**Report and Recommendations of the Maritime Autonomous Surface Ships (MASS) Navigation (MASS PT)**

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| ***Submitted by:*** | Mark Casey |
| ***Related Documents:*** | N/A |
| ***Related Projects:*** | S-100 |

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| ***Chair:*** | Mark Casey, United Kingdom |
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| ***Secretary:*** | Annie Biron, Canada |
| ***Member States:*** | Brazil, Canada, China, Denmark, Finland, France, Islamic Republic of Iran, Japan, Malta, Norway, Republic of Korea, Singapore, Sweden, United Kingdom, United States of America |
| ***Expert Contributor Organisations:*** | N/A |
| | *Annex A - Regional reports*<br>*Annex B - Issues and Requirements spreadsheet*<br>*Annex C - S-100 Gap Analysis Reports* |

## Meetings Held During Reporting Period

The Inaugural meeting was on 17th December 2021
The 2nd was held on the 25th Feb 2022
The 3rd was held on the 25th May 2022
The 4th was held on the 5th Oct 2022
The final and 5th was held on the 25th Jan 2023

All meetings were held online using Microsoft Teams and with the exception of the 4th meeting we had almost 100% attendance.
The use of online meetings allowed the team to move at pace and meet more frequently than in person meetings. This method of working was chosen due to the constrained time lines the Project Team were working to.

## Executive Summary and Recommended Actions

The MASS Project team has met it remit ahead of time and has gathered navigation data requirements from the MASS industry and analysed the impact of these requirements against each S-100 product specification. Unsurprisingly, the biggest challenge or problem space is in the context of Degree 4 MASS. That said, in high level terms, S-100 certainly goes a long way in addressing many of the MASS navigation requirements. However, a number of challenges still remain, which are highlighted throughout this report. The main areas of concern are as follows:-

- The MASS industry is still in its infancy and new requirements will emerge as it matures.
- A number of requirements currently fall outside the scope of the S-100 standards landscape.
- More regional representation is required from members states to address gaps from regional MASS activity.

- Closer MASS industry and academic collaboration is required to further develop standards as the MASS industry grows and matures.
- Complimentary work is required in adjacent bodies such as IALA and WMO to ensure interoperability and machine readability of the wider S-100 family standards.
- Data quality needs to be ensured from data providers to ensure fit for purpose data is provided for MASS.

In order to address the points above, it is the recommendation from the MASS Navigation Project Team for HSSC to establish a permanent MASS Navigation Working Group. The purpose of the group will be to address the points above by ensuring the following activities occur:-

- It will pick up any outstanding issues/requirements for further analysis and make recommendations on how to address these gaps.
- It will add new member states to gain greater global coverage to ensure all regional activity is captured.
- It will invite representation from industry and academia into the group to keep gathering requirements as the industry develops.
- It will repeat the discovery and analysis exercise on an annual or biennial basis.
- It will work with the S-100 Working Groups and Project Teams alongside the Data Quality Working Group to ensure product specifications and data standards are aligned to MASS requirements and to provide appropriate challenge to groups and data providers in meeting the standards.
- It will work with complimentary organizations such as IALA and WMO to ensure their data will cater for MASS navigation and operations.

**Background**

The maritime world is changing, and the impact of new technologies to allow for reduced manning onboard vessels, leading eventually to unmanned large ships has taken huge steps forward over the last decade.

These vessels utilise powerful onboard processing and software to read, interpret and combine sensor data, (typically from AIS, Radar, Cameras, Lidar) and align this with historical onboard data about the world around them (typically traditional electronic static charts).
They create a digital world model and make decisions on safe navigational routes that not only comply with COLREGs but also move them towards their end goal or destination.

As interest in Maritime Autonomous Surface Shipps (MASS) grows and autonomous ships become larger, they will enter into the regulatory landscape and eventually will be able to truly operate independently of human operators. One area of concern is the current lack of specific navigational data that is required to “drive” a MASS or more importantly the lack of any stated rules, regulations or standards relating to navigational data in a MASS.

**What does autonomous mean?**
It is important here to describe what we mean by autonomous, as the term is often used to describe several modes of operation. The International Maritime Organization (IMO) has defined 4 distinct degrees of autonomy as shown below (note the IMO defined these degrees for their MASS regulatory scoping study and these terms may change in the future):

**Degree one:** Ships with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.

**Degree two:** Remotely controlled ships with seafarers on board: The ships are controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.

**Degree three:** Remotely controlled ships without seafarers on board: The ships are controlled and operated from another location. There are no seafarers on board.

**Degree four:** Fully autonomous ships: The operating system of the ship can make decisions and determine actions by itself.

**Definition of the problem**
Whilst remote controlled vessels (degrees two and three) can use traditional navigational data such as charts and publications due to the human operation, the fully autonomous vessel (degree four) can't operate with these traditional products. Whilst MASS will become self-aware and use sense and avoid technologies, these vessels will still need navigational data to get from A to B, to avoid dangerous or regulatory areas and operate appropriately when entering a specific area (e.g. Ports, Environmental Protected Areas, MARPOL boundaries, Traffic Separation Schemes).

To suggest that MASS will use current Electronic Navigation Charts (ENC) in their current form is inappropriate for the following reasons:

- ENCs are fundamentally designed to be viewed and interpreted by a human being and they are used to inform mariners and help them make decisions based on the chart information, their knowledge and what they see out of the window.
- A lot of ENCs are derived or constructed using traditional paper chart production techniques or ENCs are derived as a result of paper chart production, and as such inherit subjective cartographic practices (e.g. data generalisation or aggregation) and therefore may only represent a cartographic and subjective interpretation of "ground truth".
- ENCs suffer from data inconsistencies (i.e. features aren't always on charts that cover the same area at different scale bands, usually because of cartographic practices), which a human can identify and resolve.
- ENCs suffer from horizontal inconsistencies (i.e. edge matching one ENC against another can highlight differences, usually because of cartographic practices or changes in scale), which a human can identify and resolve.

**S100 Impact on Autonomous Navigation**
Although S-100 and the associated product specification (S-1xx) series of standards represent a significant step forward, at present they are still in relatively early stages of development and are being designed with a human end user in mind. The main benefit of the S-100 framework is that it is extensible and therefore the data model can be adapted as new requirements emerge.

**HSSC 13 establishment of MASS Navigation Project Team**

Due to the international nature of shipping, the problems outlined above are very much an international challenge. Whatever the future looks like for navigational data for unmanned ships, the problems above can only be solved on an international level.

No one Member State can produce and define its own approach to navigation services, ultimately the solutions must be governed by international standards and mandated by the IMO. The IHO community should start to work together to address these challenges and start to ensure future requirements are considered now to ensure MASS can utilise the data produced by hydrographic offices around the world for machine based decision making. The IHO Community needs to be ready to support the transition from manned vessels to unmanned vessels and work collaboratively in doing so to ensure that the future of navigation remains safe.

At HSSC 13 in May 2021 it was recommended that the IHO increase its focus on autonomous vessels through endorsing the establishment of a new Project Team for MASS navigation to ensure a collaborative, joined up and holistic approach is adopted and to start to gather new requirements for MASS navigation. The HSSC unanimously endorsed the MASS Navigation Project Team with a 2 year remit to carry out the following:-

- To identify and prioritize MASS navigation requirements.
- To analyse their impacts on hydrographic standards and services (i.e. S-100).
- To develop a set of recommendations/issues to be addressed by existing working groups.

**The MASS Navigation Project Team and Project Plan**

The chair role of the Project Team was given to the UK (the author) and a membership list was provided after canvassing IHO member states. The membership of the group is made up with representation from Brazil, Canada, China, Denmark, Finland, France, Iran, Japan, Norway, Rep of Korea, Sweden, UK, USA, Singapore & Malta. A reasonable membership list with a number of MASS activity hot spots covered within the group.

A plan was defined to ensure the Project Team achieved its objectives. The plan was split into 2 phases. The first phase was a Discovery & Reporting stage which commenced in December 2021 and identified MASS Navigation requirements in each region covered by the MASS navigation Project Team's membership. The findings were then collated and fed into the second phase, which was an Analysis and Recommendations phase, which was a gap analysis of the issues found in phase 1 against the existing S-100 product specifications with recommendations on how each gap could be addressed. These findings have been presented to each S-100 Working Group or Project Team Chair for their consideration and implementation.

**Report on Discovery & Reporting Phase**

The Discovery and Reporting phase consisted of a number of work packages covering the following activity:-

- Revisit the IMO scoping study into autonomous shipping, considering the four defined degrees of autonomy, identify any gaps in its findings and for the MASS PT to then make recommendations to HSSC to be considered for submitting to the IMO by the IHO.
- Identify and report what test bed activities are happening in each region and which degree of autonomy is predominantly used.
- Report on what data MASS operators and MASS navigation systems are using today.
- Report what navigational data each PT Member States' regulators are specifying should be used for MASS navigation in either trials or operations of MASS.
- To what degree are PT Member States involved in MASS trials or operations and what data are they currently providing.
- Report on what trailing has been done with new navigation standards (e.g. S-100) for MASS, or what research into machine readable data has been carried out in each region?
- Conflation of reports and synthesis of detailed navigation requirements for MASS.

The above led to each Member State creating a report on the activity in their region in relation to the above work packages (See **Annex A**). This was then consolidated into an Issues and Requirements spreadsheet (See **Annex B**) outlining any requirements or issues to be examined against the S-100 Product Specifications. In this phase, 45 individual issues and requirements were captured covering a number of themes:-

- Modelling certainty/uncertainty of positions
- Modelling certainty/uncertainty of tidal height information and seabed mobility.
- A need for more visually conspicuous features to be shown along with more land based topography.
- A need for more geospatial polygon features with appropriate attribution to capture constraints and restrictions.
- A need for near or real time data feeds.
- 3D synthetic environments for navigation purposes.
- Removal of verbose natural language text paragraphs to be replaced with machine readable attributes and enumerations.

**General conclusions from the Discovery and Reporting phase**
Whilst most Member States' hydrographic offices have been involved or aware of MASS activity and test beds in their regions, very few have provided any data other than S-57 data. Furthermore, there is still a huge void in global or localised regulation for MASS activity with most projects being handled on an ad hoc case-by-case basis. There has been very little research or testing carried out using machine readable data and due to the current draft nature of the S-100 product specifications, very limited exposure of these data sets to MASS operators has been or can be achieved. In summary, the MASS industry to date is aware of limitations in S-57 and other related navigation products (e.g. Tidal Almanacs and Sailing Directions etc), but is making do or implementing their own work arounds to overcome these limitations. S-100 is not known by many MASS operators or developers, and whilst this could be seen as a negative situation requiring work to do to raise awareness, it presents the IHO and HSSC working groups with an opportunity to address issues and requirements whilst maturing the S-100 product specifications and as the MASS industry evolves.

**Report on Analysis & Recommendations Phase**

The Analysis and Recommendations phase immediately followed phase 1 and commenced in May 2022. Each Member State of the MASS Navigation Project Team were assigned one or more S-100 product specifications and along with the Issues and Requirements spreadsheet, were to perform 2 keys tasks against their assigned S-100 product specification:-

- To identify if the reported issue still existed in the new S-100 product specification
- If the reported issue was still present (i.e. there is a gap), to then make a recommendation how to address the issue.

A gap analysis template was provided to each Member State and a time frame of 4 months was allocated to carry out the analysis and recommendations against each S-100 product specification. See **Annex C** for each Member State's gap analysis reports.

The following table describes which Member State performed analysis against 1 or more S-100 product specifications:-

| Member State | Product Specification |
|---|---|
| UK | S-101 + S-131 |
| Finland | S-102 |
| China | S-104 + S-111 |
| Denmark | S-122 |
| Norway | S-123 |
| USA/NGA | S-124 |
| Korea | S-125 |
| Brazil | S-126 |
| USA/NOAA | S-127 |
| Canada | S-128 + S-129 |
| Japan | S-130 + Security Protection Scheme |

Once all gap analysis reports were complete, all Member States responsible for carrying out the gap analysis were then requested to present their findings and recommendations to each Working Group of Project Team chairs for consideration for implementation in the development of their S-100 product specification road maps.

**Gap analysis overall findings**
On the whole, I am very pleased to report that a number of key issues identified have already been considered or addressed in the S-100 product specifications. However, a number of issues and requirements did identify gaps or issues that needed to be catered for in the S-100 product specifications and some of the requirements we

gathered from the MASS industry are not covered at all by a S-100 product specifications. A high level outline of gaps follows:-

**S-101**
A number of natural language free text fields exist, however on analysis only one attribute should change to enumerated values which is the Radar Band attribute.
Attribution should be added to various features to model certainty or uncertainty of position.
Linking features that span multiple product specification should be considered, potentially using the Marine Resource Name as a foreign key.
Use of augmented geometries for items such as Traffic Separation Schemes to ensure MASS follow traffic measures appropriately.
Adding tolerance values on Buoys to cater for drift on chain.

**S-123**
Many feature classes allow for natural language free text. Whilst a good data model does facilitate breaking down some of the text into features and attributes that can be understood by machines. The concern is that the data model also allows for georeferenced natural language text, which most hydrographic offices will opt for due to the relative ease of implementation and migration of data from traditional radio signals books to a georeferenced data model.

**S-126**
Wind information should be considered for S-126 and described as a percentage value in strength.
Also natural language text as per S-123 is present in this product specification.

**S-127**
The product specification needs to allow MASS to report route information, this may need to be different to how humans do it today.
S-127 includes Concentration of Shipping Hazard Area features but does not include natural conditions or patterns of life, timetables could be used here in a machine readable format for MASS.
Also natural language text as per S-123 is present in this product specification.

**S-128**
Again it is common to have natural language free text within S-128.
The catalogue/s must be machine discoverable.
There needs to be an attribute against catalogue features to denote whether updates are regular or irregular with an interval of updates field also used.

**S-131**
Applicable Load Line Zones should be enumerated values.
Bollard Description should be a combination of enumerated values and a numeric value for safe working load.
Communication channel should be a real number with an enumerated suffix where appropriate.
Country name should be an enumerated value.
Language should be an enumerated value.
MMSI code such be an integer value.
Nationality should be an enumerated value.
Protocol should be an enumerated value.
Tug information could be broken down and the use or enumerated values could be used with the name of the tug.

**New standards and product specifications?**
However, a number of different requirements do not easily fall into one of the S-100 product specifications and demand for these data types or products will naturally increase as MASS matures. These requirements include:-

- 3D models or Digital Twins of port environments, constrained or restricted water space and fairways.
- Historic marine accident or incidents for risk profiling and modelling.

- Seabed conspicuous features (similar to land but marked on the Seabed for navigation fixes).
- Reflective nature of Seabed for INS navigation fixes.
- Acoustic qualities in the water column for INS navigation.
- MASS degree level of operations areas or routes.

How are these requirements to be met?

**Remaining challenges and considerations**

Of the 45 issues and requirements we discovered, a number of issues came up several times that are currently not planned for S-100, for example 3D models and Digital Twins came up several times. There is no standard planned for this at the IHO level, indeed there is no official standard for geospatial or maritime Digital Twins currently in existence. Digital Twin technology will undoubtedly evolve and become an import part of the navigation tool kit in a similar way that city Digital twins are being used for autonomous cars. The Project Team suggest that the IHO needs to take a more proactive part in developing Digital Twin standards for navigation and situation awareness.

It's important to recognise that the MASS industry is still developing and evolving. As such the Project Team have gathered requirements and issues at an early stage in the development and evolution of MASS. As the industry matures and moves towards larger autonomy degree 4 vessels, there will undoubtedly be new requirements emerging which we need to capture and cater for in the S-100 ecosystem. To facilitate this, re-running the Discovery and Reporting phase followed by the Analysis and Recommendation phase is recommended periodically.

Furthermore, whilst the Project Team had some good representation from regional areas of MASS activity, we didn't cover all areas of the globe and may have missed regional developments and requirements in areas such as Australasia.

From the project Team's engagement with related bodies, such as IALA and WMO, there is complimentary work that the IHO Project Team could help support (i.e. IALA are developing S-200 and the WMO are developing the S-400 standards). IALA have their own MASS Task Force and the Project Team think there is much both organisations can do to ensure S-100 and S-200 cater for MASS. However, in discussions with the WMO, they have not considered MASS in their development work on S-400 and aren't thinking about machine readable data at this point, so there is an opportunity for the IHO MASS Project Team to assist in the WMO standards development.

Given the tight timeline the MASS project team had to work within, we never invited the MASS industry developers into the Project Team, rather we went out to them. With the best will in the world we couldn't speak to everyone that is involved in developing MASS. As such there is a real potential that we have missed key developments and associated requirements for MASS navigation.

Another remaining aspect of concern surrounds the data that data providers will need to supply in the future conforming to S-100 product specifications. Having had discussions with the chair of the Nautical Information Provision Working Group (NIPWG - responsible for S-122, S-123, S-125, S-126, S-127, S-128 and S-131 which could be deemed the standards covering Nautical Publications such as Sailing Directions) there is still a lot of unstructured natural language text present in the S-100 product specifications. Whilst there has been work done to formalise a data structure supporting feature and attribute modelling within these product specifications, they also support the ability to simply georeferenced large swathes of free text. The implications for this are that it would be an easy migration path for most data suppliers (i.e. Hydrographic Offices) to choose to geo-reference large extracts of text to meet the base level of the product specification and whilst this would work for manned shipping, it would not be acceptable for MASS. This scenario has been presented to the Data Quality Working Group (DQWG), who recognise the challenge and as such are keen to work with the MASS Project Team to ensure that data suppliers produce the data for both manned and unmanned navigation.

**Justification and Impacts**

It is clear that the MASS industry is gaining momentum and moving to Degree 3 and 4 levels of autonomy. The IHO must keep pace and ensure S-100 is fit for safe navigation in manned and unmanned shipping situations. The need for an International Working Group to monitor the developments in the MASS industry and gather requirements for the relevant IHO Working Groups to implement is clear and will complement the work of the existing Working Groups. Once the MASS Navigation Working Group is established, a new plan of activity will be created, agreed and implemented with Member States and other relevant members of the Working Group.

**Action Required of HSSC**

The HSSC is invited to:

a. endorse the permanent formation of a MASS Navigation Working Group.

**Annexes**

**Annex A - Regional reports**

**Annex B - Issues and Requirements spreadsheet**

**Annex C - S-100 Gap Analysis Reports**

# Member State: Brazil

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

| Project | Purpose | Web site | Mass degree |
|---|---|---|---|
| USV TUPAN | Multi-purpose vessel, to operate in offshore environment. It can be integrated with a full suite of sensors for collection of environment data. | https://www.tidewise.io/usvtupan?lang=en | 3. Test program in place to achieve degree 4. |
| VSNT-E (USV-E) (Experimental) | Experimental USV designed to serve as laboratory for test and evaluation of AI decision making, classification, algorithms and sensors used in maritime autonomous systems. Usage focused on logistics, bathymetry, and surveillance missions. | https://www.marinha.mil.br/casnav/?q=node/169 | 4 |

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region.

| MASS Degree | MASS operators | MASS navigation systems |
|---|---|---|
| 3. Ship is remotely controlled and operated from another location. There are no seafarers on board. | Operators use onboard and external situation awareness sensoring. The USV Tupan collects, process and delivers to the operator targets detected by: visual cameras (360deg), AIS, LiDAR and Radar. Navigation data is published to the operator, such as: water depth, speed over water, speed over ground, positioning (lat/long), heading and course.<br>System status is also published: Generator's status (on/off/failure/starting), power load, | Tidewise proprietary autonomous navigation software, WiseControl™ utilizes the following data: 6 DoF motion data, heading and course, speed over water, speed over ground, water depth. Data fusion happens on board, is available to the system but is not used for fully autonomous navigation yet. Fused obstacle avoidance data (AIS, radar, cameras, LiDAR). |

| | | |
|---|---|---|
| | shafts RPMs and rudder angle. The USV integrity is also monitored via alarms like : water ingress, over temperature, voltages and currents thresholds.<br>Data transmission from USV Tupan and fairway infrastructure enables situational awareness for remote seafarer. Situational awareness tools comprise of static and dynamic data from the vessel, fairway imaging, VTS data, fairway radar imaging, digital twin of the fairway and vessel, ECDIS chart and shared route data with the vessel. | |
| 4. Ships is able to conduct a navigation mission without seafarers on board. | Operators rely in a Command and Control (C2) data link for telemetry and streaming of cameras for safety of operation and assuming control in case of any need. | Navigation systems use GNSS positioning with differential correction, computer vision pattern recognition and inertial navigation system (IMU). Data from radar, AIS, echo sounder and sidescan sonar also feed guidance and control algorithm. |

Have any data limitations been identified?
No information.

**WP4:** Report what navigational data each member states' regulators (e.g., MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

"Provisional Regulation for the Operation of MASS" was issued in Brazil for MASS, considering its interaction and coexistence with conventional vessels. In this regulation, it is highlighted that MASS with a length of more than 12 meters are not authorized to operate in Brazilian waters. The regulation defines levels of control and not levels of autonomy, as shown in the table below:

| MASS Degree | MASS operators | MASS navigation systems |
|---|---|---|
| 0. Seafarer on board | Vessel is controlled by seafarer on board | Seafarer on board |
| 1. Controlled | All functionality is up to the seafarer on board. He has total control of the vessel and makes all decisions, directs, and controls all functions | Seafarer on board |
| 2. Directed | Under directed control, some degree of assessment and responsiveness is implemented on the vessel. It can assess the environment, report its situation, and suggest one or several actions. It can also suggest possible actions to the operator, requesting information or decisions. However, the authority to make decisions rests with the operator. The vessel will only act if commanded and/or allowed to do so | Seafarer on board |
| 3. Delegate | MASS is authorized to perform certain functions. It assesses the environment, report the situation, define actions and report your intent. The operator has the option of modifying the vessel's reported | Program on board |

| | | |
|---|---|---|
| | intentions for a period, after which the vessel and decision-making is shared between the operator and the vessel | |
| 4. Monitored | MASS assesses the environment and reports its status. defines actions, decides, and acts by reporting its action. The operator can monitor the events. | Program on board |
| 5. Autonomous | MASS, endowed with a maximum degree of independence and self-determination, assesses the environment and its situation. It defines actions, decides and act. | Program on board |

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

Directorate of Hydrography and Navigation (DHN) is not involved in MASS trials or operations. Brazilian Navy and mainly oil and gas industry have been demonstrated interest in autonomous vehicle, recently in surface ships.

The growth of research on MASS seems to be growing in view of the information from recent partnerships between academia and companies that need the type of service provided by MASS.

There have been no tests or operations of MASS in navigation channels or access to ports despite its enormous potential.

Have any data limitations been identified?
No information.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state's region.
There is no information about this.

Have any data limitations been identified?
No information.

# Member State: Canada

**WP2:** Identify and report what **test bed activities** are happening in each member state's region and **which degree of autonomy** is predominantly used.

- Canadian Hydrographic Service (CHS) procured 4 Autonomous Hydrographic Surface Vehicles from Searobotics (2.5m) (2 in March 2017, and 2 in March 2018).
  - 2 are fully active and integrated in CHS data acquisition processes.
    - Degrees 1 to 3 of autonomy: pre-planned survey autonomy, assisted, and real time fully controlled. No use of S-100 data for navigation, the only incoming real-time data used is related to detection of obstruction around the vehicle (lidar/camera).
    - An interesting feature: the bathymetric acquisition module allows for input from acquired data to update survey plan (limited artificial intelligence).
- CHS converted one survey launch (8m) to a dual-manned/unmanned mode (Autonomous Hydrographic Survey Launch) with technology from ASV Global (June 2017).
  - Degrees 1 to 3 of autonomy: pre-planned survey autonomy, assisted, and real time fully controlled. Lots of issues, not efficient technology because bathymetric equipment and navigation controls do not interact. High logistical burden. No use of S-100 data for navigation, the only incoming real-time data used is related to detection of obstruction around the vehicle (lidar/camera/radar). ○ CHS was never permitted to use the AHSL in full unmanned mode (always 2 people on board) due to legislation restrictions and lack of confidence in the system. ○ Supplementary financing and human resources were required to exploit and experiment but never awarded.
  - Due to system faults, the unmanned module was removed from launch in 2021.
- CHS contracted out 1 survey in Ontario (CSMart 2020), AHSV type (autonomous survey and/or partially controlled remotely, degrees 1 to 3 of autonomy). No use of S-100 data for navigation.
- CHS produces S-102 data (S-104 & S-111 to come) in specific areas:
  - St-Lawrence River test bed with Corporation of Lower St-Lawrence pilots: No navigation autonomy, just integrating dynamic S-100 data in Portable Pilots Units (SEAIq). Interaction with water levels through API. Data available : https://cartes.gc.ca/data-gestion/index-eng.html#s100
  - In collaboration with PRIMAR, Teledyne CARIS and SEAIq, there is an opportunity to test S-100 Products for a 3-month free trial period. In 3 areas: Vancouver Harbour, St-Lawrence river and St-John Harbour : https://www.primar.org/#/S100
- CHS St-Lawrence channel virtual surveys:
  - No autonomy (launch staff on board, but hydrographers are virtual) ○ surveys are conducted partially in virtual mode. Either bathymetric data acquisition and/or processing is done virtually.

  - Communication links are tested as well as processes: Real-time Remote interaction access to network/computer/equipment.
- S131: digitization of port infrastructure and logistical information: upcoming projects with port of Montreal, Halifax and Vancouver. Canada will also finance IHO NIPWG project. No autonomy : development of technologies, data structuration.
- Canadian Coast Guard E-NAV infrastructure in development:
  - No degree of autonomy envisioned, but centralize all information required for navigation safety. (S-200, S-400, S-100)
- Cyber Security Research for MASS, Memorial University

Computer Security & Cybersecurity | Research | Faculty of Engineering and Applied Science | Memorial University of Newfoundland (mun.ca)
- Intelligent Maritime Corridors International Council: offers a structure solution path by creating an ecosystem of research and innovation and particularly a promising avenue for development in the Quebec part of the St Lawrence commercial corridor and the Great Lakes system. Collectively working at developing it as a high-performance innovation zone for next generation of ships and testing them on short sea shipping routes.
- Canadian National Research Centre sponsors several projects for the development of technologies related to MASS:
  - Use of Machine Learning for Identification and Characterization of Vessel Operational Best Practices ○ Digital Twin Technology for Autonomous Operation in Harsh Environment ○ Prediction of Ice in the St. Lawrence Waterway Using Artificial Intelligence ○ Ship Situational Awareness in Ice
  - St. Lawrence Seaway Autonomous Marine Testbed
  - Extension of Driving Automation Research Activities at NRC to the Marine Use Ca
- Canadian MASS Interdepartmental Working Group: trying to establish test bed areas/sites for (physical) experimentation and testing of autonomous technologies
- Canadian S-100 Interdepartmental Working Group: regroups all federal departments responsible for S-100 data stream production and development.
- Companies, organizations:
  - CSmart- bathymetric data acquisition with small launches ○ ALGOMA Central :introducing automation to their Lakers ○ Robert Allen: automation to their fireboat
  - Memorial University: autonomous small vessel procurement ○ University of British Columbia: autonomous sailboat procurement

**WP3:** Report on what **data MASS operators** and **MASS navigation systems** are using today in each member state's region.

- CHS is producing S102 data (S104-S111 to come): WP2
- CHS St-Lawrence channel virtual surveys: WP2
- S131: WP2
- Canadian Coast Guard ENAV infrastructure in development: WP2

Have any data limitations been identified?
Software development is slow and often needs to be financed by government $, interoperability of data streams is lacking, availability of data streams requires high bandwidth, data is not always up to date (ex: chart updates).

**WP4:** Report what **navigational data each member states' regulators (e.g. MCA in the UK) are specifying should be used** for MASS navigation in either trials or operations of MASS.

- Policy on the Oversight of Small Maritime Autonomous Surface Ships (SMASS policy) sets requirements for vessels:
  - not more than 12 metres in length as defined in the Small Vessel Regulations, or not more than 15GT
  - Remotely controlled (level of autonomy 3 as defined by IMO)
  - The policy does not apply to MASS that have crew on board or that are tethered to a mother vessel or a shore install
  - Policy highlights:
    - Vessel to be fitted with a Class A or B AIS system
    - SMS for the control centre
    - Collision avoidance, surveillance, communications and operating systems
    - Emergency pollution response plan
    - Sufficient liability insurance coverage
    - Towing plan
    - Remote control centre staffed at all times with a qualified person
    - Risk analysis

- Small MASS, including pleasure craft, of not more than2 metres in length and 100 kg displacement must:
- Be operated within sight
- During daylight and good visibility
- Means of towing in place
- PCO competency or higher
- Registered and marked
- Be operated away from other vessels or persons, outside of prohibited navigation areas
- Not contain any pollutants

**WP5:** To what degree are **member states Hydrographic Offices involved in MASS trials** or operations and what data are they currently providing.

- Canadian MASS Interdepartmental Working Group :
  - Regroups Canadian governmental departments, agencies, + partners ○ create a technology roadmap for enabling MASS in Canadian waters, ○ coordinating all MASS-related research and activities,

  - develop a multi-party project to increase enabling MASS technologies created in Canada,
  - establish Canada as the global leader in testing and evaluation of MASS technology.
- Canada is targeting smaller vessels (e.g.: fishing boats, tugs…), and targeting the development of enabling technologies (under the blue economy program umbrella: Clean, Quiet and Connected)
- The Facility for Intelligent Marine Systems (FIMS):
  - federal collaboration between the Department of Fisheries and Oceans (DFO), Natural Resources Canada and Defence Research and Development Canada/Department of National Defence. Located in Dartmouth, Nova Scotia.
  - Leverage Government of Canada's infrastructure, equipment and resources from multiple Science based Departments and Agencies (SBDAs) to achieve real property efficiency, collective opportunities and scientific synergies in supporting government funded marine science programs.
  - Will support the use of state-of-the-art unmanned surface and underwater data collection platforms and nurture the development and testing of new systems to observe Canada's marine environment (e.g., Unmanned Underwater Vehicles, Unmanned Surface Vehicles, gliders, and moored and floating sensor arrays).

Have any data limitations been identified?
No early stage only

**WP6:** Report on **what trailing has been done with new navigation standards** (e.g. S100) for MASS, or what **research into machine readable data has been carried out** in each member state's region.

- Projects with pilotage corporations and different research projects from CNRC (very early stage and pre-MASS)

Have any data limitations been identified?

Comments from pilots: Systems and protocols are not yet interoperable. The communication infrastructure necessary to sustain data exchange is not reliable and affordable. The GAP is huge and not addressed properly by legislators and technology providers yet.

# Member State: China

In China, the development of MASS is still far behind at its early stage. Some Maritime institutes and universities have initiated some projects and research of MASS. Meanwhile, some companies have started the works of development and trial of MASS. At present, most of the projects are being developed and on trial. Quite a few institutes and universities have put their project of MASS on trial aiming the alignment of scientific research and teaching, etc.

**SECTION ONE: Summary of MASS trials platform of China**

At present, two MASS trials are ongoing in China.

1.ZhiFei Hao

ZhiFei Hao, as the first autonomous container ship in China, is built by Qingdao Shipyard in June of 2021.Her particulars are as follows: displacement 8,000 tons, capacity 316 TEU, LOA 110 meters, Width 15 meters, Depth 10 meters, power-driven propulsion, speed 12 knots, endurance 4,500 nautical miles. She is on her trial along the coastal waters for container shipment and intelligent system trial.

Her trial areas are covered the coast waters of Qingdao in Shandong Provence. She sails along the typical route which departs from Qingdao port (automated container terminal) to Dongjiakou port. This integrated trial platform is undertaking the works of MASS trial development, trial verification, marine equipment industry, inspection approval and operating management.

Installed with the system of shipborne navigating assistance, ZhiFei Hao enables her sailing within three modes: man-driven, remote control, unmanned autonomous. In the man-driven mode, the navigating assistance system will provide relevant supports to the operator with surroundings identification, collision-avoidance actions, safety alert, etc.

Zhifei Hao has realized intelligent functions of surroundings identification, route tracking, autonomous route planning, intelligent collision-avoidance, automatic berthing and unberthing, remote control drive. With multi-model communication system of 5 G and satellites, this ship can coordinate with ports, shipping industry, maritime safety administrations and ship insurances for the shore-based services including production, service, dispatch control, inspection, etc.

An integrated sensing system has been applied with the S-57 ECDIS, navigating RADAR, AIS, visual light/laser equipment, wind anemometer, ship movement sensors to check and acquire the information of sailing surroundings, dynamic and static dangers etc.

2.Jing Dou Yun 0 Hao

Jin Dou Yun 0 Hao is a scale test ship designed and built in 2019 for autonomous navigation trials. In compliance with the Classification Rules issued by China Classification Society, an additional autonomous navigation system was installed on board the ship. The ship has been used for the research, development and trials of autonomous navigation system, without impairing the safety and reliability of the basic platform. At present, the ship is capable of basic autonomous navigation, such as remote control navigation, autonomous tracking navigation, autonomous collision avoidance, etc. in certain scenarios. Remote control navigation is used for berthing and departing and for the navigation in heavy traffic areas. In this mode, the ship is remotely operated from the shore, and it is mostly used for tracking navigation and emergent collision avoidance in the navigational environment when performing tasks. 500 tons, LOA 50 meters, endurance 500 nautical miles with power-driven propulsion.

To ensure the stability of cyber security and data transfer, the ship has:

A. Adoption of a designated communication protocol. B. Usage of safe internet channel within public internet. C. Internet backup equipment. D. The ship has top priority to shift to manual control onboard ship when the cyber security is threatened. E. Public internet and designated internet can be shifted as necessary, designated internet is with security packages. F. Any delay and data miss will be remedied by programming

Jing Dou Yun 0 Hao navigation system was based with S-57 ECDIS, provided with traditional sensors such as shipborne echo sounder, GPS, other data of ocean currents, tides, meteorological information, camera, etc.

The data of tides and ocean currents will be transferred in the form of electronic file or paper file between ship and control center. the meteorological data will be collected by shipborne weather instrument and be transferred to the navigating system.

**SECTION TWO: Regulations on navigating data used in MASS trial or MASS under operation operating issued by national regulators**

The national regulators in China is at her early stage of the research on navigating data during MASS trial or MASS under operation operating process. The summary is as follows:

Rules for intelligent ships 2015 was issued by CCS, which is in accordance with IMO instruments on MASS and practices on the application of MASS Guidelines. In 2020, guidelines for autonomous cargo ships were issued by CCS, with the amendments of remote control ships and autonomous ships with their clear functional requirements. The guidelines 2020 specify six functions: intelligent sailing, intelligent hull, intelligent engine room, intelligent energy efficiency management, intelligent cargo management and intelligent integration platform. The guidelines is the first guidelines for intelligent ships in the world, which is written in the format of GBS. It includes specific aspects of intelligent ships: the objectives, the functional requirements, the verification requirements, etc. The guidelines specify the annexes and functional symbols of intelligent ships to provide the supports and evidence for the registry of intelligent ships in the near future.

2.3.2.4 in open waters, the autonomous ships are capable to sense and acquire the following information at all times, for her autonomous sailing：

(1) live weather data en route：

① wind force, wind direction；

② visibility at sea.

(2) ship live information：

① position, speed, course；

② ship motion，including but not limited：roll, pitch, yaw；

③ port&starboard bow/beam/quarter drafts

(3) AIS data of objects at sea；

(4) update of ECDIS；

(5) live information of other objects at sea：

① other ships: positions，course，speed, size, actual distance, bearing, sailing signals and status；

② other fixed dangers and mobile objects.

(6) actual depth of water at ship's position

For the fully autonomous ship, besides of the situational awareness of 2.3.2.4, she is capable of capturing the following information for her navigation:

(1) live awareness of the distance and bearings from ship's bow and stern to the shore.

(2) tides, currents speed, currents set and other information related within the port and fairway.

In particular, it is clearly specified the ECDIS data and updates, tides, currents speed, currents set and other information related within the port and fairway.

In November,2021, CCS drafted technical guidelines of MASS trials(drafted) and Test Areas regulations on MASS trials(drafted). For technical requirements, they specify the sensor system of ship movement shall include but not limited to the information of position, heading, radar, charts, speed, AIS, etc. All these sensors shall meet the requirements of IMO instruments. Other sensors are also applicable including camera, laser radar, etc. On the control panel, the following information will be displayed:

data source of live position, course, speed

sensor information: position, course and speed

planned trail(including collision avoidance),displayed on charts or in other forms or images

wheel order, rudder angle

TCPA , DCPA

Dangerous targets, will be plotted on radar, for instance.

**SECTION THREE: China practices on MASS trials**

China MSA are promoting the research and development of MASS, and coordinating the MASS trials nationwide. CMSA, CCS and Yunzhou Intelligent organized the trial of the IMO Guidelines in China and report the trial experience and practices.

With the cooperation of CMSA, Zhifei Hao was started to be on trial and Jingdou Yun 0 Hao started her trial as an unmanned intelligent ship. CMSA has completed the MASS trials report and submitted to IMO. The proposal covered sorts of intelligent technology elements including remote control, autonomous tracking navigation, autonomous collision avoidance, etc. The recommendations included trial risks assessment, infrastructure, manning and qualification on trial, communication and data transfer, sailing symbols and marks, information sharing, safety and security liabilities, etc. The report has provided a practical evidence for further revising and improving the Guidelines. Meanwhile, it laid a solid stand for regulation system of safety sailing of MASS and explored the possibility of the commercialized operation of MASS .

**SECTION FOUR: Summary on Data supply to MASS from China Hydrographic Office &New standardized navigating data for MASS(S-100 etc.)**

At present, the MASS trials in China are established on ECDIS with S-57 format, integrated with tides, currents, weather data as reference for MASS navigation. China Hydrographic Office provides the S-57 ECDIS, tides and currents data in digital form.

In the recent years, China is tracking the new navigating data standard-S-100 and its progressing research. The prototype of the data cluster including S-101, S102, S124, S127 is being developed and testing, ECDIS with high-density depth contour is of trial production, and it is being tested in designated areas with the alignment of E-navigation. S-100 trial platform is still on an early stage, the existing ECDIS has no compatibility of S-100 standardized data. As a result, the trial data is not applied into the MASS trials for the time being.

# Member State: Denmark, Danish Geodata Agency

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

The list of current and recent activities in Danish waters.

| Number | Name | Degree of Autonomy | Relevant for the report Y/N |
|---|---|---|---|
| 1 | Remote Controlled minor working vessel. - TUCO Yards, Faaborg & Sea Machines, USA, 2017-2018 | 2 | No |
| 2 | Remote Controlled Tug vessel, Port of Copenhagen – SVITZER, 2018-2021 | 1/2 | No |
| 3 | Autonomous Drone in Svendborg. Unmanned survey vessel – DanaDynamics, 2019-2021 | 4 | Yes |
| 4 | Electronis lookout. Two ferries has been used as test vessels – Ærø ferry & Skarø/Drejøferry 2017-2018 | 1/2 | No |
| 5 | ”Cyber resilient Navigation for Highly Automated Surface Vessels”. Technological University of Denmark and Danish Maritime Authority - Faaborg Fjord, 2020-2021 | N/A | No |
| 6 | Autonomous Ferry ”Fjordbussen” across Limfjorden, Aalborg - Center for Logistik og Samarbejde, 2019-2021 | 4 | Yes |
| 7 | SeaMachines - Mission around the Danish Waters, september 2021 | 2/3 | No |
| 8 | Test by land based pilotage by drone in Nyborg Fjord – DanPilot, 2019-2020 | 1 | |

Relevant comments from report published by Danish Maritime Authority related to this report.

- The four grades of autonomy are perhaps too few. The report suggest six grades of autonomy combined with four ways of reaction for the navigator.
- Fully autonomous vessels are for now on realistic in very simple cases – there will still need to be some form of human control in some grades of autonomy. The report mentions that small channel crossing ferries, service vessels for offshore platforms or barges more easily can be fully autonomous.
- Two of the biggest problems for full autonomy are potential errors in predicting other ships movements and irregular action by other ships. In the past research about creating a COLREG algorithm have been tried without success, and since there has not been a breakthrough in the development.

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region.

Regarding navigation, MASS developers use the usual navigation data such as ECDIS (ENC S-57). Some developers use raw bathymetric data. The raw bathymetric data is being converted into 'GO/NO-GO' areas where the ship can maneuvers within.

In addition to data provided by the Hydrographic Offices, a several different electronic optics are used. Here among IR optics, RADAR, LIDAR etc. The sensors are used to detect objects on the water surface. The objects are then correlated with objects (AtoNs) in the ENCs if possible. Then an analysis and calculation of maneuverability can be made in relation to COLREG but also in relation to the surrounding waters.

For situational awareness, AIS and radar are used to determine the movements of other ships, which is used to calculate maneuverability.

Regarding the use and usage of data and sensors, attention should be directed to the following link were Technical University of Denmark collect their reports on Autonomous Ship development and testing results:

https://www.researchgate.net/project/Autonomous-marine-surface-vessels-ShippingLab-Autonomy

A project plan and some results about the MASS development I Denmark can be found on:

https://shippinglab.dk/

As previously mentioned, the Technical University of Denmark has an important role in much of the development on going in Denmark. Much of their work is open source and can be read online. Through the attached links, you can read, among other things, how the S-57 DEPARE is automatically read and corridors are created for sailing. Subsequently, AIS tracks from ships with the same draft is added to the corridors, and so an optimal route can be planned.

Have any data limitations been identified?

It is already a fact that data for autonomy sailing must be of better quality or resolution than the S-57 data. This is especially relevant when autonomous ships are intended to operate or navigate close to shore, in ports or in areas where the under keel clearance is small.

**WP4:** Report what navigational data each member states' regulators (e.g. MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

The Danish Geodata Agency is not responsible for issuing regulations for autonomous shipping. This responsibility lies with the Danish Maritime Authority.

For now, there are no separate data requirements for autonomous ships compared to non-autonomous ships.

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

The Danish Geodata Agency is not deeply involved in MASS trials and development. The primary contribution is bathymetric data and ENC's (S-57). However, the Danish Geodata Agency works closely together with the Danish Maritime Authority and the Technological University of Denmark, especially on sparring and guidance in the use of hydrographic data.

Have any data limitations been identified?

Our bathymetric data and ENC's are not always adequately for the trials purpose.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state's region.

Nothing to report.

# Member State: Finland

**WP2:** Identify and report what test bed activities are happening in each region and which degree of autonomy is predominantly used

| Project | Purpose | Web site | Mass degree |
|---|---|---|---|
| Sea4Value-Fairway | To help in creating safer, more efficient, sustainable, and reliable service chains to meet the requirements for a better quality of life and global prosperity. | https://www.dimecc.com/dimecc-services/s4v/ | 1-4 |
| Smarter | SMART terminals will continue the fairway digitalization process by digitalizing ports, terminals, and port operations. | https://www.dimecc.com/dimecc-services/smart-terminals-smarter/ | 1-4 |
| Applied Research Platform for Autonomous Systems | To create an ambitious new platform for applied research on autonomous systems. | https://arpa-project.turkuamk.fi/ | 1 & 2 |
| STM Baltsafe | Contribute to increased safety of navigation in the Baltic Sea by providing Sea Traffic Management enabled maritime services to the tanker traffic in the Baltic. | https://www.seatrafficmanagement.info/projects/stm-balt-safe/ | 1 & 2 |
| Callboats | To offer autonomous, silent and clean Callboat for commuting or just enjoying the sea with your friends. | https://callboats.com/#1 | 4 |
| IstLab | To create a smart joint-use Intelligent Shipping Technology test Laboratory | https://istlab.samk.fi/ | 1-3 |
| AutoMare EduNet | To ensure high quality education in the era of autonomous shipping. | https://www.aboamare.fi/AutoMare-EduNet-Project | 1-4 |
| Port Oulu Smarter | To develop and promote utilisation of modern port digitalisation between Port of Oulu customers and actors. | https://ouluport.com/en/harbours/harbour-digitalisation-port-oulu-smarter-2/ | 2 |
| 5GFINLOG | To create a new type of 5G based testing and innovation platform for port logistics. | https://www.xamk.fi/tutkimus-ja-kehitys/5g-finlog-5g-future-innovation-platform-for-logistics/ | 2 |
| Intelligent sea | To improve the safety and efficiency of maritime fairways through digitalization. | https://www.arctia.fi/en/arctia-ltd./intelligent-sea-project.html | 1 & 2 |
| ECAMARIS | ECAMARIS focuses on autonomous ship technologies and concepts which serve as enablers for three use cases: relocation of ship bridge, conditionally and periodically less-manned bridge, and conditionally and periodically unmanned bridge. | https://cris.vtt.fi/en/projects/enablers-and-concepts-for-automated-maritime-solutions | 2-4 |

**WP3:** Report on what data MASS operators and MASS navigation systems are using today – all PT member states.

| MASS Degree | MASS operators | MASS navigation systems |
|---|---|---|
| 1<br>***Ship is controlled locally using data originating to systems that can, at times, function unsupervised but humans being on board ready to take control at tall times*** | Conventional navigation systems known today are used, such as:<br>ARPA radar, speed log, DP system, ECDIS, compass, AIS, GNSS, motion sensors, GMDSS and communication systems and other integrated bridge navigation support systems known to date. | Current navigation systems include but are not limited to following data sources:<br>Bathymetric, AIS, GMDSS, GNSS position, differential correction data, engine status, propulsion status, ice conditions, weather condition data, ship movements in six degrees of freedom, speed log, echo sounder. |
| ***2 Ship is controlled from remote location with seafarers on board ready to take control.*** | See, 1-degree<br>Data transmission from vessel and fairway infrastructure enables situational awareness for remote operator. Situational awareness tools comprise of static and dynamic data from the vessel, fairway imaging, VTS data, fairway radar imaging, digital twin of the fairway and vessel, ECDIS chart and shared route data with the vessel. | See, 1-degree<br>Data transmission tool is on board and situational awareness is based on data collection from the vessel navigation systems, such as Bathymetric, AIS, GNSS position, differential correction data, engine status, propulsion status, ice conditions, weather condition data, ship movements in six degrees of freedom, speed log, echo sounder. ARPA radar, DP system, ECDIS, compass, motion sensors, GMDSS and communication systems. |
| 3 | No current applications | No current applications |
| 4 | No current applications | No current applications |

**WP4:** Report what navigational data each PT member states' regulators are specifying should be used for MASS navigation in either trials or operations of MASS - all PT member states.

| MASS Degree | MASS operators | MASS navigation systems |
|---|---|---|
| 1 | See, WP 3 | See, WP 3 |
| 2 | See, WP 3 | See, WP 3 |
| ***3.<br>Ship is controlled from remote location with no seafarers on board.*** | Operators are able to use and monitor remotely all the current navigation systems, including their input data. For this purpose, new kind of user interfaces and data transmitting options are required to facilitate novel construction of situational awareness. Sufficient situational awareness enables decision-making and vessel control. There is also a need for resiliency, redundancy and independent systems to ensure the safety and security of the operation. Moreover, new procedures and training requirements are necessary for e.g. shore-based crew and maritime inspectors. | In MASS 3-degree, all the vessel and fairway data are transmitted into Remote Operation Centre (ROC) with minimal latency. There is also need, for example, to online video connection, high-resolution image, and robust command/control interface between the ROC and MASS vessel.<br>Additionally, the following new data sources are likely needed:<br>• ENC data of fairway landscape, digital twins of MASS ships, port areas, canal locks, etc, exchange of route information and vessel-status between different ships, VTS, MRCC and ROC. |
| 4 | It has been argued that operators are no longer needed in MASS 4-degree. However, this argument has also received a lot of criticism, as some people see this stage unrealistic. | It has been argued that in MASS 4-degree AI will analyse all the input data and makes the decisions accordingly through e.g. Bayesian, Naural networks and Non-linear velocity obstacles approaches. Therefore, all the earlier noted input data for navigation systems will be still needed. Yet, there will be no longer a need to facilitate ROC operations. |

**WP5:** To what degree are PT member states involved in MASS trials or operations and what data are they currently providing – all PT member states.

Finland has been active in MASS related projects and trials, including international cooperation merging technology providers and research. The role of administration has been mainly focused on the regulatory and financial matters. This comprises, for example, an active participation in the IMO,

EU and IALA work addressed to MASS evolution and providing financial support for project initiatives.
For the time being, the administration has not opened up new significant data sources for private sector to support MASS evolution. However, this work is still in progress in both international and national regulatory bodies.
In Finland, research efforts with MASS solutions have focused into solutions with near future potential for commercial use and upscaled usability for a variety of fairway users. Fairway infrastructure is the one element unifying all fairway users as shared operational environment. Therefore, we see the development of fairways and their potential of contributing to the situational awareness of fairway users, as integral element of the MASS development.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each region? – all PT member states.
Not so much information about this matter. Yet, it has been noted that there is need for 3D applications, including dynamic data on currents, ice conditions, winds, waves, sea level and so on.

# Member State: FRANCE

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

Test bed activities in France mainly concern remote operation of either drones or ship.
Hence, the relevant autonomy level is between IMO's 3 and 4 degree of autonomy.

3 companies have undertaken or undertake projects using drones and vessel: IX Blue, Sea Owl and Sea Proven.
IX Blue drone objective is to recover hydrographic and bathymetric data. It is operated under degree 3 of autonomy.
Sea Proven tests an USV dedicated to the tracking of cetaceans and pollutants. The referred degree of autonomy is 3.
Sea Owl drone is to be used for security missions within oil platforms. It is operated with a degree of autonomy comprised between 3 and 4: the action of the drone is triggered by a specified factor but the mission must be validated by the human remotely operating the drone. The COLREG management is the only autonomous part of the drone action.
Sea Owl also tests a remotely operated 80 metres vessel intended to manage drones within oil platforms. It is operated with degree of autonomy 3.

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region.

In the Sea Owl project, the remotely operated drone uses S57 data, enhanced with company data (e.g go and no-go areas), converting the conventional chart into a decision chart. Further, all the relevant maritime safety information are inserted in the vessel monitoring and alert system.

Regarding the remotely operated vessel, crew is onshore and operates the vessel through the same supporting functions (including ECDIS) as if it were onboard.

**WP4:** Report what navigational data each member states' regulators (e.g. MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

French regulations draws a line between drones and vessels, based on criteria such as length, power, speed, gross tonnage and presence of human onboard or not.
Taking this into consideration, there is so far no requirement of any navigational data for the testing of drones.
Intended autonomous or remotely operated vessels however must be fitted with the same level of navigational data that conventional vessels. This means that the same SOLAS or national requirements apply.

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

Shom is part of a project aimed at renewing the future French hydrographic capacity by using a fleet of unmanned surface vehicles and autonomous underwater vehicles.
The data collected in this way are intended to be used in the Shom's official products and services.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state's region.

Some academic work is carried out on ontology and knowledge database (KB) to structure and store maritime regulations information and nautical instructions (mainly based on RDF (Resource Description Format) data model and semantic web standards).
The text in "natural language" of these publications is not machine readable whereas information structured in a knowledge database consisting of a network that represents semantic relations between concepts is machine queryable.

The ENC data (S-57 or S-101 using ISO 8211) is not adequate for software based on spatial analysis (e.g algorithm able to determine the best route using features of the ENC). Spatial indexation of ENC data, e.g Hexagonal Hierarchical Spatial Index, could be a solution to foster spatial analysis.

# Member State: Japan

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

There are two major MASS test beds carried out around Japan. One is led by the Government of Japan. The core organization of this test bed is the Ministry of Land, Infrastructure, Transport and Tourism, our parent organization. Another one is called MEGURI 2040, led by a public interest incorporated foundation, the Nippon Foundation.

Since 2018, the government of Japan has conducted first serious trials of MASS to improve the environment for its development such as establishing safety requirements, which is needed to put MASS into practical use. Autonomous operation trials were conducted with an advanced battery powered ship equipped with autonomous operation function to avoid collision and grounding. Remote control trials were conducted in the Tokyo Bay with a tugboat, which was controlled from an onshore facility in Nishinomiya City 400 km far away from Tokyo. Autonomous berthing/un-berthing trials were conducted with a large vessel more than ten thousand gross tons at a temporally installed offshore pier. The government of Japan aim at achieving Phase II, that is, controlling ships from land facilities and/or utilizing action proposals led by AI to support mariners, by 2025.

The Nippon Foundation has assembled and made a decision to fund five consortia to conduct verification testing for unmanned ship navigation. So MEGURI 2040 is composed of 5 small projects shown in right part of the slide.

- Smart ferry development is to confirm the effect of strengthened monitoring in detecting engine breakdowns in addition to autonomous navigation including departing and docking of a large coastal ferry.
- Autonomous navigation of small vessels is to develop technologies for fast, inexpensive, unmanned navigation of existing small vessels to realize autonomous navigation technologies for a broad range of small vessels.
- Grand design drawn by diverse specialists is open collaboration to achieve a "new age domestic logistics society" supported by unmanned navigation, created by a diverse group of specialists.
- Verification testing of unmanned technologies is to avert marine accidents caused by human error, and reduce labour requirements in the face of an aging, contracting maritime workforce, through testing using container vessels and car ferries.
- Development of unmanned amphibious driving technology is to conduct open-source development for unmanned driving of amphibious vehicles at the lake. The vehicles will enter the water from land, self-navigate on the water, and return to land.

Each consortium is to begin verification testing by the end of March 2022, with a target of implementing autonomous shipping by 2025. Some of the testing were conducted this year.

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region.

On MEGURI 2040 project, a MASS support centre on land collects and analyses S-57 ENCs, MASS condition, meteorological condition, AIS information, navigational warnings and past maritime accident information, and provide feedback for securing safety and efficiency of MASS navigation.

**WP4:** Report what navigational data each member states' regulators (e.g. MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

In December 2020, the government of Japan has compiled points of concern at designing phase of MASS and published Safety Guidelines for MASS "Design", based on the result of discussion among experts in "Working Group for the safety of MASS". This guideline is only for safety designing of MASS.

In February 2022, the Japanese government updated the guidelines. Topics regarding on-board Automated Operation System and MASS navigation are added to the original one, however, the updated one still does not contain regulation or rules regarding specific hydrographic or navigational data.

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

Japan Coast Guard (JCG) provided navigational warning data, AIS information and past maritime accident information for Meguri 2040 trials, however, we have not been involved in the MASS trials as a core member.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state's region.

Above mentioned two test beds have been conducted without any S-100 standards. Hydrographic and Oceanographic Department, JCG, has not received information on MASS trials which are carried out around Japan with new navigation standards or researches into machine readable data.

# Member State: Norway

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

Much work is being done in Norway related to the development and testing of autonomous vessels an associated infrastructure

**Test Areas:**

Five test areas have been established in Norway:

1. Trondheim's Autonomous Vessel Test area: Worlds first established in 2016
2. Ålesund –Storfjorden
3. Horten
4. Haugesund – Newest opened in August 2021
5. Tromsø- Arctic University of Norway Project.

Aims

- To be used in the development of autonomous vessels.
- Facilitate knowledge gathering.
- Stimulate the development of new technology and innovation.
- Develop rules and standards for autonomous vessels.
- Test and verify solutions and concepts.
- Collaborate with other test areas and initiatives.

**Projects:**

**IMAT – Integrated Maritime Autonomous Transport Systems Project**

- 3-year Project (2019-2022) funded by the Norwegian Research Council
- Partners, Kongsberg, Massterly, NTNU, Sintef Ocean.
- The main project objectives are to define, develop, adapt and test infrastructure that supports maritime autonomous transport systems and has the following focus areas:
    - Sensor and communication infrastructure
    - Local Monitoring Centre (LMC)
    - Shore Control Centre (SCC)
    - Collaboration
- Project Paper

**AutoSea**

- Main goal of the project is to develop methods for guidance and navigation of autonomous ships. A central component of this is collision avoidance, also known as sense-and-avoid.
- Sensor fusion and collision avoidance for MASS.
- Technology developed and used as foundation for Autoship project.

**AUTOFERRY -Autonomous all –electric passenger ferries for urban water transport**

- Project aiming to develop small autonomous passenger ferries for use in urban water transport.

- Predicts that the 'Captain' will be just as important as with manually controlled ships' – the job will just look a bit different.
- Working on developing 'Shore Control Lab' for use in remote operations.
- Mission: 'keep humans in the loop.
- **Focus on Autonomy Grade 3**

**NAVISP –Navigation Innovation and Support Program**

- Project financed by the European Space Agency (ESA).
- Investigating ways to improve Satellite navigation, alternative position and new navigational service and applications.
- Positioning sensors, satellite navigations and Artificial Intelligence used to help establish the Trondheim Autonomous Vessel Test area.
- Final presentation of project 28.2.2022.

**Hull –to-Hull Project (H2H)**

- Project ran 2017-2020
- Cconcepts of hull to hull positioning and uncertainty zones used to assist navigators and operators to perform safe navigation.
- Data from position sensors and geometry (2D/3D) shared between vessel's/land to help calculate distances between objects and avoid collisions
- The concept will support safe navigation of vessels and objects which are in close proximity of each other. H2H will assist mariners in making correct navigation decisions.
- Data exchange protocols will be based on IHO S-100 Standards

**Vessel Testing:**

Unmanned Surface Vessels (USVs) - Maritime Robotics

- Being trialed in Trondheim's test area
- *The Otter* – Portable USV solution
- Remotely controlled from either the vehicle Control Station (VCS) or mobile phone app – **Autonomy Grade 3**
- *The Mariner* Larger multipurpose USV system
- Remotely operated from the VCS which features electronic charts, engine and navigation info. The operator can monitor the surrounding sea areas and get collision avoidance warnings based on AIS, radar and video information.

**Autonomy Grade 3**

Ocean Space Drones 1 & 2

- Unmanned vessels equipped with ECDIS, Radar GNSS, AIS camera, VHF, MBR (Communication)

- Used for testing Collison avoidance systems.
- **Autonomy Grade 3**

Yara Birkeland

- World first fully electric autonomous container vessel.
- Will be put into operation 1st April 2022

- Initially it will start a two-year trial to become autonomous and certified as an autonomous, fully electric container vessel. Before it is put into operation,
- First phase of testing will include a degree of autonomy 'auto docking' and 'auto crossing' but crew on board – **Autonomy Grade 1-2**
- 2024/25 – aim to be fully unmanned and remotely operated – **Autonomy Grade 3**

<u>Asko Autobarge</u>

- Unmanned electric barges being developed by Kongsberg Maritime
- Same timeline as Yara Birkeland:
- First phase of testing will include a degree of autonomy 'auto docking' and 'auto crossing' but crew on board – **Autonomy Grade 1-2**
- 2024/25 – aim to be fully unmanned and remotely operated – **Autonomy Grade 3**

<u>Zeabuz in collaboration with NTNU</u>
- MilliAmpere Project - 2 x Autonomous and electric passenger ferries.
  - Vessels to be put into public operation in 2022.
  - **Autonomy Grade 1-4**

<u>Reach Remote</u>

- Project focusing on developing autonomous and remote solutions for offshore operations.
- Testing of Reach Remote Unmanned Surface Vehicles (USVs) began in 2021 expected delivery of first two vessels 2023
- **Autonomy Grade 3**

**General comments from interviews:**

- "Autonomous does not mean without human interaction"
- The four grades of autonomy are perhaps to narrow.
- Fully autonomous vessels are unrealistic except in very simple cases – there will still need to be some form of human control to differing degrees.
- Two of the biggest problems for full autonomy are potential errors in predicting other ships movements and irregular action by other ships.
- Much of the testing has focused on a mixture of grades of autonomy- different degrees at different stages of voyage with a focus on achieving autonomy grade 3.

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region

1. Traditional navigation sources are being used for route planning and route monitoring from control centres – ECDIS, ENCs Paper charts (in some cases)

- RTZ recommended routes and fairways published by Coastal administration

2. Key focus on the real time data from:

- AIS Data Bank

- ATONS
- DGNSS
- GNSS
- Rader
- Weather Data

3. Also key focus on development and use of sensors to provide situational awareness and avoid collisions.

**Have any data limitations been identified?**

- Need for full bathymetric coverage datasets/DTM
- Need for a better standardisation and accessibility to harbour infrastructure datasets.

**WP4:** Report what navigational data each member states' regulators are specifying should be used for MASS navigation in either trials or operations of MASS

The Norwegian Maritime Authority and The Norwegian Coastal Administration are jointly responsible for regulating both the trials and operation of MASS in Norway.

A formal regulatory framework in in the process of being prepared in tandem with the relevant testing activities taking place.

Navigational data requirements are the same as non-autonomous vessels.
-ENCs/ECDIS
-AIS
-VTS
- Coastal administration has created a network of 'Recommended Sailing Routes' for Norway these are available in RTZ format and are used in testing activities.

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

The Norwegian Hydrographic Service has been following developments in MASS in Norway very closely and is an active member of several groups including:

- ISTS Norway – Intelligent Sea Transport Systems Norway
- NFAS – Norwegian Forum for Autonomous Shipping

NHS is not currently not providing any additional data to that already available but have begun discussions to determine specific user needs and to determine if we can begin to supply test data.

- Have established a production system for HD ENCs and S-102 for selected harbours and it is believed these products will assist MASS testing.
- Also, in process of establishing S-111 production.

- In addition, we have worked to improve the quality of data in or ENCs covering the recommended routes determined by the Coastal Administration.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state's region.

**S-100 Demonstrator Project**

- To define how the new standards combined can create value for the maritime industry
- How new and improved products can be designed and developed based on the new standards.
- Focus on the use of:
  - S-101 (ENC)
  - S-102 (Bathymetry)
  - S-104 (Water Level information)
  - S-111 (Surface Currents)
  - S-129 (Under Keel Clearance Management)

- Autonomous shipping will rely on precise secure and official data combined with local sensor defined information to secure safe and precise operations and voyages.
- Through the S-100 demonstrator project ECC is developing an effective S-100 data delivery service that can support autonomous navigation.

S-100 Demonstrator Project Link

# Member State: ROK

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

ROK has been conducting the national research & development project named as KASS (Korea Autonomous Surface Ship Project) and the project outline is as follows:

- Project name : Development of Autonomous Ship Technology
- Funded by : Ministry of Oceans and Fisheries & Ministry of Trade (Industry and Energy)
- Project Period : 2020-2025 (1st~4th year : System development & integration / 5th~6th year : Demonstration)
- Budget : 160.3 billion won (133.3 million dollars)
- Objectives : Development of Core technology of Autonomous ship, Laying the foundation for Commercialization through Phased demonstration

The core technology of autonomous ship that are being considered in the KASS project can be defined as follows.

- Intelligent Navigation System
- Machinery Automation System
- Performance Demonstration Center and Demonstration technology
- Operational Technology and Standardization

The KASS project focuses the MASS engaged on international voyages (Mid-sized merchant ship) and aims to develop a testbed of IMO level 3 for ocean and IMO level 2 for coast in the level of autonomy.

Detailed information on the MASS testbed project in ROK can be found at the below address

https://www.kassproject.org/en/main.php

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region

MASS operators and MASS navigation systems are mainly using ENCs and marine weather data. Hydrographic data like ENC, navigational warnings, bathymetric surface data, tidal water level should be used for calculating the optimal safety route of MASS.

As a similar research project to KASS, the Korean e-navigation project has been promoted, and one of the main technologies has been developed to calculate and provided the optimal safety route for ships operating at sea. At this time, S-101 ENC, S-124 navigational warning, S-102 bathymetric surface grid, S-104 tidal water level were used. Referring to the research results developed in the e-Navigation project, it's expected that it will be similarly used for calculating the optimal safe route of MASS.

**WP4:** Report what navigational data each member states' regulators (e.g. MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

There is not a national data required by regulators (Maritime safety administration in ROK) for MASS operation and navigation

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.
KHOA (Korean Hydrographic Office) in not currently involved in testing and operating MASS. KHOA produces S-10X dataset and provides it as a Korean e-Navigation services, and the provided data is used for safe operation of ships and calculation of the optimal safe route algorithm.
As it’s expected that hydrographic data such as S-57 ENC and S-10X series dataset will be absolutely necessary in Korea’s MASS project, discussions are ongoing between KHOA and the MASS project group on what data is required and can be provided.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state’s region.
The MASS project team in ROK is considering standards for data exchange between shore and ships included in ISO standards which is the ISO 19848 ship and marine technology - Standard data for shipboard machinery and equipment, and is being applied as a standard for information exchange between shore and ships during MASS research.

# Member State: United Kingdom

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

There's significant activity happening in the UK covering the full range of MASS Degrees. That said, it is fair to say that most of the vessels being used are smaller craft which fall into the MCA's workboat description, though there are a few developments happening with Ocean Infinity and Promare which will see vessels being developed way over 24m in length.

There are two main hotspots of activity in UK waters (though the testing of MASS can happen in any part of the UK waters with permission from the MCA and local Harbour Maters). The first area is based in the Plymouth region, which is known as Plymouth Smart Sound (https://www.smartsoundplymouth.co.uk/). The Smart Sound area covers approx. 1,000 sq. kilometres of authorised and de-conflicted water space that is used for the trials, validation and proving of marine innovative technologies, with an emphasis on marine autonomy. Furthermore, there is a cluster of autonomous vessel operators, builders, system integrators and academic institutions known as the Future Autonomous at Sea Technologies (FAST) cluster that operate and use the Smart Sound (https://smartsoundplymouth.co.uk/Industry). UKHO is a partner of this cluster and engages the members on aspects of navigation relevant to MASS.

The Solent is another hot spot of activity with a number of MASS developers operating from the area around Southampton and Portsmouth. The UK's National Oceanographic Centre with its Marine Robotics Innovation Centre being one of the main players in the Solent area along with world leading players such as Ocean Infinity and their new Armada fleet, L3 Harris and Atlas Elektronic.

One of the most high-profile MASS projects is the Mayflower Autonomous Ship (https://mas400.com/). The Mayflower Autonomous Ship (MAS) is an initiative led by marine research non-profit Promare with support from IBM and a global consortium of partners. It can spend long durations at sea, carrying scientific equipment and make its own decisions about how to optimize its route and mission. With no human captain or onboard crew, MAS uses the power of AI and automation to traverse the ocean in its quest for data and discovery. The ships' AI Captain performs a similar role to a human captain. Assimilating data from a number of sources, it constantly assesses its route, status and mission, and makes decisions about what to do next. Machine learning and automation software ensure that decisions are safe and comply with collision regulations. The UKHO has been involved and continues to be involved in a number of MASS navigation projects with the Promare team using the Mayflower as a platform, which will be outlined further in this report.
It is also worth reporting that Warsash Maritime Academy, which is part of Solent University Southampton, has just established the Warsash Maritime Autonomous Surface Ships Research Centre. The Warsash MASS Research Centre (WMRC) aims to develop into a world-class 'Centre of Maritime Excellence' and become an international leader in maritime research. The centre will explore the future possibilities in developing MASS technology and study the impact of these innovative technologies on human elements while working in tandem. The centre will also explore the pedagogical, professional education and training needs to make the workforce future-ready to operate with these technologies either onboard MASS or remotely from shore stations.

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region.

Due to the nascent nature of MASS, the industry is trying to make do with traditional products and services that are used by manned vessels. We have seen examples of Google Earth used for planning MASS missions, paper charts hung on walls for situation awareness and unofficial charts and publications being used. The more advanced operators are using S57 data, despite some of the limitations of the data. In our discussions with MASS operators the main focus to date has been on implementing sense and avoid technologies using computer vision, radar and AIS, little thought has been spent on the navigational data if at all. That said, those that are using traditional products and services, such as S57 and Tidal data have expressed a number of limitations and issues with these traditional products, some of which may still be present in the new S100 framework as the primary use for S100 is still an ECDIS and human being.

The issues encountered have been outlined below: -

**Sonardyne**:- Met at their Head Office and Production Facility in Blackbushe. Initially there seemed very little for both organisations to collaborate on or little they could contribute to the IHO MASS requirements work due to their main business being centred on Inertial Navigation System (INS) equipment, their flagship product being the Sprint NAV which uses doppler log technologies. They spoke of a number of projects where they want to use their INS coupled with terrain following capabilities to act as an alternative positioning system for GNSS denied or spoofed situations. However, they talked about not wanting terabytes of bathymetry data and were interested if significant seabed features could be categorised for INS systems to lock onto. This is a similar construct to land based visually conspicuous features only on the seabed and the feature could be obstacle and pinnacles or even trenches. However, they would need meta data of the S102 (e.g., you can have very high-resolution data that is subject to continuous change like to Humber) so certainty of the data (which has been mentioned several times in previous discussions with other MASS operators) would be crucial before any reliance of the data could be ascertained.
Furthermore, they were interested if the reflective nature of the seabed could also be categorised, which is useful in the technologies they use in the INS systems. Whether this could be derived from the seabed characteristics or not is something to be determined (i.e. is sand more reflective than rock). They also were interested in modelling acoustic qualities as some of the INS systems struggle in waters with poor sound qualities.

**BlkSail**:- their decision support system is capable of Degrees 1 + 2 currently with plans to go to degrees 3 and 4 in time. The biggest issue they face is the scheming of charts and edge matching issues when moving from one chart to another, often with discontinuation of data (contours and depth areas being an obvious area of data discontinuity). They describe a "leap of faith" when moving from one chart to another. Humans can make this leap easily, but computers find this an issue. A number of solutions could be provided here, one could be to have seamless and scaleless data for MASS, another could be a consistent gridding approach and another could be some method of describing what is happening at a chart edge if there are data discontinuity issues, or even allowing overlap of data to allow for continuity.

They also desire more visually or radar conspicuous features to be captured which can be used to triangulate a position in a GPS denied environment. That said, there need to be some form of attribute that describes the certainty of a features' position. Some features are immovable (e.g., lighthouses) whilst some features can move (e.g., a buoy), so having a sense of how certain a position is will be crucial for systems trying to auto triangulate itself.

They also want the main shipping lanes to be made available. HO's typically steer away from showing these due to clutter, but this may be crucial information for MASS.

Tidal heights and surface currents are also important for under keel clearance. They need predictions and forecast tides and surface currents, but again certainty factors surrounding the predictive and forecast heights and currents is very important. They suggested having a percentage factor (e.g., 80% certain the tidal height at this location and time will be 3m).
The temporal nature of data is also of concern. Data always being as up to date as possible is paramount, the example given was for seabed areas that are dynamic in nature or highly mobile. There may be a need for an expiry date on the data, or as mentioned above a certainty factor could also help in this regard and help the MASS make decisions based on certainty factors and risk.

MASS operators are tending to use a combination of existing data supplemented in conjunction with sensor inputs, namely AIS, conventional and IR cameras, radar.

**ASV (now L3 Harris)** – UKHO conducted a report into the future of navigation for MASS for the UK Govt Dept for Transport utilising the Transport – Technology, Research and Innovation Grant process. Some of the key findings from that report (which will be referred to as the T-TRIG report), are outlined below.

**Computer vision and visually conspicuous features and imagery**
Vision, or 'what is out of the window' is without doubt one of the most important elements to situational awareness. Monitoring dynamic objects, identifying static objects, confirming position relative to the coast or navigational marks, monitoring the weather and sea-state are all critical to safe navigation.

The performance of these visual systems is heavily dependent on large training/reference sets of images and databases of the coastline/navigation marks.

Despite a notable absence from the primary working document of the modern navigator, imagery provided for illustrative purposes still plays an important role in navigation and is featured extensively in coastal 'pilot' books, port familiarisation and approach guides, Sailing Directions as well as some electronic chart displays.
In addition to still photographic images, larger vessels with more stringent safety requirements may also provide on-board simulation facilities that allow bridge crew to rehearse harbour approaches and docking manoeuvres in a synthetic environment; utilising detailed 3D models that capture both the underwater and the above-water environment.
All these documents and systems work together to help the mariner build up a mental model of the approaches to a port, supporting situational awareness, planning, and overall helping to ensure safe operation in these congested waters.
Looking forward, the use of synthetic and photographic imagery by human mariners seems certain to increase substantially, driven by both advances in technical capability and expectations set by the availability of consumer information services such as 'Google Street View'.

As an example of the art of the possible, the 'Chart of the Future' research programme funded by the US National Oceanic and Atmospheric Administration (NOAA) and carried out at the University of New Hampshire has shown the potential of panoramic photographic imagery integrated into electronic navigation tools and illustrated the benefits that it can provide to mariners in reducing cognitive load and improving safety.

Autonomous surface vessels have a rapacious appetite for imagery data and consume it in industrial quantities. However, unlike imagery intended for the human mariner, this data is not destined for the masters of individual vessels, and nor is it (only) consumed at sea, but rather it is also exploited on land by the engineering process which produces and maintains those vessels.
Almost every stage of the product life cycle has the potential to consume imagery data.
The first demand for non-trivial quantities of imagery data arises from the development and training of the learning algorithms which are typically used to detect and classify potential hazards in the waters around the autonomous vessel.

With systems in service, the need to maintain that assurance against the background of a continually evolving and changing world will raise its head, creating a potential need to keep simulations up to date with real world conditions and to identify incipient risks and hazards.

It is likely that systems for navigating harbours and inland waterways will operate in a similar fashion, making use of detailed three-dimensional maps or Digital Twins, built using a combination of Lidar, radar and camera sensor data. These maps enable high precision manoeuvres and help to counter the possibility of malicious GPS spoofing attacks.

These are entirely new data flows, ones which challenge our preconceptions of the role of charts and of the role of maritime geospatial data and of how we might use these things to assure the safe operation of vessels at sea.

This imagery could include but not be limited to:
- Coastal terrain (possibly from several offset distances with the camera height carefully recorded)
- Navigation marks
- Harbour approaches
- Dock / quay walls
- Major buildings or landmarks
- Bridges and other man-made structures extending out to or over the water.

Another significant element of potential for navigation is the integration of 3D coastal imagery, and recent work looking at Digital Twins of the port or coastal environment could offer much potential as a navigation tool.

**Contextual data found in text boxes or Nautical Publications**
The amount of information that can be placed on human readable charts is limited. It is typically graphically represented with side information notes and if too much is added the chart becomes over-cluttered and information can be missed. The situation for an autonomous system is vastly different, a computer can handle very complex, multi-layered information sets with ease and therefore opens the potential for significantly more information to be included. These need not

be limited to simple graphical representations but can be defined co-ordinate geographical ‘fences’ with logical machine-readable instructions for actions.

For computer-based systems, reading in data sources like these is particularly difficult due to the complexity of the retrieval of the data and its need for interpretation. As a human looking at a chart it is relatively easy to understand information like coloured buoys marking the edge of a channel, but for a computer linking these buoys correctly to form a line and thus a channel can be non-trivial. With information like this in a suitable format for autonomous and smart vessels to understand, it makes it possible for them to plan paths and obey the rules of the sea. Instructional layers are going to be a method of supplying a smart or autonomous vessel with this information, in a way which it can successfully interpret, enabling it to make safe and sensible decisions.
The aim of instructional layers is that they are a machine-readable set of data, where location-based information can be accessed. The instructional layers would contain a location, identifying name, description, unique number and any additional information.

Before departure this information will allow for more sophisticated planning as information like speed limits in areas will be available to the software when it starts calculating a passage, enabling it to arrive on time at its destination.

The data contained will be of a factual nature, rather than offering guidance. An example of this would be a zone identifying a natural kelp bed. It is then for the autonomous vessel to decide if it can safely traverse this area or not. This allows the vessel to make use of on-board sensors to identify the depth of the kelp, which will be seasonally dependent, rather than being instructed to avoid and area due to the possibility of kelp tangling in the vessels’ propellor blades.

Accurate depth mapping could also be useful for an autonomous vessel as a navigational aid, beyond the basic calculation of if the vessel can safely traverse an area. Navigationally, the depth recorded by the vessel can be used to identify a likely current location, and thus can be used as a secondary source of positioning data.
Extra information for a depth instructional layer would be the material of the seabed along with the uncertainty for the depth. For soft seabed materials, like sand, the depth can change significantly. This makes the depth measurement inaccurate, and for an autonomous vessel it would be helpful to have an indication of the variation observed within the area, and thus an error in the measurement. For a rock-based seabed, the depth will not change, thus the error in the depth measurement would be minimal.

Speed limits are another area that would work well for instructional layers. They would be larger polygons identified by longitude and latitudes marking the vertexes. These would simply specify the speed limit within the given area, e.g., within a port. By having this information digitally, the vessel is not expected to be able to identify and ‘read’ speed signs on a harbour wall, making obeying them a simple procedure. An autonomous vessel would be aware that its planned path would pass through a speed limited zone and could plan its passage to adhere to the limit, whilst still reaching its destination on schedule. Including information like the reason for the speed limit may also help an autonomous vessel make educated decisions. For example, if the speed limit is a temporary limit around harbour works the autonomous vessel may plan to totally avoid the area as there is a higher risk collision with working vessels.

Communication zones would be of particular use as currently the rules for radio communications are within the Admiralty list of radio signals volumes 1-6. These volumes are particularly difficult for an autonomous vessel to understand.

National infrastructure zones would also be necessary to identify areas of importance which could have security implications. For example, undersea pipes which transport oil and gas may be marked approximately on a chart, but the exact locations are not displayed as they supply an important service that could be maliciously targeted. For these areas a polygon larger than the infrastructure would be used to obscure the exact location of the resource, and thus protect it.

For each instructional layer/feature there would be a list of longitudes and latitudes connected to form a polygon. There would then be a list of attributes for the polygon, containing the information the vessel needs to act correctly within the area.

Most of the layers/features will be for permanent information, but it would also be possible for temporary layers to be added, with vessels receiving this information as they enter a port. These layers may include the time and path of a cruise ship leaving port, or a temporary exclusion zone around a dredger. This type of temporary layer is most likely to be controlled by harbour masters, containing information that they would typically disseminate to captains. Navigation warnings could also be added to temporary instructional layers, as they contain a location and information about that area. This then allows autonomous vessels to use the most current information during its passage.

**Unique Identifiers**

A chart may show an area of 'mooring posts' but not define how many or where, this information would overload a human readable chart. If, however they were identified with unique ID numbers and positions in a machine-readable format they would be a highly accurate method of the MASS in verifying its position, progress against goals and navigational status.

**Updating data**

In the world of autonomous vessels, it is expected that communications between the vessel and shore will be continuous, uninterrupted and as such this could enable more frequent or real-time updates to be pushed from official sources (such as the UKHO) that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS.

**Sea-Kit** - They are using Degree 3 (i.e., remotely operated), but at the lowest end of that spectrum, all decisions are made by the human remote operator and for Degree 3 they foresee that they will still use traditional and next generation navigation products as mariners on board do today.

That said, some similar themes as mentioned in previous discussions came out. The need for very accurate data and a sense of assurance on the accuracy is key for their operations.

They also mentioned discrepancies in Tidal data (i.e., Prediction and Forecast isn't always right), so do we need to reconsider 'real time' being put back into S104 and the certainty aspect mentioned above with BlkSail?

**RoboSys** – Their Voyager system operates somewhere between Degree 3 and 4. The system takes in a predefined route which it will follow, but it will make decisions and deviate if hazards are detected and then come back on track. It can also aid the mariner in evaluating a predefined route and can determine if a route is safe or not.

Issues they have are accurate Tidal Height and Surface Currents (speed through water versus speed over ground is crucial). The quality of the data is vital, specifically in congested water space areas. This theme is common across operators we have spoken to.

Another big factor for them is restricted water space. The examples given included military exercise areas or firing ranges, they need to understand when these are active and associated restrictions in force. Currently, this information is not clear. The example he went on to describe was that Voyager will see that feature on a chart and recognise it as a no-go area and traverse around it (could be some distance). However, the range may only be briefly active, and the vessel may be safely transit this area at the intended time thus avoiding a lengthy detour. So, temporality of features and their use is very important for MASS systems.

They also mentioned that speed restrictions are not shown on charts which was identified by ASV in the T-TRIG report referred to above. The restrictions are often captured in Sailing Directions or text boxes on the edge of charts and are very verbose text, not really suitable for machines to read and interpret.

He also suggested free text in Nav Warnings could be a problem for machines to interpret and act upon. Indeed, we have spoken to the Chair of the WWNWS and S124 chair, and the free text aspect of navigation warning is an area that needs to be addressed.

Temporality coupled with additional attribution may also be very important. An example given was fish farms, whilst they may be marked on charts, it might be useful to know that at certain times in the season, these features need a wider berth due to breeding etc. Whilst at other times, it is perfectly safe to travel in close proximity to the fish farm.

Unsurprisingly, confidence levels in the data needs to be articulated (this is becoming a theme), specifically related to tidal heights. Bramble Bank in the UK was used as an example, where being at variance by 0.5m (shoaler) could lead to a grounding.

Another big factor for their system is knowing that the vessel needs to go through a traffic separation scheme. Voyager can pick its own route and will avoid hazards, but how would it know it needs to join the TSS when entering the English Channel? Whilst it’s not our role yet to identify solutions, there are two possible options or perhaps both could be employed.
The first would be to have a constricted water space feature with an attribute that states TSS is present. The MASS can then do a spatial search within the feature for the TSS and then route to and through it accordingly. The second option is to have a buffer attribute on the TSS of say 50nm, then when a MASS route intersects the buffer, the MASS knows that it must now use the TSS. Both used together could work, but this is a simplification and other factors such as directionality etc would need to be factored in.

The idea of a conditional hierarchy for autonomous decision making was discussed. An 'if this, then that' approach. As an example, the previously mentioned TSS’s reporting points and speed limits are relatively fixed so are high up within the hierarchy, other temporal features are not and can be further down the hierarchy. Furthermore, “if, then, else” type parameters could be used for temporal features such as active gunnery ranges requiring specific action during the active phase (e.g. if feature is a range and it is active then avoid, if not active else safe to pass through).

Reporting points also need to be made available spatially with appropriate attributes. The example they gave was knowing at what point to contact Falmouth Coastguard to say whether you were passing between UK mainland and the Isles of Scilly or not.

A generic comment from Market Research carried out by the UKHO suggested that dynamic areas of restriction would be really useful, these are not on charts currently but will be important for MASS in deciding where they can and can’t go. This chimes with the ASV DfT T-TRIG report and RoboSys need for areas of restriction to be made available in machine readable formats.

**L3 Harris** –
They operate mainly at Degree 3 but can do 4, when in deep water, away from shore and usually when conducting survey activity.
Their general concern is that all data should be machine readable as that is crucial for MASS, human written language is a big issue.
They think it may be useful in the future to have polygons in the ENCs that show what degree of MASS is allowed, so for example in a port Degree 4 may not be allowed, this should be available as interrogable data so the MASS knows whether it can enter a region or not or whether someone needs to take over and operate remotely. This is analogous to the pilot pick up points, where vessels sail to the pilot pick up point and then a pilot comes on board and takes over.
They also feel there will need to be protocols in place to allow MASS to communicate with the shore. This is similar to that mentioned by RoboSys, how would a MASS know who to contact depending on the reporting region it is in. This is shown diagrammatically in Radio Signal, but it isn't shown on charts, will it be covered in S-123?
Speed limits and constraints or rules of the road need to be captured geospatially with appropriate attribution to allow the MASS to interrogate the feature whilst entering it or whilst looking ahead in order to avoid, or behave appropriately, this has been mentioned several times by a number of operators. Generally, they feel a lot more polygons are required. Channels are a good example, they are marked on charts with red and green buoys, but how does a MASS recognise that as a channel, it should be captured as a polygon, again mentioned in the T-TRIG report.
They mentioned a library of real-world images for use by computer vision systems to use for approximation and comparison, which is also outlined in the T-TRIG report. Digital Twins were also discussed as being useful and they described a need for something similar to Google Street View for ships. Particularly when entering a new port.
Certainty of position came up again, with buoys being mentioned as the main example.
They also mentioned the need to understand regular patterns of timings, such as ferry routes, could these routes be captured as corridors with the ferry timetable being made available as attributes.

**Kongsberg-**
They described the Yara Birkeland (it uses Kongsberg’s systems) as a sophisticated level 3 MASS in that it has sophisticated auto pilot features, but it isn’t quite capable of Degree level 4. Some

of their main issues centred on a need for more topography data or visually conspicuous data for alternate positioning systems.
They mentioned that light sectors can also be an issue for their systems, and they need to know if a light feature will be blocked by land mass that is in front of the light, so they need to understand line of sight from the light feature or any significant navigation mark for that matter.
They talked about the resolution and certainty of bathymetry data being a very important aspect. The certainty of data allows them to model risk and vessel behaviour accordingly (e.g., less certainty = high risk profile = behaviour change).
They also would like to understand the drift on buoys, so knowing the length of chain and tidal range would be useful for them.

**Ocean Infinity-**
We visited their new purpose-built building in Southampton, which is an extremely impressive set up. They are building a fleet of vessels ranging from just under 24m, up to 37m and 5 larger 78m vessels. The smaller vessels will operate remotely at Degree 3, though are capable of operating at Degree 4 of autonomy. The larger vessels will operate at Degree 1 initially with minimal crew, however in time, as regulations allow, they will also be able to operate at Degree 3 and 4. Their Remote Control Centre (RCC) is incredibly impressive. It is a purpose-built room, with lighting, temperature and sound control strictly monitored and controlled. There's 20 state of the art booths with a captains' chair, multiple control surface and screens that can be used to remotely operate vessels anywhere around the world via Sat Comms or 4G.

Dan Hook, their CTO contributed to the T-TRIG report extensively and didn't have much more to add over and above the comprehensive issues and ideas identified in the report. However, in the discussions, real time or actual tide height is becoming increasingly important to them in their business as they are being asked to survey shallow waters and knowing the actual height of water at a given time and location is becoming a key factor for them.

**National Oceanographic Centre-**
They mainly use AUVs and two smaller USV (sub 2m). They use these somewhere between Degree 3 and 4, in that much of the time the vessels (particularly Wave Gliders) are operating autonomously, but they are continually monitored and receive instructions remotely. Despite their limited use of USVs they had some interesting requirements for data.
They mainly need the data in their Command and Control (C2) systems and not on board the vessel itself. That said, there were some common themes that came out in discussion that came out from the larger operators. For example, they want to be able to extract features relevant to them such as Traffic Separation Schemes and any exclusion or restriction zones, they talked about a need for more polygons with attribution that can be extracted from an ENC.
They talked about wrecks features being extremely important, today wrecks may be generalised on a chart due to scale, this will probably be the case in S101 going forward. An example of this was offered as wrecks within recognised fishing areas. The implication being that the existence of snagged or discarded nets which may represent a hazard to underwater 'flight' by ROVs. They wanted all of the wrecks data and information about scatter of different parts of the wreck, this is very important for their AUV work. A discussion then ensued around scaleless data for MASS, at the end of the day, scale is a human issue not a machine issue?
Again, they talked about certainty of data, the example being areas that may not have been surveyed recently. CATZOC would probably help here and there is undoubtedly an education

piece for NOC as they are not ENC users. But certainty of data is becoming a regular theme so people can modify their risk appetite or mission parameters based on the certainty of data. Shipping lanes being made available was also mentioned by them, which was also mentioned by BlkSail.
They also talked about the need for more granular information on offshore Infrastructures, for example is the feature still in use, is it being decommissioned, is it no longer in use, how high off the seabed is it etc. The same requirement exists for Wind Farms.
They also mentioned 3D models of Ports and the Seabed becoming increasingly more important, in fact he used the phrase "these are becoming critically important for Remote Control Centres", and we saw 3D digital twins being used in the Ocean Infinity set up, should we move to an official IHO standard for Digital Twins?

**WP4:** Report what navigational data each member states' regulators (e.g., MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

The Maritime and Coastguard Agency is the UK regulator. To date they have no regulations that cover MASS navigation requirements.

The MCA is working on a new Work Boat Code, which will have an annex that will cover regulations for Remotely Operated Unmanned Vessels (ROUVs) which is being finalised before going for consultation this spring.

With regards to the work on guidance for vessels utilising innovative technologies the MCA are primarily focused on informing vessel owners/applicants requesting certification to the UK on the process from start to finish including any additional evidence required outside of the conventional survey and inspection process. This is being handled on a case-by-case project basis. In the assessment of MASS or USVs at the moment, the MCA are generally looking for them to have the same or equivalent navigation equipment as current ships or equivalent size. In general, this means using approved marine equipment such as radars or AIS which share the same information as could be read on board. For chart data, this would involve using official sources of chart data, but this generally needs to be processed to turn it into a format that is readable by the system.

One MCA colleague stated that "there's a chasm between the MASS operations and any national/international regulations". Whilst this is true, the UK under the banner of Maritime UK, has established the Maritime Autonomous Ships Regulatory Working Group (MASRWG) which has produced the Maritime Autonomous Ship Systems UK Industry Conduct Principles and Code of Practice (https://www.maritimeuk.org/priorities/innovation/maritime-uk-autonomous-systems-regulatory-working-group/mass-uk-industry-conduct-principles-and-code-practice-2021-v5/). Whilst it must be stated that this document has no legal standing, in the absence of regulations, it is used by the industry and is seen as best practice. Version 5 was published in November 2021 and for the first time, it states that for planning, execution and monitoring of MASS operations, official and up to date navigation products, services or data (i.e., issued by or on the authority of a government or authorised Hydrographic Office) should be used for the intended voyage or area of operation.

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

The UKHO have been fairly proactive when it comes to working with the MASS industry to identify the requirements for MASS navigation. We have created a MASS navigation strategy, which covers items such as: -

- Supply of free data to MASS operators and builders
- Partnerships in Defence projects particularly the UK's Defence Science & Technology Laboratory
- Conduct Thought Leadership projects– including academic projects and PhDs
- Influence Regulation
- Invest in S100 standards and capability

The supply of free data to the MASS operators in the UK has been a fruitful exercise in engaging the industry and having conversations about some of the limitations in the current navigation products and standards. Indeed, much of the information and issues outlined in WP3 above has come from this strategy and we have worked with L3 Harris, Thales, RoboSys, BlkSail, Ocean Infinity, Polaris, Atlas Electronik and the Mayflower Autonomous Ship project to name a few. In most instances we have provided S57, Tidal information via an API to allow system to system interrogation, and high-resolution gridded bathymetry.

One of the challenges we have had with the industry, which has been mentioned above, is that little thought has gone into the MASS navigation data requirements. There's been significant development in sense and avoid technologies and collision regulations algorithms, but in most cases, the industry is trying to make do with S57 and extracting textual information from publications, despite the challenges with these products. The industry, to some degree, is not aware that something new may be required and that S100 is on the horizon. Indeed, most have never heard of S100. As an example of industry making do, we have seen examples of an organisation reverse engineering S57 date to make a 3D elevation model of the seabed. This approach is flawed as the S57 data had 10m contour intervals and was therefore a filtered view of the seabed, when we showed them the seabed in a higher resolution gridded format (similar to S102), they stated that it was exactly what they needed, but didn't know the data was available. In this example we have technologists bringing new technology to the maritime industry without having previous maritime experience.

The UKHO has also sponsored a number of academic PhD projects with the University of Swansea. We have 2 specific PhDs relating to MASS, both looking at Position, Navigation and Timing and operation of MASS in GNSS denied environments. Clearly MASS will have a strong reliance on GNSS, however, it is easily spoofed or denied and there won't be humans on board Degree 3 or 4 vessels to use alternate methods (such as using a sextant) to determine position. The first PhD has a use case of deep ocean where there are no physical features to triangulate your position from. In this instance the PhD will look at automating celestial navigation to allow the MASS to determine its position. Not trivial in all sea states, poor weather, and a rolling and moving platform. The second PhD has a use case where the vessel is closer to the shore, the intent is to use computer vision techniques to identify visually conspicuous shore features such as buildings or even the topography of the land to then triangulate its position. Both of these PhDs are using machine learning and artificial intelligence and machine-readable data. Whilst the original intent of the PhDs had a MASS use case, the technology could also be employed in manned shipping where the GNSS denial threat is present.

The UKHO have also been exploring how Digital Twins of the marine environment, specifically close to shore and the port and harbour environment, could be used for MASS. The initial use case centres on synthetical trails of MASS for proving the technology prior to operators getting out on water. That said, the Digital Twin as a virtual 3D model of the real world could potentially be used a s a 3D model for MASS to use as a navigation tool, a 3D chart of the future. The PhD mentioned above that is using computer vision techniques to identify shore-based features, could use a georeferenced Digital Twin of the marine environment to compare what it sees on the shore and what it can see in the twin and use that as a method to position itself accurately. Digital Twins of cities have been used in autonomous car developments; it is only natural that this capability would lend itself to MASS in the future. The UKHO has been involved in Digital Twin concepts of the Plymouth Smart Sound and is also producing a Digital Twin of a UK port for future MASS related projects. Some of the challenges with the production of Digital Twins relate to no official standardisation of Digital Twins, joining multi resolution bathymetry together, gaps in survey or very old survey data and joining land and seabed data due to vertical datum shifts.

**WP6:** Report on what trailing has been done with new navigation standards (e.g., S100) for MASS, or what research into machine readable data has been carried out in each member state's region.

Another project that the UKHO is excited to be working on is how the use of S100 could be used to sail a MASS safely into a port. To that end, the UKHO has commissioned a project with Promare who will use the Mayflower Autonomous Ship to simulate a large Frigate and use UKHO's S101, S102, S104 and S111 to sail into Devonport in Plymouth. This will possibly be the world's first MASS to use S100 and the intent is to both demonstrate the utility of S100 for MASS, and also identify any issues with the data and standard for future development. The integration of the S100 into the Mayflower's AI Captain is currently underway, and the trials will commence on the water in late March. A full report of the challenges of the data standard will be produced for the UKHO, which will be shared with the MASS Nav PT and HSSC. Early feedback from the Mayflower team is that they like S100, far better than S57!

# Member State: USA

**WP2:** Identify and report what test bed activities are happening in each member state's region and which degree of autonomy is predominantly used.

USA is working on mostly on autonomy levels 1-3. Testing at level 4 is closely monitored and navigation is mostly pre-planned and autonomy is more with regards to COLREGs decisions during voyage.

Commercial test activities include tug boat operations (Kirby and Foss) and small (20 meter) cargo vessel (First Harvest Navigation). All are using autonomy levels 1-2. Commercial, civilian government, and commercial testing at autonomy levels 3-4 is being conducted with small boats or purpose-built uncrewed vehicles that do not meet the definition of MASS.

**WP3:** Report on what data MASS operators and MASS navigation systems are using today in each member state's region.

Navigation planning was primarily done external to autonomous vessels using currently available data (DNC/ENC).

The MASS navigation systems vary in the ability to integrate and process navigation inputs, including AIS, radar, cameras, and ENC data. At the most fundamental level the inputs are displayed for the MASS operator. Some MASS navigation systems have the ability to process the data to alert the operator of potential conflicts or recommend navigational manoeuvres. The capabilities exist for the MASS navigation systems to execute navigation decisions, but they have not been implemented in MASS test bed activities.

Have any data limitations been identified?

Currently no data limitations have been identified or communicated.

**WP4:** Report what navigational data each member states' regulators (e.g. MCA in the UK) are specifying should be used for MASS navigation in either trials or operations of MASS.

US Coast Guard / Federal Regulators are in early stages of developing regulations and there are currently no regulations that explicitly state requirements for MASS or other autonomous marine vehicles. Local Coast Guard authorities have monitored test bed activities and provided ad hoc approval.

The US Coast Guard has established the Autonomous Policy Council to coordinate MASS activities across districts. The council will evaluate domestic laws and regulations with the results of the IMO Maritime Safety Committee's Regulatory Scoping Exercise for the use of MASS (MSC.1/Circ. 1638), determine manning and credentialing requirements, conduct risk assessment, and develop project development and compliance tools to help incorporate MASS in the marine transportation system.

Additional federal government level coordination is conducted through the US Committee on the Marine Transportation System (CMTS).

https://www.federalregister.gov/documents/2020/08/11/2020-17496/request-for-informationon-integration-of-automated-and-autonomous-commercial-vessels-and-vessel

**WP5:** To what degree are member states Hydrographic Offices involved in MASS trials or operations and what data are they currently providing.

Some test vessels for proof of concept. Navigation data was not specifically designed / requested for trials.

NOAA has not been involved in the commercial MASS trails. The navigation data used are the published ENCs. NOAA has conducted testing and operational demonstrations of small autonomous vehicles, not meeting the definition of MASS, which have incorporated ENC data into the operator display and autonomy decision making.

Have any data limitations been identified?

No data limitations have been identified or communicated.

**WP6:** Report on what trailing has been done with new navigation standards (e.g. S100) for MASS, or what research into machine readable data has been carried out in each member state's region.

None

## Annex B - Issues and Requirements spreadsheet

| Issue/Requirement | Source country | Degree of Autonomy affected | Applicable Standard to be addressed | Increased content only | Notes |
|---|---|---|---|---|---|
| MASS will require fairways to be captured as polygons and features in their own right. | Finland, Brazil | 3 & 4 | S101 & S124 | | |
| Mass will require canal locks to be captured with relevant attribution, such as width of lock. | Finland | 3 & 4 | S101& S124 (S125, S126, S131?) | | Canal locks will require human intervention, e.g. mooring during lock flooding |
| MASS will require port areas/limits to be captured as polygons with relevant attribution. | Finland | 3 & 4 | S101 & S131 & S121 & S124 & S131 | | |
| MASS will require the ability to exchange route information between vessels. | Finland | 3 & 4 | S127 | | |
| MASS will require VTS areas to be captured as polygons with relevant attribution. | Finland | 3 & 4 | S101 & S124 & S127 | | |

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| MASS will require 3D applications or Digital Twins. 3D models or Digital Twin for rehearsal of Port entry both above and sub surface will be increasingly important for situation awareness in Degree 3 and 4. Digital Twins could be a useful 3D chart in the future that a MASS can use with computer vision sensors to compare the real world with the Digital Twin and triangulate its position. | Finland, UK, Brazil | 3 & 4 | New standard required | | |
| MASS will require dynamic data on surface currents. | Finland | 3 & 4 | S111 | | I don't think it is a standard development issue but more an availability issue of that data stream in certain areas... |
| MASS will require Ice conditions and areas. | Finland | 3 & 4 | | | This should be part of S411 |
| MASS will require wind information. | Finland | 3 & 4 | | | This should be part of S412 |
| MASS will require wave height information. | Finland | 3 & 4 | | | This should be part of S413 |

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| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | France, UK | 4 | S101, S123, S124, S125, S126, S127, S130 and S131 | | Are there gaps in the standards that are needed to cover all Nautical Publications such as Sailing Directions? |
| MASS will be required to perform spatial analysis (e.g. algorithm able to determine the best route using features of the ENC). The ENC data (S-57 or S-101 using ISO 8211) is not adequate for software based spatial analysis. Spatial indexation of ENC data, e.g. Hexagonal Hierarchical Spatial Index, could be a solution to foster spatial analysis. | France | 4 | S101 | | |
| MASS will require historic marine accident or incident layers for risk profiling a particular area. | Japan | 1, 2, 3 & 4 | S101 or S127 a new standard? | | |

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| MASS will require more frequent or real-time updates of the data contained in the S100 products, which should be pushed from official sources that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | Canada, UK | 4 | All standards. | | |
| The communication infrastructure necessary to sustain data exchange is not reliable and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | Canada | 4 | All standards | | |

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| MASS will require historical traffic pictures, and if there are any anomalies in operations compared with historical traffic or adverse weather or unforeseeable events (e.g. freak wave) and behave differently, they can alert the human overwatch who can then revert to a Degree 3 control. | Norway (Journal paper) | 3 & 4 | S127 or a new standard for historic pattern of life vessel movements. | | |
| MASS will require ferry routes and the ferry route timetables. Ferry routes could be captured as polygons or lines with attribution in a machine readable format that shows the ferry timetable. | UK | 4 | S101 or S127 or a new standard? | | |
| MASS will require full bathymetric coverage datasets/DTM, gaps in data will pose a problem for MASS. | Norway | 3 & 4 | S102 | Increase content and coverage? | |
| MASS will require a better standardization and accessibility to harbor infrastructure datasets. | Norway | 3 & 4 | S131 | | |

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| To avoid large volumes of bathymetric data (i.e. S102 gridded data), there is a need for conspicuous seabed features to be highlighted (such as sea mounts, obstacle or trenches) for use with Inertial Navigation Systems in GNSS denied environments. Similar to land based visually conspicuous objects captured in ENCs today. | UK | 4 | S102 & S103 or possibly a news standard? | Possibly capturing meta data in S102 | leverage GEBCO's undersea features library<br><br>https://www.gebco.net/data_and_products/undersea_feature_names/ |
| MASS will require certainty of seabed and associated features. High resolution data is great, but if it changes regularly, then that needs to be made clear and articulated in some way (example Humber estuary). Understanding when highly mobile seabed was last surveyed will also be important. | UK | 4 | S102 | Possibly capturing meta data in S102 | silting models? information on bottom type (rock, sand, etc...) |

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| MASS will require an understanding of the reflective nature of the seabed, possibly associated with grab sample data for use in Inertial Navigation Systems. | UK | 4 | S101 | | |
| MASS will require an understanding of the acoustic qualities of the water column for Inertial navigation Systems. | UK | 4 | New standard required? | | |
| MASS has an issue with edge matching on charts. Often there is a discontinuation of data, particularly on depth contours. Described as a "leap of faith" when transitioning from one chart to another. | UK | 4 | S101 | | Multiple options to address. Gridded approach could help. Seamless scales data would be ideal for MASS Degree 4. A method of describing what is happening at a chart edge if there is a discontinuity of data. Overlapping data from one chart to the next. |

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| MASS will require more visually and radar conspicuous items required for alternate means of position fixing using computer vision techniques. Also a measure of certainty of the features position would be required. Features to include could be (but not limited to)<br>Coastal terrain<br>Navigation marks<br>Harbor Approaches<br>Dock/quay walls<br>Major buildings or landmarks<br>Bridges and other man made structures extending out over the water. | UK | 4 | S101 (pick reports) or a new standard. | | Lighthouses don't move, buoys do, hence the need for certainty of position. |
| MASS will require shipping lanes to be made available and captured as polygons with suitable attribution. | UK | 4 | S101 or a new standard? | | |

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| MASS will require certainty of tidal heights and surface currents at a given point and time, particularly in congested water space and shallower waters. Bramble bank in UK was used as an example, being shoalier by 0.5m could lead to a grounding. Predicted and forecast tidal height and surface currents are essential but certainty factors surrounding the predictive nature is important for decision making and risk profiling a route for MASS. | UK | 4 | S104 & S111 | | e.g. 80% certainty that the tide at this point and time is going to be 3m) |
| MASS will require more use of photographic imagery, specifically panoramic photographic imagery. | UK | 4 | S101 (pick reports) or a new standard. | | |

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| MASS will require more geographical polygons to describe areas (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions or Pick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based containing attribution such as name of feature, type of feature, unique number, reason for speed restriction or constraint etc in a machine readable format. | UK | 4 | All standards and possibly new standards | | |

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| MASS will require areas defined by buoys such as the edge of a channel captured as polygons. Humans can make the relationship between the buoys and a channel, machines can-not. This will allow MASS to plan paths and obey the rules. | UK | 4 | S101 or a new standard? | | |
| MASS will require communication zones to be captured as polygons with appropriate attributes. As an example currently the rules for radio communications are within the Admiralty list of radio signals volumes 1-6, these volumes are particularly difficult for an autonomous vessel to understand. | UK | 4 | S123 | | |

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| MASS will require national infrastructure zones to identify areas of importance which could have security implications. For example, undersea pipes which transport oil and gas may be marked approximately on a chart, but the exact locations are not displayed as they supply an important service that could be maliciously targeted. For these areas a polygon larger than the infrastructure would be used to obscure the exact location of the resource, and thus protect it. | UK | 4 | S126 or a new standard? | | |

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| MASS will require unique identifiers for features which could be another means of position fixing. As an example charts may show an area of 'mooring posts' but not define how many or where, this information would overload a human readable chart. If, however they were identified with unique ID numbers and positions in a machine-readable format they would be a highly accurate method of the MASS in verifying its position, progress against goals and navigational status. | UK | 4 | S101 | | |
| MASS will require real time tidal data which is crucial in shallower waters. | UK | 4 | S104 | | |

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| MASS will need to know when restricted water space is active or inactive for example military exercise areas or firing ranges. When inactive it is perfectly safe to traverse these but not when active. Another example could be Fish farms and understanding when they need to be given a wider berth if it is breeding season etc. | UK | 4 | S101 & S124 | | |

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| MASS need to be aware of and go through Traffic Separation Schemes, but today there is no way for a Degree 4 MASS to know that a TSS exists. A method of identifying TSS and then transitioning towards it and through it safely will be crucial. | UK | 4 | S101 & S127? | | There's a number of methods that could be employed to resolve this situation. The first would be to have a constricted water space feature with an attribute that states TSS is present. The MASS can then do a spatial search within the feature for the TSS and then route to and through it accordingly. The second option is to have a buffer attribute on the TSS of say 50nm, then when a MASS route intersects the buffer, the MASS knows that it must now use the TSS. Both used together could work, but this is a simplification and other factors such as directionality etc would need to be factored in. |

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| MASS will need to know where reporting points or areas are geographically. As an example knowing at what point to contact Falmouth Coastguard to say whether you were passing between UK mainland and the Isles of Scilly or not. | UK | 4 | S123 | | will the reporting point organization will be able to receive and process digital information from a MASS, or issue commands digitally? S-127 |
| MASS will require polygons denoting what level or Degree of MASS operation is allowed. As an example Degree 4 may not be allowed in a port. MASS and MASS operators will need to know what areas they can go into or not as they may need to move from Degree 4 to 3 when entering specific areas. | UK | 3 & 4 | S101 or new standard. | | How will MASS process or interpret general and specific regulations in an area? It could be more complicated than a binary choice. Will all regulation have to be translated into machine readable language or data structured? |
| MASS requires more land based topographical data such as contours for visual reference. | UK | 3 & 4 | S101 | | |

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| Light sectors can sometimes be blocked by land mass or other features. MASS will need some method of determining line of sight, maybe having attribution that determines visibility in degrees. | UK | 3 & 4 | S101 or S125? | | what about synthetic ATON? |
| MASS will need to understand the drift of Buoys, the length of chain and tidal range can mean Buoys could be several metres out of position, humans can understand this MASS will need to know that a Buoy may have a tolerance of position if they are using them for navigation purposes. | UK | 4 | S101 | | the S-111 surface current stream will enable such prediction ? |

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| MASS will need the accurate fully resolution detail of wrecks. Today we generalise wreck features at certain scales, but MASS needs the rich detail, particularly in shallower waters. One of the main reasons given is that wrecks are often fishing locations and discarded nets are a hazard to smaller MASS. This raises the scaleless data question, scale is for human readers of data, machines don't care about scale or generalisation. | UK | 3 & 4 | S101 | | Sometimes wreck locations are not broadcast to prevent looting, unless they are a danger to navigation. |
| MASS need to have richer detail on offshore infrastructure, for example is the feature still in use, is it being decommissioned, how high off the seabed is it etc. This requirement also exists for Wind Farms. | UK | 3 & 4 | S101 or S126 | | |
| MASS will require precise information regarding the interface between autonomous and human operation at points such as mooring operations, canal transit | Finland, Japan, Norway | 3 & 4 | S126 S131 | | |

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| Designated operating areas for MASS small craft? Geo-fencing | Canada | 3 & 4 | S121 S127 | | these areas will enable MASS technology testing, and in Canada for the moment we don't expect large ships |

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| **Member State/Organization** | United Kingdom – UK Hydrographic Office |
| **S100 Standard Reviewed** | S101 |
| **Maturity of Standard** | Currently at V1.0 but moving to V1.1.0 at end of year, still in test and development phase |
| **S100 Standard Chair** | Tom Richardson |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
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| MASS will require fairways to be captured as polygons and features in their own right. | ✓ | ✓ | ☐ | | |
| Mass will require canal locks to be captured with relevant attribution, such as width of lock. | ✓ | ✓ | ☐ | | |
| MASS will require port areas/limits to be captured as polygons with relevant attribution. | ✓ | ☐ | ☐ | | |
| MASS will require VTS areas to be captured as polygons with relevant attribution. | ✓ | ☐ | ☐ | | |
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ☐ | ✓ | Analysis of S-101 has identified that 22 text attributes remain. This is a reduction from S-57 due to improve modelling, but analysis of these attributes should be done to understand which would affect MASS. A list of these has been added at the end of this document.<br><br>Some text attributes are used across many features and as S-101 data emerges it would be useful to conduct analysis of these "generic" attributes to identify changes that could be made to S-101.<br><br>See Annex A below | |
| MASS will require more frequent or real-time updates of the data | ✓ | ☐ | ☐ | | |

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| contained in the S100 products, which should be pushed from official sources that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | | | | | |
| MASS will require certainty of seabed and associated features. High resolution data is great, but if it changes regularly, then that needs to be made clear and articulated in some way (example Humber estuary). Understanding when highly mobile seabed was last surveyed will also be important. | ✓ | ☐ | ☐ | | |
| MASS will require more visually and radar conspicuous items required for alternate means of position fixing using computer vision techniques. Also a measure of certainty of the features position would be required. Features to include could be (but not limited to)<br>Coastal terrain<br>Navigation marks<br>Harbour Approaches<br>Dock/quay walls<br>Major buildings or landmarks<br>Bridges and other man made structures extending out over the water. | ☐ | ☐ | ✓ | Whilst these features are modelled in S101, work needs to be done to model the uncertainty of positions. Recommendation is that attribution is added to these features to model the certainty/uncertainty of the features position. | Easy |
| Cross referencing of features contained in multiple standards e.g restriction area where S101 will have the feature and speed restriction but S127 will also have the feature but additional attribution maybe included in the S127 feature | ☐ | ☐ | ✓ | Recommendation is that features should have some form of link, whether this is Marine Resource Name (unique ID) or some form of foreign key that links the features to allow systems to link features and get the additional attribution. | Moderately |
| MASS will require areas defined by buoys such as the edge of a channel captured as polygons. Humans can make the relationship between the | ✓ | ☐ | | | |

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| buoys and a channel, machines can not. This will allow MASS to plan paths and obey the rules. | | | | | |
| MASS will require unique identifiers for features which could be another means of position fixing. As an example charts may show an area of ‘mooring posts’ but not define how many or where, this information would overload a human readable chart. If, however they were identified with unique ID numbers and positions in a machine-readable format they would be a highly accurate method of the MASS in verifying its position, progress against goals and navigational status. | ☐ | ☐ | ✓ | Consider Marine Resource Names attribute for certain features such as conspicuous features. | Easy |
| MASS will need to know when restricted water space is active or inactive for example military exercise areas or firing ranges. When inactive it is perfectly safe to traverse these but not when active. Another example could be Fish farms and understanding when they need to be given a wider berth if it is breeding season etc. | ✓ | ☐ | ☐ | However, the cross-referencing issue above needs to come into play. | |
| MASS need to be aware of and go through Traffic Separation Schemes, but today there is no way for a Degree 4 MASS to know that a TSS exists. A method of identifying TSS and then transitioning towards it and through it safely will be crucial. | ☐ | ☐ | ✓ | Recommendation is to add augmented geometry to the TSS features which acts as a virtual buffer that MASS can use when it intercepts the buffer and route to and through appropriately. | Moderately |
| MASS will need to know where reporting points or areas are geographically. As an example knowing at what point to contact Falmouth Coastguard to say whether you were passing between UK mainland and the Isles of Scilly or not. | ☐ | ☐ | ✓ | Although not explicitly an S101 issue, it is another case for cross referencing as S101 will have reporting points as features, but S123 will have more detail. | Moderately |
| MASS requires more land based topographical data such as contours for visual reference. | ✓ | ✓ | ☐ | | |

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| Light sectors can sometimes be blocked by land mass or other features. MASS will need some method of determining line of sight, maybe having attribution that determines visibility in degrees. | ✓ | ☐ | ☐ | | |
| MASS will need to understand the drift of Buoys, the length of chain and tidal range can mean Buoys could be several metres out of position, humans can understand this MASS will need to know that a Buoy may have a tolerance of position if they are using them for navigation purposes. | ☐ | ☐ | ✓ | Recommend adding a tolerance value on buoy's position to cater for drift, length of chain etc | Easy |
| MASS will need the accurate fully resolution detail of wrecks. Today we generalise wreck features at certain scales, but MASS needs the rich detail, particularly in shallower waters. One of the main reasons given is that wrecks are often fishing locations and discarded nets are a hazard to smaller MASS. This raises the scaleless data question, scale is for human readers of data, machines don't care about scale or generalisation. | ✓ | ✓ | ☐ | | |
| MASS need to have richer detail on offshore infrastructure, for example is the feature still in use, is it being decommissioned, how high off the seabed is it etc. This requirement also exists for Wind Farms. | ✓ | ☐ | ☐ | | |

S-101 Text Fields (Edition 1.0.2) Feature Catalogue 20220413

| **Attribute** | **Potential Solution** |
|---|---|
| callSign | It is appropriate for this to remain natural language. |
| communicationChannel | This is Ok as long as the formatting suggested in the standard is used. Confirm validation rules confirm this formatting is used. |

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| destination | It is appropriate for this to remain natural language. MRN will link this to S-127 and other S-100 standards. |
| ReferenceLocation | It is appropriate for this to remain natural language. Could consider use of UNLOCODE either to replace ReferenceLocation or as an additional attribute. |
| mMSICode | It is appropriate for this to remain natural language. Validation checks should ensure this is 9 digits as per standard. |
| nationality | It is appropriate for this to remain natural language. Validation checks should ensure this valid ISO 3166 code. |
| pictorialRepresentation | No concern at this point, we need to understand the scale of usage and some examples and test how MASS will use this data. |
| radarBand | Consider changing to enumeration value to be either X or S. |
| regulationCitation | It is appropriate for this to remain natural language. |
| SignalGroup | It is appropriate for this to remain natural language. Validation checks should ensure it meets format structure as outlined in the standard. |
| sectorCharacteristics | It is appropriate for this to remain natural language (probably an edge case). |
| shapeInformation | It is appropriate for this to remain natural language (probably an edge case). |
| Source | It is appropriate for this to remain natural language. |
| stationName | It is appropriate for this to remain natural language. |
| surveyAuthority | It is appropriate for this to remain natural language. |
| updateDescription | Not relevant for MASS. It is appropriate for this to remain natural language. |
| vesselClass | It is appropriate for this to remain natural language. MRN will link this to S-127 and other S-100 standards. |
| information | We need to analyse how many of these will exist in the real data once used. It may become a redundant feature or used very little and have no application for MASS. |
| featureName | It is appropriate for this to remain natural language. Could consider use of |

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| | UNLOCODE either to replace featureName or as an additional attribute. |

**Member State/Organization** FINLAND Traficom

**S100 Standard Reviewed** S-102

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
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| **ALL:** MASS will require more frequent or real-time updates of the data contained in the S100 products, which should be pushed from official sources that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | ✓ | ☐ | ☐ | This is not a problem from the S-102 perspective. Theassociated products are delivered only via network download. | Easy |
| **COMMENTS of the S-102 Group: S-102PT concurs that this issue is not a problem from the S-102 perspective. Rather, it is an issue for producers, distributors, and maintainers of the distribution infrastructure.** | | | | | |
| **ALL:** The communication infrastructure necessary to sustain data exchange is not reliable and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | ✓ | ☐ | ☐ | The S-102 can be applied for this purpose. It includesinformative file-size limit of 10 MB. | Easy |
| **COMMENTS of the S-102 Group: While communication infrastructure reliability is not uniquely an issue for S-102, it is nevertheless an issue. S-102PT concurs that thought needs to be given to data packet size as regards MASS.** | | | | | |

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| **S-102**: MASS will require full bathymetric coverage datasets/DTM, gaps in data willpose a problem for MASS. | ✓ | ☐ | ☐ | This is not a direct problem of the S-102. That is, the coastal states should ensure the availability of data within its administrative sea area. Depth data is also available in S-101 format and can be used to produceredundancy as needed. Additionally, it could be necessary to add the associated metadata into S-102 products. | Easy |
| **COMMENTS of the S-102 Group: S-102PT concurs that gapless coverage is not a direct problem of S-102. At bottom, HOs will determine where they do or do not have S-102 coverage. While S-102 makes sense in fairways/approaches to harbours, shallow waterways, harbours, etc., it does not make sense in deep water (where S-101 would provide sufficient coverage for safe navigation).** | | | | | |
| **S-102:** To avoid large volumes of bathymetric data (i.e. S102 gridded data), there is a need for conspicuous seabed features to be highlighted (such as sea mounts, obstacle or trenches) for use with Inertial Navigation Systems in GNSS denied environments. Similar to land based visuallyconspicuous objects captured in ENCs today. | ✓ | ☐ | ☐ | The current S-102 can be used for showing the seabed, including conspicuous seabed features. Highlighting and/or displaying selected features as individual objects (=vector data) is not possible withina gridded bathymetry product as S-102. For this purpose, another vector-based product should be utilized or developed. | Easy |
| **COMMENTS of the S-102 Group: S-102PT concurs that no meaningful gap exists as regards this issue.**<br>**While we agree that vector (feature) data should not be stored in a raster product (such as S-102), we contend that the algorithms available in general image processing allow for sufficient derivation of feature data from the raster data. As such, another vector product (beyond S-101 and S-102) is not necessary.** | | | | | |
| **S-102:** MASS will require certainty of seabed and associated features. High resolution data is great, but if it changes regularly, then that needs to be made clearand articulated in some way (example Humber estuary). | ✓ | ☐ | ☐ | The current S-102 already includes a cancellation mechanism, and the producer of data is responsible on its reliability. The application of the associated metadata could also applied to provide additional information. Rapidly changing data, such as migrating mud-banks, might require additional | Easy |

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| Understanding when highly mobile seabed was last surveyed will<br>also be important. | | | | work or new products. | |

**COMMENTS of the S-102 Group: S-102PT concurs that this issue is addressed well. In particular, S-102 Version 2.2.0 will introduce certain metadata elements to clarify and articulate such tendency for rapid geomorphological change.**

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| **ALL:** MASS will require more geographical polygons to describe areas (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions orPick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based containing attribution such as name of feature, type offeature, unique number, reason for speed restriction or constraint etc. in a machine readable format. | ✓ | ☐ | ☐ | This is not a problem for the S-102 perspective, as it isnot a vector based product. | Easy |
| **COMMENTS of the S-102 Group: S-102PT concurs that this issue is not within the remit of S-102. If descriptive text is not machine readable, it cannot be processed by MASS. Such issues are more the province of S-101 and product specifications such as S-126 (Marine Physical Environment).** | | | | | |

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| **Member State/Organization** | China |
| **S100 Standard Reviewed** | S-104 S-111 |
| **Maturity of Standard** | V1.0.0 |
| **S100 Standard Chair** | Chris Jones (UK) hristopher.jones@ukho.gov.uk |

| **Issue/Requirement** (take from Spreadsheet) | Issue addressed? | More cnontent? | Gap in standard? | **Potential Solution/s** | Ease to implement? |
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| MASS will require certainty of tidal heights and surface currents at a given point and time, particularly in congested water space and shallower waters. Bramble bank in UK was used as an example, being shoalier by 0.5m could lead to a grounding. Predicted and forecast tidal height and surface currents are essential but certainty factors surrounding the predictive nature is important for decision making and risk profiling a route for MASS. | ✓ | ☐ | ☐ | This requirement can be divided into two aspects. Firstly, the MASS navigation system requires the acquisition of tidal level and current information at a specific position and time range. S-104 is planned to provide tidal level information for sailing ships, and S-111 is also designed to provide current information for sailing ships. According to S-100 roadmap and IMO arrangement, The S-104 and S-111 will be produced and made available during the transitional period from 2026 to 2029. This requirement should be met by IHO communities. The second aspect is mainly about the accuracy of prediction data of tidal level and tidal current. In S-104 and S-111 product specifications, a module has been designed to contain the certainty of data, which divides the uncertainty of data into four categories: tidal level uncertainty, tidal current uncertainty, horizontal position uncertainty, vertical position | |

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| | | | | uncertainty and time uncertainty. Data uncertainty data are derived from tide level and tidal current observations, forecast models, from station observation criteria for tidal levels, or from data calculation processes. The source of uncertain data and its representation in the standard are specified. If the producer of S-104 and S-111 data collects and codes uncertainty data in accordance with the standard, the data user can obtain the uncertainty of S-104 and S-111. In order to improve the reliability of tidal level and tidal data, it is necessary to improve the accuracy of prediction and calculation in terms of tide gauge construction, data observation and data calculation. For example, by setting more tide gauges in tidal level-sensitive water or using more refined tidal models will ensure the reliability of data. In summary, requirement 1 can be met, and S-104 and S-111 can meet the requirements of MASS. | |
| MASS will require real time tidal data which is crucial in shallower waters. | ✓ | ☐ | ☐ | This requirement is same with requirement 1, dynamic water level information, tide current, the trend and forecast information can be coded in the S-104, S-111, and provide for | |

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| | | | | MASS through the appropriate channels. The data can be forecast data file, load in advance in the MASS navigation system or through real-time data flow transmission to the MASS, either way, S-104 and S-111 provided standards for coding and schemata of tide level and tide data, and this requirement can be met without any gap.<br>In addition, S-104 and S-111 also are lack of technical specifications for online data exchange, which need to be further aligned with S-100 5.0.0 Part 14 to meet the real-time data exchange requirements. | |
| MASS will need to understand the drift of Buoys, the length of chain and tidal range can mean Buoys could be several metres out of position, humans can understand this MASS will need to know that a Buoy may have a tolerance of position if they are using them for navigation purposes. | ✓ | ☐ | ☐ | The requirement of this item is mainly about the influence of current on buoy's position.<br>MASS need to predict the moving range of buoy, firstly ,as I know, there is no readily available and reliable channel to get the information buoy chain's length, maybe in S-125?<br>Secondly, the position of buoys are affected by tide, current, wind, passing ships, There may be a big offset with the designed position of the buoy and the real position of buoy.<br>Maybe the perception of the buoy position range can be solved by other manner and | |

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| | | | | technical means. For example, the AIS, radar transponder on the buoy or by computer vision technology may be more reliable and simple. This requirement does not require any change from the S-104 and S-111 standards perspective. | |
| MASS will require dynamic data on surface currents. | ✓ | ☐ | ☐ | This requirement is same with requirement 1, dynamic water level information, tide current, the trend and forecast information can be coded in the S-104, S-111, and provide for MASS through the appropriate channels. The data can be forecast data file, load in advance in the MASS navigation system or through real-time data flow transmission to the MASS, either way, S-104 and S-111 provided standards for coding and schemata of tide level and tide data, and this requirement can be met without any gap.<br>In addition, S-104 and S-111 also are lack of technical specifications for online data exchange, which need to be further aligned with S-100 5.0.0 Part 14 to meet the real-time data exchange requirements. | |

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| **Member State/Organization** | Denmark – Danish Geodata Agency |
| **S100 Standard Reviewed** | S-122 – Marine Protected Areas |
| **Maturity of Standard** | Reasonably mature at V3.0 (issued 2019) |
| **S100 Standard Chair** | S122 – Eivind Mong (Can) – Eivind.mong@dfo-mpo.gc.ca |

| **Issue/Requirement** (take from Spreadsheet) | Issue addressed? | More cnontent? | Gap in standard? | **Potential Solution/s** | Ease to implement? |
|---|---|---|---|---|---|
| MASS will require more geographical polygons to describe areas (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions or Pick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based containing attribution such as name of feature, type of feature, unique number, reason for speed restriction or constraint etc. in a machine-readable format. | ✓ | ☐ | ☐ | According to the specification, Marine Protected Areas are already made as polygons. For the polygons, information and restrictions can be selected from a predefined list, which will be machine readable, and it will be possible for MASS ships to interrogate and act upon.<br><br>At this stage, the predefined lists seem complete. Whether some feature types or attributes will need be added is unknown. If this is the case, it is considered easy to implement. | |
| The communication infrastructure necessary to sustain data exchange is not reliable and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | ✓ | ☐ | ☐ | The data regarding Marine Protected Areas are mostly static. It is assessed that only small or minor data packages or exchange sets will be relevant for these areas. The current infrastructure will be sufficient for this.<br>The assessment is written with thoughts on how the infrastructure is expected to be when S-100 is fully operational. | |
| MASS will require more frequent or real-time updates of the data contained in the S100 products, which should be pushed from official sources that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time | ✓ | ☐ | ☐ | Marine Protected Areas are mostly static data that not require real-time updates. | |

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| updates will be required for MASS as MASS will always need to be up to date. | | | | | |

## Comments:

- Working times and schedules
  - For some MPAs different working times and schedules are effected. Working hours and schedules with different exceptions is already known as a challenge to programme regarding the fact it have to be machine readable. This challenge recurs to many other S100 specification, and a solution is being worked on at the moment.
- Reporting Requirements
  - In some MPAs, it is required to report to relevant authorities when certain events occur such as an animal strike or pollution event. It is assessed that this will not be possible for MASS degree 3 or 4 ships to note if such events should occur.
  - The specification gives the opportunity for mariners to send report information categorized as free text. Without knowing what this information may include, it will not be possible for MASS ships to send such free text reports. If such, unknown information is relevant and important, it will have to be converted into new feature classes and attributes.

## MASS GAP analysis

- In conjunction with the issues and requirements spreadsheet, use the attached template and use one template per standard you are looking at (i.e. if you have 2, then you will create 2 forms).
- Enter the information at the top of the form to capture your country or organisation, the S100 standard you have assessed, the maturity of that standard and who is the chair of the standard WG or PT.
- Look at all of the issues captured and assess against your standard. I have suggested the appropriate standard per issue, but that is from my own understanding and I may have missed something, so please be thorough.
- Ensure you find out the current state of the standard/s you have been assigned, for example S101 is undergoing review, so I will ensure that UK speaks to the chair of the S101 PT to make sure that the latest version is assessed as the new changes may address some of the concerns.
- Ascertain if each issue or requirement from the spreadsheet, relevant for your standard is either met and no further action is needed, the standard caters for the issue but HOs may want to consider adding more content (example more land based contours) or is unmet and therefore there is a gap identified in the standards.
- Please have a go at suggesting a solution for the problem that will address the gap. Be as detailed as you can be, for example there is an issue with natural language text and it not being machine readable, but please don’t put a simple statement that says “make all data machine readable”. Our job is to help the respective WGs and PTs.
- Also use the pulldown to assess whether the solution you have identified is “Easy”, “Moderately” or “Hard” to implement.

**Member State/Organization** Norway

**S100 Standard Reviewed** S123

**S-123**

**Title:** Marine Radio Services Product Specification.

**Abstract:** Marine radio services product specification describe the means to capture **availability and reliability** of radio stations, radio position fixing systems, radio beacons, services offering navigational warnings and weather forecasts in the maritime domain. This may include details on the service areas, services offered and**Content:** Datasets conforming to this specification will contain all relevant maritime radio service information for the area of coverage. Additionally, there will be relevant metadata data quality, production authority, data sources and publication date.

**Spatial Extent:** **Global coverage of maritime areas**.

**Specific Purpose:** Describing radio services in the maritime domain for utilization **in ECDIS**, and to **allow the producer to exchange radio services information with interested stakeholders.**

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More content?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
|---|---|---|---|---|---|
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made **machine readable and interpretable**. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ☐ | X | All S-123 features and information classes are derived from one of the abstract classes FeatureType and InformationType. Especially the Information type may cause the biggest problem for MASS because it gives room for textual information in natural language, that will be difficult for machines to read and interpret.<br><br>InformationType has attributes for fixed and periodic date ranges, name associated with the individual information object if any, source information, and a textContent attribute that allows **text notes or references to be provided for individual instances** where appropriate.<br><br>There are three main information types which | Hard |

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| | | | | represent regulations, restrictions, and recommendations respectively, and **a fourth information type for general or unclassifiable information.**<br><br>The fourth class, **NauticalInformation**, is intended for **general notes or other information that cannot be categorized** as one of the other three classes.<br><br>S-123 Radio services data products include marine radio stations and services as well as **safety and information broadcasts and radiocommunications.**<br>The scope of the S-123 domain model **therefore includes NAVTEX and weather or ice forecasts and warnings.**<br>It can be difficult to make such kind of information in a coded standard message for a machine to readable and interpret.<br><br>Suggestion: Discuss if this part of the S-123 should be transported to the S-124 Navigational-warnings<br><br>Comment from S-123 task group NIPWG: The suggestion is not recommendable since S-123 and S-124 serves two different purposes.<br><br>See S-123AppA_EN_Data Classification and Encoding Guide_Ed1.0.0 in chapter about *6.2.1.1 Overview of domain features and information types*<br><br>*6.2.1.2 Regulations, information notes, etc.*<br><br>*7.2.5.1 Simple Attributes (CharacterString)* | |
| MASS will require more **frequent or real-time updates** of the data contained in the S100 products, which should be pushed from | ☐ | x | ☐ | S-123 gives the producers room to choose the frequencies of updates.<br>It says: | Moderately |

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| official sources that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. **Event driven data updates** and near real time updates will be required for MASS as MASS will always need to be up to date. | | | | **The maintenance and update frequency of MRS datasets should be defined by the producers (official national authority) implementing this specification.**<br>And also: **This should specify the expected frequency of updates**.<br>Suggestion: The S-123 must describe the need of 'event driven data updates' and recommend the producers to make a choice of how often to update and it should be as soon as possible. The different producers of the world will make different choices regarding their available resources.<br><br>See S-123AppA_EN_Data Classification and Encoding Guide_Ed1.0.0 about<br>*12. Data Maintenance* | |
| The communication infrastructure necessary to sustain data exchange is not **reliable** and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | ☐ | X | ☐ | The information about reliability in communication infrastructure will be described in S-123. And it also includes modelling of locations where the availability of a service is intermittent or uncertain, usually dependent on atmospheric and weather conditions which is a challenge to a MASS.<br><br>But MASS will require 100% communication 24/7/365 and that depends on other things than this standard.<br>The expectation is that the LEO SAT services will provide this and that it will be the norm at sea.<br><br>Suggestion: none<br><br>See S-123AppA_EN_Data Classification and Encoding Guide_Ed1.0.0 about<br><br>*11.2 Dataset size*<br>*11.3 Exchange Set* | Hard |

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| MASS will require more **geographical polygons to describe areas** (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions or Pick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based containing attribution such as name of feature, type of feature, unique number, reason for speed restriction or constraint etc in a machine readable format. | ☐ | x | ☐ | S-123 is a feature-based vector product and state global coverage of maritime areas. The standard describes feature as points and areas. And it says: S-123 datasets shall not overlap other S-123 datasets.<br><br>But it also describes the possibility of fuzzy areas and uncategorized additional information which will be a challenge to MASS.<br><br>This is a known issue that S-123 task group NIPWG will be seeking a good resolution for.<br><br>Suggestion: none<br><br>Also see S-123AppA_EN_Data Classification and Encoding Guide_Ed1.0.0 about<br>*6.2.1.9 Generic fuzzy area model*<br>*6.2.1.12 Uncategorized additional information* | Moderately |
| MASS will **require communication zones to be captured as polygons with appropriate attributes.** As an example currently the rules for radio communications are within the Admiralty list of radio signals volumes 1-6, these volumes are particularly difficult for an autonomous vessel to understand. | ☐ | x | ☐ | S-123 is a feature-based vector product and state global coverage of maritime areas. The standard describes feature as points and areas.<br>And it says: S-123 datasets shall not overlap other S-123 datasets.<br><br>But S-123 also describes the possibility of fuzzy areas and uncategorized additional information which is a challenge to a MASS.<br><br>This is a known issue that S-123 task group NIPWG will be seeking a good resolution for.<br><br>The S-123 application schema also includes modelling of locations where the availability of a service is intermittent or uncertain, usually dependent on atmospheric and weather conditions which is a challenge | Moderately |

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| | | | | to a MASS.<br><br>Suggestion: none<br><br>Also see S-123AppA_EN_Data Classification and Encoding Guide_Ed1.0.0 in chapter about<br>*6.2.1.9 Generic fuzzy area model*<br>*6.2.1.12 Uncategorized additional information* | |
| MASS will need to know **where reporting points or areas are geographically.** As an example knowing at what point to contact Falmouth Coastguard to say whether you were passing between UK mainland and the Isles of Scilly or not. | ☐ | X | ☐ | S-123 is a feature-based vector product and state global coverage of maritime areas. The standard describes feature as points and areas. And it says: S-123 datasets shall not overlap other S-123 datasets.<br><br>But it also describes the possibility of fuzzy areas and uncategorized additional information which is a challenge to a MASS. This is a known issue that S-123 task group NIPWG will be seeking a good resolution for.<br><br>Suggestion: Points are not very useful for MASS and should be interpreted into Areas and Lines.<br><br>Also see S-123AppA_EN_Data Classification and Encoding Guide_Ed1.0.0 in chapter about<br><br>*6.2.1.9 Generic fuzzy area model*<br>*6.2.1.12 Uncategorized additional information* | Moderately |

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| **Member State/Organization** | USA (NGA) |
| **S100 Standard Reviewed** | S124 |
| **Maturity of Standard** | Reasonably mature V2.0 issued 2019 |
| **S100 Standard Chair** | Mr Eivind Mong (Canada) - S-124 Project Team (S-124PT) |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
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| MASS will require fairways to be captured as polygons and features in their own right. | ☐ | ☐ | ☐ | More applicable to S101 | Easy |
| Mass will require canal locks to be captured with relevant attribution, such as width of lock. | ☐ | ☐ | ☐ | More applicable to S101 | Easy |
| MASS will require port areas/limits to be captured as polygons with relevant attribution. | ☐ | ☐ | ☐ | More applicable to S101 | Easy |
| MASS will require VTS areas to be captured as polygons with relevant attribution. | ☐ | ☐ | ☐ | More applicable to S101 | Easy |
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | X | ☐ | S124 is designed to create vector features with attributes read/displayed on ECDIS. This is readily transferable to MASS.<br><br>However, some data in S124 will go out as natural language. The question is, how applicable will this be to MASS. Because the natural language is often describing something for which to keep a look out, an autonomous ship without a traditional lookout would not have a way to even use the information. | Moderately |
| MASS will need to know when restricted water space is active or inactive for example military exercise areas or firing ranges. When inactive it is perfectly safe to traverse these but not when active. Another example could be Fish farms and understanding when they need to be given a wider berth if it is breeding season etc. | X | ☐ | ☐ | S124 is designed to create vector features with attributes read/displayed on ECDIS. This is readily transferable to MASS. | Easy |

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| MASS will require more geographical polygons to describe areas (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions or Pick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based containing attribution such as name of feature, type of feature, unique number, reason for speed restriction or constraint etc in a machine readable format. | X | ☐ | ☐ | S124 is designed to create vector features with attributes read/displayed on ECDIS. This is readily transferable to MASS. | Easy |

Description (high level):
S-124 is a vector product specification designed to encode the nature and extent of Navigational warnings for navigational purposes.
Questions: None
Comments:
S-124 is specifically designed to move from a text based message system to creating overlays for use in an ECDIS. The specification under development and currently in its second draft does not contain large gaps applicable to autonomous shipping. As autonomous shipping systems are developed, they should have little issue programming the navigation systems to use the vector data for autonomous navigation decisions. The additional text information will likely not be applicable to autonomous ships (i.e. ships without a look out).

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| **Member State/Organization** | Korea – KHOA(Korea Hydrographic and Oceanographic Agency) |
| **S100 Standard Reviewed** | S-125 Marine Aids to Navigation |
| **Maturity of Standard** | Working draft, S-125 draft for 1.0 will be provided in early 2023 to NIPWG, IHO |
| **S100 Standard Chair** | Sewoong OH (S-201 Task group of ARM/IALA on behalf of NIPWG/IHO) |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
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| S-125 Marine AtoN data can be a an extended list of lights required in SOLAS Chapter V. The S-101 ENC already includes Aton data, but the main difference is that S-125 dataset is to be updated more frequently than S-101 dataset. | ✓ | ☐ | ☐ | | |
| S-125 data needs to be provided for MASS to identify the latest status information of AtoN included in the S-101 ENC.<br>S-98 Interoperability between S-101 and S-125 should be applied. | ✓ | ☐ | ☐ | The S-125 is included as Step 2 of the S-100 implementation roadmap, and interoperability between S-101 and S-125 needs to be defined. | Moderately |
| In order to provide S-101 AtoN Status through S-125, the unique identifier needs to be the same. | ✓ | ☐ | ☐ | It's recommended to consult on the use of same unique identifiers between S-101 ENC production and S-125 marine Aton production | Moderately |
| AtoN status (Unlit, Missing, Damaged, Off position, Withdrawn, Removal, Replacement) are frequent and varied. In order to retain the latest navigation information in MASS, the service cycle of S-125 data including Aton status should be short | ✓ | ☐ | ☐ | Supplements the S-125 in parts of data delivery and dataset maintenance | Easy |
| Since MASS identifies the own ship's position through the GNSS and positioning sensor, it does not determine their position using the Aton included in the S-125 data. It is necessary to provide information suitable for the purpose of MASS. | ☐ | ☐ | ✓ | Review the use cases of using Aton in MASS and supplement the Aton data to be suitable for the operation of MASS | Hard |
| MASS can make routes by using the Aton included in the S-125 data. However, when monitoring the route, proper thematic attributes and spatial attributes should be provided to understand the intentions of the | ☐ | ✓ | ☐ | Revision of the data model so that the intended content of Aton can be expressed with spatial attributes and thematic attributes. | Hard |

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| Aton (lateral, cardinal, isolated, safe water, special purpose) in the MASS AI algorithm. | | | | | |
| The floating Aton(eg. Light buoy) continuously changes its position within the mooring chain length limit due to the influence of currents. The ship can receive real-time position of floating Aton through AtoN AIS, but a real-time position update method at the S-125 level needs to be considered. | ☐ | ☐ | ✓ | Consider a data model and service method that can update the position of floating Aton in real time | Moderately |
| Since special purpose AtoN, such as marine operation, become obstacles to MASS navigation, it's necessary to use a indication method that can accurately represent the marine construction boundary rather than a single position. | ☐ | ☐ | ✓ | Review of the spatial coordinate marking method that can indicate the boundary of the marine construction area based on the representative point of the Aton installed to inform the construction area. | Moderately |
| Since the virtual AtoN (Virtual, Synthetic) included in the S-125 data are useful for the route planning and route monitoring of MASS, the active creation and utilization of virtual Aton should be considered. | ✓ | ☐ | ☐ | Guidance on the production and operation of virtual Aton is needed. | Moderately |
| The S-125 data can be produced as integrated dataset for the responsible area, but considering the ease of service to MASS, it's necessary to produce and service for each route. | ✓ | ☐ | ☐ | Need reference guidance on S-125 dataset and cell design. | Moderately |

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| **Member State/Organization** | Brazil / Directorate of Hydrography and Navigation (DHN) |
| **S-100 Standard Reviewed** | S-126 |
| **Maturity of Standard** | No edition published yet. First Edition to be published by the end of 2024. |
| **S-100 Standard Chair** | Eivind Mong |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More content?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
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| MASS will require wind information. | ✓ | ✓ | ☐ | S-126 would need to add more content regarding wind climatology (e.g. monthly average wind direction and monthly average wind speed). | |
| MASS will require wave height information. | ✓ | ✓ | ☐ | | |
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ☐ | ✓ | It should be considered as part of S-126 the development of MASS common language. | |
| MASS will be required to perform spatial analysis (e.g., algorithm able to determine the best route using features of the ENC). The ENC data (S-57 or S-101 using ISO 8211) is not adequate for software based spatial analysis. Spatial indexation of ENC data, e.g., Hexagonal Hierarchical Spatial Index, could be a solution to foster spatial analysis. | ☐ | ☐ | ✓ | S-126 would need to address geological information, as hydrothermal deposits, submarine springs, volcanic eruptions. | |
| MASS will require more frequent or real-time updates of the data contained in the S-100 products, which should be pushed from official sources that the vessels | ✓ | ☐ | ☐ | | |

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| can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | | | | | |
| To avoid large volumes of bathymetric data (i.e., S102 gridded data), there is a need for conspicuous seabed features to be highlighted (such as sea mounts, obstacle or trenches) for use with Inertial Navigation Systems in GNSS denied environments. Similar to land based visually conspicuous objects captured in ENCs today. | ✓ | ☐ | ☐ | | |
| MASS has an issue with edge matching on charts. Often there is a discontinuation of data, particularly on depth contours. Described as a "leap of faith" when transitioning from one chart to another. | ✓ | ☐ | ☐ | S-126 information provided would be independent of the scale. | |
| MASS will require more use of photographic imagery, specifically panoramic photographic imagery. | ✓ | ☐ | ☐ | | |
| MASS will require more geographical polygons to describe areas (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions or Pick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based | ☐ | ☐ | ✓ | About creating a new standard to address this requirement, NIPWG Chair said that IHO does not expect to create new standards specifically for MASS. | |

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| containing attribution such as name of feature, type of feature, unique number, reason for speed restriction or constraint etc. in a machine-readable format. | | | | | |

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| **Member State/Organization** | USA (NOAA) |
| **S100 Standard Reviewed** | S127 |
| **Maturity of Standard** | Version 1.0.0 (Dec 2018) released for implementation and testing purposes; V1.0.1 (Dec 2019) under WG review |
| **S100 Standard Chair** | Elvind Mong (Canada) |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
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| MASS will require the ability to exchange route information between vessels. | ☐ | ☐ | ✓ | MASS will also require the ability to report route information to vessel traffic services<br><br>*Comments from S-127 Chair: Out of scope for S-127* | Hard |
| MASS will require VTS areas to be captured as polygons with relevant attribution. | ✓ | ☐ | ☐ | S-127 includes Vessel Traffic Service Area feature<br>*Comments from S-127 Chair: Concur* | |
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ☐ | ✓ | As with other standards, all S-127 features and information classes are derived from one of the abstract classes FeatureType and InformationType. InformationType has attributes for fixed and periodic date ranges, name associated with the individual information object if any, source information, and a textContent attribute that allows text notes or references to be provided for individual instances where appropriate.<br>*Comments from S-127 Chair: Concurs that natural language presents an issue for all S-100 standards, as it is difficult to extract the pertinent information. Appreciates the MASS PT recommendation to move from natural language to discrete values.* | Moderately |
| MASS will require historic marine accident or incident layers for risk profiling a particular area. | ☐ | ☐ | ✓ | Inclusion of additional features is easy, but identifying source of historic data may be hard.<br><br>*Comments from S-127 Chair: Possibly within the scope of S-* | Hard |

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| | | | | *127.* | |
| MASS will require historical traffic pictures, and if there are any anomalies in operations compared with historical traffic or adverse weather or unforeseeable events (e.g. freak wave) and behave differently, they can alert the human overwatch who can then revert to a Degree 3 control. | ☐ | ✓ | ✓ | S-127 includes Concentration Of Shipping Hazard Area feature, the standard explicitly does not include natural conditions (see note below)<br>*Comments from S-127 Chair: Concurs with the inclusion of some of the information based on historical traffic within Concentration of Shipping Hazard Area. Weather and natural conditions fall under S-126.* | Hard |
| MASS will require ferry routes and the ferry route timetables. Ferry routes could be captured as polygons or lines with attribution in a machine readable format that shows the ferry timetable. | ☐ | ✓ | ☐ | Possible inclusion with Concentration of Shipping Hazard Area; timetables could be included in Information Type<br>*Comments from S-127 Chair: Ferry routes are a feature class in S101. There is currently no means of estimating the location of ferry based on timetables. Current attributes include broad operating hours. It is possible to model, but would require more effort to keep it up to date.* | Moderately |
| MASS need to be aware of and go through Traffic Separation Schemes, but today there is no way for a Degree 4 MASS to know that a TSS exists. A method of identifying TSS and then transitioning towards it and through it safely will be crucial. | ✓ | ☐ | ☐ | S-127 includes Routing Measure feature type<br>*Comments from S-127 Chair: Traffic separation schemes and routing measures are included in S-101; the S-127 Routing Measure feature type provides enhancements.* | |
| Designated operating areas for MASS small craft? Geo-fencing | ☐ | ✓ | ☐ | Addition to other included specially designated locations (such as military practice areas, security areas, and areas need special caution)<br><br>*Comments from S-127 Chair: Nav Warnings could be used to provide details of MASS operating in a particular area. Designated MASS operating areas could be included in Supervised Areas with some enhancement to the model.* | Easy |

Notes:

#### 6.2.1.1 Overview of domain features and information types

Marine Traffic Management data products include tracks and routes, vessel traffic services, pilot services, underkeel clearance, and certain types of specially designated areas which affect ships routing. It does not include protected areas, radio services (radio stations, NAVTEX, weather or ice forecasts, NAVAREAs, METAREAs, etc.), natural conditions, or harbour services. The broad categories of geographic features included in the S-127 domain are:

- Tracks and routes, including IMO and non-IMO routing measures and recommended tracks.
- Vessel traffic services and related features such as calling-in points, radar ranges, and signal stations.
- Pilot districts, pilot boarding places, and pilot services.
- Water level information features, including underkeel clearance information features and waterways.
- Specially designated locations which affect navigation or provide traffic services, such as military practice areas, security areas, places of refuge, and areas needing special caution for reasons other than natural hazards or environmental protection.

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| **Member State/Organization** | Canada |
| **S100 Standard Reviewed** | S-128 |
| **Maturity of Standard** | Reasonably mature at V1.0 (issued 2022) |
| **S100 Standard Chair** | NIPWG –S128– Eivind Mong (Can) – Eivind.mong@dfo-mpo.gc.ca |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
|---|---|---|---|---|---|
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ☐ | ✓ | Mostly metadata information, and in a predefined list (enumeration) of choice options. There are still some free text fields.<br>Figure 6.2:<br>Feature type, catalogue elements, copyright: text<br>Information type, nauticalproduct, contactinstructions: text<br>Figure 6.3:<br>Complex attribute type, defaultlocale, character encoding : text<br>Complex attribute type, defaultlocale, country : text<br>(...)<br>It is specified in table 7.1 that «CharacterString» can be used. That text might not be hard to decipher by a machine when it is simple words (like a location), but could be an issue if sentences, or longer description are involved.<br>Need to make sure the free text fields are for human consumption and not machine, and/or easy to decipher by machine without interpretation, and/or not mandatory information. A question is: Why do you need something for human and not machine, especially in a context of degree 4 of autonomy, where no human will be involved in the whole process. | Moderately |
| MASS will require more frequent or real-time updates of the data contained in the S100 products, which should be pushed from official sources | ☐ | ☐ | ✓ | Some standards have a high update frequency, and synchronizing national catalogues (S-128) to their update rate will not be possible | Moderately |

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| that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | | | | (e.g surface currents S-111 and water-levels S-104: observation and forecast). It was discussed (for a future version)to have a note (specific filed) mentioning of the update rate for such standards.<br>Also some standards have an unpredictable nature and therefore an unpredictable update rate, since they are prompted by unforeseeable events, but have a large amount of update. (e.g NAV warns S-124, weather info S-4XX). In that case it was discussed (for a future version) that a note (specific field) should warn the mariner of the irregular interval of upcoming updates, and maybe an interval period to which the mariner should inquire for updates. | |
| The communication infrastructure necessary to sustain data exchange is not reliable and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | ☐ | ☐ | ✓ | S-128 compresses well but will still be an issue for normal connectivity.<br>In 11.2 it is mentioned that CPN datasets shall not exceed 20MB, and update datasets shall not exceed 500kB. | Easy |

Description (high level):

- Catalogue of Nautical Products (CNP) datasets describe the availability of paper charts, ENCs and other nautical products, applications for navigational purposes, online services and e-Navigation services. This includes their issue date, status, producing agency, and coverage.

From discussion with Eivind:

- S-128 was 1st developed to be a catalogue for human, to be put on a website and easily converted into pdf. It is mostly machine readable in its present form, but there are a couple of gaps to be fully machine readable (WG aware of that). It is intended for all products and services.
- S-128 could be used for the S-63 (encryption) readme file to know what is the latest version of the standard.
- Hydrographic offices will not be solely responsible for all S100 standards, many national organizations will likely be involved in producing the different standards. It is not yet a given that there will be only 1 S-128 catalogue per nation. For logistical reason, to have more than 1 catalogue per nation will be a challenge for mariners and MASS. There will need to be a lateral integration.
- The distribution of S-128 : machine discoverable might be an issue (multi-organizations). MCP vs RENCs.

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| **Member State/Organization** | Canada |
| **S100 Standard Reviewed** | S-129 |
| **Maturity of Standard** | Reasonably mature at V1.0 (issued 2019) – live testing done - updates planned for 2023 |
| **S100 Standard Chair** | S129 – Jason Rhee (Aus) – j.rhee@omcinternational.com |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
|---|---|---|---|---|---|
| MASS will require fairways to be captured as polygons and features in their own right. | ☐ | ✓ | ☐ | The gap is in other standard like S101 but will affect S-129<br>Areas requiring UKC will need to be identified (and defined) as objects (polygons), in order for proper MASS planification and operation, conform with regulated areas. | Easy |
| MASS will require port areas/limits to be captured as polygons with relevant attribution. | ☐ | ✓ | ☐ | The gap is in other standard like S101 but will affect S-129<br>Areas requiring UKC will need to be identified (and defined) as objects (polygons), in order for proper MASS planification and operation, conform with regulated areas. | Easy |
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ✓ | ☐ | The gap is in other standard like S101, S-126, S-131 but will affect S-129<br>Information pertaining UKC Areas (regulation, operational process, communication info, etc..)will be required in language readable and interpretable by machine | Moderately |
| MASS will require more frequent or real-time updates of the data contained in the S100 products, which should be pushed from official sources that the vessels can 'listen' out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | ☐ | ✓ | ✓ | The update rate might need to be more frequent for better planning and operation purpose.<br>As of now, a UKC plan is sent 24h previous, and then 5-10 minutes prior to passage.<br>Maybe several intermediate updates will be necessary (eg: 12h-6h-2h-1h-…)<br>Requires only push of ship data, recompilation of passage data by UKC agency, and pull of data by ship | Easy |
| The communication infrastructure necessary to | ✓ | ☐ | ☐ | The size of S-129 exchange set does not seem to be large. | |

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| sustain data exchange is not reliable and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | | | | | |
| MASS will require full bathymetric coverage datasets/DTM, gaps in data will pose a problem for MASS. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn’t have to analyze data to make the plan, therefore a lack of data is not an issue per se. | |
| To avoid large volumes of bathymetric data (i.e. S102 gridded data), there is a need for conspicuous seabed features to be highlighted (such as sea mounts, obstacle or trenches) for use with Inertial Navigation Systems in GNSS denied environments. Similar to land based visually conspicuous objects captured in ENCs today. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn’t have to analyze data to make the plan, therefore a lack of data is not an issue per se.<br>In GNSS denied environment, data might be necessary in order for MASS to position itself to follow plan. | |
| MASS will require certainty of seabed and associated features. High resolution data is great, but if it changes regularly, then that needs to be made clear and articulated in some way (example Humber estuary). Understanding when highly mobile seabed was last surveyed will also be important. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn’t have to analyze data to make the plan, therefore a lack of data is not an issue per se.<br>In GNSS denied environment, data might be necessary in order for MASS to position itself to follow plan. | |
| MASS will require an understanding of the reflective nature of the seabed, possibly associated with grab sample data for use in Inertial Navigation Systems. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn’t have to analyze data to make the plan, therefore a lack of data is not an issue per se.<br>In GNSS denied environment, data might be necessary in order for MASS to position itself to follow plan. | |
| MASS will require an understanding of the acoustic qualities of the water column for Inertial navigation Systems. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn’t have to analyze data to make the plan, therefore a lack of data is not an issue per se.<br>In GNSS denied environment, data might be necessary in order for MASS to position itself to follow plan. | |
| MASS has an issue with edge matching on charts. Often there is a discontinuation of data, particularly on depth contours. | ☐ | ✓ | ☐ | The gap is in other standard like S101 but will affect S-129<br>Areas requiring UKC will need to be identified (and defined) as | Easy |

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| Described as a "leap of faith" when transitioning from one chart to another. | | | | objects (polygons), in order for proper MASS planification and operation, conform with regulated areas. | |
| MASS will require shipping lanes to be made available and captured as polygons with suitable attribution. | ☐ | ✓ | ☐ | The gap is in other standard like S101 but will affect S-129<br>Areas requiring UKC will need to be identified (and defined) as objects (polygons), in order for proper MASS planification and operation, conform with regulated areas. | Easy |
| MASS will require certainty of tidal heights and surface currents at a given point and time, particularly in congested water space and shallower waters. Bramble bank in UK was used as an example, being shoalier by 0.5m could lead to a grounding. Predicted and forecast tidal height and surface currents are essential but certainty factors surrounding the predictive nature is important for decision making and risk profiling a route for MASS. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn't have to analyze data to make the plan, therefore a lack of data is not an issue per se. | |
| MASS will require more geographical polygons to describe areas (such as speed restriction and constraints), with suitable attribution for MASS to interrogate and act appropriately. This information is often captured in text boxes, Sailing Directions or Pick Reports in natural language with very little geographic descriptors, making it impossible for MASS to interrogate, read and act upon. These could be created as instructional layers which are geographically location based containing attribution such as name of feature, type of feature, unique number, reason for speed restriction or constraint etc in a machine readable format. | ☐ | ✓ | ☐ | The gap is in other standard like S101, S-126, S-131 but will affect S-129<br>Information pertaining UKC Areas (regulation, operational process, communication info, etc..)will be required in language readable and interpretable by machine | Moderately |
| MASS will require communication zones to be captured as polygons with appropriate attributes. As an example currently the rules for radio communications are within the Admiralty list of radio signals volumes 1-6, these volumes are particularly difficult for an autonomous vessel to | ☐ | ✓ | ☐ | The gap is in other S-100 standard, but info will be required to unable data exchange for UKC plan transmission | Moderately |

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| understand. | | | | | |
| MASS will require real time tidal data which is crucial in shallower waters. | ✓ | ☐ | ☐ | The UKC plan will provide the ship navigation plan, therefore, MASS doesn't have to analyze data to make the plan, therefore a lack of data is not an issue per se. | |
| MASS will need to know where reporting points or areas are geographically. As an example knowing at what point to contact Falmouth Coastguard to say whether you were passing between UK mainland and the Isles of Scilly or not. | ☐ | ✓ | ☐ | Reporting points might be used for UKC plan updating. Information pertaining UKC Areas (regulation, operational process, communication info, etc..)will be required | |
| MASS will require polygons denoting what level or Degree of MASS operation is allowed. As an example Degree 4 may not be allowed in a port. MASS and MASS operators will need to know what areas they can go into or not as they may need to move from Degree 4 to 3 when entering specific areas. | ☐ | ✓ | ☐ | The gap is in other standard like S101, S-126, S-131 but will affect S-129 Information pertaining UKC Areas (regulation, operational process, communication info, etc..)will be required in language readable and interpretable by machine | Moderately |
| MASS will require precise information regarding the interface between autonomous and human operation at points such as mooring operations, canal transit | ☐ | ✓ | ☐ | The gap is in other standard like S101, S-126, S-131 but will affect S-129 Information pertaining UKC Areas (regulation, operational process, communication info, etc..)will be required in language readable and interpretable by machine | Moderately |

Description (high level):

- S-129 is a vector product specification: extent and nature of UKCM info
- The Ship's master selects approximate time window (ship's passage plan )to transit through area and sends info (draught, stability, speed, position,…) to UKCM provider. The UKCM provider completes calculations, and sends a UKCM plan back. The UKCM plan contains a route (vector) with control points. Plan is updated and validated as ships arrives near (under) the UKCM area.

Questions (answers from S129-WG chair):

- How will communications be done with UKCM provider (data transfer)? Is communication infrastructure/protocols machine to machine ready? (Does it link to VTS?)
  The current PS states that the S-129 dataset distribution media or transmission method is at the discretion of the of the producer.
  As an example, OMC International currently provides a web API to which an end user product can connect to, and retrieve S-129 datasets.
  A possible limitation for potential UKCM areas is the dataset sizes, should a very large area is to be covered.
  From MASS perspective, does communication assume a certain level of 'commercial' network connectivity by either terrestrial or satellite communications?

- Is there a way to automatically trigger the exchange of data from the ship to UKCM provider?
  If end-user software/interface is set up to automatically receive live updates, exchange of the latest S-129 data can happen automatically, at certain refresh/update rates.
  MASS might need more UKCM plan updates, other than 24h prior, then 5-10 min prior, and as it progresses? Maybe 12h-6h-2h-1h updates prior to estimated passage. Is it possible?
  The UKCM service is able to provide updates in more frequent intervals leading up to the passage.
  Hence, as long as the consumer software is able to receive live updates, data exchange intervals such as proposed would be possible.
  I will revisit the S-129 PS Section 7.1.1, as it may not be providing a clear indication of the expected update intervals of "actual plans".
  However, Sections 7.1.2 and 15.1 seem to outline the following:
  **Section 7.1.2:** "Approximately 24 hrs before the time when a ship enters the UKCM area, the ship will need a more detailed
  UKC plan. This plan usually considers more up to date information and will typically need to be updated more
  frequently. In this case, the non-navigable and almost non-navigable areas, any tidal windows (via Control Points),
  and some metadata will have changed. Depending on the variability of the met-ocean conditions, the update
  frequency could vary between 10 and 60 minutes." (From S-129 UKCM PS Ed 1.0.0 Final(13Mar19).docx)
  **Section 15.1:** *"About 24 hours before the time when the ship enters the UKCM area the ship will need a more detailed*
  *passage plan, which will be updated more frequently. Depending on the variability of the observed and*
  *forecast conditions in the UKCM area, the update frequency might range between 10 minutes to 60*
  *minutes."*

- Is there a way (imbedded data exchange protocol mechanism - back and forth validation checks) to confirm reception, acknowledgement of reception of plan by MASS? In the same way confirmation that plan will be followed by MASS as provided? (I saw the action pt5 in the last WG meeting document on data encryption.)

Acknowledgement of reception by the data consumer doesn't seem to be mandated by S-100 (but I may be wrong, I can double check), nor in scope of current S-129 PS.
I also had a look at S-100 14-8.2.4 (S-100_OC_ExchangePattern), but from what I'm understanding, it does not seem to cover consumer's response back to the provider.
Action item PT5-5 around data encryption requirements is not something I had a chance to clarify yet. I am happy to keep you updated on this.

- Is the ship master required to validate plan or is the UKCM provider fully responsible for the issued plan? in the sense that ship maser is ultimately responsible for all navigation maneuvers… if ship master is responsible, how will the MASS be able to assess the validity of the plan, in the case of lack of data (bathymetry, water level,…)?
  While the UKCM service enforces a level of validation checks of plan inputs, the user (e.g. ship master, pilot, VTS) is ultimately responsible for providing the accurate inputs.
  Currently, I'm unsure what the best method would be to enable MASS to assess the plan validity. Perhaps some form of new attribute or accompanying metadata could be used to indicate if an S-129 output is valid or not? E.g. to indicate the status of bathymetry or water level underlying the S-129 calculation?
  As far as I'm aware, this is currently out of the S-129 scope, but it's something the PT can think about, and I'm happy to discuss ideas.

- Will the route and way points account for other ships' passage (same and opposite direction) at the same time in the UKCM area? Or will it be a general route (like middle of passage way)? If it is general, MASS will have to create its derived precise navigation plan in order to account for surrounding navigation.
  In terms of the extent and location of the route and waypoints, they would reflect a "general route" in S-129.
  Expected passing time & speed at each waypoint would be predetermined by calculations in the UKCM service based on user input (such as route, speeds), which may have taken traffic into account.
  Are you aware of any other S-100 standards (such as S-421, maybe?) that might be dealing with MASS encounters with other vessels?

- Are there free text fields? Or all field with textual information contain predefined choices?
  Under the current specification, all attributes are defined with required types.
  While there are textual attributes as currently specified in the S-129 PS, they would be predetermined by the UKCMS service. For example, the UKCM service for a particular a port or waterway should provide "route name" from predefined options.

Comments (notes from S129-WG chair):

- UKCM areas will need to be defined as polygons, and all information pertaining them will need to be machine readable. (independent of S-129 standard) Do we know what format MASS requires the polygons to be in? Would it be .GML or otherwise?
- MASS doesn't need to use available data to calculate time window and route. MASS must use UKCM plan provided.
- MASS doesn't require display features imbedded in the S129 product.
- Any field with free text cannot be analyzed properly by MASS. Need predefined choices, predetermined remarks fields…
- Involvement with pilotage authorities if UKCM area is under their responsibility.

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| **Member State/Organization** | Japan - JHOD |
| **S100 Standard Reviewed** | S130 |
| **Maturity of Standard** | The draft application scheme was created by Sub-Group, but not approved yet by the S-130 PT |
| **S100 Standard Chair** | Britt Lonneville (britt.lonneville@vliz.be) |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
|---|---|---|---|---|---|
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ✓ | ☐ | ☐ | | |

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| **Member State/Organization** | United Kingdom |
| **S100 Standard Reviewed** | S-131 |
| **Maturity of Standard** | Quite immature V0.2 |
| **S100 Standard Chair** | Eivind Mong |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
|---|---|---|---|---|---|
| MASS will require canal locks to be captured with relevant attribution, such as width of lock. | ✓ | ☐ | ☐ | Canal locks and other associated features (e.g. bridges) have been moved to S-127 and are not part of S-131. | |
| MASS will require port areas/limits to be captured as polygons with relevant attribution. | ✓ | ☐ | ☐ | | |
| MASS will require a better standardization and accessibility to harbour infrastructure datasets. | ✓ | ☐ | ☐ | That is the purpose of S-131, it will allow port operators to send information to Hydrographic Offices in a standardised way and ensure the Hydrographic Offices publish data in a standardised way. | |
| MASS will require the natural language data in publications, charts (pick reports) and MSI to be made machine readable and interpretable. Natural language is difficult for machines to read and interpret, we need to move to a feature and attribute model for all aspects of data for MASS. This will also need to cover meta data for the actual data. | ☐ | ☐ | ✓ | There is likely to be a gap, however, the S-131 standard provides contextual information that humans would need, but MASS would not need (e.g. is there a hospital or a station at the port). Most free text is used to describe features.<br><br>We need to examine each instance of a free text field being used and look at it context as to whether it is appropriate to remain free text, this has been done below. | Moderately |
| Below are textual fields found throughout the standard which we feel could be changed to allow for enumeration thereby more appropriate for MASS. | ☐ | ☐ | ☐ | | |
| Applicable Load Line Zone | ☐ | ☐ | ✓ | Consider enumeration for this as there's less than 10 types | Easy |
| Approach Description | ☐ | ☐ | ✓ | Can this free text supplemented by a defined track or could it be? | Moderately |
| Bollard Description | ☐ | ☐ | ✓ | This should be a combination of enumeration for the type of bollard and a numeric value for safe working load | Easy |

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| Communication Chanel | ☐ | ☐ | ✓ | This should be a real number with an enumerated suffix where appropriate. | Easy |
| Country Name | ☐ | ☐ | ✓ | Should be enumerated with an official list of countries. | Easy |
| Language | ☐ | ☐ | ✓ | This could be enumerated. | Easy |
| MMSI Code | ☐ | ☐ | ✓ | Should be numeric only | Easy |
| Nationality | ☐ | ☐ | ✓ | Could be enumerated. | Easy |
| Protocol | ☐ | ☐ | ✓ | Could be enumerated | Easy |
| Tug Information | ☐ | ☐ | ✓ | Could be broken down and then use enumerated values and could have a textual component such as the name of the tug. | Moderately |

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| **Member State/Organization** | Japan - JHOD |
| **S100 Standard Reviewed** | Security Protection Scheme |
| **Maturity of Standard** | Edition 5.0.0 |
| **S100 Standard Chair** | - |

| **Issue/Requirement** (take from Spreadsheet) | **Issue addressed?** | **More cnontent?** | **Gap in standard?** | **Potential Solution/s** | **Ease to implement?** |
|---|---|---|---|---|---|
| MASS will require 3D applications or Digital Twins. 3D models or Digital Twin for rehearsal of Port entry both above and sub surface will be increasingly important for situation awareness in Degree 3 and 4. Digital Twins could be a useful 3D chart in the future that a MASS can use with computer vision sensors to compare the real world with the Digital Twin and triangulate its position. | ☐ | ☐ | ✓ | Data protection scheme itself does not have a gap. However, in addition to processing of data protection scheme, processing of real time data (acquired by sensors on a vessel and/or received from a navigation support center on land) may place a heavy load to the on board system and reduce processing capability of the system for judging the safety navigation.<br>As solutions;<br>・ Separate or prioritize safety determining system over data processing system<br>・ Small data size, low frequency of data updating<br>・ Partial application of data protection scheme | |
| MASS will require more frequent or real-time updates of the data contained in the S100 products, which should be pushed from official sources that the vessels can ‘listen’ out for and update their navigational database and products automatically irrespective of where they are in the world. Event driven data updates and near real time updates will be required for MASS as MASS will always need to be up to date. | ☐ | ☐ | ✓ | See above | |
| The communication infrastructure necessary to sustain data exchange is not | ☐ | ☐ | ✓ | See above | |

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| reliable and affordable today. Thought needs to be given to data packets sizes for data and updates for MASS. | | | | | |
| MASS will require certainty of seabed and associated features. High resolution data is great, but if it changes regularly, then that needs to be made clear and articulated in some way (example Humber estuary). Understanding when highly mobile seabed was last surveyed will also be important. | ☐ | ☐ | ✓ | See above | |
| MASS will require more use of photographic imagery, specifically panoramic photographic imagery. | ☐ | ☐ | ✓ | See above | |