Paper for Consideration by S-100 WG TSM7

Bridge Usage of S-100 Data Products

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Executive Summary:	Analysis designating S-100-based products as front or back of bridge products, mainly for their potential inclusion in a front-of-bridge interoperability catalogue as defined in the draft S-98 Interoperability Specification.
Related Documents:	--
Related Projects:	S-98

Introduction / Background

This paper is intended to initiate an in-depth discussion on the navigation usages of S-100 based products, where on the bridge they are used, and how that usage is influenced by external factors. The paper contains an analysis of existing and proposed S-100-based data products for the purpose of designating them as front-of-bridge products. The analysis is general but the immediate purpose is to consider which products should be included in a front-of-bridge interoperability catalogue based on the draft S-98 Interoperability Specification.

The first discussions of S-100 product interoperability occurred about February 2015, at TSMAD 29. The scope was discussed at TSM3 (September 2015) and S-100 WG1 (March 2016). A list of candidate products was identified at S-100 WG1, considering products for which specifications were under current or imminent development. An analysis of interoperability issues and a design document were prepared following S-100 WG1, and an experimental XML "interoperability catalogue" (including a UML model and XML schema) was developed and presented at TSM4 (September of 2016). A revised version accounting for the feedback at TSM4 was presented at S-100WG2 (March 2017). Following a decision to frame the interoperability catalogue in terms of an S-100 product specification, version 0.1 of the interoperability product specification was presented at TSM5 (September 2017) and S-100 WG3 (April 2018). KHOA organized an interoperability workshop to validate the concept of interoperability and the interoperability specification in August 2017, produced sample Level 1 and Level 2 interoperability displays combining S-101, S-102, S-111, and S-412, and presented the results at the same TSM5 and WG3 meetings. The "S-98" number was assigned by HSSC9 (November 2017), and IHO Council (C-2) endorsed development of the S-98 product specification. After circulation of the draft S-98 to IHO working groups for review and consideration of comments, the current draft of S-98 was prepared for S-100 WG4 and slightly updated for HSSC11.

References

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Discussion/Analysis

Definitions

The scope of the word "system" in this paper is limited to ECDIS, whether a conventional standalone ECDIS or part of an Integrated Navigation System (INS).

"Front-of-bridge" versus "back-of-bridge" is determined by the role being filled by a system, regardless of its location.

Front of bridge system: A front-of-bridge (FoB) system is a **system in use by the operator responsible for ship's handling, usually at the main or relief workstation for ship's handling**. It is normally the system at the "workstation for navigating and manoeuvring" as described in IMO Circ. 982 (reproduced in Appendix B of this paper). The system (if any) at the "workstation for monitoring" is normally also included as front-of-bridge when it is shared with, or being used as a reliever for, the workstation for navigating and manoeuvring. (Circ. 982 does not specify a separate ECDIS at the workstation for monitoring.) The front-of-bridge system can be one or more independent ECDIS systems (e.g., main and backup, according to the IMO ECDIS performance standards).

If a system in another location on the bridge (e.g. bridge wing) is temporarily playing the role of the main workstation for ship's handling, it must be treated as a front-of-bridge system for the time being.

Back of bridge system: A back-of-bridge (BoB) system can be any system which is not being used as a front-of-bridge system, has a part in ensuring the ship complies with SOLAS Chapter V REGULATION 34, and is capable of loading S-100 based data products. In the context of this paper, it is normally the system at the "workstation for planning and documentation", as described in Circ. 982. It may be the same system as the backup ECDIS (but the same physical system cannot play both roles simultaneously).

Regulatory factors

The data layers allowed on ECDIS are defined in terms of minimum requirements for data which must be available and categories of features (and other information) which must or should be displayed in different modes of ECDIS operation. Adding several other data layers invites regulatory efforts to mitigate problems with clutter and information overload by determining which specific products are allowed or not allowed to be used on the ECDIS, which may result in significant delay in approval of products for use on ECDIS.

IMO Circ. MSC.232(82)/Annex §7.1 states:

> Radar information and/or AIS information may be transferred from systems compliant with the relevant standards of the Organization. Other navigational information may be added to the ECDIS display. However, it should not degrade the displayed SENC information and it should be clearly distinguishable from the SENC information.

Further, MSC.232(82) Appendix 2 lists the categories of SENC features to be displayed in ECDIS base and standard modes, and also permits "All other information, to be displayed individually on demand ..." (All 3 lists are reproduced in Appendix B of this paper.)

Front-of-bridge products – as a collection, not just individually – should stay within the spirit of §7.1 of MSC.232(82).

Human factors

Avoiding information overload for navigation and ship handling is imperative.

The appearance of multiple alarms and indicators is a significant contributor to information overload – and if more products are added to the primary navigation window, the tendency will be towards even more alarms and indicators.

Whether the symbols and portrayal rules in the portrayal catalogues of individual products are suitable for their use under bridge conditions (e.g., day, night, or dusk) is obviously relevant to whether the products will actually be used FoB.

Proliferation of different shapes and colors of symbols and styles of symbols would increase the cognitive load the ECDIS imposes on navigation and monitoring officers, and detract from their overall situational awareness. If many products are added to the FoB display set, the tendency will be toward increasing the variety of shapes and symbols within the view of front-of-bridge operators, since there will be a natural tendency to develop different symbols for features which represent different concepts in different product specifications.

The variation in system styles and interface controls between systems built by different suppliers has been reported as another human factors issue important to mariners.

Visual and physical conditions are often challenging and bridge personnel may be fatigued.

S-98 interoperability can be a double-edged sword in addressing the human factors issues. Introducing new and distinct portrayals for all front of bridge products will make things worse when they are all displayed on the ECDIS. On the other hand, suitably harmonized and unified portrayals, alarms and indicators, all designed to address human perceptions and cognitive capability, should actually be able to mitigate the human factors problems.

The imperative in MSC.232(82)/Annex §7.1 that other navigational information "should be clearly distinguishable from the SENC information" may need to be qualified in the future in terms of exactly what "other navigational information" is meant. This will probably be a long-term project with proper testing, and in the near future, front-of-bridge products may have to work within this limitation.

Different navigators have different work styles and different levels of comfort with ECDIS user interface technology and controls. Some navigators may prefer having fewer information layers to choose from, while others may prefer having the ability to choose from a wider set of layers, even when they end up choosing to display only a few of them.

The utility of specific products obviously depends on circumstances, e.g., ice charts are relevant only when and where ice might possibly be encountered.

Relevance to ongoing or near-term navigation tasks is another factor – "relevance" meaning proximity to the ship's location or route in the near[1] future. For example, navigators prefer not to be forced to acknowledge navigational warnings about distant obstructions which cannot affect the ship's movements.

Masters should be offered the ability to take work styles, local circumstances, relevance into consideration in determining whether the product should be used FoB.

The decision about which of the FoB-qualified data products to actually use FoB, and when, should become (is?) part of voyage planning.

Lastly, consideration should be given to MSC.1/Circ. 1512 Guideline on Software Quality Assurance and Human-Centred Design for E-Navigation that helps ensure that user needs and safety are met.

Production schedules and delivery to end-user systems

Product availability compared to ENCs, as determined by production cycles and delivery mechanisms will be an important factor for selecting or rejecting a data product for front-of-bridge use, because acceptance by end users will play an important role in the rationale for including products in interoperability catalogues.

If production schedules cannot keep up with changing conditions in the physical environment, end-users may be reluctant to use the product FoB even if they use it BoB. For example, if S-102 (Bathymetric surface) or S-111 (Surface current) datasets cannot be updated frequently enough to keep up with changes over time, that may make these products better suited for back of bridge usage.

Determinations of "too low production frequency" would have to be product-specific, probably also producer-dependent (different producers may commit to different production frequencies), and the threshold for acceptability could for example depend on the reliability of forecasts and the rate of data decay over time.

[1] "Near future" would be determined by circumstances, but durations of one watch or one day may be reasonable approximations. Navigators or planners can set the precise time window depending on circumstances.

The actual availability of data on the end-user system is another important consideration. Availability to the end-user will be affected by such factors as release schedules, transmission channel bandwidth relative to data volumes, streamed vs. exchange-set transfer modes, provision of web services with well-defined APIs for location-specific feature retrieval, etc.

Product specification development teams or their sponsoring groups should be encouraged to discuss dataset production frequency and delivery expectations in S-100-based Product Specifications, or in an adjunct document.

For both vector and coverage data, the delivery aspects should be addressed, including data volume (including tiling to limit transmission package size), delivery channels (especially wireless delivery), streamed data, and well-documented APIs for web services.

Consideration should be given to developing a template at the S-100 level for producers to describe product availability and delivery (potentially drawing on IALA maritime service portfolio specifications).

Consideration should also be given to adding temporal validity attributes to metadata (S-100 Parts 4a/4b/4c).

Masters should be offered the ability to consider the production and delivery aspects of a product when determining whether a product should be used FoB. Data about product availability, delivery, and validity can be used to generate "data service briefs" which can be used during voyage planning to decide whether localized datasets from an FoB product specification should be displayed on the navigator's system.

Data quality factors

A product which is intended to replace or enhance information in other products must be at a quality level that is at least as high as the data it replaces or enhances. A complicating factor is whether the importance to safety of navigation is high enough to counter-balance lower quality. A further important consideration is whether the data quality can be indicated to the mariner in an intuitive manner.

Criteria for classification as front or back of bridge product

Considering the above factors, the criteria proposed for designating an S-100-based data product as a front-of-bridge product are:

- The product contains geographic feature data that is **critical or important for ship's handling and monitoring** and which is **capable of replacing, substituting for, or updating** information in the ECDIS used by navigators for ship's handling and monitoring. "Information critical or important for ship's handling and monitoring" of ship movement on ECDIS would normally be ENC data. For example, an S-124 Navigational Warning which updates the location or operational status of a navigation aid in an ENC.
- The product contains geographic feature data that is **critical or important for ship's handling and monitoring** and which **enhances or supplements** similar information in the systems used by the navigators responsible for ship's handling and monitoring. This means that a data product which enhances ENC information with additional information meeting this criterion is qualified for front-of-bridge. It does not have to be a replacement or substitute for ENC data, nor does it need to meet the same quality requirements as ENC data. An example is fast ice features from S-411 which effectively change the shoreline. Underkeel clearance information from S-129 is another example.

"**Capable of replacing, substituting, or updating**" means data that conveys equivalent knowledge (e.g., high definition gridded bathymetric depths for vector area depth ranges) within known, tolerable uncertainty (which should be encoded in the replacement dataset). Dates of observation should be compared to the original (if date information is available) to determine whether the knowledge conveyed is equivalent in terms of aging or validity period.

"**Enhances or supplements**" means the product provides additional or more up-to-date information, e.g., additional features like weather hazards, additional attributes for existing features, or more accurate values for some attributes, but is not a complete replacement for a feature layer.

Classification of data products

This section classifies known S-100-based data products as front or back or bridge. Table 1 is a summary classification. A detailed classification of all known S-100-based products is provided in Table 3 in Appendix A, along with recommendations for front/back of bridge use and reasons for the recommendation.

Table 1. Summary classification

Candidacy for FoB use	Data products	Inclusion in normative FoB interoperability catalogue (IC).
Certain or highly likely	S-101 (ENC) S-102 (Bathymetric surface) S-104 (Water Levels) S-111 (Surface Currents) S-124 (Nav. warnings – selected types) S-129 (UKCM – only go/no-go areas?)	All products should be Covered by the FoB IC. Inland navigation may need a different normative IC. S-401 and S-402 are not listed because they belong on Inland ECDIS.
Probable	S-412 Weather and Wave Hazards – features selected by proximity, timeliness. (Perhaps also the size of the area, e.g., warnings covering relatively large areas may be better communicated to navigators by other means.)	Covered.
Possible or conditional	S-411 (Ice Information – selected feature types) – depending on release frequency and timeliness of data S-413 (Weather and Wave Conditions) or S-414 (Weather and Wave Observations) – depending on localization and timeliness of data.	Covered/Not Covered TBD, pending discussions with the respective project teams.

Criteria for data replacement

Implementing the general criteria for classification of data products as FoB requires specifying rules for when individual datasets qualify to "replace, substitute for, or update" data, or "enhance or supplement" FoB data. An initial set of rules is listed below. Discussions to formalize these rules are needed, engaging all stakeholders including mariners and IMO.

Table 2. Proposed rules for data replacement

Product	Rule	Suggested implementation
S-102 Bathymetric surface	S-102 data must originate from an official source such as a hydrographic office.	Compare producer in metadata to IHO S-62 list of producer codes.
	S-102 data can only replace ENC depth information in dataset originating from the same source.	Compare producer in metadata of S-102 and ENC datasets.
S-104 Water levels	S-104 data must originate from an official source such as a hydrographic office.	Compare producer in metadata to IHO S-62 list of producer codes.
	S-104 data can only replace ENC depth information in dataset originating from the same source.	Compare producer in metadata of S-104 and ENC datasets.
S-111 Surface currents	S-111 data must originate from an official source such as a hydrographic office.	Compare producer in metadata to IHO S-62 list of producer codes.
	S-111 data can only replace surface current information in datasets originating from the same source.	Compare producer in metadata of datasets.
S-124 Nav. warnings	Must be valid according to most recently received in-force bulletin, or received afterwards.	Check list in the in-force bulletin. Check if warning date/time is after the most recent in-force bulletin.
	Must be within any filtering parameters	Spatial filter by proximity to planned route. Temporal filter by difference from time of planned passage. Filtering parameters may depend on type of event and be customizable on board.

	(Display)	Is an overlay and does not replace ENC data directly, rather provides navigational safety information that may impact the reliability of some ENC data.
S-129 UKCM	Must be an updated dataset from a UKCM service along route.	Check producer in metadata to IHO S-62 list of producer codes. Compare production or validity time to time of planned passage.
	Updates must be received at regular and/or prescribed intervals.	Compare production or validity time to time of planned passage.
	(Display)	Is an overlay, but may be created from more recent sources than ENC data and therefore be fit to replace depth information.
S-411 Ice	Must be an updated dataset from an Ice Service	Compare production or validity time to time of planned passage.
	(Display)	Temporary overlay to validate safety and efficiency of route execution.
S-412 Weather and wave hazards	PS in development, rules tbd. (Similar to S-124 rules?)	Is an overlay product and do not replace ENC data.
S-413 Weather and wave conditions	PS in development, rules tbd. (Similar to S-124 rules?)	Temporary overlay to validate safety and efficiency of route execution.
S-414 Weather and wave observations	PS in development, rules tbd. (Similar to S-124 rules?)	Temporary overlay to validate safety and efficiency of route execution.

Note that implementing some of these rules may require extensions to S-100, such as in metadata and rules governing metadata content required of products which are candidates for FoB use, which will have to be incorporated into the respective product specifications (as well as S-101, so metadata can be compared).

Other matters

Ancillary issues noted while preparing this paper:

- While this analysis focuses on determining which products should be considered “front of bridge”, broadening it to also determine which products should be considered “back of bridge” may be a useful exercise for voyage planning by mariners and also for developers of ECS and similar systems other than ECDIS.
- Since a voyage plan must take into consideration several types of information, as indicated by SOLAS V Regulation 34 (see Appendix B), the person compiling the voyage plan must annotate the voyage plan with additional information, or make references to data layers at the various locations.

Conclusions

This paper is intended to advance the process of deciding which data products should be considered “front-of-bridge.” Stakeholder input to this paper is invited, especially about the factors, their relative importance, and the assessments of individual S-100-based products.

Given the variety of viewpoints, likely variations between data producers, varying navigational circumstances, and varying mariner work styles, consideration should be given to both technical and regulatory aspects of allowing choice to mariners in deciding when and how to use front-of-bridge products.

Some products may be partially front-of-bridge and partially back-of-bridge. For future editions of the product specifications, consideration should be given to defining which parts are FoB and which BoB.

Recommendations

Near term:

1) For the initial interoperability implementation, use the products classified in Table 1 (as revised after IHO WG and stakeholder review) as certain, likely, or probable. The initial list is:
   a) S-101 (ENC)
   b) S-102 (Bathymetric surface)
   c) S-104 (Water levels)
   d) S-111 (Surface currents)
   e) S-124 (Navigational Warnings)
   f) S-129 (UKCM)
2) Agree upon definitions of terms like FoB, BoB, "replace, substitute for, or update" data, or "enhance or supplement" FoB data, etc.
3) Obtain wider stakeholder input on the list of products considered FoB and covered by the interoperability catalogue (i.e., to Tables 1 and 3 in this paper). The process for doing this could involve:
   a) circulating this paper as-is for stakeholder feedback on the classification of products as FoB/BoB;
   b) circulating a factorial matrix analyzing candidate products on the basis of each of the factors identified in this paper, inviting stakeholder input on the analysis;
   c) clarification of what, if anything, is expected of data producers regarding FoB products – e.g., will they be expected to (eventually!) produce all the products which are classified FoB?
   d) other methods, as determined at TSM7 and other discussions.

   To save time, products which are clearly not suitable for either FoB or BoB use should be excluded.
4) Extend S-100 metadata (Part 4a) so that the *specificUsage* attribute of dataset discovery metadata blocks (**S100_DatasetDiscoveryMetadata**) can be used to specify FoB or BoB use (or both) for datasets.

Medium term (after publication of S-100 5.0.0?):

5) Review the FoB list against upcoming products, e.g. consider adding S-412 when its PS becomes available.
6) Request product specification project teams to develop suitable descriptions of their data products as soon as possible. An adequate description of a product's purpose is important for proper classification as front or back of bridge.
   a) The S-100 WG should develop criteria for what constitutes an adequate description for this purpose.
7) For products where only selected feature types are expected to be used front-of-bridge, request project teams to:
   a) include specification scopes in the product specification, distinguishing FoB from BoB features (and potentially attributes too), and
   b) define separate portrayal catalogues for Fob/BoB use, suppressing BoB feature (or attribute) display when the product is being used FoB.
8) Extend S-100 metadata (Part 4a) with metadata attributes that allow indication of the specification scope(s) included in a dataset. (Ref. similar recommendation in TSM7-4.7.)
9) Develop a model of temporal validity for FoB use and extend S-100 metadata with (optional) temporal validity attributes.

Actions Requested

The TSM is invited to:

1) Endorse or revise the analysis of individual product specifications in Table 3, providing justifications for selection or rejection for front-of-bridge or back-of-bridge use.
2) Based on the results of action 1, endorse or revise the summary classification in Table 1 including coverage/non-coverage by the initial normative interoperability catalogue.
3) Further development of the rules for data replacement in Table 2.
4) Discuss means for obtaining wider stakeholder input to classification of products as FoB.
5) Endorse the recommendations set forth in the Recommendations section, as modified during the meeting.
6) Take further action as appropriate.

Appendix A. Detailed analysis of S-100 products respecting their use front-of-bridge

Key for Table 3: Y or N = definitely use / definitely do not use
? = undetermined
C = conditional use; the notes column elaborates on the conditions.

Undetermined or conditional classifications will change to Y or N as the relevant product specification is better defined and production issues arise and are clarified over time. Products classified as undetermined must not be used in front of bridge systems; products classified as conditional must not be used unless the conditions are satisfied and there is a well-defined process and product metadata for indicating that they are satisfied. In short, if this paper evolves into a specification or guideline, only the products classified as "Definitely Use" for front-of-bridge systems may be used on them.

The question "What is the timeframe for beginning production and dissemination of data?" applies to all products in this table.

Table 3. Candidacy of S-100 products for front-of-bridge use

Product	FoB	Notes
International Hydrographic Organization (IHO) (S-101 to S-199)		
S-101 Electronic Navigational Chart	Y	Base information
S-102 Bathymetric Surface	Y	Detailed gridded data about depths. It is reported that some HOs or defense agencies are of the opinion that S-102 is covered by S-101 (the reason should be determined – perhaps arguing that S-101 will make it easier to have higher intervals of depth areas than S-57?). Availability being likely especially given some producers' (NOAA; others TBD) plans to produce and distribute high-definition bathymetry, this is a likely candidate for FoB use. Delivery aspects (volume, etc.) may need to be addressed.
S-103 Sub-surface Navigation	?	Not enough information available for classification vis-à-vis FoB or BoB. Unlikely to be relevant to surface navigation – likely to be more relevant for military (submarines) which would generally use WECDIS. If this is also used for remotely operated submersibles or autonomous underwater vessels, "front-of-bridge" must be interpreted in that context.
S-104 Water Level Information for Surface Navigation	Y	Gridded data and localized data about water levels. Real-time or near real-time availability TBD, but expected to be available. Availability being likely especially given some producers' (NOAA; others TBD) plans to produce and distribute datasets, this is a likely candidate for FoB use. Delivery aspects (volume, etc.) may need to be addressed.
S-111 Surface Currents	Y	Gridded data and localized station data about surface currents. Real-time or near real-time availability TBD, but expected to be available. Availability being likely especially given some producers' (NOAA; others TBD) plans to produce and distribute surface current datasets, this is a likely candidate for FoB use. Delivery aspects (volume, etc.) may need to be addressed.
S-121 Maritime Limits and Boundaries	N	Format for encoding claims as to limits, boundaries, and claimed rights over maritime regions. The project team's intentions regarding use as FoB or BoB are TBD. May be FoB for military vessels.
S-122 Marine Protected Areas	N	BoB, under the assumption that all the navigation-critical information is in the ENC. That is, the MPAs with navigation or movement-related restrictions are coded in the ENC as restricted areas. Described on the NIPWG web site as "protected areas and related features, regulations, and similar information about protected areas." Provides additional information about MPAs which is useful for planning. May provide details useful for monitoring (rather than navigation or manoeuvring), e.g., regulations regarding overtaking or passing. Depends on whether the

Product	FoB	Notes
		monitoring workstation is classified as FoB or BoB (or being used in an FoB or BoB role).
S-123 Marine Radio Services	N	Radio information which may be immediately needed at FoB workstations, such as communication channels for radio calling points, should be in the ENC or provided by other means at the workstation. The NIPWG web site describes S-127 as "indicating the location, availability, type of radio communications, frequencies, and content of radio services for navigational information and other maritime radio communications." As such this is intended to be a BoB product rather than FoB.
S-124 Navigational Warnings	Y	Navigational Warnings (subset of MSI) is needed in FoB and BoB, but there are potential issues with information overload and screen clutter (reported during discussions with navigators and Sea Traffic Management test-bed participants). Also, S-124 covers one part of the whole global navigational warning provision system. WWNWS-SC currently considers S-124 an additional method to provide navigational warnings and not as a replacement of existing methods. S-124 is developed for ECDIS, and as an enhanced version of todays NAVTEX and recognized mobile satellite service. As noted in the 'S-124 Training manual for NAVAREA Coordinators draft'; 'Some ECDIS manufacturers may provide an interface into the ECDIS for information received over NAVTEX or recognized mobile satellite service. This interface will use a text convertor to interpret the received text in order to identify positions and facilitate the geo-location of the information using the symbols unique to the manufacturer'. Navigational warnings received via NAVTEX or recognized mobile satellite service are both of direct printing type, and interpreted by a system that attempt to geo locate this information. Errors can occur from a variety of causes such as receipt error, missing characters, misinterpretation by software etc. The draft Training manual further notes that 'Within S-124, the standardized format for conveying navigational warning information is facilitated by the data model and its encoding format. The risk of reception errors is eliminated since S-124 will make use of the integrity measures as defined by S-100'. Other integrity measures like data validation checks will further improve the quality of S-124 Navigational Warnings versus NAVTEX and recognized mobile satellite service. The human factors considerations suggest that only a carefully selected subset of feature types, filtered by timeliness and relevance to the vessel's route should be displayed FoB. Views differ at this time about what kinds of filtering should be applied. Wider review of this paper should endeavor to develop either a common view, or a strategy allowing on-board customization of filtering. The position of the S-124 CG is that navigation warning information should be filtered only by time and all other navigation warning information within the chart screen should be on all the time in route monitoring mode. The MSI report list would be used to tell the mariner about MSI outside the screen but with an area affected which intersects the screen
S-125 Marine Navigational Services	N	Probably will be intended only for voyage planning and therefore not FoB. The NIPWG Web site describes S-125 as "navigationally [significant] features including lights and other navigation aids, both physical and virtual, temporary and seasonal marks, and local AIS application-specific messages."
S-126 Marine Physical Environment	N	Expected to be climatic or oceanographic information, or notable information about the physical environment of significance to navigation. The NIPWG Web site describes S-126 as "marine and terrestrial topography, prevailing, seasonal, and hazardous currents, tides, weather, and other environmental conditions." Does not include real-time or near real-time data. Intended for voyage planning and therefore a BoB product rather than FoB. Navigationally

Product	FoB	Notes
		significant hazards or other significant features should be encoded as features in the ENC.
S-127 Marine Traffic Management	N	Intended for planning use rather than navigation or manoeuvring. The NIPWG Web site describes S-127 as "vessel traffic services, pilotage, routeing systems, and ship reporting systems." The actual specification also includes basic descriptions of underkeel clearance management areas.
S-128 Catalogue of Nautical Products	N	Catalogue of data products, intended for product lookup, online product catalogues, and preparations for voyage planning. The NIPWG Web site describes S-128 as containing "the product, coverage, and publication information of various products, ranging from paper publications such as paper charts and printed sailing directions to digital products such as ENCs and e-Navigation services."
S-129 Under Keel Clearance Management (UKCM)	Y	Go/no-go areas are potentially relevant to navigation. FoB use will require sufficient temporal detail and/or timeliness to be relevant to current or near-future water level conditions. Note that since ECDIS is assumed NOT to have direct internet access, dynamic UKCM information is not accessible directly from the ECDIS (unless it arrives over a different, allowed, comms medium). Perhaps it can be routed via an intermediate back-of-bridge system which can act as a firewall?
S-1xx Marine Services	N	Scope to be determined, but almost certainly for voyage planning.
S-1xx Digital Mariner Routeing Guide	N	Intended for voyage planning, as a digital equivalent of S-49.
S-1xx Harbour Infrastructure	N	Intended for voyage planning and planning in-harbor non-navigational activities. Harbor charts expected to be used for within-harbor ship movements.
S-1xx (Social/Political)	N	For voyage planning.
International Association of Light Authorities (IALA) (S-201 to S-299)		
S-201 Aids to Navigation Information	N	Focuses on management and maintenance of navigation aids. Potentially an input to S-101 and S-125, but not of use for navigation due to redundancy with S-101 features and potential incompatibility with navigational aid feature types in S-101.
S-210 Inter-VTS Exchange Format	N	Intended for shore to shore information exchange.
S-211 Port Call Message Format	N	BoB use for notifications, scheduling port calls and services, and service management with port authorities. No effect on ship handling or manoeuvring and therefore not for FoB. May need an interface to voyage planning (BoB).
S-230 Application Specific Messages	?	Need more information on what this covers, presumably AIS ASM but its utility for voyage planning and criticality for navigation depends on what information is conveyed. As of August 2019, work on S-230 appears not to have begun.
S-240 DGNSS Station Almanac	N	Input to HO products, e.g., S-101 and S-125. Navigationally useful information will presumably be added in S-125 datasets.
S-245 eLoran ASF Data	N	Presumably eLoran signal propagation Additional Secondary Factors, and therefore potentially relevant for planning? Navigationally useful information will presumably be added in S-125 datasets. Need more information. As of August 2019, work on S-245 appears not to have begun.
S-246 eLoran Station Almanac	N	Need more information. Presumably the same role as the DGNSS station almanac, but for eLoran stations. Navigationally useful information will presumably be added in S-125 datasets. As of August 2019, work on S-246 appears not to have begun.

Product	FoB	Notes
S-247 Differential eLoran Reference Station Almanac	N	Need more information. Presumably the same role as the DGNSS station almanac, but for differential eLoran stations. As of August 2019, work on S-230 appears not to have begun.
Intergovernmental Oceanographic Commission (IOC) (S-301 to S-399)		
(unknown)	N	Presumably intended for scientific use, not navigation or voyage planning applications.
Inland ENC Harmonization Group (IEHG) (S-401 to S-402)		
S-401 IEHG Inland ENC	Y	FoB, but for Inland ECDIS.
S-402 IEHG Bathymetric Inland ENC	Y	FoB, but for Inland ECDIS.
Joint Technical Commission for Oceanography and Marine Meteorology (WMO/IOC JCOMM) (S-411 to S414)		
S-411 JCOMM Ice Information	C	FoB use depends on timeliness. If datasets are produced frequently enough (daily?), they may be useful in FoB to indicate hazardous "open water" areas with drift or pack ice, or variation of the nominal shoreline or sea floor depth due to fast ice or pack ice lodged against the shore. Or possibly only some types ice features may be suitable for FoB. (To do: check what features S-411 includes; and refer to JCOMM for advice.)
S-412 Weather and Wave Hazards	?	Part of Maritime Safety Information. Weather messages (watches, warnings, advisories, outlooks, synopses). Weather systems (cyclones, thunderstorms, tracks, cone of uncertainty). Spatial representations hazard and warning polygons, curves & splines for weather systems. Probably GML datasets. Timely information about localized hazards near the route may be useful FoB. Longer-term and larger warning areas and text forecasts are probably more suited for BoB use.
S-413 Weather and Wave Conditions	?	Conditions charts, grids, forecasts, nowcasts(?). Precipitation, wind, temperatures, etc. Probable formats HDF5, GML.
S-414 Weather and Wave Observations	?	Ship and buoy observations, satellite data. Source data is point-based data. Probable formats HDF5, GML. In principle timely observational data would be useful FoB, but may not be in a form suitable for direct use FoB by navigators. Filtered spot observations especially concerning anomalies are potentially useful, but should probably be ingested and analyzed on BoB systems before passing to FoB systems.
International Electrotechnical Commission - Technical Committee 80 (IEC-TC80) Numbers (S-421 to S-430		
S-421	Y	Route exchange information is important for both FoB and BoB operations.
NATO Geospatial Maritime Working Group (GMWG) for Additional Military Layers (AML) Numbers (S-501 to 525		
Additional Military Layers	N	Intended for WECDIS. Out of the scope of this analysis.

Appendix B. Extracts and Definitions

Definitions from IMO MSC/Circ. 982, Guidelines on ergonomic criteria for bridge equipment and layout.

Workstation for navigating and manoeuvring:

Main workstation for ship's handling conceived for working in seated/standing position with optimum visibility and integrated presentation of information and operating equipment to control and consider ship's movement. It should be possible from this place to operate the ship safely, in particular when a fast sequence of actions is required.

Workstation for monitoring:

Workstation from which operating equipment and surrounding environment can be permanently observed in seated / standing position; when several crew members are working on the bridge it serves for relieving the navigator at the workstation for navigating and manoeuvring and/or for carrying out control and advisory functions by master and/or pilot.

Workstation for planning and documentation:

Workstation at which ship's operations are planned (e.g. route planning, deck log). Fixing and documenting all facts of ship's operation.

SENC INFORMATION AVAILABLE FOR DISPLAY DURING ROUTE PLANNING AND ROUTE MONITORING - Appendix 2, IMO MSC. RESOLUTION MSC.232(82):

1 Display base to be permanently shown on the ECDIS display, consisting of:

.1 coastline (high water);
.2 own ship's safety contour;
.3 isolated underwater dangers of depths less than the safety contour which lie within the safe waters defined by the safety contour;
.4 isolated dangers which lie within the safe water defined by the safety contour, such as fixed structures, overhead wires, etc.;
.5 scale, range and north arrow;
.6 units of depth and height; and
.7 display mode.

2 Standard display consisting of:

.1 display base
.2 drying line
.3 buoys, beacons, other aids to navigation and fixed structures
.4 boundaries of fairways, channels, etc.
.5 visual and radar conspicuous features
.6 prohibited and restricted areas
.7 chart scale boundaries
.8 indication of cautionary notes
.9 ships' routeing systems and ferry routes
.10 archipelagic sea lanes.

3 All other information, to be displayed individually on demand, for example:

.1 spot soundings
.2 submarine cables and pipelines
.3 details of all isolated dangers
.4 details of aids to navigation
.5 contents of cautionary notes
.6 ENC edition date
.7 most recent chart update number
.8 magnetic variation
.9 graticule
.10 place names.

SOLAS Chapter V REGULATION 34 - Safe navigation and avoidance of dangerous situations

1 Prior to proceeding to sea, the master shall ensure that the intended voyage has been planned using the appropriate nautical charts and nautical publications for the area concerned, taking into account the guidelines and recommendations developed by the Organization.*

2 The voyage plan shall identify a route which:

.1 takes into account any relevant ships' routeing systems;

.2 ensures sufficient sea room for the safe passage of the ship throughout the voyage;

.3 anticipates all known navigational hazards and adverse weather conditions; and

.4 takes into account the marine environmental protection measures that apply, and avoids as far as possible actions and activities which could cause damage to the environment.

3 The owner, the charterer, or the company, as defined in regulation IX/1, operating the ship or any other person, shall not prevent or restrict the master of the ship from taking or executing any decision which, in the master's professional judgement, is necessary for safe navigation and protection of the marine environment.

* Refer to the Guidelines for Voyage Planning, adopted by the Organization by resolution A.893(21)