ECDIS Test datasets

Supporting Type Approval in S-100 ECDIS.

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1 Contents.

2 Revision History

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Reviewed	J Pritchard.	

3 Introduction and Aims

The stated aim of this report is to:

"Carry out an analysis in order to determine which types of test data sets will be necessary to fulfil the requirements to accomplish testing of an S-100 based ECDIS for type approval purposes."

This document does not attempt to define the actual test datasets themselves but to set a reasonable scope and level of detail on the test datasets likely to be required as the IHO and associated communities move towards S-100 as the basis for ENC and ECDIS. This report uses as assumptions and background:

1. The current state and trajectory of the S-100 and S-100 product specifications related to primary navigation within the IHO community.
2. The current structure and process established for type approval of navigation equipment under the various international conventions, standards and their implementations by regulatory authorities (in various forms)
3. How type approval has been approached by the IHO community alongside IMO/IEC representatives in the past when implementing ECDIS/ENC.

To this end this paper addresses the question posed by first looking at the existing set of standards and test datasets in conjunction with the defined performance standards and test standards used for ECDIS (and a consideration of how these have been developed and evolved since the introduction of ENC/ECDIS). The paper then looks at the prime "candidates" for the replacement of (and addition to) the existing ENC/ECDIS regime and determines what test datasets will be necessary for development in order to properly complement an associated test standard. A detailed examination of the current S-64 test dataset is presented which elaborates on how those existing tests may need enhancing or reformulating and a tabulated summary of likely future tests based on the current extent of the S-100 product specifications is presented.

In this way a systematic view of how type approval could be implemented is presented which can be adapted based on the options still under discussion within the IHO working groups. The aim of this paper is to be systematic, therefore all references and detail from the existing standards is included at the expense of brevity. A covering paper summarising the details has been produced separately to this main document.

4 Operation of ECDIS with S-100

There is clearly much work still to be done to gain formal acceptance of S-100, S-101 and other product specifications within the broader IMO/IEC standards which is not the prime focus of this document. The focus of this document is on the role and likely content of test datasets in supporting a process for type approval as well as the parameters and constraints of that process based on the existing regime and emerging standards.

The dialogue and development of the type approval regime is likely to take a significant amount of time; informed and focused support by the IHO community including lessons learnt from the last 20 years of

development represents an optimal path for the community. In order to examine the likely required test datasets there is a need to make some assumptions in two areas:

1. The operation and extent to which legacy IHO S-57 data has a place within an S-100 enabled ECDIS.
2. The scope of S-100 product specifications for which an S-100 ECDIS is certified/tested.

In terms of co-existence of S-57 with S-100 data the assumption has been made that a "dual-fuel" operation of future ECDIS during the transitionary period will take place. The exact nature of this operation is still to be defined but it represents a function of ECDIS requiring a maximal set of test cases and therefore in order to be systematic it is included in this document within test overviews and descriptions.

In terms of (2) this paper does not seek to establish exactly which S-100 product specifications should form the basis for the minimum standard for digital navigation, nor the timescales/processes for how those should be introduced (if necessary) into the IMO community through a revision of either the IMO Performance Standard or IEC61174[1]. Instead a "most likely" list of product specifications are considered along with tests required for their implementations. In this way should the list of "required" product specifications change it can be revised using a similar methodology to the one used here.

This paper also does not seek to propose any fundamental changes to the methodology used for testing itself, nor the maintained IMO regime under the performance standard. It may well be that the (fairly fundamental) nature of the move to IHO S-100 in comparison to IHO S-57 based ENCs would be better served by a differently structured testing process (and some notes on such developments are presented here) but in order to focus on the immediate goal of defining test datasets (and a "most likely" to-be-defined IHO workplan for their supply) the structure of the testing methodology is assumed (for now) to be the same (and is defined/described in the next section of this document) – certainly the fundamental restructuring of S-100 in allowing a far greater number of product specifications representing (in some cases) elements of the existing SOLAS requirements presents some unique challenges, described here, and these have been described and their impact on existing test datasets defined in section 7.4.3.

Short summaries of how existing IHO documents may have to be developed to reflect the progress towards supporting formal type approval of S-100 ECDIS is included in the final sections of this document, section 12

The level of detail specified in this document extends to individual test/groups of tests level in consideration of IHO S-64 (the prime current source of test material) but a more detailed analysis in some of the documentation may need to wait until test datasets are to be defined. In all cases the intention is to form a direct line between the stated requirement in relation to the IMO Performance

[1] All subjects currently in discussion with the relevant bodies and standards development groups.

Standard for ECDIS and how that requirement is fulfilled/elaborated on in the applicable IHO standards and tested in IEC61174.

In this document the IMO Performance Standard is commonly abbreviated to “IMO PS” and IHO Product specifications are abbreviated as merely “PS” – in all cases the context should be clear.

5 Overview of current process

The IMO Performance Standard refers only to the underlying IHO standards in a single section:

> **4.9** ECDIS should be capable of accepting both non-encrypted ENCs and ENCs encrypted in accordance with the IHO Data Protection Scheme[3].
>
> **4.1** The chart information to be used in ECDIS should be the latest edition, as corrected by official updates, of that issued by or on the authority of a Government, government-authorized Hydrographic Office or other relevant government institution, and conform to IHO standards[2].
>
> [2] IHO Special Publication S-52 and S-57 (see appendix 1).
> [3] IHO Special Publication S-63 (see appendix 1).

This in turn is expanded by IEC61174 and its references to the underlying technical standards of the IHO and the test datasets to be used. An overview of the extent of the current ecosystem for definition and testing of ECDIS is shown in the following diagram. In this diagram the individual IHO standards supporting the IEC61174 test process are shown:

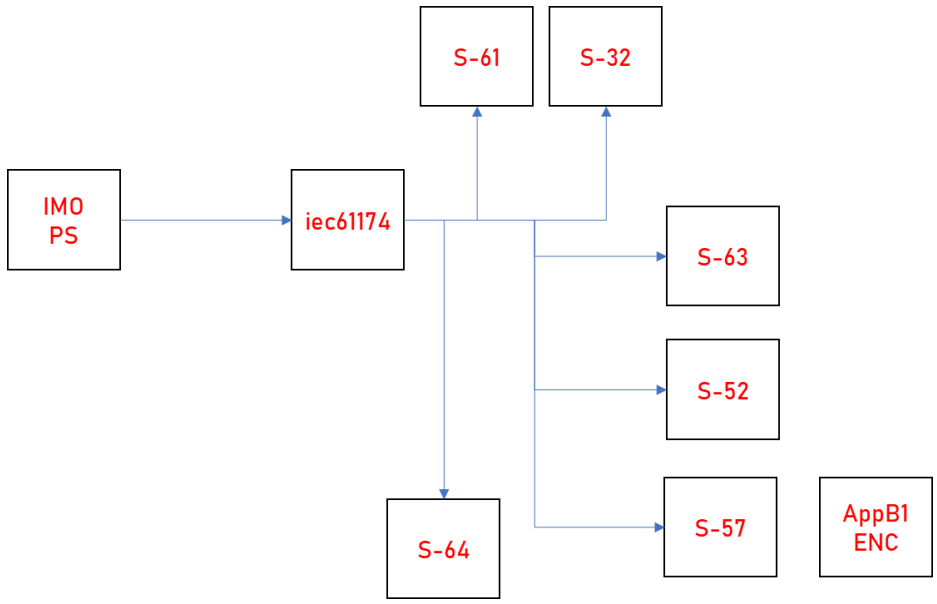


Figure 1: Current Standards defining ECDIS

In this diagram IHO S-57 contains the features/attribute definitions as well as dataset structure and content specifications (alongside Appendix B1 – the ENC product specification). IHO S-52 deals with all ECDIS display aspects of ENC and S-63 the elements of ENC loading and status reporting. IHO S-61 is concerned with raster data operations and S-32 acts as a normative reference for definitions of ENC related terms.

A slightly more detailed diagram shown below which shows the main functions of each group of standards.

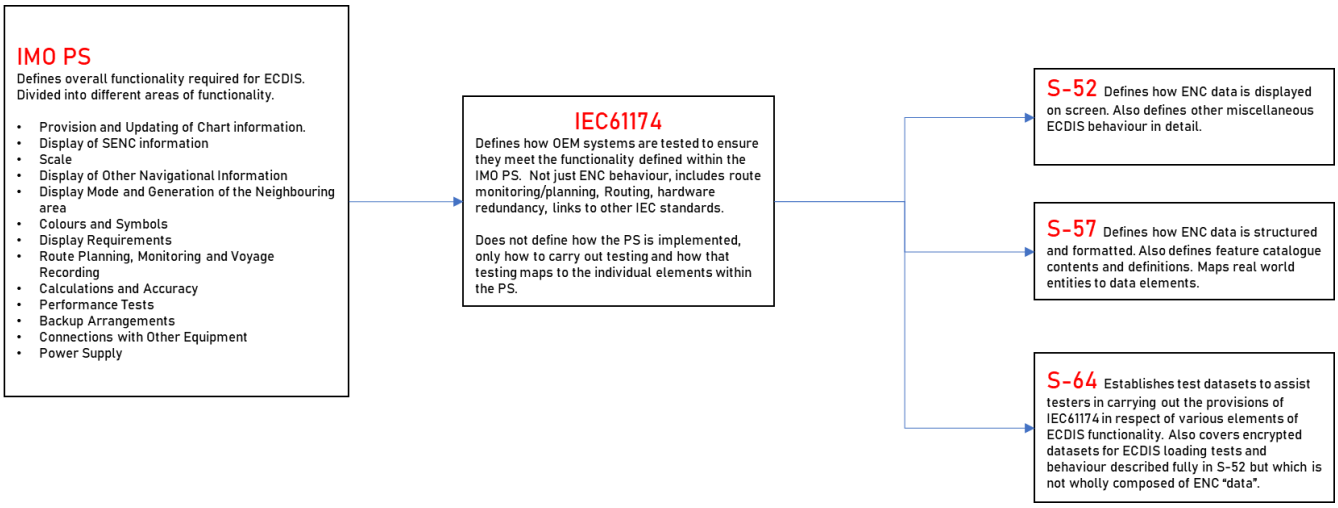


Figure 2: Current ECDIS definition and Testing standards

It should be noted that the various IHO standards and IEC61174 effectively fill in the detail of the IMO Performance Standard in relation to specific ECDIS functionality. That is, where tighter standardisation of functionality is required, a combination of S-57, S-52 and S-64 currently provide that tighter standardisation all in reference to the performance standard – i.e. implementing its provisions. In that sense the IHO standards (both in their specification and datasets) support the type approval testing process with a baseline of tests to unequivocally test a piece of equipment for conformance with the IMO PS and hence to certify it "type approved" (or not).

This process/structure is seen reflected many times also in the current IHO standards for ECDIS. For instance the diagrams presented are similar in nature to the diagram within IHO S-64

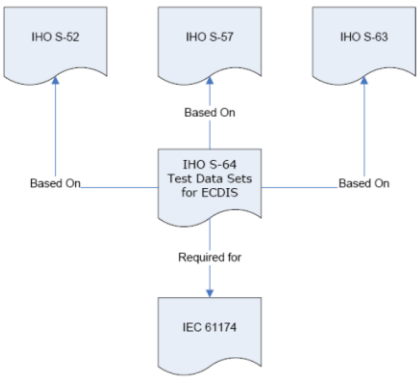


Figure 3: S-64 and its references.

And a yet more complex diagram taken from the current edition 6.1 of IHO S-52:

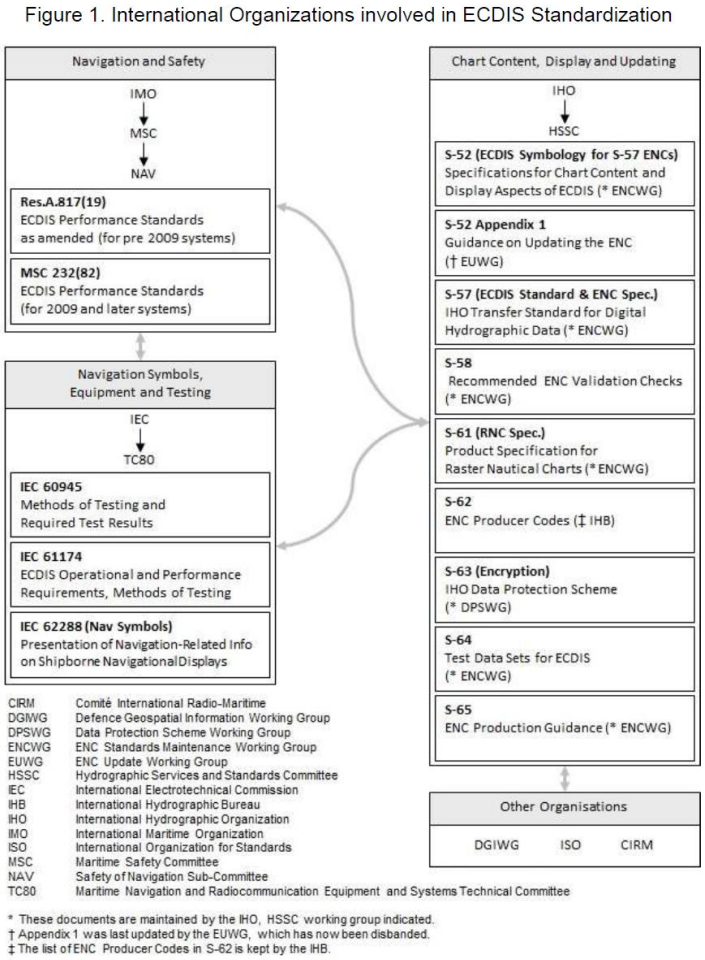


Figure 4: Standardization of ECDIS (from IHO S-52)

IHO S-52 contains much of the functionality of the ECDIS in detail, a fuller explanation of those sections is contained later in this document (Section 7.1), making the point that if IHO is to replace S-52 then merely replacing the ENC portrayal may not be sufficient to provide a coherent requirement to future ECDIS manufacturers in the S-100 ecosystem.

IHO S-52 contains many provisions which indirectly specify ECDIS functionality itself and has been arrived at after many years of development by the global ECDIS community. These elements of its content may still be valid and a view on their continued existence within the IHO standards base should be taken as part of the process of moving towards the new generation of ECDIS, learning the lessons from past experience within the community.

IEC61174:2015 refers to the following IHO standards (from the last revision of the standard):

IHO S-52, appendix 1:2012, *Guidance on Updating the Electronic Navigational Chart edition 4.0*

IHO S-52, Annex A:2014, *Presentation library edition 4.0*

IHO S-57, *IHO transfer standard for digital hydrographic data*

IHO S-57, appendix B.1, *ENC product specification*

IHO S-61:1999, *Product specification for raster navigational charts (RNC)*

IHO S-63, *IHO data protection scheme*

IHO S-64, *Test data sets for ECDIS*

Figure 5:IEC61174:2015 IHO standards references.

From these references a detailed picture of the interlocking standards supporting ECDIS manufacture, type approval and use emerges and the following structure of the standards and tests which support the manufacture of ECDIS can be described as follows:

1. IMO agree the SOLAS convention as the over-arching convention to promote safe shipping and within it chapters devoted to the carriage and use of charts and navigational publications (this is documented by IHO extensively) and provides the legal framework for the implementation of the convention by IMO member states in their requirements for carriage of navigational products and services by all vessels. SOLAS also makes explicit the provision of digital equivalent "versions" of those navigational materials (as ECDIS and ENC as referenced by the appropriate standards) and the need to keep them up to date.
2. The ECDIS performance standard (IMO) defines how an electronic piece of equipment meets the carriage requirement (and the essential functional building blocks of that system). It describes in overview the required major modules of functionality within ECDIS, e.g.
    a. Data loading/unloading and verification. Its update and the ability to perform manual updates within the SENC of the system
    b. The various display layers and their optional nature including the groupings of Base, Standard and standardised nomenclature for other layers
    c. The requirement and behaviour of Alarm and Indication functionality and its triggers.
    d. The definitions of route planning and monitoring modes and the requirement to automate checks and monitoring for conditions which may threaten the safety of the vessel during navigation.
    e. Other required functionality not directly connected with the display and behaviour of ENC data. This includes everything from other screen elements required, precision/accuracy of measurements to hardware resilience and voyage recording.
3. IEC61174 defines how an arbitrary piece of equipment can be tested (against the individual clauses in the IMO PS) to be conformant with the provisions of the IMO PS.
4. IEC61174 refers to IHO standards for the testing process.
    a. S-57 for definition, content and format of ENC
    b. S-52 for symbology, display and miscellaneous items of ECDIS functions. In addition S-52 provides mappings from IMO specified feature descriptions to those within the data for alarm/indication and safety contour generation
    c. S-63 provides a normative standard for packaging, transport and loading of data within the ECDIS system itself.

Therefore, in support of ECDIS and ENC development the following IHO standards are most relevant:

1. S-57 – basic framework for data format and structure (e.g. topology, update, datasets etc)
2. S-57 Appendix B1 – product specification for ENC – defines ENC features/attributes, metadata, encoding (iso8211), cataloguing, scale/precision/accuracy and, through the UOC, the mapping of these features/attributes to real world features themselves.
3. S-63 – packaging, encryption, digital signatures and "service revision" information as well as update status report information for the ECDIS
4. S-52 – display of ENC charts (+ other elements of ECDIS functionality (see section below for a fuller description of these elements.)
5. S-64 – test datasets for ECDIS manufacturers – references for display and also behaviour of loading data onto systems
6. S-58 – Not currently part of formal type approval. Validation of data, primarily by states and intermediaries (RENCs). Non-mandatory but as ECDIS became carriage requirement it was recognised that a certain "minimum level" of validation was necessary to ensure safe (in some respects) and consistent performance of ECDIS (and reduce the requirement to run such validation on ECDIS) – so called "critical checks". S-58 test datasets are used by developers of software to ensure that tests are processed correctly and test cases identified (discussed further in Section 0).
7. Other publications. ECDIS Check dataset (edge cases in display functionality – can support testing). IHO S-62 – not currently referenced but used for data producer codes to differentiate official from non-official data.

Therefore, the "functionality" required by ECDIS is stated at an overview level by the Performance Standard itself – this is then "implemented" by the testing standards which more completely define what level of functionality is required by a candidate system – this level of functionality is, in part specified by the IHO Standards which are then supported by IHO test datasets. In this way a complete ecosystem of specification, standardisation and testing, supported by test data is implemented.

For example: Base Display is defined in the IMO Performance Standard with the following text items:

> **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.

Table M.1 – Minimum ECDIS mariner viewing group layer selectors

Number of viewing group layer	Mandatory name of the viewing group layer in the ECDIS	Viewing groups included
Display base		
1	Display base	10000 – 19999

M.3 Display base category

M.3.1 Coastline layer

- IHO viewing group 12000:
  - IHO viewing group 12010:
    - i) land area (LNDARE)*;
- IHO viewing group 12400 – shoreline:
  - IHO viewing group 12410:
    - i) coastline (COALNE),
    - ii) crib (OBSTRN, CATOBS = 4)*,
    - iii) dolphin (MORFAC, CATMOR = 1)*,
    - iv) floating dock (FLODOC)*,
    - v) floating oil barrier (OILBAR, CATOLB = 2),
    - vi) flood barrage (DAMCON, CATDAM = 3)*,
    - vii) gate (GATCON)*,
    - viii) glacier (ICEARE, CATICE = 5)*,
    - ix) hulk (HULKES)*,
    - x) ice boom (OBSTRN, CATOBS = 8)*,
    - xi) log pond or booming ground (LOGPON)*,
    - xii) pile (PILPNT),
    - xiii) pontoon (PONTON)*,
    - xiv) shoreline construction (SLCONS)*,
    - xv) tie-up wall (MORFAC, CATMOR = 4)*,
    - xvi) wellhead (OBSTRN, CATOBS = 2)*,
  - IHO viewing group 12420:
    - i) canal (CANALS)*,
    - ii) dock area (DOCARE)*,
    - iii) lock basin (LOKBSN)*.

NOTE The terms shoreline and coastline are generally used as synonyms

M.3.2 Safety contour layer

- IHO viewing group 13000 – safety contour:
  - IHO viewing group 13010:
    - i) depth contour (DEPCNT) output from conditional symbology proc
  - IHO viewing group 13030:
    - i) depth area (DEPARE)*,
    - ii) dredged area (DRGARE)*.

M.3.3 Isolated underwater dangers layer

Isolated underwater dangers in water deeper than the safety contour:

- IHO viewing group 14010:
  - mooring cables (MORFAC, CATMOR = 6)*,
  - rocks, wrecks and obstructions from conditional symbology procedur
    - i) obstructions (OBSTRN)*,
    - ii) underwater/awash rock (UWTROC),
    - iii) wrecks (WRECKS)*.

M.3.4 Isolated above-water dangers layer

M.3.4 Isolated above-water dangers layer

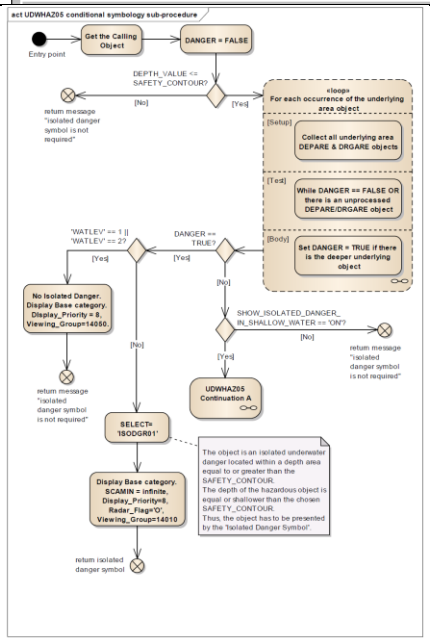
Isolated above-water dangers in water deeper than the safety contour:

- IHO viewing group 12200 – dangers above water:
  - bridge (BRIDGE)*,
  - conveyor (CONVYR)*,
  - pylon (PYLONS)*,
  - offshore platform (OFSPLF)*,
  - overhead cable (CBLOHD),
  - overhead pipeline (PIPOHD);
- IHO viewing group 14050 – rocks, wrecks and obstructions which ar conditional symbology procedure UDWHAZ04:
  - obstructions (OBSTRN)*,
  - underwater/awash rock (UWTROC),

And IHO S-52 contains much more detail on exactly how the Base display should be drawn on screen such as:

DISPLAY BASE	STANDARD DISPLAY	OTHER INFORMATION
00000-09999 reserved for administrative purposes		
10000 reserved *40000 reserved*	20000 reserved *50000 reserved*	30000 reserved *60000 reserved*
11000 A,B information about the chart display *41000 tools*	21000 A,B 51000 tool	31000 A,B *61000 tools*
12000 C, D, E, F land features *42000 own ship, planned route*	22000 C, D, E, F *52000 own ship etc.*	32000 C, D, E, F *62000 own ship etc.*
13000 H, I depths & currents *43000 Mariners' features*	23000 H,I *53000 Mariners' features*	33000 H,I *63000 Mariners' features*
14000 J,K,L obstructions, pipelines *44000 other vessels*	24000 J,K,L *54000 other vessels*	34000 J,K,L *64000 other vessels*
15000 M traffic, routes *45000 manufacturers' features*	25000 M *55000 manufacturers' features*	35000 M *65000 manufacturers' features*

A, B	CHART FURNITURE
11000	Information about the Chart Display
11010 11020	cursor [symbol SY(CURSRA01)] na (not assigned)
11030	scalebar, latitude scale [SY(SCALEB10),SY(SCALEB11)]
11040	north arrow [SY(NORTHAR1)]
11050	no data [colour NODTA, AP(NODATA03)], unsurveyed (UNSARE), incompletely surveyed area
11060	Non-HO data boundary LC(NONHODAT)



== 2?	
No Isolated Danger. Display Base category. DIsplay_Priority = 8, Viewing_Group=14050.	Object is an isolated above water danger, and is in own ship safe water and should be 'DISPLAYBASE' with no isolated danger symbol.
	Display Category DISPLAYBASE **Display Priority** 8 **Viewing Group** 14050
return message "isolated danger symbol is not required"	Return to the calling procedure with the message that Isolated Danger Symbol is not required.
SELECT= 'ISODGR01'	The object is an isolated underwater danger located within a depth area equal to or greater than the safety contour. The depth of the hazardous object is equal or shallower than the chosen Safety Contour. Thus, the object has to be presented by the 'Isolated Danger Symbol'. Select symbol name 'ISODGR01'
Display Base category.	Set SCAMIN (minimum scale) attribute to infinite

Figure 6: IHO S-52 Base display definition extracts

The picture emerges of the layers of performance standards, testing and underlying IHO standards working together at increasing levels of detail to specify how ECDIS should behave under testing and live conditions. There are areas of functionality within IHO standards which are not solely concerned with the display of chart/publication information but which complement other standards such as the IMO PS and IEC61174 in fleshing out how ECDIS behaves and therefore these form an important part of how type approval and the related test datasets are specified in the future and which will be considered as part of the IHO scope.

Thus, from a standards perspective there are three areas to consider in looking at the future of IHO S-100 within the context of ECDIS and type approval.

- How the enhanced capabilities of multiple S-100 product specifications can be seen to be within the scope of the ECDIS performance standard (IMO PS) as related to the concept of a chart and “ENC”
- How the IMO PS and testing standards approach the issue of referencing the use of (potentially) multiple product specifications in meeting the provisions of SOLAS (IMO PS and IEC 61174)
- How those product specifications are then supported by other IHO standards for testing purposes. (IHO Standards, S-100, S-101, S-64, S-63 + Other “arbitrary” S-100 product specifications) as tested by IHO S-64.

There is no reason why the current structure of the standards layout can not be reused as IHO S-100 does not seek to redesign any SOLAS provisions or the broad functionality within the ECDIS as defined by the IMO PS. The definition of S-100 product specifications in support of SOLAS enhance its potential presentation and use as part of the IMO processes.

The initial approach, therefore, in this document is to examine:

1. Broadly how ECDIS type approval could encompass multiple S-100 product specifications and the options for doing so within the current regime.
2. A look at the test content of IHO S-64 to assess whether corresponding tests are required in a new edition which replicate the test content in an S-101 context (and whether extensions for other S-100 product specifications are also required.
3. Identification of those elements of IHO S-52 which are not covered by the existing S-101 product specification (and the underlying S-100 portrayal mechanism)
4. The identification of "new" functionality which is defined by IHO S-100 and which may be relevant to the overall ECDIS functionality as defined by the IMO Performance Specification. These new elements will require support within a revised S-64 and associated test datasets.
5. The current gaps in the IHO standards baseline required in order to fully define the required tests (and, in part, the operation of the S-100 ECDIS in respect of the proposed dual-fuel mode). Although the primary output from this document is the setting out of revised (and new) test datasets to support the type approval of IHO S-100 enabled ECDIS a by-product is the identification of areas of functionality still required and those which may require redefinition (primarily from IHO S-52) in order to present a coherent view of ECDIS operation to IEC61174.

6 Current and Future Scope of ECDIS Type Approval

This section presents a concise picture of the ways in which type approval can approach the challenge of testing against S-100. S-100 was originally designed to mitigate several shortcomings in the existing standards base (i.e. IHO S-57, Appendix B1, ENC product specification and the associated standards concerned with ENC definition, transport and loading.). These were:

1. The frozen nature of the standard
2. The fixed nature of the standard's feature, attribution and portrayal mechanisms
3. The resultant hard-wired nature of the ECDIS system's user interfaces developed against the standard
4. An inability to represent complex attribution of feature data within the ENC.
5. Lack of alignment with overarching, existing global standards under the ISO 191xx framework

In solving these issues S-100 has become a richer and more complex standard and there are options in terms of how much of its scope forms the basis for type approval testing. Although this is still emerging within the IMO community and being driven by the IHO and its working groups some assumptions have been made in this document concerning that scope which area explained in this section.

Currently, ECDIS type approval is based on the testing of ECDIS Equipment Under Test (EUT) against a set of tests defined in IEC61174:2015 using IHO defined test datasets and standards where required. These standards tightly control the breadth of content permitted on the ECDIS and the formats in which it is prescribed.

Currently the underlying IHO standards wholly define "ENC" data, i.e. data which is sufficient for primary navigation on the ECDIS under SOLAS. Under the current regime ENC data is defined completely within the standards and its vocabulary is tightly defined as the object/attribute catalogue embedded within IHO S-57 Appendix 1 and 2. ECDIS itself is certainly not prohibited from loading and displaying non-ENC data as long as it is clearly delineated from the ENC data onscreen.

Note that this is for "non-HO" sourced data, potentially an important distinction.

5.4.2.1 Additional display functions

(See 6.8.7)

(S-52/2.3.1a) *Additional information from non-HO sources, may be displayed provided this does not degrade the display of ENC data. This additional information* shall *be distinguished from the ENC data.* (See IHO S-52, Annex A. Part I)

Display of information from non-HO sources may use presentation based on IHO S-52 or proprietary presentation. Display of information from non-HO sources shall be indicated with permanent indication "non-ENC data" (see 4.3.2 and 4.8) and the area of the non-ENC data shall be marked as defined in IHO S-52, Annex A, Part I, 10.1.7.

Figure 7: Display of additional data on ECDIS

S-100 changes the picture fairly fundamentally by defining any number of (potentially interacting) product specifications which (potentially) could be installed onto an ECDIS.

The core question to answer, therefore, is how type approval testing should be extended to S-100 product specifications other than S-101. The Dual-Fuel ECDIS concept already admits the possibility of

adding multiple product specifications to the ECDIS under the S-100 regime – the key question here is to what extent that extensibility feature should be tested under IEC61174.

There are a number of options for approaching this situation.

1. **Just S-101**. Add only S-101 (with S-100 as a normative reference) to the type approval regime as the definition for "ENC data" on the ECDIS. This would effectively replicate the current regime replacing the existing S-57 content with S-101 content as defined by the feature catalogue. This also delivers ENC as a "bare minimum" for safe navigation and obligates the ECDIS manufacturer to implement only S-101 support.
2. **S-101 + specified other products**. Add only S-100 and a selection of S-100 product specifications along with the interoperability specification, S-98, to ECDIS type approval testing. The requirement to load arbitrary product specifications under the S-100 format is not required to pass testing.
3. **All S-100 data**. Add S-100 to the regime along with S-101 as the minimum standard for ENC. Also add the ability to load/view and interrogate multiple layers in addition to S-101. Also add the interoperability mechanism as a way of intelligently managing multiple datasets relating to ECDIS planning and monitoring. Navigational datasets are drawn from a prescribed list (reflected in the testing standard). The ECDIS is also able to load other S-100 data layers and interrogate their content even though they may be not necessary as a minimum for primary navigation. Even in this option however the quantity, description and type of S-100 product specification capable of import is likely to be restricted by supported encodings and suitability of data for use in voyage planning/monitoring. The exact definition of which families of products supported should be the subject of careful debate in the working groups to define them completely.

Looking at the structure of the standards in development the following product specifications are frontline in the ECDIS in respect of S-100 and should be considered for potentially extending the baseline for navigation.

- S-101 Electronic Navigational Chart (ENC)
- S-102 Bathymetric Surface
- S-104 Water Level Information for Surface Navigation
- S-111 Surface currents
- S-129 Under Keel Clearance Management
- S-98 – Part A/B/C/D – Describes each interoperability level from Level 1 to 4 and will provide the application schema that is specific to each level.

Additionally the following product specifications may be contenders for initial inclusion in S-100 ECDIS:

- S-122 Marine Protected Areas
- S-123 Radio Services
- S-124 Navigational Warnings

Option (2) above restricts the tested functionality of S-100 ECDIS to certain navigation-specific product specifications (such as the list given above) and would require future re-definition should other layers (e.g. MSI information or navigational publications) become widely available through the IHO (or other) communities.

The entire basis of S-100 in respect of ECDIS is to introduce the "catalogue" concept which describes dynamic content and functionality in specification form. In order to avoid "hard-wiring" functionality into ECDIS (which is then expensive and difficult to update) S-100 defines a series of catalogues which allow functionality inside the ECDIS to be updated dynamically.

The argument, in favour of testing extended functionality, as per option (3) to the ECDIS is to ensure that should layers which enhance voyage planning and monitoring (and potentially are already required under SOLAS) become available through IHO member states then the mariner is benefited from their availability within an integrated navigation environment without modification to existing equipment or functionality. This is supported by the fact that product specifications like IHO S-124 and those relating to navigational publications are already part of the carriage requirement at a SOLAS level and their digitisation and rendering as S-100 product specifications would (if ECDIS was suitably implemented) enable their import into an integrated bridge system. This also allows member states to determine what the minimum data level required for safe navigation in their waters is and to issue revised/enhanced data depending on their ability to produce and issue it. The other core issue is that problems/issues discovered post-implementation can be fixed by the update of catalogues delivered to the ECDIS rather than by expensive maintenance and upgrade cycles of extant equipment on vessels.

There are certainly debates to be had over the complexity of the systems and the testing regime (as well as the operation of a dual-fuel ECDIS as stated earlier). This document makes no recommendation in this regard – the mechanisms for updating IHO documents are in place to reflect whatever eventual regime is arrived at in conjunction with the appropriate industry bodies and representatives.

The issue at hand is establishing what an effective testing structure looks like and how to support it with comprehensive test data. The assumption within this document is that the testing and supporting data is similar in structure to the existing structure (effectively a "black box" style of testing where the EUT is tested with prescribed datasets and specified functionality only) – it may be possible to enhance testing to gain more assurance that data/functions outside the boundaries and scope of test datasets are risk-free but advice should be taken from the broader ECDIS and IEC community on this topic[2].

The approach taken in this document is that option (3) is taken by the international community – this allows a complete picture of required test datasets to be presented. Should options (1) or (2) eventually be adopted then test dataset definition can easily be adjusted accordingly.

[2] It should be noted too that the current testing scheme does not test every eventuality of data, does not test every combination of feature and attribute value, nor the entirety of ECDIS functionality but has been evolved over the years by noting where weaknesses lie. So the concept of partial testing of data extent and functionality is not a new one.

7 ECDIS functionality coverage by IHO standards

Currently the IHO suite of standards cover the standardisation of a range of IMO PS functionality and, as stated in the introductory section of this document, define that functionality in some detail. Most of the functionality in the current IHO standards set is related to

1. Data definition, encoding, dictionary (feature and attribute) detail
2. The transport of data via export, encoding, optional encryption/digital signatures and its introduction to an ECDIS system (both initially and for update)
3. Its display and interrogation on screen on the ECDIS following the IHO-established rules for portrayal.

IHO S-57 covers in detail the definition, formatting, encoding and carriage of ENC data to the ECDIS and IHO S-63 covers a range of functions for media packaging, service elements and transport to the ECDIS for installation. Additionally standards exist in IHO for dealing with raster elements of chart portrayal.

7.1 IHO S-52 and ECDIS

There is a range of other ECDIS specific functionality covered by the IHO standards, most notably IHO S-52 which is not directly "display of ENC" in nature.

Some examples drawn from the current IHO S-52 are given in the following table:

<table>
<tr><th>S-52 content</th><th>Comment (if applicable).</th></tr>
<tr><td>1. Installation of updates, manual updates</td><td>IHO S-52 contains an entire section devoted to the operation of the ECDIS in respect of updating, including manual updates, their storage, application, verification of automated updates and other functions.</td></tr>
<tr><td>2. Validation of data content and revision status</td><td>IHO S-63 contains ECDIS functionality for ECDIS status reports to report revision information for ECDIS holdings for the entire service. S-52 contains provisions on rejection of data and updates should it be required.</td></tr>
<tr><td>3. Minimum data content for Pick Reports</td><td>IHO S-52 was updated to reflect best practice in data interrogation via the ECDIS "pick report". This functionality is likely to require update for the new generation of ENC and associated data products by making Pick Report specifications machine readable.</td></tr>
<tr><td>4. Display of Units, particularly for position</td><td>Not just in pick reports but mappings of DUNI/HUNI units and how they are relayed to the end user (also in S-64)
<table>
<tr><th>No</th><th>Cursor Pick Rules</th></tr>
<tr><td>1</td><td>Full S-57 Object and Attribute names must be displayed</td></tr>
<tr><td>2</td><td>Enumerate value names must be displayed</td></tr>
<tr><td>3</td><td>There must not be any padding of attribute values, e.g. a height of 10 metres must not be padded to 10.000000 metres as this could potentially confuse or mislead the Mariner.</td></tr>
<tr><td>4</td><td>Units of measure must be included after all attribute values which are weights or measures.</td></tr>
</table></td></tr>
<tr><td>5. Display of IEC Mariner's Navigational Objects.</td><td>Contents of S-52 Part II contains all Mariner's Objects, for which IEC and IEC62288 are the authority. If these are to be defined within the S-101 portrtayal then the content of S-52 related to them should be reproduced as well. IMO is the current authority on these symbols.</td></tr>
</table>

<table>
<tr><td>6. Hover-Over functions</td><td>

10.8.5 Hover-over Function

OEMs may wish to include hover-over functions for Mariners to access important charted feature details without having to select a pick report. If this function is implemented within an ECDIS the Mariner must be able to configure the system function on and off.

The hover-over function must only be used on the following feature objects and for the symbols SY(INFORM01) and SY(CHDATD01):

<table>
<tr><th>Feature</th><th>S-57 Acronym</th></tr>
<tr><td>Lights</td><td>LIGHTS</td></tr>
<tr><td>Beacon, cardinal</td><td>BCNCAR</td></tr>
<tr><td>Beacon, isolated danger</td><td>BCNISD</td></tr>
<tr><td>Beacon, lateral</td><td>BCNLAT</td></tr>
<tr><td>Beacon, safe water</td><td>BCNSAW</td></tr>
<tr><td>Beacon, special purpose/general</td><td>BCNSPP</td></tr>
<tr><td>Buoy, cardinal</td><td>BOYCAR</td></tr>
<tr><td>Buoy, installation</td><td>BOYINB</td></tr>
<tr><td>Buoy, isolated danger</td><td>BOYISD</td></tr>
<tr><td>Buoy, lateral</td><td>BOYLAT</td></tr>
<tr><td>Buoy, safe water</td><td>BOYSAW</td></tr>
<tr><td>Buoy, special purpose/general</td><td>BOYSPP</td></tr>
<tr><td>Landmarks</td><td>LNDMRK</td></tr>
</table>

</td></tr>
<tr><td>7. Guidelines on Updating the Electronic Chart (not tested explicitly in S-64 but some elements relevant). In particular S-64 tests re-issues and cell cancellations</td><td>Re-Issues and cell cancellations are dealt with in the ECDIS functionality in S-52. Needs to be reproduced within S-101.</td></tr>
<tr><td>8. Design considerations – general statements, screen furniture, layout etc… Not tested for explicitly but certainly implied by other IEC/IMO standards and not currently within existing S-100 equivalent standards.</td><td>There are a considerable number of generic statements about ECDIS display (not specific to ENC itself) and design considerations in S-52. These could be located in a portrayal/ECDIS annex of S-101 or within a separate IHO document relating to ECDIS manufacture in the S-100 sense as they should probably be expanded to cover multiple S-100 products and the issues that may entail.</td></tr>
<tr><td>9. Look-Ahead (70cm rule), delays in preparing data for display</td><td>

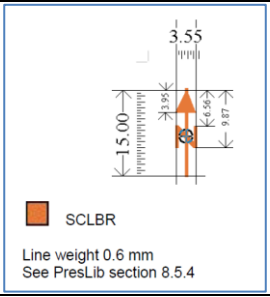
2.2.3 Route Planning / Route Monitoring: Look-ahead

The IMO Performance Standards for ECDIS distinguish between the route planning and route monitoring modes of using ECDIS. It is expected that in route planning the display will be viewed, without urgency, from the normal screen viewing distance of about 70 cm, and so the display can contain considerable detail without causing confusion.

</td></tr>
<tr><td>10. Clarification that own ships display and selected planned route remain in Display Base.</td><td>

Ergonomic specialists point out that, to avoid ambiguity, important features, such as those in the IMO PS Display Base, should be redundantly coded. (Two examples are the own-ship safety contour, which is a thick line and has a sharp change in the colour of the depth shade, and the planned route, which is red and is the only heavy dotted line on the display). This serves to improve the visibility of important features on the route monitoring display, and it also helps to distinguish features in bright sun or at night.

</td></tr>
<tr><td>11. Manufacturer’s information on the display including unofficial/non-HO data,</td><td></td></tr>
</table>

12. Radar image display	
13. Display of features related to absolute and periodic date ranges.	An area which received considerable revision in the last edition of S-52 – considerable thought was given to how date ranges can be interpreted by the system, user feedback, warnings etc.
14. The wearing of black cotton watch-coat to prevent screen reflections(!)	S-52 2.2.6 *The face of the display screen acts as a mirror to white shirts, sometimes seriously obscuring the chart display. Wearing a black cotton (not synthetic) watch-coat will greatly improve viewing on a sunlit bridge.*
15. Legend	
16. North Arrow display	
17. Scale range indicators	
18. Detail on priority layers	
19. No Data available (S-52 10.1.8)	
20. AIS symbols (IMO PS Appendix 3)	
21. Chart 1	Currently Chart 1 is included in S-52 and referenced by IEC61174. This would need full specification and supporting test datasets. Also consideration should be given to whether Chart 1 should include symbology from the minimum core set of other S-100 product specifications directly relevant to ECDIS type approval.

These elements (mainly detailed in S-52 section 2 and 3) are not primarily concerned with the display of Chart information on screen and may be therefore be currently unspecified by the existing S-100/S-101 standards.

Some enhancements to the portrayal sections of IHO S-101 would be necessary in order to update the guidance given in these areas of S-52 and ensure that the IHO standards maintain the current standards base to support IEC61174. A current proposal is to locate some of these elements within accompanying IHO ECDIS standards such as S-98.

7.2 Other elements of ECDIS functionality

It should also be noted that IHO S-64 itself specifies some areas of ECDIS functionality. For example, confirmation messages to users have their text currently specified in IHO S-64, e.g.

Results
The update process shall install the updates up to update no. 3 and reject the installation of updates no. 4 and 5 with a permanent indication, "Chart information not up-to-date" when this chart is in use (either displayed or used as largest scale available for the chart related alerts and indications) until the not up-to-date situation is removed by successful application of a re-issue, a new edition or complete sequence of updates.

This is taken from IHO S-64 test 2.2.3. The text of the message given to the user is specified in S-64 and although the references in the test refer to IHO S-52 and IEC61174 (which in turn references the IMO PS) the actual text itself is only specified in IHO S-64.

For this reason it makes sense to highlight and preserve such textual messages and ensure the user experience is changed as little as possible as migration of data from S-57 to S-100 is achieved. Whether these messages should be specified within other ECDIS standards or left within the S-64 revision remains to be defined.

7.3 ECDIS and ENC transition from S-57 to S-101

The process envisaged by the current standards regime to migrate from S-57 to S-100 based navigational products is to support a period of dual-fuel operation both in standards and data.

Although the exact timescales and allowed compatibility periods are to be proposed and agreed (i.e. how long to support S-57 for, when the allowable period of use of S-101 for primary navigation will be) the basic structure of the standards is for IEC61174 to be adapted to refer to both the S-57/S-52 regime as well as the S-100 regime and to test, effectively, both until such time as S-57 is no longer part of the carriage requirement. Functionality, therefore which is generic in nature will need to be drawn out of the current standards (primarily S-52) and a place found for it in the new S-100 scheme.

This dual-fuel system for transition to S-100 requires no modifications to the IMO PS other than ensuring that the correct (and probably just S-100) standards are noted as references and, following previous cooperation, a joint update of IEC61174 and the publishing of the relevant IHO standards would then introduce the option of testing the S-100 compatibility within the type approval regime.

The full extent of the testing would then be implemented, as today, within S-64 with references in the S-100 standards and product specifications.

7.4 Existing IHO test standards supporting type approval.

IHO S-64 is the prime test dataset used in the type approval process (IHO S-58 is another important standard, and its relationship to live data production should not be ignored) and the content of IHO S-64 is worth considering in some detail

7.4.1 Revising IHO S-64

S-64 datasets are grouped into the following categories (taken from the current test instruction manual):

Current S-64 Structure.

1. Chart Loading and Updating (Section 2) – covers encrypted and non-encrypted data
2. Chart Display (Section 3)
3. Functions associated with Chart display (Section 4)
4. Detection and Notification of: (Section 5,6 and 7)
    a. Navigational Hazards
    b. Areas for which Special conditions exist
    c. The safety contour

The structure maps to the broad areas of functionality under the IMO PS.

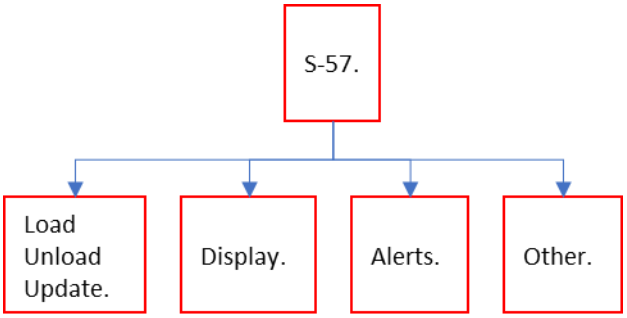
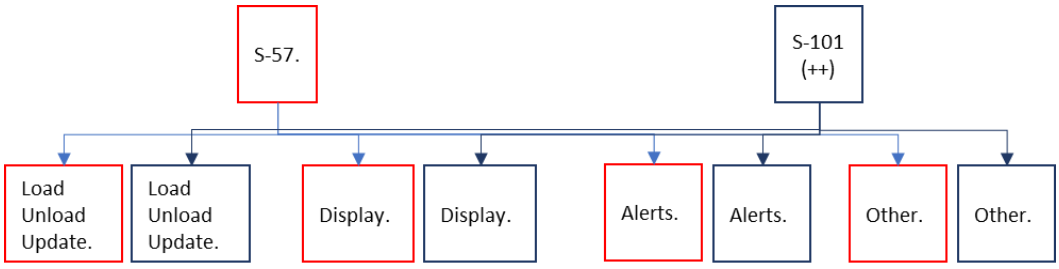


Figure 8: S-64 S-57 based structure

In building an S-100 enabled edition of S-64 therefore the chart elements can be restated as "navigational data" (in whatever set of IHO S-100 product specifications are defined as forming the IHO baseline for navigation).

It would be advisable to maintain the structure and implementing S-100 dataset, for example, simply expanding the structures concerned with ENC data and ensuring new S-100 features are accounted for as system functions crucial to effective operation, i.e. as per the following diagram:



This would place the tests for S-100 data alongside those of current S-57 data. Additional tests for "co-existence" of S-57 data with S-100 data on the ECDIS (in relation to dual-fuel operations) can then be defined for each section of functionality.

Revised S-64 structure (Proposed)

1. Data Loading and Updating (all product specifications, including existing S-57 tests))
    a. Loading/Unloading of S-100 catalogues (Feature/Portrayal, Interoperability, Alarm/indication if applicable + others as defined in S-100)
    b. Loading/Unloading of data, S-101 and other product specifications.
    c. Loading of arbitrary product specifications into the system
2. Data Display and interoperability.
    a. S-101
    b. Other predefined S-100 product specifications (i.e. S-102, S-111)
    c. Arbitrary S-100 product specifications
    d. Testing of interoperability and flexible interrogation (e.g. pick report formatting)
    e. Any co-existence tests required for side-by-side S-57/S-101 display.
3. Associated functions (existing chart display marginalia + any others required by e.g. interoperability) – expansion of Section 4.
4. Detection and Notification of:
    a. Navigational Hazards
    b. Areas for which Special conditions exist
    c. Rendering of safety contour
    d. Interoperability tests between stated S-100 product specifications using pre-defined alert/indication catalogues including safety contour rendering
    e. Ability of new S-100 product specifications to expose features which make up hazards, areas and safety contour to operate correctly.[3]
    f. Any co-existence tests required for side-by-side S-57/S-101 operation

S-64 will certainly require considerable expansion in some areas in order to deal with the new functionality defined by S-100 and its component product specifications but the methodology should be, overall, to maintain the mapping to the IMO PS and the existing provisions within IEC61174 and enhance them with new data. The new version of S-64 should be written in such a way that all marginalia and extra functionality is still tested even when S-57 is finally retired, i.e. the structure is such that the S-57 sections and tests are independent and can be removed in a future revision when S-57 is retired.

7.4.2 IHO S-64 structure.

It is worth considering, at this stage, how S-64 could be restructured as a document to make the tests more accessible and easy to manage in terms of its revision process. In terms of specifying tests this document lists them out in sequential order but it may be easier to align tests in tabular fashion, e.g.

Table 1: Example tabular layout of S-64 tests.

	Product Specification					
	S-57	S-101	S-102	S-111	S-124	New

[3] The exact protocol for the S-100 Dual-Fuel ECDIS to follow in respect of alerts/indications are currently under discussion within the relevant working groups.

Existing S-64 Test cases Data Loading and Update Data Display Alarm/Indication behaviour Marginalia						
S-100 Specific Content New content (Information Types) Text Orientation Exchange Set Catalogues Supplementary Files Feature Catalogue updates Portrayal Catalogue Updates Interoperability Testing Data interrogation Safety contour definition alarm/indication conditions Hazard Detection Route Planning.						

Testing can then be achieved by checking each product specification against tests written for them. The final column "New" is for the product specification defined within the test datasets for testing the introduction of generic data to the system.

7.4.3 Current IHO S-64 content breakdown

In terms of an S-100 enabled type approval process we now look at each of the S-64 test groups and their scope in detail in the following table.

Alongside each of the existing S-64 tests this table contains notes on how potential enhancements and modifications which might be necessary in an additional S-100-enabled test in an updated S-64. These revised tests should be added into a structured revision of S-64 and supported with test datasets.

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
2.1.1	Loading of initial datasets and indication of own ship stationary position	Still Required - would also need initial data for other PS when included. [4]
2.1.2	Loading of initial datasets and confirmation of presence in chart library	This test loads all data – this should be replaced with a test containing a broader dataset with all initial relevant PS in it.
2.1.3	Loading additional cell and confirmation of its addition to the chart library	Test of one additional cell. This should also do addition of other PS cells and confirm their addition to the system.
2.1.4	Removing a cell and confirmation of its removal from the chart library	Still Required – also needs removal of some/all other PS across all types of core data.
2.1.5	Loading corrupt data	Still Required – also corrupted other PS too
2.2.1	Loading corrupt updates	Still Required – also corrupted updates to other PS
2.2.2	Loading correct sequential update files	Still Required – also sequential other PS (other schemes? Data which isn't updated mixed with data that is updated.)
2.2.3	Loading updates files in an invalid sequence	ENC plus other PS. Is there a need to test PS which don't support update?
2.2.4	Loading update file of a newer edition than base cell installed.	Still Required – also other PS. Test where update is from another edition of the dataset.
2.2.5	Loading update file of an older edition than base cell installed	Still Required. Also other PS.
2.2.6	Loading a reissue of a dataset	For datasets which support them (S-101). Need to test any equivalent structures in other PS if applicable.
2.2.7	Loading cancellation update	As per reissues – S-101. If other product specifications support reissues then it should be tested too (is this generic S-100 functionality or just S-101?)
2.2.8	Manual rejection of an automatic update	Only requires an update to be rejected manually. This should be verified against other product specifications too.
2.3	Manual updates	Manual updates can apply to any product specification and this should be made clear, (i.e. which data is updated in a multi-product specification environment (ref: S-52 guidance on updating)).

[4] All Section 2 tests will need to replicate S-57 loading as well. The co-existence testing for dual-fuel ECDIS here will need to be composed of combined datasets (depending on support by S-100 Part 15 for datasets including legacy S-57).

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
		So, updating over a combined data picture with other PS content present too. e.g. Manual updating of S-102 would be good – marking wrecks/hazards and exposing to Alarm/Indication behaviour as well as checking interoperability behaviour. These tests also include date-dependent features (CTNARE) which should be factored into test updates.
2.4	SENC delivery	TBC but can support if permitted. Will SENC providers support other product specifications?
2.5	Encrypted test datasets….	All encrypted test datasets should be remade in accordance with the new S-100 part. The encryption model has not fundamentally changed and although it needs to be expanded to include bundling of multiple product specifications the structures should carry over largely. Most tests will need to test bundles of different product specifications and verification of encryption/authentication. Since the S-100 part is These tests also include the Update Status report (currently in IHO S-63 which will need revision). These tests also expand on the basic tests of revisions, updates and cancelled cells and would need enhancing of those functions to cover multiple product specifications. Update status report is covered here too which requires enhancement to cover multiple product specifications (it already deals with multiple providers) to mitigate user confusion over legacy (and yet legal) carriage of S-57.
3.1.1	Display Base	Exhaustive datasets required. Need revising to add/mod any changes to features (and names/acronyms). Also requires SC/SD and symbolised boundaries. Check equivalence of all these and any others in other categories between S-101 PC and S-57. This also requires regression testing with S-57 and tests for seamless display when S-57/S-101 co-exist. These tests could host the functionality of S-57/S-101
3.1.2	Display Standard	See previous comments. Should be an extension of the coverage of the previous test set.
3.1.2	Text Groups	Does this need revision? Needs reviewing with S-101 portrayal. This should also exercise S-100 ability to tailor such displays and be interoperable with other product specifications.

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
3.1.3	"Other"	Exhaustive – can be extended to exhaustive display of other PS too. Suggest grouping into each PS and then switch on/off each category. Interoperability can be demonstrated in these tests too.
3.1.4	Viewing Groups	Standardised naming of viewing groups. Needs to be maintained and to check groups retain standard naming. E.g. Drying Line, Buoys, Beacons, Aids to Navigation etc… "Ships Routeing Systems and ferry routes". These can be done by defining maps based on existing test datasets. Tests of update (and introduction of new ones via product specification). If these are to be part of the PC configurable set then their update and management should be tested (as well as rollback)
3.1.5	Viewing Groups (Other)	Magnetic Variation, Seabed, Tidal. Need to be expanded and defined for each product specification in the core set. Should be exhaustive but form a distinction between IMO defined and product specification defined (may require standard messages in S-64 to be defined).
3.1.6	Text groupings	Need to make sure Important Text, Other Text + others are specified. Partly standardised as subdivisions, e.g. "Names" under "Other Text". See comments in previous tests as to whether configuration by user is allowed and should be tested too.
3.2.1 a) + 3.2.2 (a-d)	Unknown object class – point, line and area. Also display of SY(QUESMRK1)	Extend to other Product Specifications. Is this also used for features not in feature catalogue (can also be part of updated FC tests) – could also test what happens when a FC is updated and features deleted but which are still in SENC.
3.2.1 b)	Pick Report specification for unknown objects	Contains details of features identified. Can translate into S-100– needs other PS test cases too. Forms part of the "unexpected data" behaviour on the ECDIS. This behaviour should be the same regardless of product specification and merely specifies how the ECDIS responds to data content it can not reconcile from any catalogue on the system.
3.3.1 a)	Exhaustive tests for paper chart symbols	Still Required – update for new Feature Catalogue. Would co-existence tests (side by side S-57 and S-101) be necessary.
3.3.2 (a-b)	Symbolised and Plain Boundaries	Still Required – update for new Feature Catalogue. See previous test re: side by side tests too.

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
3.3.3	Date dependent objects	Need to ensure equivalents exist and specified. Other product specification features needed too where S-98 specifies they can be substituted. This covers set dates and date ranges. Functionality specified in S-101?
3.3.3 d)	Route checking of date dependent objects	Required. Also, route checking with other PS data? Requires alarm/indication machine readable solution too. Includes S-52 specified messages about date dependent object config (permanent message)
3.3.4	Default Safety Contour	Still Required. Also with other PSs which may contribute to safety contour as per alarm/indication catalogue (and interoperability). This should test configurability and introduction of new PS to the system.
3.3.4 c)	Safety contour and isolated dangers	As per safety contour.
3.3.4 d)	Depth shades	Still Required.
3.3.5	Safety Depth	Still Required
3.3.6	Shallow pattern	Still Required.
3.3.7	Contour labels (if provided – mariner's option)	Still Required.
3.3.8	Palettes	Day/Dusk/Night still exist and to be tested (also extend Supplementary file display to these palettes too (in line with S-52))
3.3.9 c)	INFORM data.	Needs translating into S-100 terms – and including for other PS too? Should PS specify what features/attributes contribute to this information? Current tests are hardwired to INFORM.
3.3.10	Disabling SCAMIN	Still Required – also requires testing of other SCAMIN facilities (per feature assignment in S-101?)
3.3.11	Full Light Lines mariner selection.	Still Required – does this option still exist?
3.3.12	Display of text in national language.	Not required but should be replaced by multilingual option with complex attributes – also >2 languages could be tested to exercise complex attribution as well as other product specifications that use feature name for naming.
3.4 a)	Non-official data.	Has non-official designation in S-57 has been carried forwards? This should also tie in a (required) mechanism for identifying official producers (from registry/S-62)
3.5	Areas of no data	Update according to S-101. This is areas of not enough data for navigation. What happens if supplementary

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
		areas but not e.g. S-101 cover an area? Different scenarios to be defined and ECDIS guidance given. Proposal would be that S-101 forms the foundation so supplementary S-100 PSs can only be used (s-98 or otherwise) when S-101 coverage underlies it.
3.6.1	Different priority and geometry?	Not sure – needs looking at and parts specific to S-57 identified. I believe the master/slave relationships will need redefining but the test needs inspection to see if it is carried through to S-101.
3.6.2	Same priority, different geometry	I believe this is still required although the S-100 mechanism may be slightly different.
3.6.3	Line Suppression	Required (if mechanism is the same) – as per previous two tests.
3.6.4	Manual Updates	Required
3.6.5 a-c)	Text display	Required (need to check mechanism for masked features is equivalent?)
3.6.6	Area borders	Required – check individual feature types to be used – can provide a spread between different PS. Other PS as well if supported.
3.6.7	Display of unknown symbols	Required. Other PS as well (and new PS by update)
3.6.8.1	Unofficial data boundary	Check in portrayal. Needs other PS too but maximal boundary is underlying S-101. The definition of “official” and its relationship with S-62 should be clarified.
3.6.8.2	Scale boundary display	check in portrayal what is required as there may be a requirement to display that other PSs (at a “larger scale” exist and are being used by IC) – larger scale data available boundary
3.6.8.3	Overscale pattern	Required but needs new loading strategy to be factored into S-100 datasets, and integration with other PS. This also needs co-existence tests and some explanation for what is required. This is a test of the new symbology mechanism.
3.6.9	Conditional symbology	Needs to cover Lua portrayal features? This should be all features where portrayal is not a straightforward lookup and should be exhaustive. It should also cover features in other PSs and features
3.6.10 a)	Centred Symbols (areas)	Check portrayal specification. These should be done exhaustively – focused on S-101 but could include other PS too.?
3.6.10 b)	Centred Symbols (Offset)	Similarly
3.6.10 c)	Centred Symbols which conflict with own ships symbol	Needs to be expanded to other PS too (if they form part of “ENC” feature set)
3.6.10 d)	Centred symbols when area is partially off screen	Expanded to other PS

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
3.6.10 e)	Display of centred symbols specifically complex areas	ok – S-122 as well maybe as an example of where complex areas are rendered. This can be tied in with interoperability catalogue too.
3.7.1 a)	Display of overscale indication	May need revision for the new loading strategy and for co-existence with S-57 data (side by side tests) – should also cover S-57/S_101 at different scales.
3.7.2	Indication of larger scale data being available.	Will probably need revision to test the new loading strategy. Should be thought about in terms of interoperability catalogue too (i.e. Other data layers being available at a larger scale as well as the same product spec available at larger scale (the original purpose may not actually be necessary with the new loading strategy))
3.7.3	Boundaries between compilation scales	Required for S-57. These are data coverage features in S-101 so not necessarily boundaries. Also needs to cover borders where interoperability has substituted data from a larger scale S-10x product? The loading strategy needs to take these elements into account. Co-existence with S-57/S-101 to be tested as well.
3.7.4 a)	Display of data from a smaller scale navigational purpose to cover display	Redefine (navigational purpose doesn't exist in S-101 for display on ECDIS) – can be restated as smaller display scale data where available. Needs to be tested with co-existence of S-57/S-101.
3.7.4 b)	Display of overlapping data	Probably not needed as overlap rule has gone (except for S-57 data and for co-existence tests) – however an equivalent for coverage areas should also be defined for S-100 data. This is a test of a permanent indication so could be replaced with a case where display scale is equal in same area (and any other prohibited cases in dataset loading strategy?)
3.7.5	Display of a graphical index of cell boundaries	Should be remade with different product specifications included as well. S-52 requirement needs to be reproduced in PS
3.7.6	Change of display scale by chart scale values and by increments of displayed range values in nautical miles	Still required – should be considered in the specification of the new loading strategy and interoperability mechanisms
3.7.7	Impact of SCAMIN values on display of charted objects	SCAMIN mechanisms have changed subtly. Needs more exhaustive testing (and SCAMAX?)
3.8.1	Display of Mariner's Features	Needs specification and test support in S-101 (S-100 portrayal) Fill styles from S-52 2.3.1b) need to be

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
		recreated and translated to S-101PC cases (should be identical)
3.8.2	Depth Information not affected by tidal height information	Needs update. Do we now believe this would be ok for mariners to do under interoperability spec? Will depend on situation re: minimum for safe navigation and whether producer specifies tidal data as a minimum?
3.9.1	Display of charts up to 85 degrees	Still required. This should also deal with cases where other datasets are included – i.e. polar versions of e.g. MSI or MPA data. This would test the ability of the interoperability catalogue to integrate at all levels.
3.9.2	Display of charts above 85 degrees	as per previous item. Polar datasets are vital for correct display and the current test datasets should be enhanced to adequately deal with them in a multiple product specification scenario
4.1 a)	Display of North Arrow.	Still Required – PC needs to include symbology.
4.1 b)	True motion operation	Still Required – PC needs to include symbology.
4.1 c)	Manual adjustment of chart display area and own ship position	Still required – work with other product specifications too?
4.1 d and e	No ENC data available.	Uses M_COVR, CATCOV=2, not required. “No ENC data Available” – not sure still do this! M_COVR, CATCOV=2 doesn’t exist in S-101 – but, we should aim for only either S-57 or S-101 to be available in any one location so potentially this test could be recast as a test of coherent, uniform coverage. This test makes the distinction between CATCOV=2 and no actual ENC extents.
4.1f	Display in Non-North up orientation	Still required – also required is ECDIS guidance in S-101 portrayal.
4.2	Display of scale bar at appropriate scales	Still Required – PC needs to include symbology.
4.3	Display of latitude bar at appropriate scales.	Still Required – PC needs to include symbology.
4.4	Pick Reports	Still Required in test datasets and needs to extend to multiple product specifications and updates via interrogation catalogue. Contains some very specific points, enumerate value names, feature acronyms, attribute padding, SORDAT etc… would need some recrafting and adding in of other PS as well as complex attribution etc... The portrayal mechanisms have yet to be completely defined but should expose labels, layouts, types etc for each product spec to allow this content to be auto-generated from the data when imported.
4.4	Pick report descriptions and sorting	Similarly.
4.4	User defined cursor pick parameters, if any	Similarly.

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
4.4d	Hover-over function for object information	Required. This should be part of the pick report catalogue specification. Potentially contains interoperability spec rules too?
4.4e	Select chart objects with unknown attribute for cursor pick report.	Are these still equivalent in the new PS and new DCEG?
4.4f	Display of tidal stream panels	have these been deleted? If so, then preserve for co-existence cases?....
4.4g	Display of Text Description.	AUX files are different but in theory these are ok.
4.4h	Display of Picture Representation	Also included in S-101. Includes display of correct palette.
4.5a	Display of radar overlays with SENC information	Required although the SENC features selected for display should be carefully considered.
4.6	Distance calculations	Required (shouldn't change) unless revision requested by IEC or others. Needs the positions to be updated if datasets change. Should these be extended to cover polar cases?
4.7.1	Display of Symbols in size shown in IHO Presentation Library	is there still an IHO Presentation Library? This is the combined portrayal catalogues on the system. Is this extracted from portrayal catalogue? Still Required (non-zooming requirement)
4.7.2	display of Check Symbol (pixels and mm)	Check symbol still in existence and scaling allows test to be performed – this presupposes the existence of Chart 1 (should Chart 1 be a combination of all symbols exposed by each product specification?)
4.7.4	Display of text within the chart display and pick report	Required.
4.8	Display units and chart legend	Required – need to ensure this is provided in portrayal catalogue
4.9.1	Display of Presentation Library edition number	Required but needs expanding to portrayal catalogue metadata and portrayal catalogues for other product specifications. (Also other catalogues like alarm/indications and interoperability?)
4.9.2 a)	ECDIS Chart 1	Required. Needs to deal with other PS and their updates.. The core set of navigation product specs should have a Chart 1 – question of whether every PC should have a Chart 1 extracted?
4.9.2 b)	Interrogation of Chart 1	Needs to have PS descriptions (or feature catalogue descriptions) added as well as feature names.
5.1 b)	Detection and Notification of Navigational Hazards	Required. As other PS are able to influence this behaviour then more comprehensive tests will be required to exercise, update etc. Needs to take S-98 into consideration.

Sect.	S-64 Test Description.	Comment (approach from S-101/S-100 and other PS perspective)
5.2	Use of Largest scale available for detection of Navigational Hazards	Similarly. Functionality is required and must extend to multiple PS. More tests to support a multi-PS environment. Also has to be interoperable with S-57 existing data.
5.3	Detection of hazards in monitoring mode	Similarly
5.4	Use of largest scale available – monitoring mode	Similarly
6.1	Areas for which special conditions exist	Similarly – requires a mapping of the S-52 table for which conditions exist (and an assessment of the DCEG to establish if any others have been created in document for S-101 to define).
6.2	Largest Scale available for areas for which special conditions exist.	Similarly
6.3	Monitoring Mode _ areas for which special conditions exist	Similarly – also need to establish product specifications where they affect these conditions. Area for development. Are the IMO categories fixed? If so then each PS could expose features for use in alarm/indications, areas of special conditions and safety contour calculation (via LUA API)
6.4	Areas for which special conditions exist – largest scale data available.	Other PS can demonstrate this.
7.1	Detection of safety contour.	Required. Similar structure and issues as per 6.3. Needs to factor in other product specifications and interoperability as well as co-existence tests with S-57.
7.2	Detection of safety contour – use of largest scale available.	Required. Similar issues to the alarm/indication functionality already stated.
7.3 and 7.4	Detection of safety contour – monitoring mode (+largest scale available)	Required. As before. Must be exhaustive.

7.4.4 Summary – changes required in existing IHO S-64 test datasets:

1. The broad structure of IHO S-64 can be preserved.
2. Many tests require expansion to deal with the situation when multiple product specifications are resident on the ECDIS (e.g. data loading and update) or where functionality needs to be updated in the case of multiple product specifications (e.g Chart 1)
3. Some tests (although a small number) aren't needed for the S-101 case because S-101 updates how ENC "works" (e.g. M_COVR, overlaps, usage bands) or where certain features have been deleted (e.g. TS_PAD, CATCOV=2)
4. Many tests need to confirm that the functionality they test is still being specified "somewhere" in the IHO ecosystem. The main issue is that S-101 portrayal is ENC chart drawing only and much of the marginalia and extra functionality may not necessarily be defined in the S-100 standards

yet. Good examples of this are ECDIS chart 1, mariner's objects and permanent textual indications

5. Alarm/indication functionality (and safety contour detection) are another case in point where it is difficult specify in total the behaviour expected of the ECDIS and ECDIS-intended product specifications may have to provide specific deliverables (alarm/indication catalogues) which provide the ECDIS with the information to self-configure (and report back to users) how this behaviour is being implemented.

8 New Areas of functionality introduced by IHO S-100

In consideration of test datasets to support the ECDIS type approval process it is necessary to consider how IHO S-100 introduces potential new functionality by virtue of its new features and structure. S-100 was originally designed to mitigate several shortcomings in the existing standards base (i.e. IHO S-57, Appendix B1, ENC product specification and the associated standards concerned with ENC definition, transport and loading.).

These shortcomings were:

1. The frozen nature of the standard
2. The fixed nature of the standard's feature, attribution and portrayal mechanisms
3. The resultant hard-wired nature of the ECDIS system's user interfaces developed against the standard
4. An inability to represent complex attribution of feature data within the ENC.
5. Lack of alignment with overarching, existing global standards under the ISO 191xx framework

To this end IHO S-100 introduced several new features which, expanded in the main body of the standard and the drafted S-101 product specification mitigate these risks. These were

1. A more highly developed system for the development of "product specifications" which define data content and portrayal for a variety of different domains. This capacity, always theoretically possible with IHO S-57 (but rarely used) opens up the ability to model, specify and encode data depending on a defined feature catalogue.
2. The existence of "information types" representing data which can be shared between geospatial features. These information types have no intrinsic geometry but represent content, some of which is likely to be in scope of the IMO Performance Specification.
3. The establishment of a global geospatial registry, located at the IHO, which contains definitions for every feature and attribute defined within product specifications and included in their feature and portrayal catalogues.
4. A comprehensive, machine readable XML feature catalogue structure which defines the geospatial features used in product specifications, their attributes, portrayal and sources for their definitions. This feature catalogue uses entities defined by the IHOs geospatial registry. This feature catalogue is supported by a much more prescriptive DCEG document which tightly defines the allowed bindings between features and attributes within ENCs and (in theory at least) restricts the data which it is possible to insert into an ENC. The relationship between these bindings and an updated version of IHO S-58 is still to be fully determined but potentially this could be a big determinant of what data is embedded within ENC.

5. A machine readable portrayal catalogue which is updatable via specified mechanisms in the target system. This portrayal mechanism provides all the facilities for chart display currently extant in IHO S-52 and allows for definition of new portrayal for new product specifications.
6. A tighter alignment with the ISO 191xx framework via specific data and metadata structures. This alignment includes a facility for much more flexible modelling of data within a particular domain via the provision of complex attributes.
7. The ability to support data which has been authored at multiple revision levels. So, the ability to display data with different levels of portrayal catalogue revision.

Additionally the IHO S-101 product specification for ENCs contains new functionality (and revisions to existing features) which improves on the existing S-57 appendix B1 product specification. This new functionality (as defined in the edition 1.0.0 of the released product specification) currently is:

1. New loading strategy for cells which does away with usage bands (and, hence, a section of ECDIS portrayal and behaviour reflected in some current parts of IHO S-64)
2. DCEG content defining ENC content in terms of its features and attributes – some of these features are new, revised and (in some cases) deleted.
3. Portrayal catalogue which takes the place of the existing S-52 documentation as far as chart content is concerned. This should also replicate the other elements of the ECDIS portrayal which are expressed in S-52 Presentation Library terms but which are not IHO/INT in nature – e.e.g Mariner's objects, IEC62288 symbology etc. The Portrayal Catalogue also contains the LUA based portrayal replacing the existing conditional symbology procedures.
4. A feature catalogue which expresses the IHO/INT content of ENC data. This develops the existing S-57 content model with some additions/deletions.

In the light of the new features of S-100 (and which are used by product specifications including S-101) this has to be the starting point for defining new test dataset content required under any type approval mechanism in the new regime.

Description of tests will be required	Comment (from S-101/S-100, other PS perspective)
New and Improved ENC functionality (specific to IHO S-101)	Testing of S-101 new functionality in respect of ENC data. Much of this is covered by porting the existing S-64 test dataset to S-101 versions but some new functionality exists. This can be approached systematically by looking at the new features within S-100 which are used within S-101 and producing tests for those areas (both functionality and feature catalogue content). For example: • Complex attribution in ENC – replacing the National Language text attributes • Checking multiple light sectors in pick reports • Loading strategy / SCAMIN/SCAMAX and the absence of usage bands • Richer association and relationship structures. So, checking that Island Groups, Mooring Trots, Bridges, Vessel Traffic systems etc (as specified by the FC for S-101) are accessible by pick report. • New features introduced in S-101 (e.g. fibre optic cables, vessel traffic systems, contact details)

	• Encrypted/Unencrypted and Signed/Unsigned data loading – these are now independent so need to be tested for separately, both for successful import and invalid (both encryption and signatures) • Any new format supplementary files, e.g. XML (w/validation), PDF, HTM (w/stylesheets) • Management and portrayal of ENCs which are defined against different versions of the FC (this applies to other PSs too). a.
Loading and update of new feature catalogues	• Loading and verification of feature catalogues • Should extend to capture of attempts to load corrupted or old FC • Rollback of FC for data already in system and management of extant data once FC has been updated. The ability to deal sensibly with data which is unrecognised by the system should be tested thoroughly as there is a greater risk of this happening on a system where the feature catalogue (and interoperability) is configurable. • Loading of arbitrary PS FC. This should cover how a new product specification is defined to the system and ideally a dummy product specification created specifically for this purpose (maybe an MSI-type PS which is concise to specify and to define test data for). This should be full product specification exercising elements like interoperability, alarm/indication functionality and dynamic portrayal. Its addition to ECDIS Chart 1 should also be tested. • The scenario where a FC imposes mandatory attribution or changes data bindings should be considered and scenarios defined for it. It seems unlikely that FC and data promulgation can be effectively coordinated so the ECDIS will need to be able to make judgements on what to do if faced with contradictory data (the existing unknown/question mark methodology should work in this case).
Loading and update of portrayal catalogues	• Similarly to FC, update/install and rollback of PC updates for prescribed and arbitrary data products. • As per FC updates, behaviour when data/portrayal are inconsistent should be considered (modelled on existing ECDIS functionality) and tested for? • Should there be a “preview” function?
Loading and update of interoperability catalogues	• IC load/unload and update. Verification and rollback (if required) should all be part of the test scenarios. IC should cover the full range of functionality envisaged by the IC specification for all data products. If arbitrary data products are being tested as well then their exposure via S-98 interoperability should be tested as well. • Testing of data at different revision levels.
Testing of new IHO Product Specifications	• In order to test the ECDIS behaviour in respect of product specifications which represent “enhanced” functionality of the ECDIS the test datasets should include specific tests for each of the product specifications. Examples (based on the candidate list given

	in section XX are included in the list below. In all these cases the aim is to demonstrate functionality which is in line with the IMO PS, which can be demonstrated in line with existing ECDIS functions defined and which allows for different S-98 interoperability to be tested: ○ S-102 – load, portrayal checks (from spec in PS), interoperability – substitution of depth areas and interrogation. If alarm/indication functionality is included then redrawing of safety contour and alarm/indication effects and route planning/monitoring tests should be included. ○ S-104 ○ S-111 ○ S-122 – tests should include the integration of S-122 data with (e.g.) MPAs already embedded within S-101. This data is designed for planning and hence the interoperability specification and interoperability level should allow substitution of these features and accessibility via pick reporting (in addition to standardised portrayal) of the richer information included. ○ S-123 – planning input. These features represent enhanced views of data which may already be in the ECDIS in the S-101 ENC and therefore an integration of the data, making it clear its source and revision information would be needed. This should contribute to the planning mode as specified in the ECDIS PS – not relevant for alarm/indication or monitoring mode ○ S-124 – display of MSI information which may be relevant to planning should be tested and accessibility of data to planning functions (through comprehensive pick reports)
Load/Import of new S-100 data products	• New subsections should test the ECDIS capability to load/unload, verify display and interrogate arbitrary S-100 vector (and potentially raster) products. Needs a dummy product specification creating modelled on a simple vector form which can be used to test the ECDIS ability to ingest, display, unload, use interoperability features and interrogate data. If alarm/indication exposure is part of the eventual S-100 PS catalogue then this should also be tested thoroughly
ENC in multiple formats	• Testing of the ability to load data in both S-57 and S-101 form. No requirement to test data in the same region (i.e. each area should be covered with only S-57 or S-101) even at different scales. • S-100 overlays of S-57 data should be tested (should be part of functionality)
Data Loading Strategy	• Need to create at least ten different test datasets that have a variety of min and max display scales and have a different generalization of depth areas depending on scale and then see if it is loading correctly

	according to the algorithm in the specification. Define the expected result. • Should be enhanced to provide comprehensive SCAMIN/SCAMAX capabilities based on S-101 PS content • Co-existence with S-57 – this will need to test the dual-fuel concept to ensure it is robust and clear to users what content they are looking at.
Alarm/Indication and safety contour functionality	• Exhaustively test alarm/indication and safety contour capability. If it is possible for other product specifications to define this functionality then this should be tested too (through a structured alarm/indication catalogue install?). If this is generic then a "new" test product specification should exercise this within a test. • The IMO definition (and breakdown) of this functionality should not be changed – the nature of these features should stay the same but if extra S-100 layers enhance their definition or replicate (via interoperability) their presence in the combined picture available to the mariner then they should be integrated into this functionality. For example if S-102 is able to redefine depth contours then they should be usable for safety contour generation. This certainly points to a required mechanism for a product specification to expose certain features as relevant to the alarm/indication definition on the ECDIS. • Current structure is to split into Alarm/Indication and planning/monitoring as well as areas of special interest vs safety contour generation as well as checking largest scale data is being used. The only structural change to this is what the effect of the interoperability level is on the system during these operations. It would seem logical to maintain the "largest scale" trigger in the system but to also allow substituted features to trigger such alerts as well. This needs some careful consideration in terms of how it is articulated in the relevant standards (i.e. S-101, S-98 and any product specifications exposing an alerts/indications catalogue or set of features).
Feature Catalogue updates – new features/attributes	• Introduction of new features, new attributes, new enumeration values and bindings via feature catalogue update. • Associations and the ability to view their content via pick report in line with existing guidelines for pick report formatting.
Updated Feature catalogue bindings	• As the S-101 feature catalogue is more prescriptive it should be tested that bindings outside the FC are validated and warnings issued to users if bindings outside those specified in the FC are present in the data. This situation is unavoidable and functionality within the ECDIS needs to be specified to deal with it (in much the same way as current ECDIS deal with missing or invalid values in data)

	• Maybe there should be a side-by-side test where data allowable in S-57 is onscreen along with S-101 equivalents where the binding isn't allowable?
Complex Attribution	• Need to exercise complex attribution especially where it has replaced S-57 attributes. Date ranges and naming in particular. Contact details etc… • Can complex attributes be viewed in pick reports? This should cover key complex attributes within prescribed data products (i.e. multi-lingual feature names (replacing national language attribute tests in S-64) as well as complex attributes in arbitrary product specifications (if permitted) – pick reporting remains to be specified but the concept of product specifications configuring the pick report information needs to be tested and a minimal machine readable configuration prepared.
Information types and auxiliary file management	• Both information types and supplementary files are present in S-100 product specifications and should be tested to ensure the information (which is not directly attributed to geospatial features) is accessible to the end user, through pick report structures. • Replacement to INFORM structures needs to be tested for both display and pick report functionality especially where (anecdotally) important information is contained within those fields.
Data Loading and verification (including metadata detail)	• Loading of data will need to be thoroughly tested, particularly those product specifications designed for primary navigation and which fall under the scope of the interoperability catalogue. • Behaviour for loading, unloading, verification, removal and display/interrogation should be specified within the product specifications and S-98 to be prescriptive about expected results and effects when only subsets of products are available. Also, existing guidelines on uncluttered displays should be respected and engineered into the relevant product specifications and test datasets.
Behaviour of interoperability catalogues and data layers.	• Test all levels of interoperability according to IC specifications • Test interoperability catalogue update for new product specifications. This would need to offer end users options for interoperability level and the expected behaviour in that level. This should cover both ECDIS/ENC product specifications and arbitrary PS as well. • Screen furniture / user options should be specified within S-98's ECDIS implementation and should cover interrogation, load/unload, verification and rollback. S-64 can specify this as it does for data loading/display messages. Permanent messages will probably be needed in order to completely specify this functionality.

Verification of S-58 critical checks?	• As discussed in the main text, if a minimum level of data integrity and consistency is to be assured via data validation tools then there should be no requirement to deal with data falling outside these parameters. For data where there is only a feature catalogue though the situation may require uniform behaviour should the system encounter data outside its operating parameters. • This could extend to data where the feature/attribute definitions are unrecognised (i.e. not in the DDR feature catalogue of the cell), where bindings are outside those prescribed by the FC, non-existent associations or where interoperability causes unpredictable results. Current ECDIS protocols for dealing with unexpected data structures could be extended to cover this eventuality and this would strengthen the resilience of the ECDIS in a "multi product specification" environment.
Service revision information.	• S-100 provides much expanded metadata for products as well as the ability to bundle different product specifications together. The ability to manage service revision in a multi-product environment should be adequately tested. This would complement (and possibly extend) the existing (S-63 based) ECDIS status report. • These tests should deliver full and subset datasets to the EUT – so, test updating of partial and full datasets as well as single vs multiple products to ensure revision and service update data is communicated to the end user in line with the existing standards. The key to making co-existence functioning intuitive to the user is informing them of the presence and revision level of both legacy S-57 and S-101 (and S-10x) data within the system. There is an existing requirement for a graphical index and this could be expanded to link to the ECDIS update status report.
Conditional Symbology functionality – needs to be incorporated into new tests for new product specifications.	• These tests should exercise the LUA portrayal elements. The existing S-64 tests should be extended to cover those features subject to conditional symbology procedures • The arbitrary product specification and PC updates should include specific test cases which update portrayal rules encoded using LUA elements to thoroughly test their updates. • Update of conditional symbology rules? Where they are being used they should eb exhaustively tested. • Should negative test cases be included where the portrayal updates fail or the LUA produces unexpected results? Should a failure mode for the ECDIS be defined under standards to account for this eventuality?

9 Test datasets in support of data production

IHO S-58 is the other major source of test datasets within the current IHO ENC ecosystem. The purpose of S-58 is to provide a comprehensive set of tests which validate ENC content, that is, given an S-57 dataset, to establish whether it is "suitable" for use as an ENC within an ECDIS context. IHO S-58 has undergone many revisions since its inception and is embedded in many COTS software packages and is considered a mature standard. IEC61174:2015 does not refer directly to IHO S-58 but its contents have undergone much debate as to whether a subset of them should be considered a mandatory part of the ENC standard to ensure coherent processing of ENC data on ECDIS. These so-called "Critical Checks" are those described below:

C	Critical Error	An error which would make an ENC unusable in ECDIS through not loading; or causing an ECDIS to crash; or presenting data which is unsafe for navigation.
E	Error	An error which may degrade the quality of the ENC through appearance or

Figure : definition of S-58 critical checks

It is also stated in S-58 that a "minimum check standard" should exist, which is:

1.3 Minimum Check Standard

S-57 Supplement 3 specifies that ENC data must meet the minimum validation requirements defined in this standard. At the time of publication of S-58 6.1.0 no checks are mandatory.

The intention is that Critical Errors will become mandatory once software conforming to S-58 6.1.0 is available and in use by ENC producers. In order to support this transition a test dataset and a mechanism to certify that the validation tools reflect the current standard has been developed. The implementation date of mandatory checks for ENC producers will be announced by IHO Circular Letter.

Figure : S-58 "Minimum Check Standard"

It is envisaged, therefore, that a certain subset of the S-58 validation tests should be mandatory for all ENC data, and a prerequisite to that data being installed on ECDIS and used for navigation, precisely because it assures a minimum level of consistency and format of the ENC. Indeed the version of the S-101 product specification at the time of writing contains the following clause:

> Only maintained datasets that conform to the mandatory requirements outlined in S-101 will be considered to be an ENC satisfying the SOLAS chart carriage requirements for use in an ECDIS.

Figure 9: Validation checks for S-101 data

and the validation checks are reinstated as a mandatory Annex of the product specification.

As S-101 is rolled out as the new standard for ENC, therefore, it is worthwhile asserting whether these tests (and dataset which support their definition) should be brought into the required test datasets for ENC on a future S-100 enabled ECDIS. Certainly the intention is that these datasets (or rather, their S-101 equivalents) should form part of the baseline for a minimum standard for ECDIS and although they will not form part of the type approval regime in itself it is worth considering what tests the ECDIS should

be performing on imported data (and providing tests in respect of those consistency tests as part of the type approval process).

The original intention of the critical tests in S-58 was relieve ECDIS OEMs of the responsibility of performing such tests to reduce ECDIS instability but this was borne out of an environment where the data content reaching the ECDIS was completely specified by the underlying standards. Arguably, because the whole essence of ECDIS is changing in the S-100 regime with the addition of extra/optional data products there may be a need to rethink this part of the process, providing test datasets which test the ECDIS ability to coherently import data. It may be a benefit for the OEM to not require validation of input data but no such assumption can be made for non-S-101 data for which product specifications may be required on the EUT and therefore a basic set of sanity checks would seem appropriate for such products.

Certainly, as part of the type approval testing process it is worth inserting a battery of tests where a hitherto undefined S-10x data product is imported into the system along with data which is inconsistent in some way (e.g. which does not match its feature catalogue, or contains fundamental inconsistencies in its content). This would establish the ECDIS is capable of resolving such inconsistencies when faced with data outside its stated parameter values and could be engineered/specified to be achievable without undue resource requirements on the ECDIS or its development.

10 Testing Strategy Options

The current test regime is a “black box” one. It treats the EUT as a closed system and tests it in the same way that an end user would “use” the system. This methodology originates from the marine electronics world where communications devices, radar etc are tested in this way – as embedded systems the systems work well and for ECDIS it provides a structured and systematic way of testing ECDIS functions against the provisions in the PS and testing standard.

ECDIS was the first of the highly computerised systems on a modern vessel bridge and the only weakness in such testing strategies is the difficulty of “exhaustive” testing – that is, the inability to test for every eventuality of data inputs, chart processes, feature/attribute combinations and processing of conditional symbology mechanisms.

This weakness is implicit in the black-box approach but is not one for which a readily available solution exists. Much discussion has been had in the broader marine electronics world of the virtues of examining/auditing the actual manufacture/engineering processes and designs of such systems but as IHO participants in the process the key enabler for ECDIS manufacture remains coherent, logical and structured standards backed up with normative test data and close working relationships with the broader IMO/IEC community to define and support type approval testing for such equipment.

11 Other High Level Considerations – IMO and ECDIS

It should be noted that the update of ENC to S-101 may require a revision of various other elements of the IHO associated publications. Some of these are noted below:

1. ECDIS Check dataset – should this be revised or its tests incorporated into the new S-64? Certainly some of its provisions are valid such as more exhaustive checks of obstructions and dangers and more structured tests for alarm/indication behaviour could be relevant?
2. Facts about chart carriage requirements should be revised. This would need to clarify the position in respect of type approval and the upgrade from S-57 to S-101. It should map out any agreed IHO methods/processes and timescales for migration to S-101 and best practice for managing that transition.
3. IHO S-32 is referred to by the IMO PS and should be checked to ensure that the definitions are consistent. In particular, clarity on legal and regulatory definitions for ENC, charts and S-57 should be updated to reflect the S-100 regime.
4. S-61 and the elements relating to RNC should be checked. Although these are unlikely to change S-100 adds considerable functionality and data breadth to the ECDIS so the RNC areas of both IEC61174 and S-61 should be checked to make sure the required tests are still coherent.
5. IHO S-62. The provision of data producer codes and the ability to ascertain official from non-official codes is not formally stated in the IHO Standards referenced by type approval. The move to S-100 ECDIS presents an opportunity to bring these into the new regime.

12 Overview of gaps in existing IHO standards baseline.

In order to progress the migration of the existing S-57/ENC/ECDIS systems towards adoption of IHO S-100 and its replacement(s) for the ENC dataset the following observations are made on the current standards baseline in IHO (and IEC):

IHO Standard	Observations and Actions
IHO S-52	• Many areas of ECDIS functionality are expanded and effectively defined within IHO S-52. Only some of these are covered wholly by the existing portrayal mechanisms • These should be gathered and equivalents specified in the relevant standard (most will fall to the portrayal Annex of S-101 but some could go into S-98 and potentially require specification in other product specifications too) • It is unlikely that S-52 itself would be required to make any changes. S-101 should define behaviour specific to ENC display/screen behaviour such that, as S-57 is phased out, the S-101 behaviour completely implements the IMO PS as tested by IEC61174 (i.e. so that S-101 has no S-52 dependencies.). This may be challenging when data is expected to co-exist on the ECDIS (which we believe it will for a substantial time).
IHO S-57 / S-100 migration	• Currently the migration path from S-57 to S-101 is not completely defined and agreed. It is highly likely that a period of dual operation will be required for some time and this should be expanded in guidance as the S-100 timetable is agreed by the various controlling bodies. • Therefore methods of testing ECDIS should be predicated on systems supporting both formats of data until such time as S-57 is no longer in operation. This, in contrast to RNC mode, cannot be a separate operating mode though – the IMO functions of chart display, interrogation and alarm/indication/safety contour generation should work in systems with a hybrid S-57/S-101 dataset loaded (and be tested for). This complicates some of the test scenarios but should be approached as a holistic test scenario to ensure user experience is not catastrophically degraded.
IHO S-61	• RNC and SRNC operating mode are still present in IEC61174 and likely to remain in place.
S-101	• Clearly elements of S-52s specification of chart operations need to be added to (probably S-101). Arguably some of these functions are generic to any navigation system (e.g North Arrow, Scalebar, User Options) but S-101 is a pre-requisite on all these systems so locating such functionality in its portrayal system makes sense. • Enhancements and implementations to support the full range of configurability required by the S-100 ECDIS will be required. This will include pick reporting and alarm/indications (when those parts are specified by S-100). Arguably the service revision information (currently in S-63) could be relocated into S-101. Although generic ECDIS functionality should be specified in S-100 arguably some of this could be specified in S-

	101 as it will be the foundation for carriage compliant data and hence will be present at all times. This may help reduce the burden on S-100 to support specific ECDIS functionality, display and interrogation processes which are better specified in detail by the S-101 product specification.
S-98	• S-98 is currently in the process of being rewritten as an abstract specification together with an "application on ECDIS". As this is completed many parts of the test datasets can be put in place.
S-100 and other product specifications.	• The only enhancements required to S-100 are those which are required by the type approval process and which are generic to product specifications as whole. For example, a generic mechanism for alarm/indication exposure by product specifications and interrogation formatting (for ECDIS pick reporting) may well require S-100 sections. Additionally, S-98 is undergoing a split into a generic S-100 version as well as an ECDIS "implementation". • The debate over which product specifications to formally verify under type approval is, at the time of writing, still to be decided although the intention (the option 3 in section 4 of this document) is to accommodate a core set (with S-101 at the centre) as well as arbitrary product specifications which the ECDIS self-configures against. A candidate set is presented earlier in this document, those products which could be said to "enhance" ENC content for those member states who wish to produce, validate and distribute it. For the purposes of the IMO PS these datasets should be considered part of the "ENC" dataset. • The S-100 ECDIS also should have the ability to load other product specifications (on receipt of signed/authenticated feature and portrayal catalogues as well as any other configuration information required). This would enable future products to be added to the system (without interfering with type approved "ENC" data) and without re-type approval. This would determine the test datasets to some extent as well as this functionality would require arbitrary product specifications to the constructed for testing. The discussion as to the benefit to the user and to safety is continuing. • S-100 should be "added" to type approval by reference. There is a question whether the behaviour of the system in respect of S-100 product specification loading, display and interrogation falls wholly within the scope of that demanded by the IMO Performance Standard. The PS is currently met by the data content within ENC (and RNC) as defined by S-57 but the current effort is enhancing that view with extra product content and their standards. • From the point of view of IEC61174 and the IHO standards it is reasonable straightforward to add as most of the standards have been written and the existing testing/dataset structure would allow such tests to be written and executed.

Functionality of other IHO Product specifications	• These may require some development in order to be fully compatible with a revised IEC61174 and reference test datasets created. Additionally, reference S-98 interoperability catalogues will be required to support their operation in the EUT ECDIS. • An example is if they require interoperability with features named in an alarms/indications catalogue in which case they should expose those features as subject to the search/display and interrogation capabilities the PS mandates (as well as the "largest scale" priority rule.
IEC61174	• IEC61174 is likely to require some substantial (although not structural) update to accommodate the testing requirements for S-100 enabled ECDIS. This should probably also include how S-101 data co-exists with S-57 in functions such as route planning, checking and monitoring as well as basic chart display/interrogation. • The basic structure of IEC61174 should be preserved. The provisions of the existing S-64 have been commented in this document together with a checklist of new functionality which should be added to the existing S-64 test dataset. From this point of view it seems unlikely the existing S-64 test dataset is to be replaced as continued testing of S-57 will be necessary for the dual fuel phase of operation. • Sections on RNC are unlikely to require substantial revision. Raster can probably remain as another "operating mode" • Should there be an informative annex detailing how S-100 product specifications work, how the interoperability mechanisms impact users and their optional nature? An Annex (similar to the polar waters (Annex O)) would be a good way of summarising the revised form and function of the ECDIS. • The main difficulty is in structuring testing to allow for dual fuel operation in the early stages of S-101 rollout and allowing S-57 to co-exist (and be tested as such) during this phase. IEC61174 is driven from functionality though, not data format, so this existing structure can be used to add S-101 (and others) alongside existing ENC data.
IMO Performance Standard	• No substantive changes to the IMO Performance Standard are envisaged although changes to its references which state how supporting standards in IHO specify the behaviour required for ENC/ECDIS will be required, not least to state S-100 and its product specifications as meeting the requirement for "ENC" data equivalent to IHO S-57. b. • See excerpt from IMO PS: c. **4.9** ECDIS should be capable of accepting both non-encrypted ENCs and ENCs encrypted in accordance with the IHO Data Protection Scheme[3]. **4.1** The chart information to be used in ECDIS should be the latest edition, as corrected by official updates, of that issued by or on the authority of a Government, government-authorized Hydrographic Office or other relevant government institution, and conform to IHO standards[2].

	[2] IHO Special Publication S-52 and S-57 (see appendix 1). [3] IHO Special Publication S-63 (see appendix 1). **Figure 10: Revised Performance Standards for ECDIS** These references should be to IHO S-100 and the primary (from the point of view of navigation/ENC) product specifications – others would be normative if included in the ECDIS but should not be listed here. S-100 and S-101 are the prime references in this section (and flow down to the other documents).