Paper for Consideration by S-100WG5

Dual-Fuel ECDIS – Definition of Capabilities

Submitted By:	IIC Technologies
Executive Summary:	Dual Fuel ECDIS has been proposed as the mode of operation during the transition to S-100 for type approved ECDIS. This paper defines several aspects of Dual Fuel ECDIS operation and highlights some questions to be resolved as the definition process continues.
Related Documents:	IHO S-52, IHO S-57, IHO S-101, IHO S-64, IEC 61174, IMO Performance Standard for ECDIS
Related Projects:	Development of S-100 enabled ECDIS.

Introduction / Background

IHO has committed to a "decade of S-100" in which to roll out S-101 ENC production and add S-100 (+S-98 and S-101) to the IMO/IEC standards base legitimising their use for primary navigation of commercial vessels under the SOLAS convention. An extract from the IHO paper to IMO NCSR is reproduced below which neatly summarises the proposed transition period during which ECDIS equipment will be expected to support both S-101 and S-57 in a "Dual Fuel" mode.

20. In order to maintain ECDIS devices already installed on SOLAS vessels which are technically not ready nor required to be upgraded to S-101 ENC compatibility, and to comply with the applicable IMO regulations pertaining to existing navigation equipment, identical coverage will be provided for S-57 ENCs and S-101 ENCs for a transition period until there is no significant number of legacy systems in the field and all ECDIS in operation have become S-101 compatible. This situation is expected near the end of the decade, but will be continuously monitored to enable a decision to be made by the responsible IMO body.

21. As a consequence, new ECDIS systems to be brought into the market at the time when S-101 ENC coverage starts (2024) will have to be capable to process both transfer standard formats: S-57 ENCs and S-101 ENCs.

22. Safety of navigation will be maintained by cartographic content of both S-57 and S-101 standards. From the user's perspective, presentation of cartographic and functional features to meet the IMO mandated content in a mixed environment of S-57 ENCs and S-101 ENCs in one ECDIS device will be seamless and presented under the identical presentation regime for charted features and navigational objects.

Figure 1: IHO Paper to NCSR

This document aims to put some detail into the concept of the Dual-Fuel ECDIS and show that its operation, data and user experience can be made consistent and logical in accordance with the relevant standards. It also tries to explain how the "identical presentation regime" and "seamless" operation is achieved in practical terms.

Analysis/Discussion

An ECDIS is basically a device for taking data in S-57 format and providing a user with a set of machine behaviours which meet the provisions of the IMO Performance Standard. In my mind this is the objective of ECDIS.

The broad functions are :

- Chart Loading, Unloading
- Updating, from automated updates and manually
- Display
- Interrogation
- Alerts and Indications, Areas where special conditions exist and Safety Contour Generation.
- Route Planning and Monitoring
- "Other" functions - those stipulated by the IMO PS.

The data in is S-57 – (within certain stipulations (obviously))

- That it is either encrypted or unencrypted

- That it doesn't overlap in a usage band
- It has a compilation scale associated with it

The user is given a set of "options" to configure the behaviour of the ECDIS. This behaviour is both display and operation of some of the required functions. The way the user sees the data is through a viewport (screen) at a particular zoom level (the display scale). So, at any one point there's a set of data to choose from which represent ENC charts. Combinations of features/attributes and metadata within S-57 precipitate specific behaviour of the ECDIS as engineered by the OEM.

The behaviour we primarily concern ourselves with are feature display and interrogation, with alarm/indication functionality coming a close second. There, however, other ECDIS behaviours scattered through the various standards relating to ECDIS manufacture which are also of relevance.

In order to build a sound (and safe) conceptual model of a dual fuel ECDIS it is necessary to look at how each element of the S-57 operation is defined and build an equivalent S-100 based operation

Fundamentals: SOLAS places an obligation on member states to produce and promulgate ENC data to support mandatory carriage of ECDIS. Currently that mandate is fulfilled by the production of S-57. The addition of S-100 to the IMO PS will allow S-100 data to also satisfy the carriage requirement. States will provide data which is safe as defined by the relevant standards (currently S-57)

Principles:

The principles of a dual fuel ECDIS should be:

1. It should allow import and use of both S-57 and S-101 data. In addition, a selection of S-100 data products should be able to be imported and used to enhance user functionality and safety.
2. ECDIS behaviour should not be any less “safe” (as defined by the IMO PS) whether S-57 or S-101 data is in use. The requirements of the IMO PS should be met in all eventualities.
3. User Experience should not be negatively impacted by the introduction of any S-100 data to the ECDIS.

The Introduction of S-100 to ECDIS

S-100 changes the behaviour of ECDIS dramatically by adding a whole new class of data. The fundamental difference is that it is possible to have multiple “types” of data within the SENC. A Dual Fuel ECDIS, intuitively, is one which is able to ingest and use both S-57 and S-101 ENCs simultaneously. In this section we try to define what "simultaneously" means and what the implications are on data producers, ECDIS users and ECDIS OEMs as a consequence of such a definition.

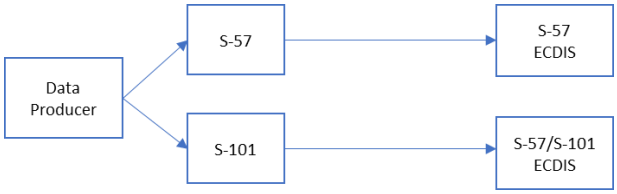
The idea of the Dual-Fuel ECDIS is to allow a gradual migration by data producers worldwide of ENC data to support primary navigation under SOLAS. During the transition period the following will take place:

1. ECDIS OEMs will build Dual Fuel ECDIS (D-F) capable of ingesting and using either S-57 or S-101 data. Over time users will have their systems refitted with the DF ECDIS and will be able to ingest S-101 (and S-10x) data for primary navigation.
2. Data producers will migrate their internal databases and datasets to the production of S-101 data.
3. The distribution chain will implement distribution of S-101 (and other S-100 products) alongside ENC of both forms.

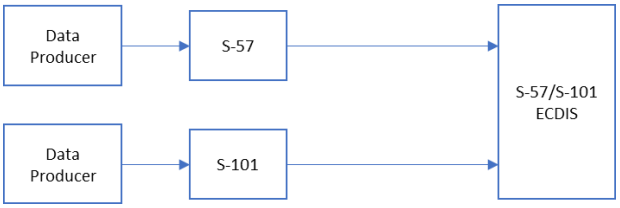
Because data producers will need to produce and promulgate data for all users (i.e. those with both S-57-only systems and those with S-101 enabled systems) it seems unlikely that they will be able to produce solely S-101

data (i.e. exclusive production of S-101 without an S-57 equivalent) for any of their coverage areas until the migration period for S-57 (i.e. the period of time where S-57 satisfies the carriage requirement) has passed.[1]

As a consequence of this it seems likely that coproduction of S-57 and S-101 will satisfy all vessels during the migration period:



The diagram shows a data producer distributing data to a legacy S-57 ECDIS as well as S-101 data (exclusively) to a DF ECDIS.

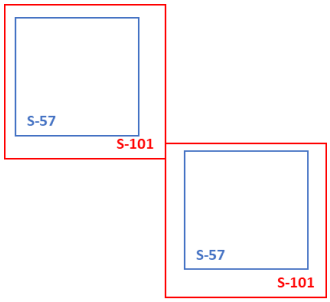


The D-F ECDIS is also able to ingest data from data producers who have not yet migrated their data holdings to S-101 as in the above diagram.

The D-F ECDIS gives maximum flexibility to the data producer in terms of meeting carriage requirements for all vessels but it also places a burden on them of co-production of data until the legacy period is over.

ENC Production

What happens on the ECDIS is directly related to the availability of charts in each of S-57 and S-101 formats. One of the key questions to answer is whether data producers will produce data in <u>both</u> S-57 and S-101 formats or whether it is possible to distribute data exclusively in S-101, without a corresponding S-57 datasets for the area.



It would seem logical to conclude that not only does co-production of ENC in both S-57 and S-101 seem likely but the extents of the charts would need to be coincident. The situation in the diagram to the left (where the producer has started S-101 production but made the S-101 charts larger in extent than the corresponding S-57 charts would also break “Rule 1” as there are areas around the border where only S-101 coverage exists – were there safety critical features in those boundaries a legacy S-57 ECDIS would not be capable of processing them.

Although it would be possible (in theory) to cover the border areas with smaller scale coverage during a transition period so that S-57 cover is complete for legacy users (this also addresses the alarm/indication issue as the largest scale data in the S-101 border area is covered by the smaller scale data too). This requires further discussion however.

[1] The only alternatives to this state of affairs is either member states forbidding use of non S-101-enabled ECDIS in waters where they produce exclusively S-101 data or the rollout of S-101 to wait until the legacy period has passed. Both seem unlikely at this stage.

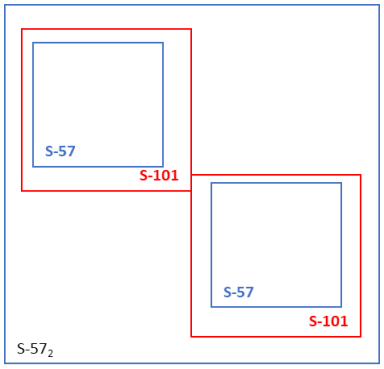


Figure 2: Filling in gaps with smaller scale ENC coverage

This would not be suitable for all situations and would also be unwieldy in terms of co-production processes requiring generalisation for the smaller scale ENC.

However, it is accepted there may be options here[2] and further discussions are necessary amongst the data producer community. The issue at hand is whether to ensure, from an ECDIS perspective how to load data and whether it is sufficient to partition the SENC by feature or by chart and whether production should be mandated so that S-101 ENCs have the same coverage as S-57, i.e DataCoverage = M_COVR?

This is certainly a question for industry as well - it may simplify the operation of the ECDIS but it may not be a big consideration technically. Logically it gives borders to datasets which means the ECDIS doesn't have to partition (potentially safety critical) features.

However, we should bear in mind it is notoriously difficult to place "restrictions" on member state production of data in this regard and then use those restrictions to partly define ECDIS behaviour. The prime example from S-57 is overlaps of data[3]. It is far more likely that through validation standards, training, conventions and content/format standards a level of coherence of global data can be achieved that have made S-57 ECDIS a success.

ECDIS Dual Fuel Operation

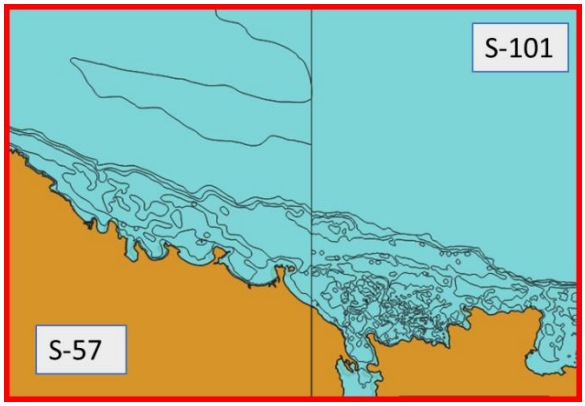
The previous section explored the options and constraints governing data production and what data the DF-ECDIS can be reasonably assumed to have access to. This section deals with how the existing ECDIS functionality is adapted when such data is loaded into the SENC.

Consideration should be given to the various ECDIS functions as outlined in the introduction, how these functions work when both S-57 and S-101 (and potentially S-10x data acting under interoperability) are loaded onto the system and any additional standards/testing required.

The following diagram shows a conceptual view of a DF-ECDIS with both S-57 and S-101 data loaded:

[2] Producers have a range of options for producing the "identical coverage" required, not least because S-101 allows the possibility of bundling multiple DataCoverage features in a single cell, potentially the (mentioned) case of including coverage at different scales or grouping adjacent coverage into single S-101 cells. The basic assumption though it that the ECDIS is provided with data sufficient for it to partition the SENC spatially into exclusively either S-57 or S-101 at a particular scale (accepting that such a partitioning does not have to extend to all scales)

[3] S-57 forbids overlaps within the same usage band and consequently S-52 provided no guidance (initially) for manufacturers on how to reconcile such overlaps on screen. A small number of overlaps persisted between member states which were unresolvable and eventually S-52 was revised to provide simple text information to users regarding the overlaps.



From a simple perspective when two adjoining charts are loaded into the SENC at the same CSCL/display scale the display can simply be partitioned with the left half drawn according to IHO S-52 Presentation library and the right half drawn using the S-101 Portrayal Catalogue specifications. This applies to all simple chart portrayal situations on the ECDIS. If the SENC is partitioned into both S-57 and S-101 data then it should draw each dataset according to the portrayal designed specifically for it.

Could a DF-ECDIS not convert all the data to S-101 and then display it according to the S-101 PC? Possibly, although there would be some issues, i.e.

1. Skin of the earth changes in the topology of the datasets
2. Features which have been discontinued from S-57 in S-101
3. Attribute bindings which have been discontinued from S-57
4. Consistent alert/indication behaviour

Although this is certainly possible a closer consideration of the conversion between S-57 and S-101 would be required to establish whether this is feasible and safe. However, from the perspective of basic operation, the simple "partitioned SENC" concept should be accepted as a feasible model of dual fuel chart display

Loading Strategy

Most ECDIS portrayal gathers data from multiple charts at different scales and renders them onscreen according to the S-52 standard. In a DF-ECDIS this is still the case. Although no exhaustive "loading strategy" was ever defined for S-52/S-57 ENCs (a situation remedied in the current S-101 draft) S-101 contains the same elements governing portrayal as S-57 does (i.e. the elements which trigger display, rather than the charted features themselves).

1. DataCoverage / M_COVR – features which are an intrinsic part of the dataset and define the extent of the data.
2. "Scale" Although there is a subtle difference between CSCL and DisplayScale they are conceptually the same thing – the scale at which the chart is optimally viewed and therefore can be used to trigger loading strategies for portrayal.
3. SCAMAX/SCAMIN

So, it should be possible for a DF-ECDIS to use the S-101 loading strategy (when agreed) to load both S-57 and S-101 datasets for portrayal. The S-101 portrayal catalogue has been built to replicate the S-52 display mechanisms and the user impact should be minimal in terms of different portrayal appearances (for future discussion, again, the extent to which it can and should be different in excess of the current S-52 portrayal). The basic idea here though is that ECDIS can use S-57 data (with its M_COVR,CATCOV=1) data and CSCL of cells together with the S-101 chart loading strategy in order to display S-57 and S-101 data alongside each other.

If (depending on how the dual loading / partitioning discussion is resolved) the SENC has both S-57 and S-101 data for the same area at the same scale, a preference should be given to the S-101 data (in the light of the previous section if the decision is taken to always produce and ingest coincident holdings during the migration

period then the ECDIS can simply not load the S-57 data when the S-101 is installed (or replace existing S-57 with S-101 when it is introduced to the system[4]).

It should also be assumed that the user needs to see an experience not fundamentally unlike that which they see today. The goal of S-100 is to "enhance" that experience - therefore the basic "ENC" should be virtually the same as far as the user is concerned with any differences in portrayal or behaviour clear (and trained for).

In portrayal terms, all the ECDIS is doing is loading a section of data from the SENC and rendering it on screen according to the portrayal library it has within the system. In IMO terms the layers, headings and categories of data are all defined within the individual product specification and an identification (mapping) of the IMO categories to the equivalent features in the ENC should be done and shown to the user.

Feature Interrogation

Following the pattern of the previous section it is possible to develop a model of how feature interrogation works. This is similar to how we built up the model of portrayal from the simple case of how a single chart is displayed.

ECDIS have a requirement under the IMO PS to show the details of features when interrogated by the user.

> **5.6** For any operator identified geographical position (e.g. by cursor picking) ECDIS should display on demand the information about the chart objects associated with such a position.

Generally most ECDIS take user interface via a “click” with a mouse and then present, through a series of GUI mechanisms, the detail for all data in the SENC located at a single position.

S-101 and S-57 are not fundamentally different in that datasets are built from vector features with predefined positions and extents. The only relevant fundamental difference is the addition of complex attributes to the GFM which drives S-101 data definition.

An S-57 pick report currently shows the feature information located at (or within in the case of polygons, or within the proximity of for line features) a picked location. This information will be all features within the chart currently displayed on screen and may extend to all charts in the SENC (at larger or smaller scale) and the display is of the “key/value” type where the S-57 feature is described along with the various attributes set and their values.

This interface is currently defined by the ECDIS OEM (and latest versions of S-52 set tighter parameters around this interface in response to user feedback and discussions within the industry). Currently an S-101 (or S-100) equivalent is undefined in this regard but apart from the addition of complex attributes (which extends the key/value mechanism described above) the algorithm should be the same – i.e. for each “product” with data in the position interrogated, format and display the feature data (whether simple S-57 attribution or in S-100’s complex attribution) to the user in an appropriate fashion.

There is clearly work to be done within the standards defining equivalents to the current guidance in respect of pick reports and test datasets will need to be done to check the co-existence elements – this, again, is where the contents of the previous section are important. If S-57 and S-101 data are co-resident (albeit at different scales) then the relevant pick reports from each chart should be displayed.

In terms of the end user there is an impact here – and a responsibility within the standards to ensure that the appearance of pick reports is harmonised and intuitive to minimise the impact on the user experience.

Alerts / Indication behaviour.

[4] Clearly loading/unloading and replacement behaviour will require definition (and testing) as part of the IHO standards baseline for ECDIS in relation to S-101 introduction over existing S-57 coverage.

What is commonly referred to as Alarm/Indication behaviour is actually a set of different functions on the ECDIS. These are best summarised in the revised Performance Standard:

ALARMS AND INDICATORS

Section	Requirements	Information
11.4.3	Alarm	Crossing safety contour
11.4.4	Alarm or Indication	Area with special conditions
11.4.5	Alarm	Deviation from route
11.4.8	Alarm	Positioning system failure
11.4.9	Alarm	Approach to critical point
11.4.10	Alarm	Different geodetic datum
13.2	Alarm or Indication	Malfunction of ECDIS
5.8.3	Indication	Default safety contour
6.1.1	Indication	Information overscale
6.1.2	Indication	Larger scale ENC available
7.3	Indication	Different reference system
8.5	Indication	No ENC available
10.5	Indication	Customized display
11.3 4	Indication	Route planning across safety contour
11.3.5	Indication	Route planning across specified area
11.4.6	Indication	Crossing a danger in route monitoring mode
13.1	Indication	System test failure

In this Performance Standard the definitions of Indicators and Alarms provided in the IMO resolution A.830(19) "Code on Alarms and Indicators, 1995" apply.

Alarm: An alarm or alarm system which announces by audible means, or audible and visual means, a condition requiring attention.

Indicator: Visual indication giving information about the condition of a system or equipment.

Figure 3: IMO PS Appendix 5 - definition of Alerts and Indications

The sections directly relevant to ENC chart data, and hence to the operation in Dual-Fuel mode of an S-100 ECDIS are as follows:

1. 11.4.3 Crossing the safety contour
2. 11.4.4 Area with special conditions
3. 5.8.3 Default safety contour
4. 6.1.1 Information overscale
5. 6.1.2 Larger scale ENC available
6. 8.5 No ENC available.
7. 10.5 Customised display
8. 11.3.4 route planning across safety contour
9. 11.3.5 route planning across specified area
10. 11.4.6 Crossing a danger in route monitoring mode

IEC61174 then makes a more detailed list of these conditions within its test specifications (IHO S-64 then has exhaustive test datasets for each condition)

Table D.1 – Alerts and indications resulting from IMO requirements

Subclause	Requirement	Category	Information
4.10.3 (232/A11.4.3)	*Alarm*	*A*	*Crossing safety contour*
4.10.3 (232/A11.4.4)	*Warning or caution as selected by user*	*A*	*Area with special conditions*
4.10.3 (232/A11.4.5)	*Alarm*	*A*	*Deviation from route*
4.10.3 (232/A11.4.6)	*Caution (*)*	*A*	*Crossing a navigational hazard in route monitoring mode*
4.10.4 (232/A11.4.8)	*Warning*	*B*	*Positioning system failure*
4.10.3 (232/A11.4.9)	*Warning*	*A*	*Approach to critical point*
4.10.4 (232/A11.4.10)	*Warning*	*B*	*Different geodetic datum*
4.10.4 (232/A11.4.15.2)	*Indication*	*n/a*	*Discrepancies between positions*
4.10.4 (232/A11.4.14)	Permanent indication	n/a	Manual position adjustment
4.13 (232/A13.2)	*Warning*	*B*	*Malfunction of ECDIS*
4.3.4 (232/A5.8.3)	*Indication*	*n/a*	*Default safety contour*
4.5 (232/A6.1.1)	Permanent *Indication*	*n/a*	*Information overscale*
4.5 (232/A6.1.2)	Permanent *Indication*	*n/a*	*Larger scale ENC available*
4.6 (232/A7.3)	Permanent *Indication*	*n/a*	*Different reference system*
4.6.2.3 (191/6.4.2.1)	*Indication*	*n/a*	*Target processing/display capacity is about to be exceeded*
4.6.2.3 (191/6.4.2.2)	*Indication*	*n/a*	*Target processing/display capacity have been exceeded*
4.6.7 (191/6.4.7.4)	*Indication*	*n/a*	*Lost target warning enabled or disabled*
4.6.3.2 (192/5.26.2)	*Caution*	*A*	*AIS target processing/display capacity is about to be exceeded*
4.6.3.2 (191/6.4.2.2)	*Warning*	*A*	*AIS target processing/display capacity have been exceeded*
4.6.3.3(191/6.4.3.2)	*Permanent indication*	*n/a*	*AIS target filter status*
4.6.3.5 (191/5.27.3) and 4.6.4	*Permanent Indication*	*n/a*	Vector mode, time and stabilization
4.7 (232/A 8.5)	*Indication*	*n/a*	*No ENC available*
4.9.5 (232/A10.5)	*Permanent Indication*	*n/a*	*Standard display is customized*
4.10.2.1 (232/A11.3.4)	*Indication*	*n/a*	*Route planning across safety contour*
4.10.2.1 (232/A11.3.5)	*Indication*	*n/a*	*Route planning across specified area*
4.10.2.1 (232/A11.3.5)	*Indication*	*n/a*	Route planning across navigational hazard
4.13 (232/A13.1)	*Indication*	*n/a*	*System test failure*

(*) As a minimum requirement "caution" shall be available. The manufacturer may provide a user selection between "warning" and "caution". The recommended default selection is "Caution" as specified by IMO.

Table D.2 – Alerts and indications defined in this standard

Subclause	Requirement	Category	Information
4.3.2, 4.8, 5.4.2.1	Permanent Indication	n/a	Chart display includes non-ENC data
4.6.6	Warning	A	Outside anchor watch area
4.8	Permanent Indication	n/a	SENC data from non-HO source is in use and presentation is different from IHO S-52
4.10.2.1	Permanent Indication	n/a	Off state of route planning across safety contour, prohibited areas and hazards indication
4.10.3	Permanent Indication	n/a	Off state of safety contour, prohibited area and hazard indication in route monitoring
5.2.1	Permanent Indication	n/a	Chart scale is not uniform over the displayed area
5.3.3 (IHO S-52/10.4.1)	Permanent Indication	n/a	Viewing date or date range does not include current date
5.8.1	Permanent Indication	n/a	Chart orientation is not uniform over the displayed area
5.9.1.4 (IHO S-52 App. 1/3.4.1(i) and /IHO S-63)	Permanent Indication	n/a	Out of sequence update
4.6.2.3, 4.6.6	Alarm	A	CPA/TCPA
4.6.2.3, 4.6.7	Warning	B	Lost target

Figure 4: IEC 61174 Alert/Indication specification

These will all need more detailed specification as the Dual Fuel ECDIS is defined more fully and there already exists numerous references and guidance for the ECDIS manufacturer in S-52, S-63 and normative tests defined in S-64 for all these cases.

Traffic separation zone
Inshore traffic zone
Restricted area
Caution area
Offshore production area
Areas to be avoided
User defined areas to be avoided
Military practise area
Seaplane landing area
Submarine transit lane
Anchorage area
Marine farm/aquaculture
PSSA (Particularly Sensitive Sea Area)

Figure 5: IMO Areas for which special conditions exist.

IMO Special condition	S-57 Object	Attribute	Geometry
Traffic separation zone	TSEZNE		AREA
Inshore traffic zone	ISTZNE		AREA
Restricted area	RESARE	RESTRN !=14 and CATREA != 28	AREA
Caution area	CTNARE		AREA, POINT
Offshore production area	OSPARE		AREA
Areas to be avoided	RESARE	RESTRN = 14	AREA
Military practice area	MIPARE		AREA, POINT
Seaplane landing area	SPLARE		AREA, POINT
Submarine transit lane	SUBTLN		AREA
Anchorage area	ACHARE		AREA, POINT
Marine farm/aquaculture	MARCUL		AREA, LINE, POINT
PSSA (Particularly Sensitive Sea Area)	RESARE	CATREA = 28	AREA

Figure 6: S-57 mapping

These can be readily translated into S-101 equivalents (from the S-101 DCEG – these are not "translated from the S-57 features but from fresh consideration of the DCEG following all changes):

IMO Area	S-101 Feature (and attribute combination)
Traffic Separation Zone	Traffic Separation Zone
Restricted Area	RestrictedAreaNavigational
Caution Area	CautionArea
Offshore Production Area	OffshoreProductionArea
Areas to be Avoided	Restricted AreaNavigational (restriction=14) Aids to Navigation (restricted area=12)
Military Practice Area	Military Practice Area
Seaplane Landing Area	Seaplane Landing Area
Submarine Transit Lane	Submarine Transit Lane
Anchorage Area	Anchorage Area
Marine Farm / Aquaculture	Marine Farm / Aquaculture
PSSA (Particularly Sensitive Sea Area)	RestrictedAreaNavigational (Restriction=18)

Note also the clarification in the DCEG.

17.6 Areas to be avoided (see S-4 – B-435.7)

If it is required to encode an IMO Area to be Avoided, it must be done using a **Restricted Area Navigational** feature (see clause X.X), with attribute **restriction** = *14* (area to be avoided). An IMO Area to be Avoided around a navigational aid must also be encoded with attribute **category of restricted area** = *12* (navigational aid safety zone).

Figure 7:S-101 DCEG note re: IMO area to be avoided.

Slightly more complex is the Detection and Notification of Navigational Hazards – under 11.3.5 and 11.4.6 of the IMO PS:

11.3.5 An indication should be given if the mariner plans a route closer than a user-specified distance from the boundary of a prohibited area or a geographic area for which special conditions exist (see appendix 4).An indication should also be given if the mariner plans a route closer than a user-specified distance from a point object, such as a fixed or floating aid to navigation or isolated danger.

11.4.6 An indication should be given to the mariner if, continuing on its present course and speed, over a specified time or distance set by the mariner, own ship will pass closer than a user-specified distance from a danger (e.g. obstruction, wreck, rock) that is shallower than the mariner's safety contour or an aid to navigation.

Figure 8: IMO Requirement for detection and notification of navigational hazards

This is translated into the following tables which are included in S-52 :

S-57 Objects	Condition (if any)	Geometric primitive
BCNCAR		POINT
BCNISD		POINT
BCNLAT		POINT
BCNSAW		POINT
BCNSPP		POINT
BOYCAR		POINT
BOYINB		POINT
BOYISD		POINT
BOYLAT		POINT
BOYSAW		POINT
BOYSPP		POINT
BRIDGE		POINT, LINE, AREA
CBLOHD		LINE
DAYMAR		POINT
PIPOHD		LINE
CONVYR		LINE, AREA
MORFAC		POINT, LINE, AREA
NEWOBJ	CLSNAM = Virtual AtoN, *	POINT
FSHFAC		POINT, LINE, AREA
ICEARE		AREA
LITFLT		POINT
LITVES		POINT
LOGPON		POINT, AREA
OFSPLF		POINT, AREA
OILBAR		LINE
PILPNT		POINT
PYLONS		POINT, AREA
OBSTRN	**DEPTH_VALUE < = safety contour value	POINT, LINE, AREA
UWTROC	DEPTH_VALUE < = safety contour value	POINT
WRECKS	DEPTH_VALUE < = safety contour value	POINT, AREA
SOUNDG	EXPSOU=2 and VE3D subfield< = safety contour value	POINT

*Denotes that all New Objects with the object class name pre-fix 'Virtual AtoN' must be indicated.
** DEPTH_VALUE is not an S-57 attribute, it is derived from CSP OBSTRNnn and WRECKSnn. The safety contour value is set by the user.

In the above table the following features have direct equivalents under the S-101 DCEG:

- BCNCAR, BCNISD, BCNLAT, BCNSAW, BCNSPP, BOYCAR, BOYINB, BOYISD, BOYLAT, BOYSAW, BOYSPP, CBLOHD, DAYMAR, PIPOHD, CONVYR, MORFAC, FSHFAC, ICEARE, LITFLT, LITVES, LOGPON, OFSPLF, OILBAR, PILPNT
- Bridge and Pylons are covered by the S-101 bridge and its aggregation (which would necessitate Bridge, Span Fixed/Span Opening and Pylon/Bridge Support.
- There are (e.g. PILPNT) possible changes to the geometry primitives supported which should be considered.
- Virtual AtoN have their own dedicated feature class in S-101

The final area where a translation to S-101 equivalents will be necessary is portrayal of Safety contour. The corresponding table in S-52 is shown below:

S-57 Object	Condition	Geometry
DEPARE	*DEPARE03 "UNSAFE=TRUE"	AREA
DRGARE	*DEPARE03 "UNSAFE=TRUE"	AREA
FLODOC	-	LINE, AREA
HULKES	-	POINT, AREA
LNDARE	-	POINT, LINE, AREA
PONTON	-	LINE, AREA
UNSARE	-	AREA
SLCONS	-	POINT, LINE, AREA

* DEPARE03 is not an S-57 attribute, it is a CSP.

Figure 9: S-52 definition of safety contour

Again, there is a dependency in part on S-52's conditional symbology procedures and an equivalent formulation in S-101 terms will need to be established for "DEPARE03, UNSAFE=true" for a complete formulation. The only difficult areas here are the features where their inclusion as navigational hazards is the result in part of a conditional symbology procedure under S-52 (the calculation of DEPTH_VALUE) – this requires some analysis of the S-101 PC and an appropriate definition of the features/attributes which precipitate this behaviour. In particular DEPARE03 (is dependent on group1 features and so needs careful consideration to establish whether the behaviour is consistent in S-101 (with its new group1 features))

Does TG1 object share?	Is the spatial object shared by another Group1 object?
Do LNDARE or UNSARE share?	Is the other Group1 object a LNDARE or an UNSARE?
Does Inland Water Object share?	Is the spatial object shared by a RIVERS, LAKARE, CANALS, LOKBSN or DOCARE object?
Does Liner Structure Object share?	Is the spatial object shared by at least one of the linear objects: - LNDARE, GATCON or DAMCON - SLCONS or CAUSWY with WATLEV=1, 2, 6 or empty.
LOC_SAFETY == FALSE?	Is the variable LOC_SAFETY equal to FALSE?
UNSAFE == TRUE && SAFE	Are the values of the local variables 'UNSAFE' and 'SAFE' equal to

Figure 10: Extract from DEPARE03

In DF-ECDIS terms though, satisfying the IMO PS requirements for alarm/indication behaviour is a case of establishing a framework under which the relevant parts of the IMO PS map to specific feature/attribute combinations within S-101 ENC as has been defined for S-57. This gives the ECDIS a normative definition which will define its behaviour both in planning and monitoring mode.

In ECDIS planning mode, route checking will be predicated on the largest scale ENC (S-57 or S-101)available in the SENC for each component of the route. Again, this illustrates the important of being specific at the outset whether the DF-ECDIS is expected to load data where S-57 and S-101 data intersect spatially. The idea of the IMO PS is to provide a unique (i.e. unambiguous) feature in every geographical position against which the alarm/indication algorithms are run. Should S-57 and S-101 overlap in the ECDIS (at the same scale) there is the possibility of ambiguity (one chart may show a hazard while the other may not because the classes of features precipitating alarms/indications are not one-to-one).

If "no overlapping data to be installed to the SENC" is the guidance given to manufacturers then there is little impact on the user but a responsibility on the data producer to ensure that safety (in terms of the feature attribute mappings contained in the tables within this section) is equivalent between the two charts of the area.

If "overlapping data is able to be installed to the SENC" then the user impact is one of repeated alerts/indications in areas where duplicate data exists.

The current trajectory of the S-100 product specifications is to allow Alarm/Indication behaviour to be specified for individual S-100 product specifications as well. This machine-readable definition will define the mappings presented here in dynamic form (this will allow for correction enhancement over time as well as their enhancement for other product specifications as well) – currently it is not clear whether there is a requirement to allow

enhancement of the IMO classes of alerts, alarms and indications or whether the aim is to satisfy only the requirements of the performance standard. This is to be agreed.

Interoperability.

The principles of using interoperability within S-100 systems is conceptually fairly simple. The Interoperability abstract framework provides a set of tools for establishing rules for (primarily) presentation when different S-100 product specifications cover the same geographic area and have features which are compatible. On ECDIS these product specifications take the form of overlays and provide enhanced portrayal (and, potentially, alarm/indication behaviour) to the end user and they are a key user benefit of S-100 enabled ECDIS.

The interoperability framework allows a variety of substitution and suppression of features between different layers installed within an S-100 ECDIS in a highly controlled and tightly specified way. An implementation of the interoperability framework for ECDIS will specify pre-defined layers and ways of controlling feature interaction to enhance the user experience.

How alarm/indication behaviour is factored into the behaviour of the ECDIS is crucial. The earlier sections of this document have shown how, once the SENC is partitioned into a seamless coverage of either S-57 or S-101 data the ECDIS behaviour can be similarly partitioned according to either S-52/S-64 and S-101.

The proposed method of DF-ECDIS operation would be

1. To ensure there is always a seamless coverage of ENC data (either S-57 or S-101 within the SENC)
2. To only allow S-100 product specifications to share a subset of the S-101 coverage within the SENC.
3. For the current alarm/indication as specified in the previous section to be a minimum for safe navigation (as per the IMO PS)
4. Alerts/indications within S-100 product specifications can either be <u>additional to</u> the existing alerts/indications within S-101 (i.e. a newly defined alarm or indication) or take the place of existing alerts/indications within the S-101 SENC as per the IMO PS – this remains to be decided.

The existing IMO mechanism of minimising the volume of alarms by relying on only the largest scale of data installed within the SENC (both for route checking and monitoring) is replaced by:

1. Triggering alerts/indications when the conditions are met within the largest scale S-101 (or S-57) ENC data ensuring that:
    a. Alert/Indication triggers trigger regardless of whether portrayal has been suppressed or not by the interoperability specification and settings on the ECDIS (this is in line with current ECDIS operation)
    b. The only circumstances under which alert/indication data within the S-101 SENC do <u>not</u> trigger alerts/indications is when the interoperability settings have explicitly "replaced" them with another feature for which the alert/indication is triggered. This requires synchronisation between the S-100 product specification and the underlying S-101 chart. For this reason S-100 data products over S-57 data may be problematic.

The basic principle is that the S-101 ENC should form a minimum layer for safety in terms of the alerts and indications. It is possible to supress alerts/indications from the S-101 but only in favour of those defined in additional S-100 product specifications which are also loaded onto the system. In that situation only are the S-101 alerts/indications suppressed. This places a responsibility on the data producer to ensure that the entire suite/combination of data in an area is safe for all combinations of installation and use by end users.

For example a hypothetical example would be where two cells adjoin each other with a vessel route across the two. In one an S-57 ENC has safety contour set to 15m. Because the S-57 only contains 10m and 20m contours the cell shows the 10m contour in conformance with S-52's CSP. A neighbouring S-101 cell similarly will draw the safety contour on the 10m contour as well. However if the S-101 cell contains an S-102 dataset with more detailed bathymetric data in theory a 15m safety contour could be drawn and this should be used as the basis on the s-101 ENC for triggering alerts/indications.

The core questions here are:

- whether the DF-ECDIS should also trigger a (potentially lesser priority) alert or indication when the vessel passes over the S-101 10m contour because it is passing over a feature which would be a hazard in the absence of the S-102 dataset.
- Whether data producers are content with S-100 product specifications which they issue effectively making alert/indication behaviour more precise or whether a duplicate alert should be triggered for the base S-101 layer as well. Potentially the user could be given the option here to decide to see alerts/indications for all data products or just the minimum guaranteed by S-101? This would require clarification in the IHO standards and guidance for ECDIS manufacturers.

The key observation is that alerts/indications are not triggered by portrayal – they are a separate mechanism, intimately related to portrayal but they are triggered by combinations of features and attributes at particular locations and at "largest scale" (to reduce volume) – for that reason, if the SENC is partitioned into S-57 and S-101 then the alert/indication behaviour can be made conceptually consistent with no possibility of anomalous behaviour. The correct operation of interoperability is best defined using key use cases and concrete examples such as S-102 and looking at cases where features are enhanced, suppressed in the light of the IMO triggers for alarms/indications.

ENC Co-Production

The final area worthy of discussion is how ENC production in the transition period is related to DF-ECDIS definition. ENC co-production is not primarily a subject for DF-ECDIS operation but the ability to make ENC in both S-57 and S-101 forms during the transition period should be investigated further. Earlier investigations into ENC conversion concluded the following:

1. Initial production of S-101 data from S-57 work up to a point and produce coherent ENCs which in many circumstances would satisfy validation testing and would, in all likelihood, be suitable for safe navigation.
2. The conversion process is not one to one and there are significant differences between the feature catalogues between the two products (insofar as S-57 has a feature catalogue – the encoding guidelines between the DCEG and UOC were considered side by side)
3. The judgement of whether an ENC is suitable and safe for primary navigation is down to the issuing authority – S-58 (and its S-101 equivalent) are not sufficient to guarantee safe navigation.
4. Much information is contained in the ENC within the INFORM attribution which could be used to generate S-101 data conforming to the new feature catalogue. In this way a more complete coverage over the S-101 feature catalogue would be possible.

So, is co-production automatable or will it require a large expenditure of resources from member states? It is likely to be largely automatable and tools will in all likelihood support such conversion. Member states are likely to require some tailoring of their data to co-produce both forms during the transition period and it is also possible RENCs could take on automated transformation. It will, ultimately be up to the member state to assess whether their co-production is capable of producing equivalently "safe" products for primary navigation and this is what the transition period will be oriented towards. IHO is in a key position to assist here is publishing model transformations, advice and assisting with training and capacity building both for the transition period and the eventual move to S-101 compilation.

The only remaining question is whether there should there be a validation process in place to ensure that the S-57 and S-101 datasets at least match a minimum standard of "equivalence"? This could check e.g. Alerts/Indications are common in both[5]

[5] The advantage of the model of alerts/indications we have is that they are rigidly specified so spatially/computationally it is possible to say whether two datasets will precipitate the same effects on the ECDIS given the same user parameters.

Conclusions

The current proposals at IMO/IEC level propose a transition period of some time during which ECDIS will be required to support both S-57 and S-101 (within an enhanced type approval regime) – this requirement has been termed “dual fuel” ECDIS but as yet is not defined rigidly within the relevant standards bodies and communities. The intention is also to support a number of different product specifications on the Dual Fuel ECDIS as well as new product specifications which, through a number of catalogues, present an integrated picture to the end user.

Intuitively there are no conceptual blocks to such support within ECDIS. The nature of the ENC products are similar enough to allow such functionality. Much of the feature content of ENC is 1-1 equivalent between S-57 and S-101 but some important differences exist in both portrayal and alert/indication behaviour which will require careful consideration to ensure the IMO mandated minimum level of safety is assured to end users at all times.

Some key decisions need to be made by the IHO community in terms of the underlying standards to ensure a consistent dataset reaches the dual fuel ECDIS. Some of these decisions have been outlined in this paper but are unlikely to be exhaustive at this early stage. The key ones raised are:

1. Whether coverage of S-57 and S-101 should be coincident by producers.
2. If other S-100 product specifications can overlay (and possibly interact with) S-57 ENC or whether they should be spatially contained within S-101 as a prerequisite.
3. Whether the ECDIS is required to ingest BOTH S-57 and S-101 in any one area or whether it is navigationally sufficient to only ingest and translate a single ENC layer for any area (giving preference to S-101), i.e. should the SENC be “partitioned” into areas which are only S-57 or S-101
4. To what extent the more complex alert/indication triggers are 1-1 compatible with the existing S-57 ones and what changes may be required to meet the IMO mandate for navigational safety (and how this affects end user experience).
5. How the “largest scale” equivalent concept is arrived at within all S-100 products.
6. Whether alerts/indications stemming from the ENC base layer are suppressed by other S-100 products or whether such additional products can only “add to” the minimum level defined by IMO
7. Whether additional validation tests are required to ensure S-57 and S-101 charts of the same area are “equivalent” in IMO PS terms (of safety) and the nature of ENC co-production required to support the transition period.

Action required of S-100WG5

The S-100WG is invited to:

- Note the contents of this paper as a summary of the current situation in regard to Dual-Fuel ECDIS
- Acknowledge the requirement for a more detailed and systematic specification of the capabilities and operation of such an ECDIS to guide both data producers (for ENC co-production), the ENC distribution chain and ECDIS manufacturers. This should explore and inform decision related to data production for member states and distribution bodies.
- Acknowledge the questions posed in this paper and decide how they can be resolved and documented in dialogue with the relevant communities (member states, IHO, regulatory bodies and end users)
- Note current gaps in the IHO standards baseline and the need to further (and more fully) define the Dual-Fuel ECDIS in order to inform the broader IMO community.