for instance fixed bridge, swing bridge, lifting bridge, aqueduct, suspendion bridge or a bridge arc, as described by the encoding guide for inland ENC [22] and listed in **CategoryOfBridgeContentType**.

In addition, we have the attribute *objectPositionGeometry* (a list of latitude/longitude and free height) that is inherited from **FixedObject**, and that describes the positioning and height of the bridge.

4.3.5.2. LOCKBASINWEIR

The **LockBasinWeir** class has the following attributes:

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- *horizontalLength*: The length of the lock basin or weir.
- *horizontalWidth*: The width of the lock basin or weir.
- *state*: **LockWeirStateContentType** contains a code list saying whether the lock is open, closed, is being opened or is being closed.
- *basinType*: The basin type is lock or weir, according to **BasinTypeContentType**.
- *mark*: This is the list of marks directly related to a lock or weir. Detailed information about these marks, including the position, is described in the class **Mark**, see Section 4.3.4. In additions, signs and other marks close to the lock or weir is also related to this infrastructure, but this is registered separately from the **LockBasinWeir**-information.

In addition, we have the attribute *objectPositionGeometry* (a list of latitude/longitude and free height) that is inherited from **FixedObject**, and that describes the positioning of the lock or weir entrance.

4.4 SOUND OBJECTS

Especially at night, during reduced visibility and in difficult navigational situations, sound signals are important. This information is described by the class **SoundSignal** with the following attributes, Figure 8:

- *typeOfEquipment*: This gives the type of equipment that is used to create the sound, whether it is a bell, trumpet/horn, a mechanically operated device or just striking of metal on metal (**SoundSignalEquipmentTypeContentType**)
- *duration*: This is the duration of the sound signal, if it is short, long or a series of very short blasts (**SoundSignalBlastTypeContentType**)
- *tone*: The sound signal can be one tone or three tones (**ToneTypeContentType**)
- *soundObservation*: The timestamp and sound observation related to the **SoundSignal**.

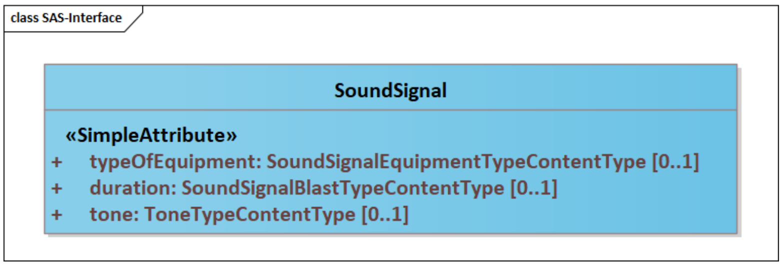

Figure 8 Interface model for sound signals

Other attributes could have been interesting, for instance the direction of the sound, and this can be added here. Also, other sounds than what is described in **SoundSignal** can be detected by the sensors onboard, for instance the sound of a ship's engine. This is currently not covered in this draft interface description.

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4.5 ENVIRONMENTAL CONDITIONS


Source: Photo by Marianne Hagaseth, © 2026

Environmental conditions include information such as winds, waves, currents, tides and visibility. [24] describes an ontology for digital maritime regulations that structures the regulatory text itself, and also the ship properties including its equipment, cargo, activities, and journey, the weather conditions and also the roles and organization. This ontology is intended to be used for easy searching in the regulatory text to explore what regulations are valid in different cases and also as a help to write new and consistent regulations. In our context, we can reuse some of the properties defined for instance for a maritime situation, that is, for weather conditions. Further, from the IMO Compendium, we have weather information as shown in Figure 9 (from [14]). This is based on definitions from WMO [36].

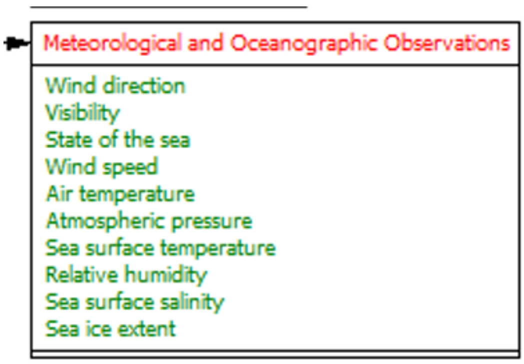

Figure 9 Weather information from the IMO Compendium (Source: [14])

Based on this, we propose the following interface model for environmental data as shown in Figure 10, including the following attributes:

- *windDirection*: The true direction in degrees from which wind is blowing.
- *visibility*: The horizontal visibility at surface or visibility towards the sea.
- *seaState*: State of the water surface in an alighting area, based on the height of waves. The value is taken from code table 3652 in [36], and contains the values as described in **SeaStateContentType**. This may be relevant for lakes that are part of inland waterways, where waves can set up.
- *windSpeed*: The wind speed.
- *airTemperature*: The measure of air temperature in degrees Celsius at own ship location.
- *atmosphericPressure*: The measure of the barometric pressure of the own ship environment in atmosphere or bars.
- *seaSurfaceTemperature*: The temperature of the sea.

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- *currentDirection*: True direction of the current.
- *weatherObservation*: This is the link to the sensor observations and the timestamp related to the weather observations.

Other measurements that are needed by the CEVNI Code can be calculated from the timestamp, for instance whether the time of the day is day or night.

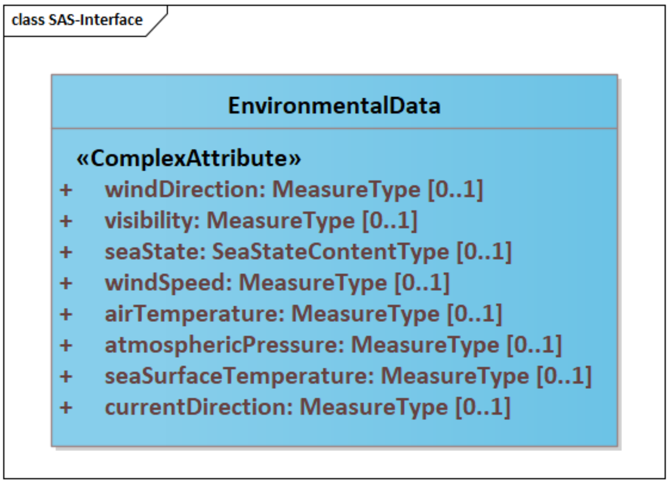

Figure 10 Interface model for environmental observations

4.6 ENUMERATED TYPES

All code lists are contained in enumerated types where the class name ends with **ContentCode**. These types are listed throughout this section for each part of the interface model.

4.6.1. ENUMERATED TYPES FOR FIXED OBJECT TYPES

The enumerated types that are used by the fixed objects are shown in Figure 11, Figure 12 and Figure 13.

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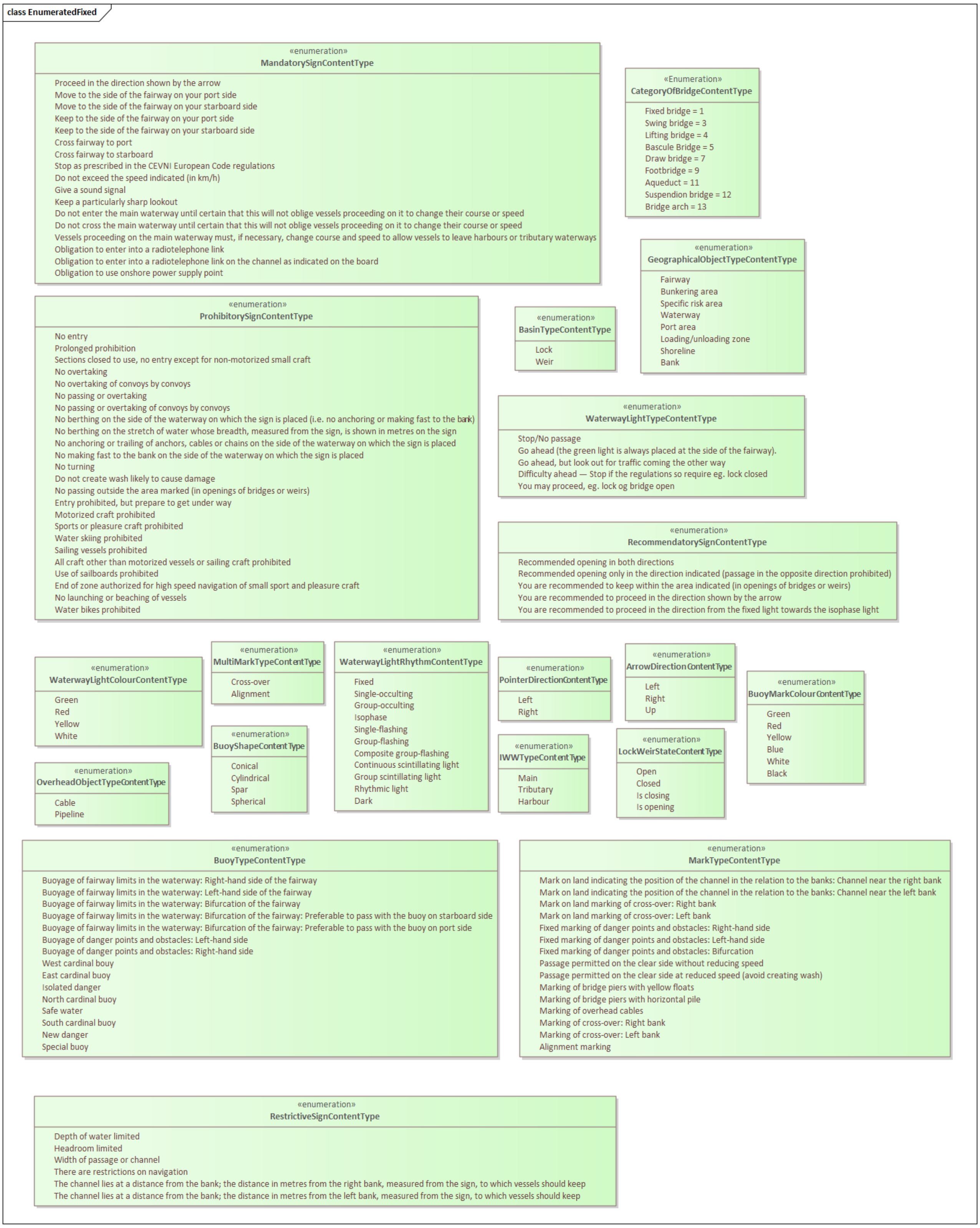

Figure 11 Enumerated Types for Fixed Objects – part 1

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class EnumeratedFixed

«enumeration»
InformativeSignContentType

Entry permitted (general sign)
Overhead cable crossing
Weir
Ferry-boat not moving independently
Ferry-boat moving independently
Berthing (i.e. anchoring or making fast to the bank) permitted on the side of the waterway on which the sign is placed
Berthing permitted on the stretch of water of the breadth measured from, and shown on the board in metres
Berthing permitted on the stretch of water bounded by the two distances measured from, and shown on the board in metres
Maximum number of vessels permitted to berth abreast on the side of the waterway on which the sign is placed
Berthing area reserved for vessels intended for navigation by pushing that are not required to carry the marking prescribed in article 3.14 on the side of the waterway on which the sign is placed
Berthing area reserved for vessels intended for navigation by pushing that are required to carry one blue light or one blue cone under article 3.14, paragraph 1, on the side of the waterway on which the sign is placed
Berthing area reserved for vessels intended for navigation by pushing that are required to carry two blue lights or two blue cones under article 3.14, paragraph 2, on the side of the waterway on which the sign is placed
Berthing area reserved for vessels intended for navigation by pushing that are required to carry three blue lights or three blue cones under article 3.14, paragraph 3, on the side of the waterway on which the sign is placed
Berthing area reserved for vessels other than vessels intended for navigation by pushing that are not required to carry the marking prescribed in article 3.14 on the side of the waterway on which the sign is placed
Berthing area reserved for vessels other than vessels intended for navigation by pushing that are required to carry one blue light or one blue cone under article 3.14, paragraph 1, on the side of the waterway on which the sign is placed
Berthing area reserved for vessels other than vessels intended for navigation by pushing that are required to carry two blue lights or two blue cones under article 3.14, paragraph 2, on the side of the waterway on which the sign is placed
Berthing area reserved for vessels other than vessels intended for navigation by pushing that are required to carry three blue lights or three blue cones under article 3.14, paragraph 3, on the side of the waterway on which the sign is placed
Berthing area reserved for all vessels that are not required to carry the marking prescribed in article 3.14, on the side of the waterway on which the sign is placed
Berthing area reserved for all vessels that are required to carry one blue light or one blue cone under article 3.14, paragraph 1, on the side of the waterway on which the sign is placed
Berthing area reserved for all vessels that are required to carry two blue lights or two blue cones under article 3.14, paragraph 2
Berthing area reserved for all vessels that are required to carry three blue lights or three blue cones under article 3.14, paragraph 3, on the side of the waterway on which the sign is placed
Anchoring or trailing of anchors, cables or chains permitted on the side of the waterway on which the sign is placed
Use of spuds permitted
Making fast to the bank permitted on the side of the waterway on which the sign is placed
Berthing area reserved for loading and unloading vehicles. (Maximum duration of berthing permitted may be added on an information plate below the board)
Turning area
The waterways being approached are considered to be tributaries of this waterway (crossing)
The waterways being approached are considered to be tributaries of this waterway (from right)
The waterways being approached are considered to be tributaries of this waterway (from left)
This waterway is considered to be a tributary of the waterway being approached (crossing)
This waterway is considered to be a tributary of the waterway being approached (entering)
End of a prohibition or obligation applying to traffic in one direction only, or end of a restriction
Difficulty ahead – stop if the regulations so require
You may proceed
Drinking-water supply
Telephone
Motorized vessels permitted
Sports or pleasure craft permitted
Water skiing permitted
Sailing vessels permitted
Craft other than motorized vessels or sailing craft permitted
Use of sailboards permitted
Zone authorized for high speed navigation of small sport and pleasure craft
Launching or beaching of small craft permitted
Possibility of obtaining nautical information by radiotelephone on the channel indicated
Water bikes permitted
Electrical power supply point
Winter harbour
Maximum number of vessels permitted to berth in winter harbour
Winter shelter
Maximum number of vessels permitted to berth in winter shelter/abreast or Maximum number of rows of vessels which are berthed abreast

Figure 12 Enumerated Types for Fixed Objects – part 2

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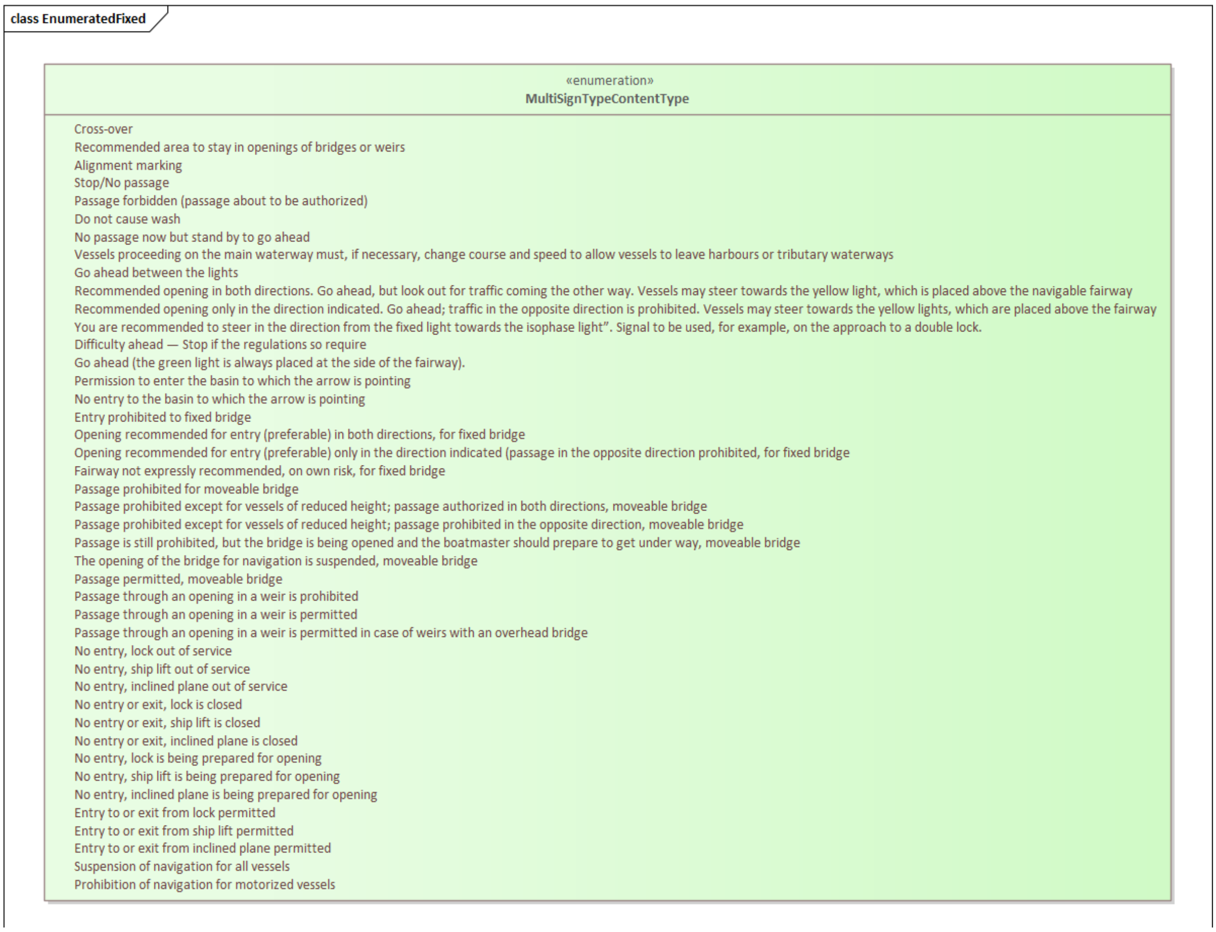

Figure 13 Enumerated Types for Fixed Objects – part 3

4.6.2. ENUMERATED TYPES FOR DYNAMIC OBJECT TYPES

Figure 14 and Figure 15 shows the enumerated types that are used by the classes describing dynamic objects. One example of how a code list is set up can be given for the enumerated type **NavigationalStatusContentType.** According to [23], the AIS denotes the following navigational status for a vessel:

- under way using engine
- at anchor
- not under command
- restricted manoeuvrability
- constrained by her draught
- moored
- aground
- engaged in fishing
- under way sailing

The rest of the codes in this code list are added from reading the CEVNI Code [20].

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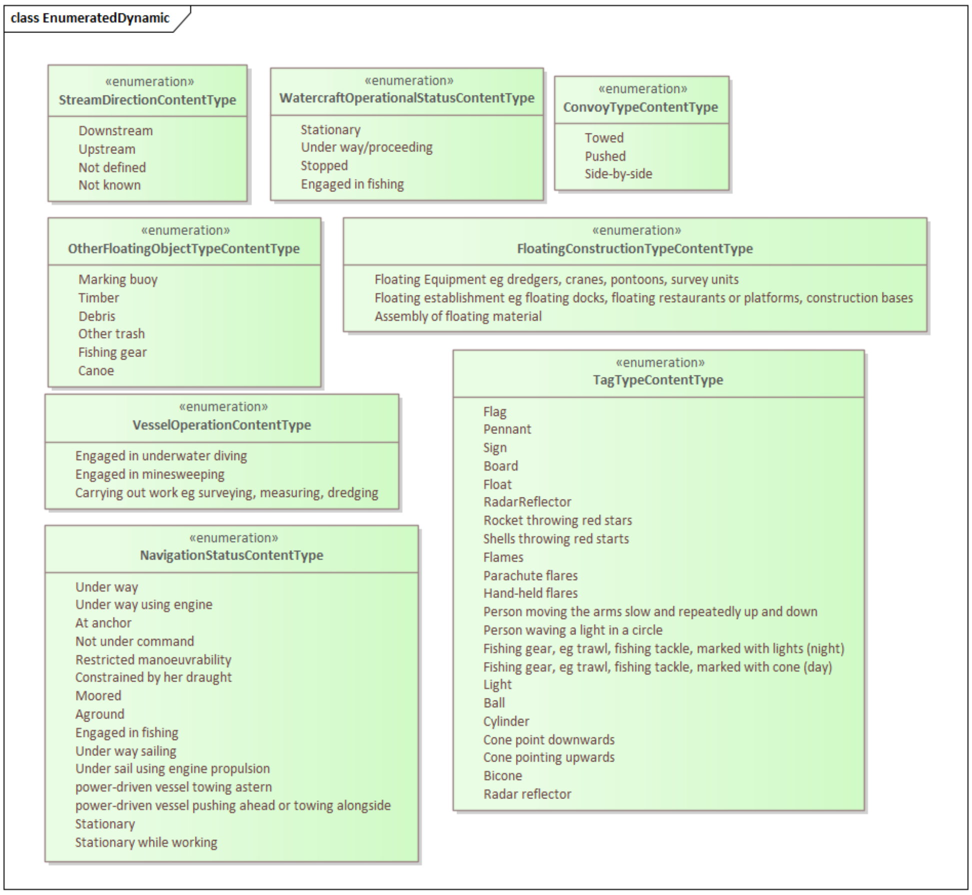

Figure 14 Enumerated Types for Dynamic Objects – Part 1

class EnumeratedDynamic

«enumeration»
MultiTagTypeContentType

Motorized vessels proceeding alone
Motorized vessels proceeding alone with a second masthead light
Motorized vessel temporarily preceded by an auxiliary motorized vessel
High-speed vessel proceeding alone
Motorized vessel leading a towed convoy or as an auxiliary.
Each of several motorized vessels leading a towed convoy or as auxiliaries, when several vessels are proceeding side by side.
Towed vessels
Section of a towed convoy more than 110 m long
Section of a towed convoy comprising a row of more than two vessels coupled side by side
Last section of a towed convoy
Towed vessels forming the last section of a convoy
Towed seagoing vessels coming directly from or leaving for the sea
Pushed convoys
Pushed convoys, when more than two vessels other than the pusher are visible from astern over the full width
Pushed convoys preceded by one or more auxiliary motorized vessels
Pushed convoys with two pushers
Side-by-side formations: two motorized vessels
Side-by-side formations: one motorized and one non-motorized vessel
Side-by-side formations preceded by one or more auxiliary motorized vessels
Sailing vessels
Vessels proceeding under sail and making use at the same time of its own mechanical means of propulsion
Motorized small craft proceeding alone
Motorized small craft proceeding alone with side lights side by side or in the same lamp at or near the bow
Motorized small craft proceeding alone: the masthead light replaced by a bright white light visible from all directions
Motorized small craft less than 7 m long proceeding alone
Small craft towed or propelled in side-by-side formation
Small sailing craft
Small sailing craft, with side lights and a stern light in the same lamp near the top of the mast
Sailing small craft less than 7 m long carrying a white light visible from all directions, and on the approach of other vessels displaying a second ordinary white light
Small craft proceeding alone, neither motorized nor under sail
Additional marking for vessels carrying out certain transport operations involving dangerous flameable substances
Additional marking for vessels carrying out certain transport operations involving dangerous substances constituting health hazards
Additional marking for vessels carrying out certain transport operations involving explosives
Additional marking of pushed convoys carrying out certain transport operations involving certain flameable substances
Additional marking of pushed convoys carrying out certain transport operations involving substances constituting health hazards
Additional marking of pushed convoys carrying out certain transport operations involving explosive substances
Additional marking of side-by-side formations carrying out certain transport operations involving certain flameable substances
Additional marking of side-by-side formations carrying out certain transport operations involving substances constituting health hazards
Additional marking of side-by-side formations carrying out certain transport operations involving explosive substances
Additional marking of pushed convoys propelled by two pushers placed side by side and carrying out certain transport operations involving certain flameable substances
Additional marking of pushed convoys propelled by two pushers placed side by side and carrying out certain transport operations involving substances constituting health hazards
Additional marking of pushed convoys propelled by two pushers placed side by side and carrying out certain transport operations involving explosive substances
Vessels authorized to carry more than 12 passengers with a hull length of less than 20 m
Ferry-boat not moving independently
Leading boat or float of a longitudinal-cable ferry-boat
Ferry-boat moving independently
Vessel having priority of passage
Additional marking for vessels unable to manoeuvre
Assemblies of floating material and floating establishments under way
A stationary vessel that is not a ferry-boat, not a floating equipment at work, or not a stationary vessel carrying out work or sounding or measuring
Vessel stationary offshore
Pushed convoys stationary offshore
Small craft stationary offshore
Additional marking for stationary vessels carrying out certain transport operations involving certain flameable substances
Additional marking for stationary vessels carrying out certain transport operations involving substances constituting health hazards
Additional marking for stationary vessels carrying out certain transport operations involving explosive substances
Additional marking for stationary pushed convoys carrying out certain transport operations involving certain flameable substances
Additional marking for stationary pushed convoys carrying out certain transport operations involving substances constituting health hazards
Additional marking for stationary pushed convoys carrying out certain transport operations involving explosive substances
Additional marking for stationary side-by-side formations carrying out certain transport operations involving certain flameable substances
Additional marking for stationary side-by-side formations carrying out certain transport operations involving substances constituting health hazards
Additional marking for stationary side-by-side formations carrying out certain transport operations involving explosive substances
Ferry-boat not moving independently when made fast at their landing stage
Ferry-boat moving independently, in service, made fast at their landing stage
Assemblies of floating material and floating establishments when stationary
Stationary vessels engaged in fishing with nets or poles
Floating equipment at work and stationary vessels carrying out work or sounding or measuring operations; fairway clear on both sides
Grounded or sunken vessels; fairway clear on both sides
Floating equipment at work and stationary vessels carrying out work or sounding or measuring operations; fairway clear on one side
Grounded or sunken vessels; fairway clear on one side
Floating equipment at work and vessels carrying out work or sounding or measuring operations and grounded or sunken vessels; protection against wash; fairway clear on both sides
Floating equipment at work and vessels carrying out work or sounding or measuring operations and grounded or sunken vessels; protection against wash; fairway clear on one side
Vessels whose anchors may be a danger to navigation
Assemblies of floating material or floating establishments whose anchors may be a danger to navigation
Anchors of vessels, assemblies of floating material or floating establishments that may be a danger to navigation
Additional marking for vessels of the supervisory authorities and firefighting and rescue services
Additional marking for vessels under way carrying out work in the waterway
Additional marking for protection against wash
Distress signals
Additional marking for vessels whose ability to manoeuvre is limited
Additional marking for vessels whose ability to manoeuvre is limtied; fairway clear on one side
Additional marking for vessels engaged in drawing a trawl or other fishing gear through the water (trawler)
Fishing vessels other than trawlers if the fishing tackle extends more than 150 m horizontally from the vessel
Additional marking for vessels used for underwater diving
Additional marking for vessels engaged in minesweeping
Additional marking for vessels on pilotage service
Meeting: Vessels proceeding upstream which leave the course of those proceeding downstream on their starboard

Figure 15 Enumerated Types for Dynamic Objects – Part 2

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4.6.3. ENUMERATED TYPES FOR SOUND AND ENVIRONMENTAL OBJECTS

Figure 16 shows the enumerated types that are used by the classes **SoundSignal** and **EnvironmentalData**.

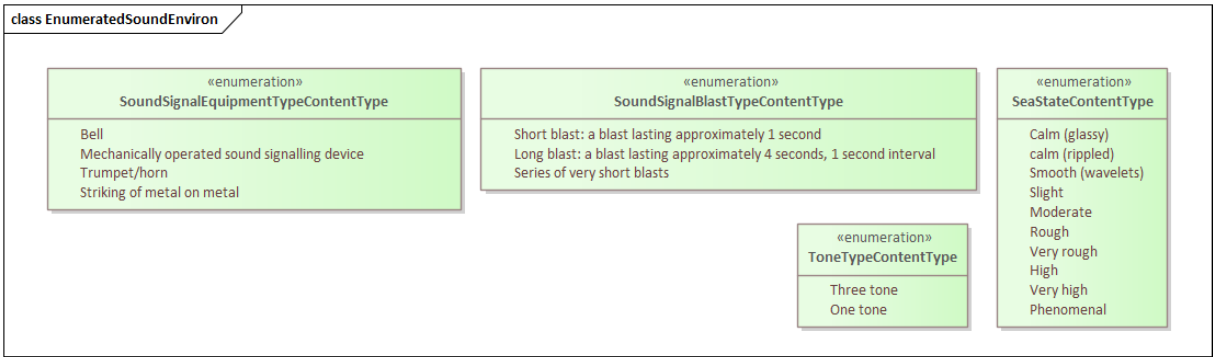

Figure 16 Enumerated Types for **SoundSignal** and **EnvironmentalData** classes

4.6.4. ENUMERATED TYPES FOR COMPLEX TYPES

Figure 17 shows the enumerated types that are used by attributes in the complex types.

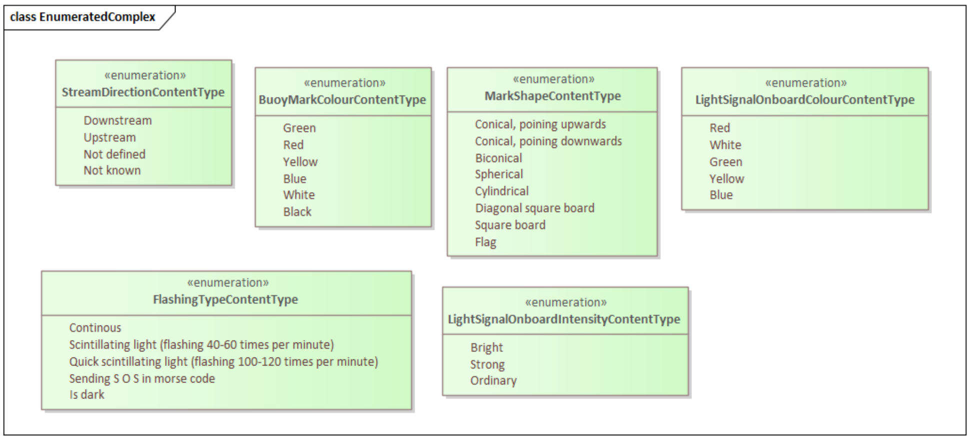

Figure 17 Enumerated Types for Complex Types

4.6.5. ENUMERATED TYPES FOR SENSOR DATA

Figure 18 shows code lists that are relevant for sensors and sensor data.

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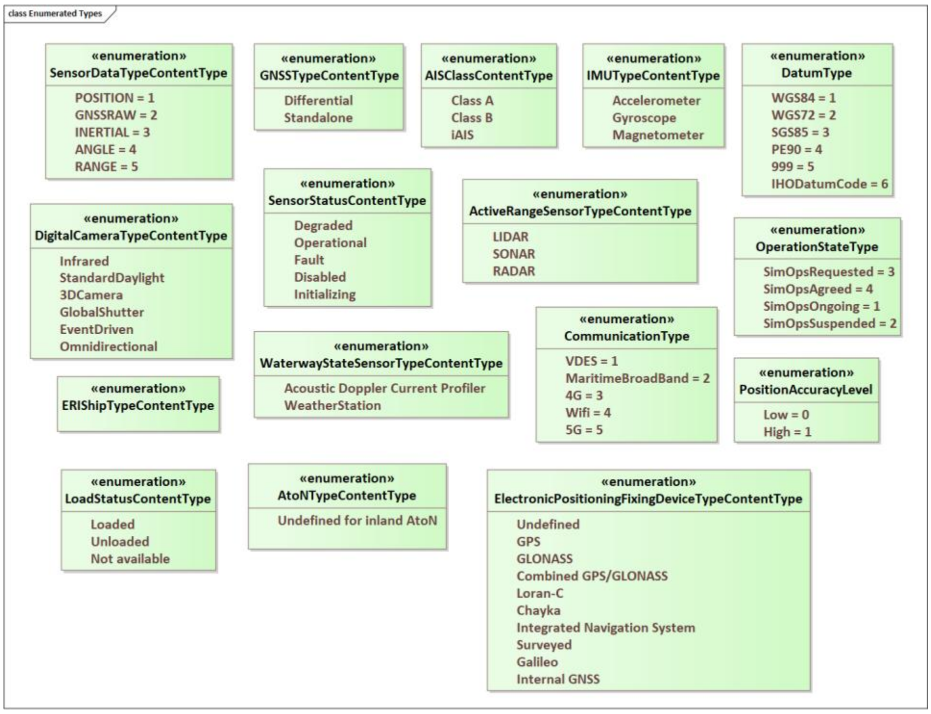

Figure 18 Enumerated types for sensors and sensor data

4.7 COMPLEX TYPES

Figure 19 shows the classes of complex types that are used in this interface model. In addition, we have listed the **dateTime** and **MeasureType** data types here. We will not go through all these classes, only mention three of them: **ShipDynamics**, **MeasureType** and **GM_Point**.

ShipDynamics: The values of the attributes in the **ShipDynamics** class are typically found for vessels with AIS or iAIS messages available, as follows:

- *draft*: Maximum ship present static draught in meters and centimeters[3] taken from AIS or iAIS messages or by reading the marks on the craft.
- *height*: The height from the waterline to the highest point of the ship[4].
- *rateOfTurn*: The vessel's rate of turn.
- *speedOverGround*: The ship current speed over ground in decimal knots[5].
- *speedThroughWater*: The average speed through water, measured in knots[6].
- *courseOverGround*: The ship current course over ground indicated in the 360 degrees notation from true north.
- *headingGyro*: Heading from gyro compass (only for own vessel).
- *headingMagnetic*: Heading from magnetic compass (only for own vessel).
- *headingGNSS*: The heading as taken from the AIS or iAIS messages.

[3] Definition from IMO Compendium data element IMO0357.
[4] Definition from IMO Compendium data element IMO0379.
[5] Definition from IMO Compendium data element IMO0333.
[6] Definition from IMO Compendium data element IMO0616.

- *trueHeading*: The direction in which the ship is pointing with respect to true north, expressed in degrees[7].
- *destination*: Destination as found from the AIS or iAIS messages.
- *streamDirection*: For waterway crafts, we need to know whether the craft is moving upstream or downstream related to the CEVNI code rules. This indicates whether the craft is moving downstream or upstream, or if it is not known, or if the direction is not defined.

When describing a vessel, we also looked into the ISO 28005 standard and the results from the H2H-project, as described in Appendix B.

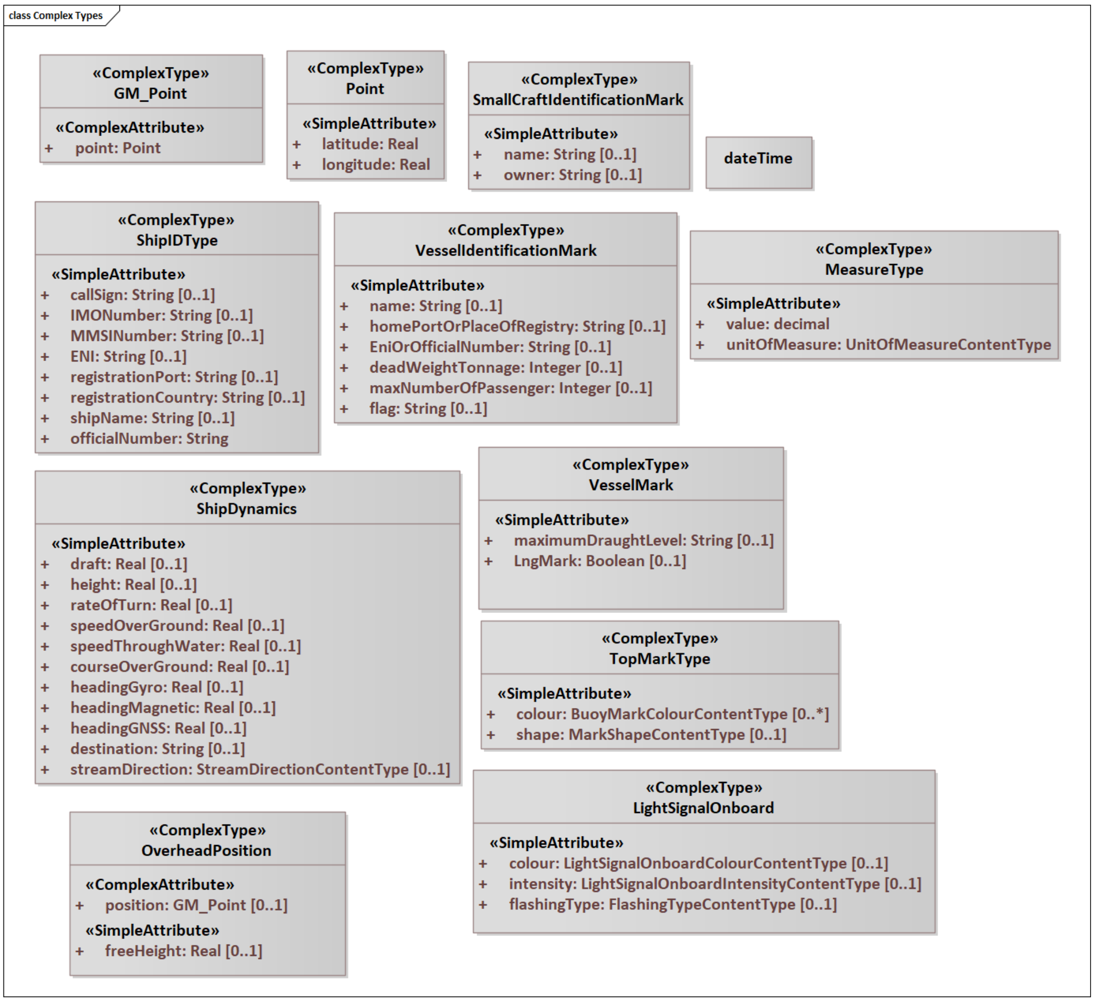

Figure 19 Classes for complex types

MeasureType: According to ISO19103, a **MeasureType** is defined containing a value and the related unit for this measurement. This is similar to what is used in S-100 (S100_Measure) and for Geography Markup Language (GML). For GML, the type gml:MeasureType is similarly used to represent a physical quantity as a numeric value paired with its unit of measure.

[7] Definition from IMO Compendium data element IMO0620.

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GM_Point: The geographic position in the map is modelled as **GM_Point**, which is the type used in the S-100 framework as ISO 19107, [25], and in the GML standard, [26]. This can be used to represent a position, where the Point is a latitude-longitude-pair described as decimal numbers.

4.8 OWN SHIP INFORMATION

Data for own ship is not part of the SAS-ANS-interface, but is added here for information, see Figure 20.

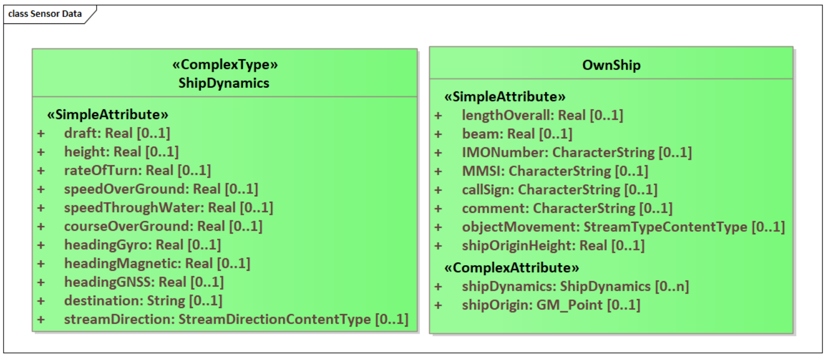


Figure 20 Own ship data

4.8.1. OWNSHIP

The **OwnShip** class is based on the ship data as found in the IMO compendium in [14]. An important part of this is the position of own ship. From [12], we have the following description of *Uncertainty Zone* which is used to define the position of the hull of a ship with a given uncertainty:

> *"The uncertainty zone represents the uncertainty in the outer boundary of the geometry of a ship or object of interest within an operational area, at a given time, as shown in* Figure 21 *as the red shadowed areas. [……..] The integrity requirement for the uncertainty zone is expressed as the probability that the actual position of the hull is outside the uncertainty zone at a point of interest. The actual meaning of the uncertainty zone can vary, depending upon the domain. Within the maritime domain, the users are familiar with error ellipses representing the 95% accuracy or 2σ, where sigma is the standard deviation. Other representation could be a protection level, which could be around 6σ over bounding of the error. The uncertainty zone is represented by a geometry around a given physical object (ship or fixed) with a certain probability given as number of sigmas."* [12], page 25.

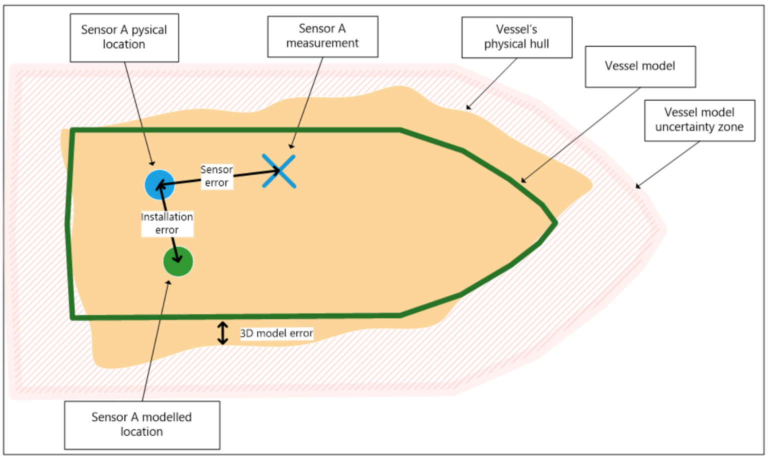


Figure 21 Various sensor uncertainties (Source: From [12])

However, in the context of autonomous navigation, we will only use the length, beam, *shipOrigin* and the *ownShipPosition* (latitude and longitude) to describe own ship's position.

4.8.2. SHIPDYNAMICS

The ShipDynamics class is described in Section 4.6.5.

4.8.3. SHIPORIGIN OF OWN SHIP

Information about the position of the sensors onboard own ship is important to be able to calibrate both cameras and other sensors used for object detection. In the Hull-to-Hull project [12], the term *virtual sensor* was used to represent a point related to the own ship origin at which a set of data values was calculated, based on some physical sensor data. In this data model, however, we do not use the concept of virtual sensors. Instead, we assume that the ANS has an overview of own ship, both the hull and the position of all sensors relative to the ship origin, where the *ship origin* is a point defined relative to the hull of own ship. The ship origin is defined in the x, y and z -directions, and is the reference point for all sensors and communication equipment onboard own ship.

For this interface, the geometry of own ship is described by a list of points, see the blue dots in Figure 22. Each of these points are related to the ship origo of own ship, and they are further mapped to geographical points latitude/longitude related to the datum of the chart. The position of the sensors for own ship is also related to own ship origo, see green dots in Figure 22.

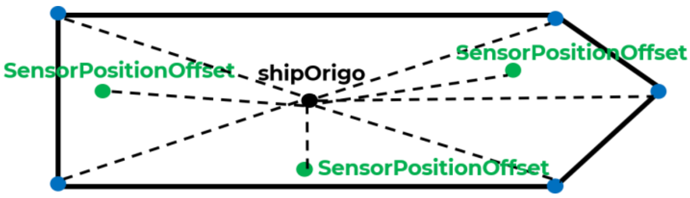
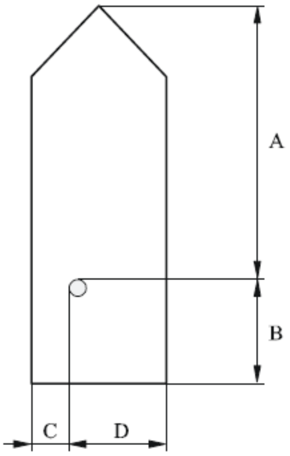


Figure 22 Ship origo, sensors' position, and ship geometry for own ship

From H2H [12], we also have the following:

"The ship origin is defined similar to what is done in [27], Figure 23, *for AIS positions, with the extension of the Z-direction. In addition, this origin is used as the reference point for all sensors onboard and also for the geometry model of the hull. The coordinate system follows the same definition as used by Kongsberg Seatex (B-frame) as shown in* Figure 24. *The distances are specified in meters including 2 decimals, meaning that each distance is specified by 16 bits."* [12]



	Number of bits	Bit fields	Distance (m)
A	9	0-8	0-511
B	9	9-17	0-511
C	6	18-23	0-63; 63 = 63 or greater
D	6	24-29	0-63; 63 = 63 or greater

Reference point of reported position not available, but dimensions of ship are available: A = C = 0 and B ≠ 0 and D ≠ 0.
Neither reference point of reported position nor dimensions of ship available; A = B = C = D = 0 (= default).
For use in the message table, A = most significant field, D = least significant field.

Figure 23 AIS Reference point for reported position and dimensions of ship (Source: [27])

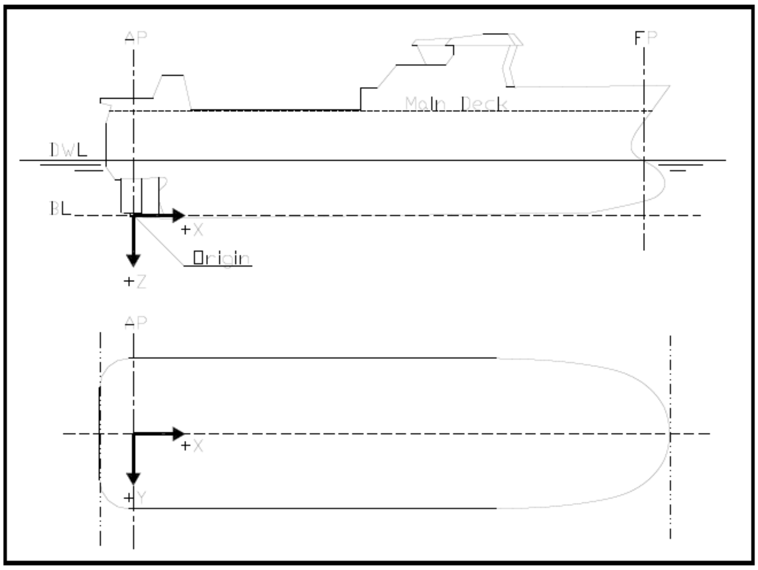
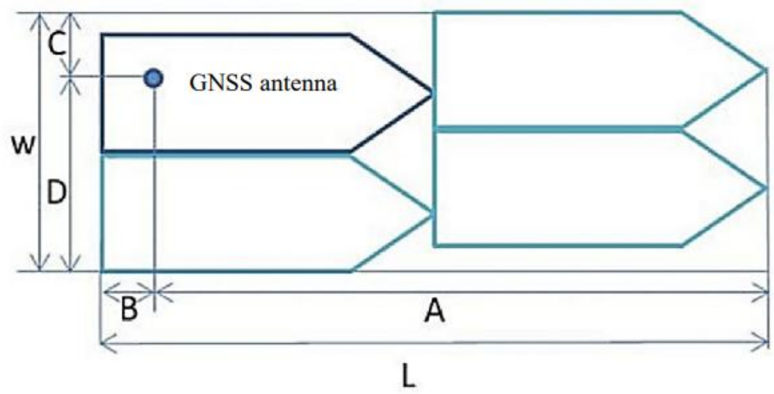


Figure 24 Location of origin and positive axis direction (Source: [12])

From [33], we have the following definition of the reference point for the GNSS antenna and other sensors on IWT vessels and convoys:



	Number of bits	*Bit fields*	*Distance (m)*	
A	9	Bit 21 – Bit 29	0 – 511 = 511 m or greater	Reference Point for reported position
B	9	Bit 12 – Bit 20	0 –511 = 511 m or greater	
C	6	Bit 6 – Bit 11	0 – 63 = 63 m or greater	
D	6	Bit 0 – Bit 5	0 – 63 = 63 m or greater	
L = A + B W = C + D	Defined in Inland FI 10			Overall dimension used in Inland AIS mobile station

The dimension should be in the direction of the transmitted heading information (bow).
Reference point of reported position not available, but dimensions of vessel/convoy are available:
A = C = 0 and B ≠ 0 and D ≠ 0.
Neither reference point of reported position nor dimensions of vessel/convoy are available:
A = B = C = D = 0 (= default). For use of the message table, A = most significant field. D = least significant field.

Figure 25 Reference point for reported position and overall dimension of the vessel/convoy (Source: [33])

In this interface model, we simplify the definition of *shipOrigin* to be the geographical position of the ship origin (latitude/longitude) and the height of the ship origin. Further, this means that the position of each of the sensors onboard own ship is described as an offset (**SensorPositionOffset**) from shipOrigo, as further described in the next section.

4.8.4. SENSORPOSITIONOFFSET CLASS

The H2H-project introduced the class ObjectPoint, which we will reuse here, with some simplifications [12]:

The ObjectPoint class represents a point that is related to a physical object, either a ship, another moveable object or a fixed object. For our use, we do not need to include the uncertainty of the position of the point. Further, for our use, the ObjectPoint represents the offset from the ShipOrigin of the position of a sensor onboard own ship. This means that the position of a sensor onboard own ship is represented by the ShipOrigin plus the sensor position offset. Therefore, we change the class name from ObjectPoint to **SensorPositionOffset** to better reflect our usage. **SensorPositionOffset** class contains the following attributes:

- *OffsetInABDirection*: distance in meters with two decimals from the ship's origo in A-B-direction (aft/forward), with the positive axis direction as shown in Figure 24.
- *OffsetInCDDirection*: distance in meters with two decimals from the ship's origo in C-D-direction (centre/side wise), with the positive axis direction as shown in Figure 24.
- *OffsetInEFDirection*: distance in meters with two decimals from the ship's origo in E-F-direction (keel), with the positive axis direction as shown in Figure 24.

A point in two dimensions is represented by OffsetInABDirection and OffsetInCDDirection. For a 3D point, OffsetInEFDirection must also be given.

4.9 SENSOR DATA

Information about the sensors and the raw sensor data is not directly part of the SAS/ANS Interface model, but it is discussed here for completeness. Figure 26 gives an overview of a proposed sensor model. The sensor classification here is based on results from the ReNew-project, see Appendix D.

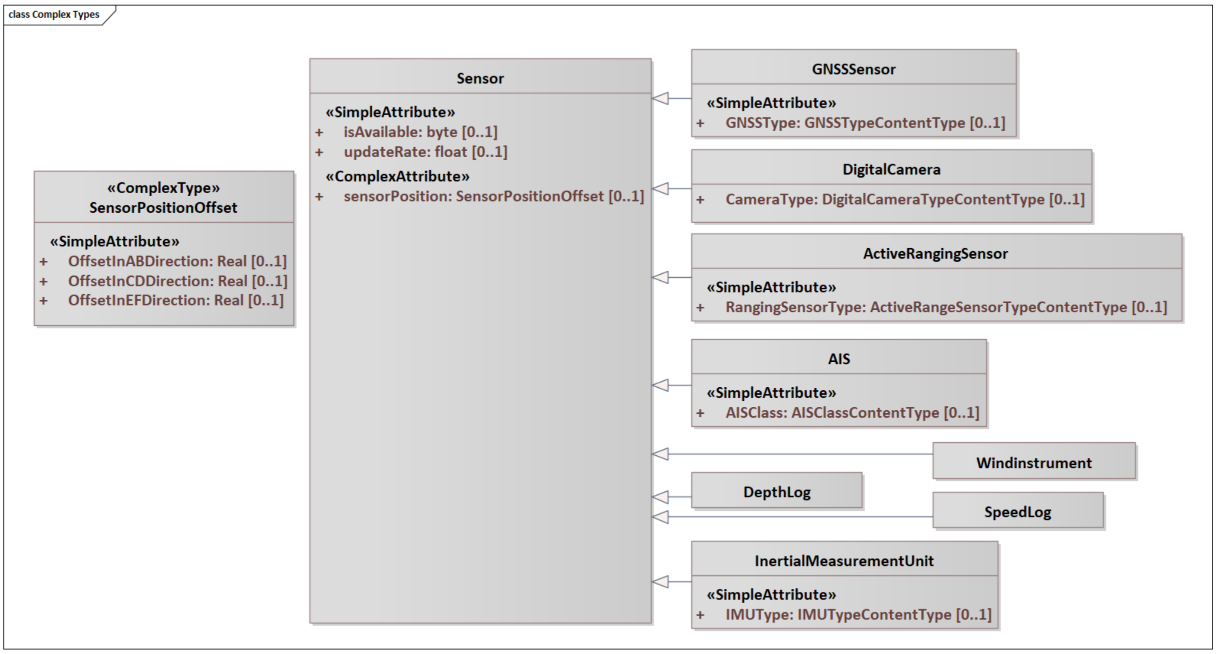


Figure 26 Sensor model

Figure 27 shows an example sensor data model that has been used when developing the SAS-ANS interface. Some of the classes are described in the following.

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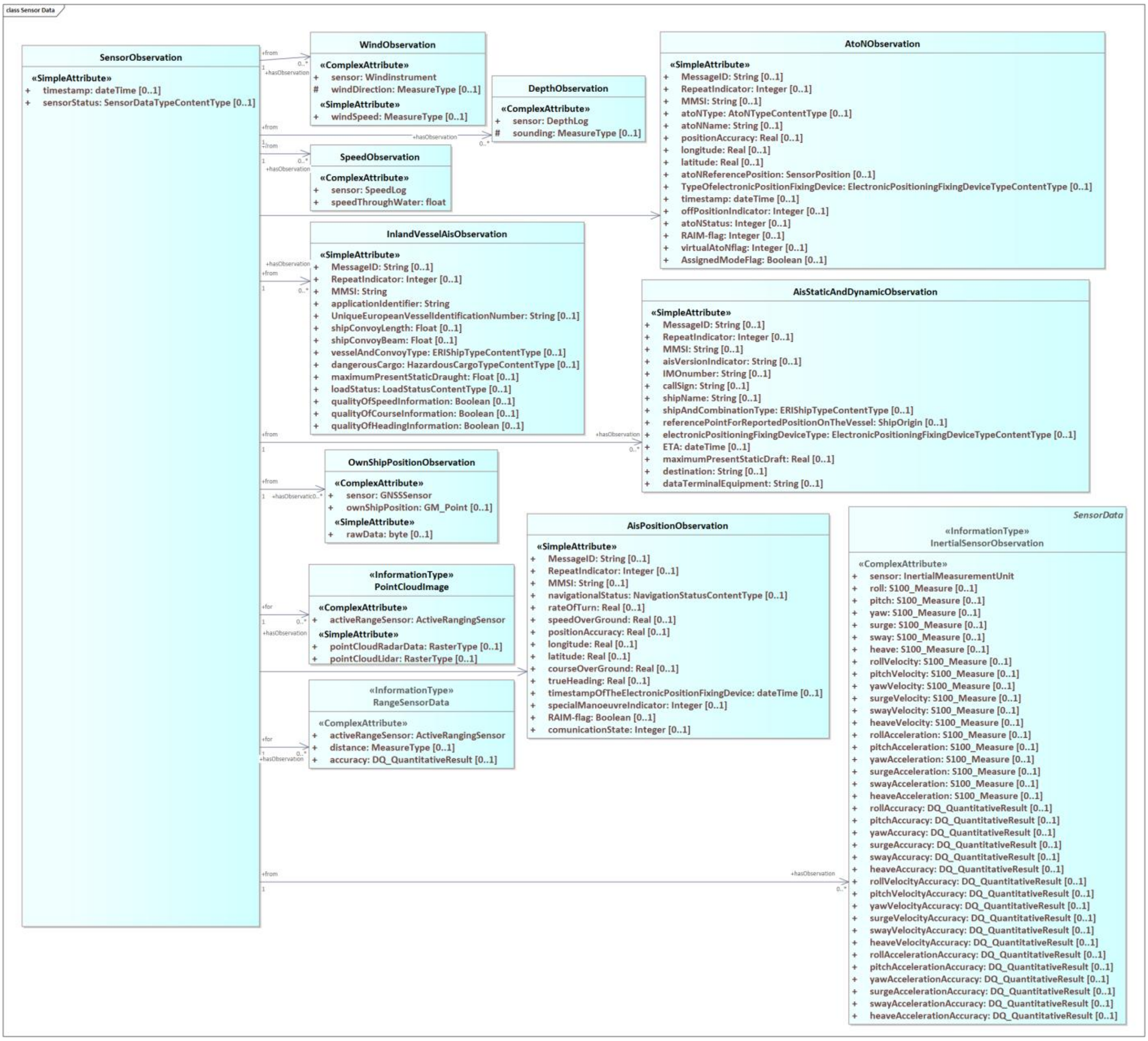

Figure 27 Example Sensor data model

4.9.1. OBJECT DETECTION

When a camera performs object detection and classification, it usually produces a data structure that describes:

- Timestamp: Time of detection
- frame-id: reference to the video image
- detected objects
- class/type: what the object is
- probability (confidence score): how certain the model is
- position in the image: bounding box (or pixel mask)
- trackingID: tracking identifier
- speed, depth, etc.

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4.9.1.1. WITH CAMERA

The steps in the object detection process by cameras are typically the following:

	Task	Description
1 SAS	Camera filming	Output raw sensor data (image frames)
2 SAS	Detection Model	What objects exist in this frame? Detect objects present in the scenery. Output: Produces the object classes, confidence and bounding box as rectangles in the image. Examples: vessel, buoy, bridge, lock, shoreline, floating object
3 SAS	Segmentation	Identify the exact occupied pixels/regions of objects, that is to find the pixels in the image: Output: Binary pixel mask or a polygon represented by a list of points, which may identify the hull outline, exact object outlines, waterline and free navigable space around the ship, bridges, lock basins etc.
4 SAS	Detect details in the objects	Examples: • For detected vessels: detect bow, stern, bridge, mast, signals (navigation lights, flags, other marks) and the position and geometry for this, • For bridges: pillars, clearance points e.g. lights and signs for passage point, access/wait lights, overhead construction or opened bridge, • For locks: lock basin layout, waterline, open/closed state, clearance points e.g. lights and signs for entrance
5 SAS	Determine details about an object's motion and orientation	Estimate precise spatial position and orientation. Combine detections from second step, masks/polygons from third step, and details from step four. From this, the output is the position in x, y, and possibly z -direction and information about the movement, heading and geometry of the detected object.

6 ANS	World mapping/geo-referencing	How to translate to geospatial coordinates in latitude/longitude with a datum-reference:
		• Need to know the following about the camera:
		  ○ camera GNSS position in latitude/longitude,
		  ○ camera orientation (yaw=which compass direction, roll= degrees shift in the horizontal direction),
		  ○ tilt angle (the pitch angle representing the downward rotation of the camera relative to the horizontal plane).
		  ○ camera height in meters above water,
		  ○ lens intrinsics (focal length to know the zoom level, optical centre to know the actual image centre, lens distortion coefficients to "flatten" the image),
		  ○ field of view in degrees (horizontal field of view (the observable area from side to side), vertical field of view (the observable area from top to bottom), diagonal field of view (the observable area from corner to corner)) ,
		• Need sensor fusion with camera, RADAR, LiDAR, AIS, GNSS (own ship position), IMU (own ship orientation) for latitude/longitude-positioning.

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	Task	Description
7 ANS	Kalman Tracking/Trajectory Estimation	Estimate motion over time and predict future states. Use Kalman filter, temporal filtering, motion models, noise reduction, multi-frame association to predict next position, speed, acceleration, trajectory, heading, turning rate prediction, and confidence/stability estimates, possibly also handling detection of noise, missing frames, occlusions, bad weather, and camera motion/shake. This is critical for collision predictions and to assess which COLREG/CEVNI rules to apply, that is, which traffic situations exist or may occur.
8 ANS	Navigation, automation, and analytics	Route planning, collision avoidance, rule-based manoeuvring, bridge and lock passage support.

4.9.1.1. WITH RADAR (POINT CLOUDS, RADAR DETECTIONS)

Radar is especially valuable in poor visibility (at night, in fog/rain/snow), when objects are partially covered, and when distance to the object is needed, also for long-range detections. Signal processing extracts targets from noise in raw radar images, with algorithms as CFAR (Constant False Alarm Rate), clustering, and thresholding. A RADAR identifies an object by:

- Position of the object in polar coordinates:
    - Range: distance from the radar in nm
    - Bearing: direction from the radar in degrees
- radial velocity: relative speed toward/away, relative to the radar
- RCS: radar cross section (target reflectivity)

4.9.1.2. WITH LIDAR

LIDAR can contribute to situation awareness by detecting other vessels, especially small ones without AIS, buoys and navigation marks, floating objects, and shorelines *on a close distance*. Also, LIDAR can more precisely than RADAR detect the 3D geometry and the accurate distance to the object. Information from objects detected from LIDARs typically includes:

- Position
- Velocity
- Dimensions
- Classification (vessel, buoy, obstacle etc)
- Confidence score

However, for MASS, LIDARs may have restricted usage, since they are typically only able to detect objects in the too close proximity of the sensor.

4.9.1.3. WITH IAIS

AIS and iAIS are very good sources of information for vessels that are transmitting those messages. Parameters defined by IALA for inland AIS systems are found in [32]. The class **InlandVesselAisObservation** contains information that are sent in AIS-messages only from IWT vessels. This comes in addition to the AIS message (message 5) sent by all vessels, also IWT vessels. In the interface model, this is listed in class **AisPositionObservation** and **AisStaticAndDynamicObservation**.

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This is in line with what is defined in the International Standard for Tracking and Tracing on Inland Waterways (VTT) (resolution No. 63) [33] and the respective ITU Recommendation [23]. At least the following data shall be transmitted:

a) User identifier (Maritime Mobile Service Identity, MMSI);
b) Name of vessel;
c) Type of vessel or convoy in conformity with the International Standard for Tracking and Tracing on Inland Waterways;
d) Unique European vessel identification number (ENI), or IMO number for sea-going vessels that have not been given an ENI number;
e) Overall length of the vessel or convoy in decimetre accuracy;
f) Overall beam of the vessel or convoy in decimetre accuracy;
g) Position (WGS-84);
h) Speed over ground (SOG);
i) Course over ground (COG);
j) Timestamp of the electronic position fixing device;
k) Navigational status in conformity with the International Standard for Tracking and Tracing on Inland Waterways;
l) Reference point for reported position on the vessel in metre accuracy (e.g. GNSS antenna);
m) Position accuracy

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5 TECHNICAL OUTLOOK

5.1 REPRESENTATION OF THE SAS-ANS INTERFACE MODEL

A promising approach for representing the interface model is to use knowledge graphs based on semantic web technologies such as RDF (Resource Description Framework) and OWL (Web Ontology Language), similar to what is described in [3], [4], [5], and [6]. These technologies provide a machine-readable representation of entities, relationships and constraints, enabling automated reasoning and facilitating the integration of external information sources. RDF provides a simple graph-based data model, while OWL extends RDF with formal semantics that support consistency checking, inference and validation of information. Such capabilities are particularly relevant for autonomous navigation systems, where information from several sources must be combined.

The use of an ontology-based data model also supports future interoperability between different vendors and system architectures. Information generated by the SAS can be expressed as semantic objects that are independent of any specific software implementation. This enables different suppliers to develop compatible SAS or ANS components while maintaining a common understanding of the exchanged information.

The interface information should be serializable into multiple implementation formats, including:

- XML for compatibility with existing maritime and river information systems;
- JSON or JSON-LD for lightweight service-oriented architectures;
- RDF/Turtle for semantic knowledge graph implementations;

The UML class diagrams presented in this document are kept at a conceptual level to ensure that they can be mapped to different implementation formats.

5.2 INTERFACE ARCHITECTURE

The proposed SAS–ANS interface should support event-driven communication patterns, since this is particularly suitable for dynamic information such as detected vessels, obstacle updates, sensor status changes, and other navigational warnings.

5.3 DETAILS OF SENSOR DATA

Autonomous navigation requires explicit handling of time-dependent information. Therefore, in an updated interface model, all dynamic entities exchanged between the SAS and ANS should contain timestamp of the observation, and also a validity period, sequence number, and confidence level. This allows the ANS to assess the freshness and reliability of information and to perform temporal reasoning when multiple observations are fused into a common world model.

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5.4 MORE DETAILS ON QUALITY AND UNCERTAINTY

A technical implementation of the conceptual interface model should give details on the quality and uncertainty of the data. The interface should therefore support representation of positional uncertainty, classification confidence, tracking quality indicators, sensor source information, and estimated accuracy of measurements.

5.5 REPRESENTATION OF GEOGRAPHICAL POINTS, CURVES AND AREAS

For a future operational standard, however, the geometric representation should be harmonised with the S-100 Universal Hydrographic Data Model and the upcoming S-401 Inland ENC standard. The S-100 spatial model is based on ISO 19107 and defines standardized geometric primitives for points, curves, surfaces and aggregates. S-100 Part 7 provides a spatial schema that supports a broad range of geometric representations while ensuring interoperability between hydrographic products. The geometry model should therefore also support multi-geometries and aggregated features where necessary.

All geographic positions should be referenced using a standardized coordinate reference system. For external interoperability, WGS 84 should be used as the default geographic reference system. Internally, implementations may use alternative local coordinate systems provided that unambiguous transformations are available. Each geometric object should contain metadata for the coordinate reference system, horizontal datum, geometric dimensionality (2D or 3D), and geometric accuracy.

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6 CONCLUSIONS AND DISCUSSIONS

6.1 SUMMARY OF WORK

This deliverable proposes a structured conceptual model for a standardized interface between the Situation Awareness System (SAS) and the Autonomous Navigation System (ANS) of autonomous inland waterway vessels. The proposed interface defines the information required to support autonomous navigation through the exchange of situation awareness data from the SAS to the ANS. This includes detected objects and their states, environmental conditions, sound signals, and infrastructure. The work contributes towards a common foundation for interoperable autonomous navigation systems and supports future standardization activities within both the maritime and inland waterway domains.

A central observation from this work is that the boundary between situation awareness and navigation is difficult to define precisely. While the SAS is responsible for detecting, classifying, and describing the world around the vessel, the interpretation of this information and the assessment of traffic situations are performed by the ANS. In practice, however, the interaction between the two systems is more complex than a simple one-way information flow. Information about the mission, navigational context, operational constraints, and chart-based features may influence how objects are detected, classified, and interpreted. Future developments should therefore investigate bidirectional information exchange mechanisms while maintaining a clear separation of responsibilities between perception and navigation functions.

The work has also highlighted several challenges regarding the information requirements for safe autonomous inland waterway navigation. AIS and inland AIS (iAIS) messages provide valuable information and is very important whenever available. However, autonomous vessels must also be capable of detecting and handling objects that cannot be identified through AIS data. For this reason, camera-based perception systems and radars are important for object detection and classification. The combination of AIS, radar, cameras, and other sensors through sensor fusion is necessary to achieve sufficiently robust situation awareness under varying operational conditions.

Sound signals represent another area where significant challenges remain. Sound-based communication continues to play an important role in inland waterway navigation, particularly during reduced visibility and in difficult manoeuvring situations. However, compared with visual detections and AIS-based information, sound signals are more difficult to detect, classify, and interpret automatically. Additional research is therefore required to determine the role that automated sound recognition should play in future autonomous navigation systems.

Another important discussion is the question of which object properties must be described to ensure safe navigation of autonomous inland waterway vessels. While regulations such as CEVNI provide guidance regarding vessels, signs, lights, marks, and waterway infrastructure, the exact information requirements for autonomous navigation have not yet been fully established. The proposed interface should therefore be regarded as a maximum information model, containing information that may be relevant for autonomous navigation, rather than a minimum implementation specification. Future operational testing and validation will be necessary to determine which information elements are required in different operational scenarios.

6.2 CLASSIFICATION CHALLENGES

One of the most difficult aspects of defining a standardized SAS–ANS interface is the classification of detected objects. While the concept of identifying an object may appear straightforward, different standards, regulations, and operational systems apply different classification schemes depending on the usage. As a result, the same physical object may be described differently by different systems.

For inland waterway navigation, the CEVNI code defines a number of vessel categories, including vessels, passenger vessels, ferry boats, sailing vessels, small craft, floating equipment, and seagoing vessels. However, these categories are not mutually exclusive. A detected vessel may simultaneously be classified as a motorized vessel, a small craft, a passenger vessel, and a high-speed vessel. Similarly, a vessel may participate in a convoy while still retaining its own vessel classification. This makes it difficult to model vessel types using a simple hierarchical classification structure.

Additional complexity arises because other standards use different classification schemes. Inland AIS messages use the ERI ship type classification, which contains a much larger number of specialized vessel categories. Inland ENC standards use yet another set of ship type classification to describe regulatory restrictions and navigational requirements. Consequently, a direct one-to-one mapping between the different classification systems is often impossible, and information may be lost when converting from one classification scheme to another.

The challenge is not limited to vessels. Similar problems exist for floating constructions, navigation marks, signs, infrastructure, and environmental observations. The level of detail required for autonomous navigation may differ from the level of detail used in charts, regulations, AIS reporting, or vessel registries. For example, a floating construction may be classified as floating equipment, floating establishment, or floating material according to CEVNI, whereas sensor systems may initially only be able to classify it as an unidentified floating object. The classification may therefore need to evolve as additional observations become available.

The classification challenge is also closely related to the architectural choice of whether chart information is available only to the ANS or also to the SAS. If the SAS has access to chart information, object detection and classification can benefit from contextual information

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about expected features in the environment. For example, a sensor detection at the charted location of a navigation mark, buoy, bridge structure, lock entrance, or traffic signal can increase confidence in the classification and reduce the risk of false detections. Similarly, chart information may help distinguish between fixed infrastructure and slowly drifting floating objects under normal environmental conditions. A radar or camera target located where a charted bridge pier or navigation mark is expected is more likely to be correctly classified than a target detected without such contextual information. However, embedding chart information in the SAS also introduces challenges. Sensor observations may conflict with outdated or inaccurate chart information, potentially biasing the classification process toward chart expectations rather than actual observations. A perception system should therefore avoid assuming that charted objects are always present or that uncharted objects are absent. Consequently, chart information is best regarded as supporting evidence that can improve detection robustness and classification confidence, while sensor observations remain the primary source of truth for describing the current environment. This illustrates that the boundary between perception and navigation is not purely technical but also influences the reliability and interpretation of object classifications within autonomous navigation systems.

Another challenge concerns uncertainty in classification. Objects detected by cameras, radar, LiDAR, or sensor fusion algorithms are identified with a given certainty. In practice, object classifications are associated with confidence levels that may change over time as more observations become available. A vessel initially classified as a generic floating object may later be identified as a passenger vessel after reading markings on the hull, receiving AIS information, or observing navigation lights and signals. This suggests that future interface standards should support gradual refinement of classifications.

The proposed model addresses some of these challenges by combining class hierarchies with additional descriptive attributes. Rather than relying exclusively on a single ship type code, the model allows a vessel to possess multiple characteristics simultaneously through attributes such as *isMotorized*, *isHighSpeed*, *isSmallCraft*, and *isPropellingAConvoy*. Nevertheless, further work is required to harmonize classifications across CEVNI, ERI ship types (see Appendix E), Inland ENC standards, AIS-based classifications, and future autonomous navigation standards.

A promising direction for future work is the use of taxonomies and ontologies rather than rigid code lists. Taxonomy-based approaches allow classifications to be represented at different levels of detail and enable objects to belong to multiple categories simultaneously. This approach is particularly well suited for autonomous navigation systems, where object classifications may be incomplete, uncertain, or progressively refined as additional information becomes available. Ontology-based representations may therefore provide a more flexible and scalable solution for future standardization than traditional static code lists alone.

6.3 FUTURE WORK

The proposed interface deliberately excludes information about the intention of own ship. Such information may be represented by a route or trajectory consisting of positions and timestamps, as illustrated in Appendix C. However, this information is assumed to be available within the Autonomous Navigation System (ANS) and is therefore outside the scope of the SAS-ANS interface. Similarly, the planned intentions of surrounding vessels are not

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represented in the current model. Nevertheless, future autonomous navigation concepts may benefit from incorporating vessel intentions obtained from external information sources such as Vessel Traffic Services (VTS), route exchange services, or coordination mechanisms between autonomous vessels. Such information may improve traffic prediction, collision avoidance, lock coordination, and navigation in constrained waterways.

The S-421 Route Exchange standard is particularly relevant in this context. Route exchange provides a standardized mechanism for sharing planned routes and trajectories and may become an important source of information for autonomous operations, especially when approaching port facilities, navigating narrow waterways, coordinating convoy operations, or passing locks and bridges. The information structures proposed in Appendix C should therefore be further evaluated with respect to future versions of the SAS-ANS interface.

A central topic for future work is the architectural allocation of responsibilities between the Situation Awareness System (SAS) and the Autonomous Navigation System (ANS). Although this proposal separates perception-related functions from navigation-related functions, practical implementations may distribute these responsibilities differently. In particular, future work should investigate the implications of providing the SAS with direct access to chart information and machine-readable regulations. Contextual information derived from charts and regulations may improve object detection, object classification, and interpretation of navigational aids, signs, lights, and infrastructure. At the same time, maintaining chart and regulatory information in multiple subsystems introduces challenges related to consistency, version control, updating, and system complexity. Further standardization work should therefore investigate efficient mechanisms for sharing contextual information between the SAS and ANS while preserving clear functional boundaries.

The role of chart information deserves particular attention. This report assumes that chart ownership resides primarily within the ANS. Future work should evaluate how chart information can best support perception functions in the SAS as well. Examples include improving the detection of charted infrastructure, verifying the existence of navigation marks, reducing false detections, and distinguishing between fixed infrastructure and slowly drifting floating objects. At the same time, limitations arising from chart inaccuracies, outdated information, and temporary modifications to waterways must be carefully considered, particularly for applications involving precise positioning and object localization.

Another important topic concerns the representation of regulatory knowledge within autonomous navigation architectures. The present work assumes that machine-readable regulations may be available to the SAS to support detection, classification, and interpretation of navigational objects and signals, while navigation decisions remain the responsibility of the ANS. Future work should investigate standardized methods for representing and exchanging regulatory knowledge, including how different regulatory frameworks such as CEVNI, COLREGs, local waterway regulations, and future MASS regulations can be integrated into autonomous navigation systems. Such work may enable regulatory analysis results to be exchanged between subsystems instead of repeatedly evaluating the same rules in multiple systems.

Future work should also investigate the representation of object positions and movements. The proposed interface standardizes exchanged information in an absolute geographical reference frame. However, many sensors naturally observe objects relative to own ship as

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range, bearing, relative velocity, or relative motion. While an absolute representation facilitates interoperability and fusion of information from multiple sources, relative representations may be more efficient for detection, tracking, and collision calculations. Future work should therefore evaluate whether both representations should be supported and how transformations, uncertainties, and reference frames should be handled.

Another topic requiring further study is the treatment of own-ship information. The current proposal assumes that own-ship navigation and ship-state information are available through mechanisms outside the SAS-ANS interface. However, some vessel architectures may choose to distribute such information through the SAS or through a common ship data infrastructure shared by multiple subsystems. Future standardization efforts should evaluate the advantages and disadvantages of alternative architectural approaches, including their implications for interoperability, modularity, and implementation complexity.

The proposed information model has been developed primarily for autonomous inland waterway navigation operating within the framework of CEVNI regulations and inland waterway operational environments. Future work should investigate how the model can be generalized to support other domains, including coastal navigation, short-sea shipping, and future applications aligned with the IMO MASS Code. Different operational environments may require additional object classes, alternative classification schemes, different regulatory frameworks, and different requirements concerning perception, navigation, and information exchange.

Future versions of the standard should also provide improved traceability between interface attributes, operational requirements, regulations, and information sources. It should be possible to identify why each information element is included, which navigation or regulatory functions depend upon it, and how the information can be obtained. Information may originate from sensor observations, sensor-fusion processes, AIS or inland AIS messages, digital charts, machine-readable regulations, external information services, or other sources. Such traceability would simplify implementation, and support interoperability.

The integration of dynamic navigational information services should also be investigated further. Notice to Mariners, S-124 Navigational Warnings, NAVTEX messages, and other Maritime Safety Information (MSI) services may provide important information that affects both situation awareness and navigation decisions. Such information sources are expected to become increasingly relevant as autonomous vessels rely more heavily on machine-readable information services.

In addition, future work should investigate how object taxonomies can be harmonized across CEVNI, Inland AIS, Inland ENC standards, S-100 products, and future MASS-related standards to ensure consistent object classification across different operational environments.

Several topics have been identified for future work. One of the most important is the inclusion of information about uncertainty, confidence, and accuracy in sensor observations, object classifications, and state estimations. Furthermore, the geometric representation of positions, curves, and areas should be aligned more closely with the S-100 framework and associated GML standards rather than relying on simple lists of geographical positions. Additional work is also needed to investigate how route exchange data, vessel intentions, and communication services can be incorporated into future versions of the interface.

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The proposed UML model should be regarded as a conceptual information model that establishes a first foundation for standardization of information exchange between perception and navigation systems for autonomous vessels. Future developments should continue to align the model with the S-100 framework and related product specifications, reusing existing concepts where appropriate. Existing S-100 products already provide concepts that can be reused and extended. For example, S-122 Marine Protected Areas and S-123 Maritime Radio Services contain definitions related to geographical and regulatory areas, communication services, and also vessel-related information.

This draft standard was presented to the ISO TC8/SC 26 Smart shipping plenary meeting in Paris in June 2026. Further development through stakeholder review, international standardization activities, and validation across different operational domains will be required before the model can serve as the basis for a future ISO or IEC standard. This proposal will be presented to IEC TC80/WG17 on Common Maritime Data Structure as a potential New Work Item (NWI) and discussed within the group's ongoing activities related to Maritime Autonomous Surface Ships (MASS).

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7 REFERENCES

[1] Endsley, Mica. (1995). Endsley, M.R.: *Toward a Theory of Situation Awareness in Dynamic Systems*. Human Factors Journal 37(1), 32-64. Human Factors: The Journal of the Human Factors and Ergonomics Society. 37. 32-64. 10.1518/001872095779049543.

[2] H-C Burmeister et al 2020 IOP Conf. Ser.: Mater. Sci. Eng. 929 012028

[3] Rongxin Song, Eleonora Papadimitriou, Rudy R. Negenborn, Pieter van Gelder: *Integrating situation-aware knowledge maps and dynamic window approach for safe path planning by maritime autonomous surface ships*, Ocean Engineering, Volume 311, Part 1, 2024, 118882, ISSN 0029-8018, https://doi.org/10.1016/j.oceaneng.2024.118882

[4] R. Song, E. Papadimitriou, R. R. Negenborn and P. H. A. J. M. Van Gelder: *Distributed Situational Awareness for Maritime Autonomous Surface Ships in Mixed Waterborne Transport: An Ontology-based Framework*, 2023 7th International Conference on Transportation Information and Safety (ICTIS), Xi'an, China, 2023, pp. 1088-1092, doi: 10.1109/ICTIS60134.2023.10243802

[5] Song, R, Papadimitriou, E, Negenborn, R, & van Gelder, P. (2022): *Constructing Knowledge Maps for Situation Awareness of Maritime Autonomous Surface Ships*. Institute of Marine Engineering, Science and Technology (IMarEST). https://doi.org/10.24868/10722

[6] Van Baelen S, Peeters G, Bruyninckx H, Pilozzi P and Slaets P (2022): *Dynamic Semantic World Models and Increased Situational Awareness for Highly Automated Inland Waterway Transport*. doi: 10.3389/frobt.2021.739062

[7] Hagaseth, Marianne & Berge, Svein. (2020): *Standardized navigational data for situational awareness during simultaneous maritime operations*. IOP Conference Series: Materials Science and Engineering. 929. 012026. 10.1088/1757-899X/929/1/012026

[8] IMO MASS Code, MSC 111/WP .9, DEVELOPMENT OF A GOAL-BASED INSTRUMENT FOR MARITIME AUTONOMOUS SURFACE SHIPS (MASS); Report of the Working Group, Annex I, 20 May 2026. https://autonomous-ship.org/standards/MSC111-WP9.pdf

[9] Amit Sharma, Salman Nazir, Jorgen Ernstsen, *Situation awareness information requirements for maritime navigation: A goal directed task analysis*, Safety Science, Volume 120, 2019, Pages 745-752, ISSN 0925-7535, https://doi.org/10.1016/j.ssci.2019.08.016.

[10] Rødseth, ØJ: *Integrating IEC and ISO information models into the S-100 Common Maritime Data Structure* https://doi.org/10.13140/RG.2.1.3075.7528

[11] Autoship: *Autoship Deliverable D3.1 – Autonomous ship design standards*, March 2021. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5da3b7aa6&appId=PPGMS

[12] Hull-to-Hull project: *Deliverable D04.04 – Proposed amendments for Standardisation and Regulations towards Safe H2H Navigation*

[13] https://www.sintef.no/projectweb/hull-to-hull/

[14] IMO Compendium https://www.imo.org/en/ourwork/facilitation/pages/imocompendium.aspx

[15] https://www.sparxsystems.eu/languages/uml/diagrams/classdiagram/

[16] Marianne Hagaseth, Håvard Nordahl, Lars Andreas Lien Wennersberg, Hans-Christoph Burmeister and Øyvind Pedersen: *A Mission Exchange Model (MEZ) for Autonomous Inland Waterway Navigation*; 2025 J. Phys.: Conf. Ser. 3123 012012; DOI 10.1088/1742-6596/3123/1/012012

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[17] Marianne Hagaseth: *ISO 28005 Electronic Port Clearance (EPC) Part 3: Data Elements for Ship and Port Operation* (Presentation) https://dynaport.eu/download/iso-28005-3-data-elements-for-ship-and-port-operation#

[18] Lars Andreas Lien Wennersberg, Renan Guedes Maidana, Håvard Nordahl, Vladimir Krasilnikov: *Technical readiness of autonomous vessels in inland waterway transport*, Ocean Engineering, Volume 343, Part 1, 2026, 123046, ISSN 0029-8018, https://doi.org/10.1016/j.oceaneng.2025.123046; https://www.sciencedirect.com/science/article/pii/S0029801825027295

[19] RENEW project: https://www.sintef.no/en/latest-news/2023/sintef-makes-important-contributions-to-the-modernisation-of-cargo-transport-on-rivers-and-canals/

[20] CEVNI: *European Code for Inland Waterways*, sixth revised edition, 2024: https://unece.org/sites/default/files/2024-11/2109540_E_pdf_web%2BCorr1-2_0.pdf

[21] *IENC Feature Catalogue*, Edition 2.5.1, 2021, https://www.cesni.eu/wp-content/uploads/2024/11/Appendices-Part1-IECDIS_BD_signed.pdf

[22] *Encoding guide for inland ENCs*, 2021, https://ienc-kennisportaal.nl/wp-content/uploads/2021/12/Encoding_Guide_2.5.1.pdf

[23] RECOMMENDATION ITU-R M.1371-1: *Technical characteristics for a universal shipborne automatic identification system using time division multiple access in the VHF maritime mobile band*, https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1371-1-200108-S!!PDF-E.pdf

[24] M. Hagaseth, P. Lohrmann, A. Ruiz, F. Oikonomou, D. Roythorne, S. Rayot: *An Ontology for Digital Maritime Regulations*, Journal of Maritime Research, Vol. 13 No. 2 (2016), https://www.jmr.unican.es/jmr/article/view/446

[25] ISO 19107:2019 (2023) Geographic information - Spatial schema

[26] GML standard: ISO/TS 19139-1:2019, Geographic information — XML schema implementation, Part 1: Encoding rules

[27] Recommendation ITU-R M.1371-2, Technical characteristics for a universal shipborne automatic identification system using time division multiple access in the VHF maritime mobile band, ANNEX 1, 2001.

[28] PAS 1883:2020: Operational Design Domain (ODD) taxonomy for an automated driving system (ADS) – Specification, https://www.bsigroup.com/globalassets/localfiles/en-gb/cav/pas1883.pdf

[29] IALA Dictionary 2023 Revision: https://www.iala.int/wiki/dictionary/index.php/Category:IALA_Dictionary_2023_Revision

[30] ISO 25934, Committee Draft of *Ships and marine technology — Guidelines for the development of verification procedures for autonomous navigation systems*

[31] ISO 25929, New Proposal on *Ships and Marine Technology — Method to determine minimum safe lookout area for MASS*

[32] https://www.iala.int/asm/inland-ship-static-voyage-related-data/

[33] ECE/TRANS/ SC.3/176/Rev.2, ECONOMIC COMMISSION FOR EUROPE INLAND TRANSPORT COMMITTEE, Working Party on Inland Water Transport, *International Standard for Tracking and Tracing on Inland Waterways (VTT)*, Resolution No. 63 Revision 2: https://unece.org/sites/default/files/2021-01/ECE-TRANS-SC3-176r2e.pdf

[34] S-401 IEHG INLAND ELECTRONIC NAVIGATIONAL CHARTPRODUCT SPECIFICATION, Edition 1.3.0, May 2026.

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https://registry.iho.int/productspec/view.do?idx=228&product_ID=S-401&statusS=5&domainS=ALL&category=product_ID&searchValue=
[35] SIGNI European Code for Signs and Signals on Inland Waterways, UN/ECE Resolution No. 90 https://unece.org/DAM/trans/main/sc3/publications/SIGNI_2019_e.pdf
[36] WMO (World Meteorological Organization) International Codes Volume I.1 Annex II to the WMO Technical Regulations Part A – Alphanumeric Codes WMO-No. 306, 2019
[37] Lars Andreas Lien Wennersberg, Håvard Nordahl: *Observability and Controllability as Criteria for Safe Navigation of Autonomous Ships*, IEEE International Conference on Intelligent Transportation Systems Print ISSN: 2153-0009, Online ISSN: 2153-0017, 2026
[38] ISO, "Ships and marine technology Vocabulary related to autonomous ship systems', ISO/TS23860, May 2022," ISO/TS23860, May 2022.

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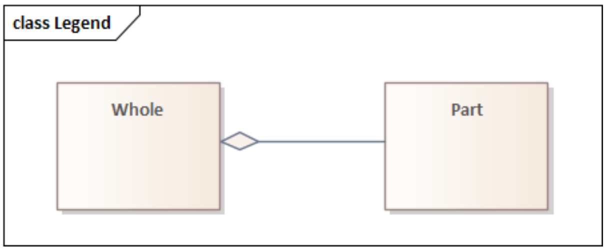
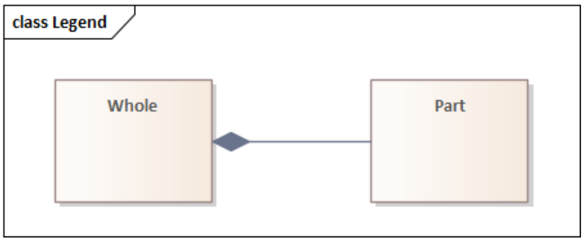
A. APPENDIX – UML CLASS DIAGRAMS

This chapter shows the UML concepts used in this deliverable as described by Sparx [15].

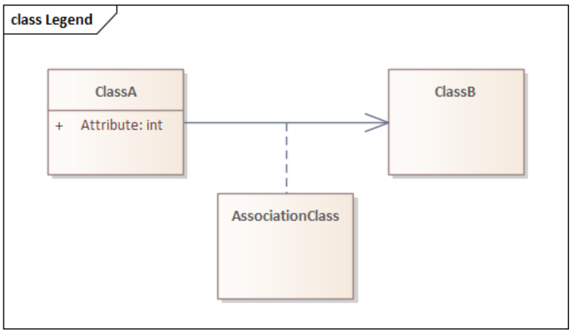
Aggregation: This is an association which describes how something as a whole is logically composed of its parts. In this example, the class **Whole** is composed of the class **Part**. Class names are written in **bold** throughout the text.



Composition: This is a strict form of association where the parts only exist as part of a whole, and not separately. Also, each part is shared with only one **Whole**-class.



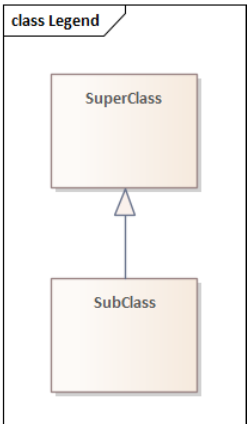
Association Class: This is a class that is linked to the relationship between two other classes, and by this is used to describe more details about the relationship. Each object in the Association Class is related to just one object of **ClassA** and one object of **ClassB**.



Association: This is a relationship between two model elements, with no association class. It is usually implemented as an instance variable in one or both classes.

Attributes describe properties of the class, and the '+' sign indicates that the attribute is public. The arrow from **ClassA** to **ClassB** indicates the direction of navigation through the model. Attributes are written in *italic* throughout the text. An attribute for a certain class, is written like this: **ClassA.***Attribute* .

Generalization/Specialization: This means that characteristics are organised in a hierarchy. More general characteristics belong to the higher-level class, while more specific characteristics belong to the subclass. The lower-level class inherits all characteristics from the class above. This means a subclass has both its own attributes in addition to those of its superclass. A subclass can add new attributes and override inherited ones.



For the attributes in the UML class diagram, we have used the following primitive data types for simple attributes in addition to user defined types for complex attributes:

- Boolean: Represents logical values (true/false).
- Integer: Represents whole numbers.
- String: Represents a sequence of characters.
- Real: Represents numeric values with fractional parts.
- UnlimitedNatural: Represents non-negative integers (0, 1, 2, including infinity)

For simple attributes where the data type is an enumeration, the class name ends with ***...ContentType***, to indicate that this contains a code list.

Most attributes are optional, since it will depend on the different use cases if they can possibly have a value or not.

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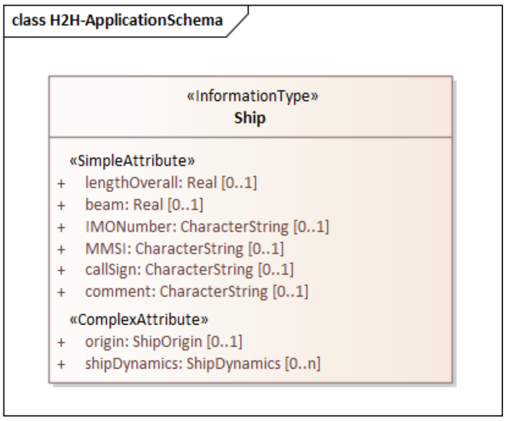
B. APPENDIX - SHIP PARTICULARS

Ship Particular class from ISO 28005 is as follows. This information is in line with the concepts described for ship/shore communication in the IMO Compendium [14].

The H2H project defines the ship information as follows [12]:



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C. APPENDIX - SHIP'S INTENTION

An important description of a ship's intention is the trajectory describing the planned route to take. This is shown in the UML class diagram in Figure 28, which contains the IEC standard 63173-1, also named IHO S-421 on route exchange[8].

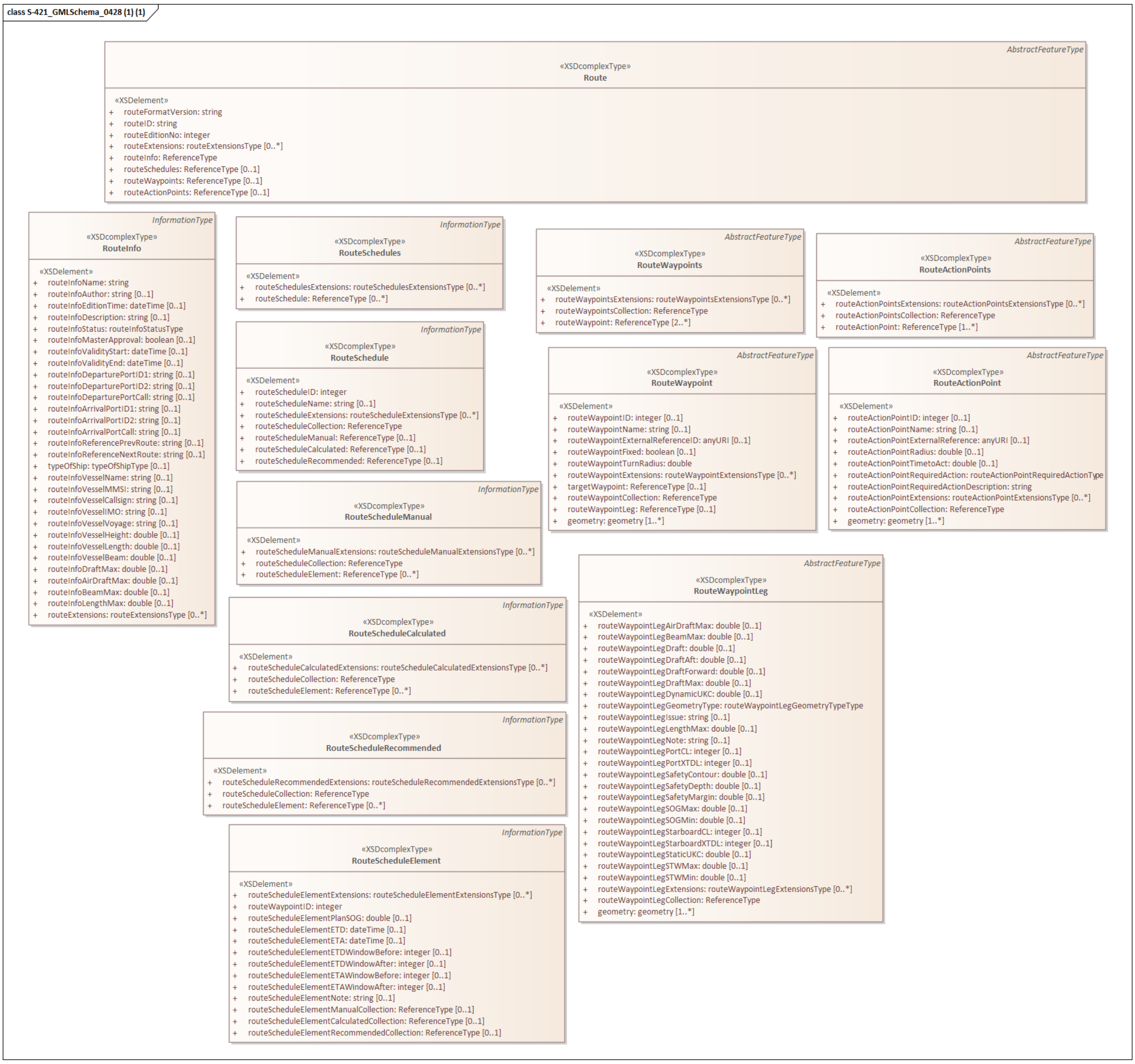

Figure 28 Route Exchange standard

[8] The final version 2.0 of S-421 is due after the submission of this report.

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In [16], the same S-421 standard is used as the starting point to describe the mission data to be sent from the ROC to the MASS to describe its voyage and intentions while sailing on inland waterways.

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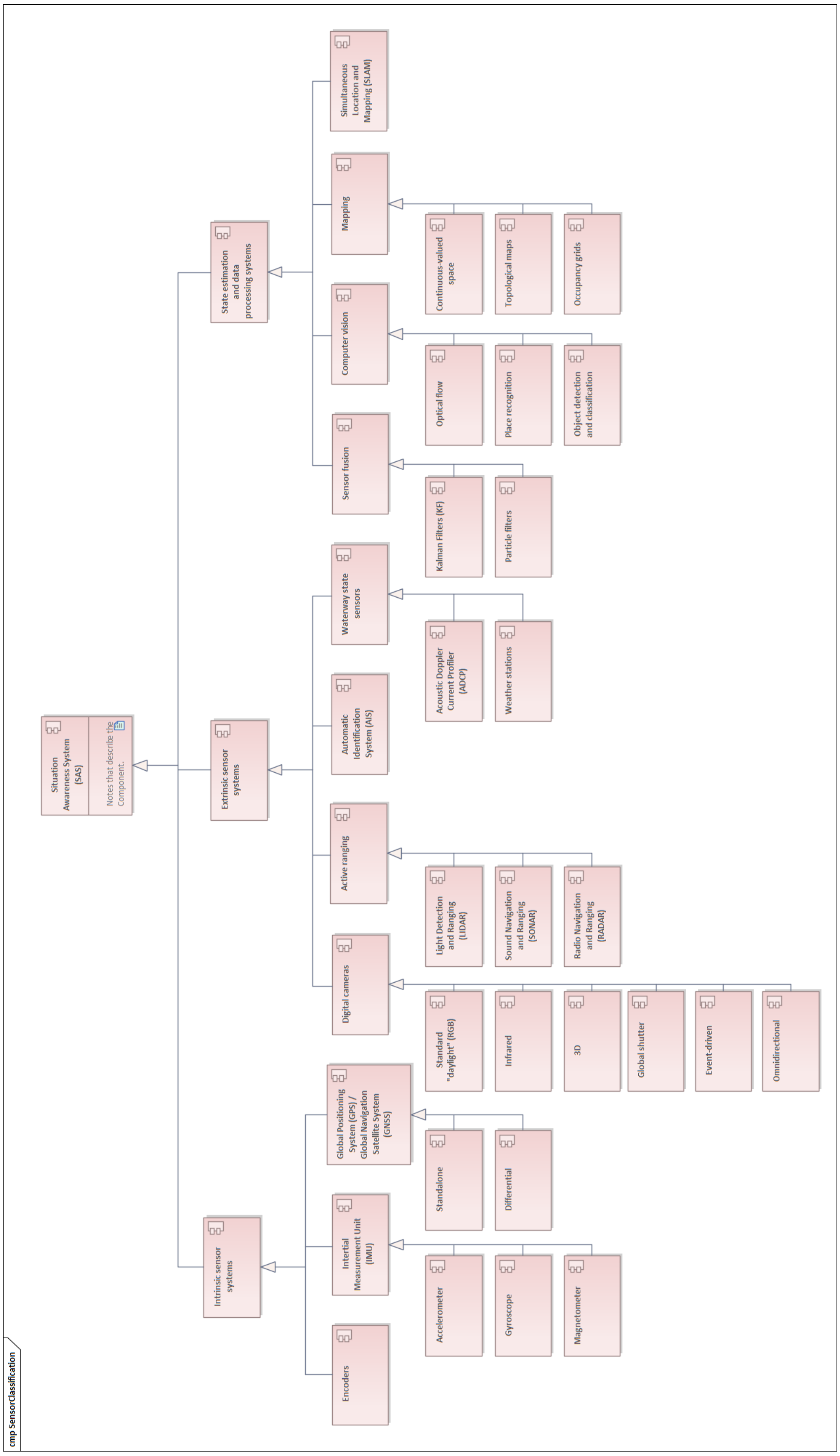
D. APPENDIX – SENSOR CLASSIFICATION FROM RENEW

The following UML diagram shows the classification of relevant sensors as described in the RENEW project [19]:



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E. APPENDIX – ERI SHIP TYPES

This appendix lists the ship types used in the iAIS messages as described in [33], based on the "Codes for Types of Means of Transport" according to UNECE Recommendation 28 and the maritime ship types as defined in Recommendation ITU-R M.1371 "Technical characteristics for a universal shipborne automatic identification system using time division multiple access in the VHF maritime mobile band" [23]. These values can be added to the code list *ERIShipTypeContentType*.

- 8000 Vessel, type unknown 9 9
- 8010 Motor freighter 7 9
- 8020 Motor tanker 8 9
- 8021 Motor tanker, liquid cargo, type N 8 0
- 8022 Motor tanker, liquid cargo, type C 8 0
- 8023 Motor tanker, dry cargo as if liquid (e.g. cement) 8 9
- 8030 Container vessel 7 9
- 8040 Gas tanker 8 0
- 8050 Motor freighter, tug 7 9
- 8060 Motor tanker, tug 8 9
- 8070 Motor freighter with one or more ships alongside 7 9
- 8080 Motor freighter with tanker 8 9
- 8090 Motor freighter pushing one or more freighters 7 9
- 8100 Motor freighter pushing at least one tank-ship 8 9
- 8110 Tug, freighter 7 9
- 8120 Tug, tanker 8 9
- 8130 Tug, freighter, coupled 3 1
- 8140 Tug, freighter/tanker, coupled 3 1
- 8150 Freightbarge 9 9
- 8160 Tankbarge 9 9
- 8161 Tankbarge, liquid cargo, type N 9 0
- 8162 Tankbarge, liquid cargo, type C 9 0
- 8163 Tankbarge, dry cargo as if liquid (e.g. cement) 9 9
- 8170 Freightbarge with containers 8 9
- 8180 Tankbarge, gas 9 0
- 8210 Pushtow, one cargo barge 7 9
- 8220 Pushtow, two cargo barges 7 9
- 8230 Pushtow, three cargo barges 7 9
- 8240 Pushtow, four cargo barges 7 9
- 8250 Pushtow, five cargo barges 7 9
- 8260 Pushtow, six cargo barges 7 9
- 8270 Pushtow, seven cargo barges 7 9
- 8280 Pushtow, eight cargo barges 7 9
- 8290 Pushtow, nine or more barges 7 9
- 8310 Pushtow, one tank/gas barge 8 0
- 8320 Pushtow, two barges at least one tanker or gas barge 8 0
- 8330 Pushtow, three barges at least one tanker or gas barge 8 0

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- 8340 Pushtow, four barges at least one tanker or gas barge 8 0
- 8350 Pushtow, five barges at least one tanker or gas barge 8 0
- 8360 Pushtow, six barges at least one tanker or gas barge 8 0
- 8370 Pushtow, seven barges at least one tanker or gas barge 8 0
- 8380 Pushtow, eight barges at least one tanker or gas barge 8 0
- 8390 Pushtow, nine or more barges at least one tanker or gas barge 8 0
- 8400 Tug, single 5 2
- 8410 Tug, one or more tows 3 1
- 8420 Tug, assisting a vessel or linked combination 3 1
- 8430 Pushboat, single 9 9
- 8440 Passenger ship, ferry, red cross ship, cruise ship 6 9
- 8441 Ferry 6 9
- 8442 Red cross ship 5 8
- 8443 Cruise ship 6 9
- 8444 Passenger ship without accommodation 6 9
- 8445 Day-trip high speed vessel 6 9
- 8446 Day-trip hydrofoil vessel 6 9
- 8447 Sailing cruise ship 6 9
- 8448 Sailing passenger ship without accommodation 6 9
- 8450 Service vessel, police patrol, port service 9 9
- 8451 Service vessel 9 9
- 8452 Police patrol vessel 5 5
- 8453 Port service vessel 9 9
- 8454 Navigation surveillance vessel 9 9
- 8460 Vessel, work maintenance craft, floating derrick, cableship, buoy-ship, dredge 3 3
- 8470 Object, towed, not otherwise specified 9 9
- 8480 Fishing boat 3 0
- 8490 Bunkership 9 9
- 8500 Barge, tanker, chemical 8 0
- 8510 Object, not otherwise specified 9 9
- 1500 General cargo vessel maritime 7 9
- 1510 Unit carrier maritime 7 9
- 1520 Bulk carrier maritime 7 9
- 1530 Tanker 8 0
- 1540 Liquefied gas tanker 8 0
- 1850 Pleasure craft, longer than 20 metres 3 7
- 1900 Fast ship 4 9
- 1910 Hydrofoil 4 9
- 1920 Catamaran fast 4 9ss

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