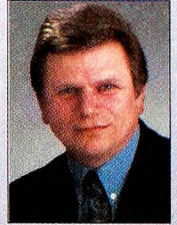


Study on ENC Loading Strategy in Relation to SCAMIN Effects and 'Overscale' Indications

By Mathias Jonas and Johannes Melles, Bundesamt für Seeschifffahrt und Hydrographie, Germany



During the last three years a number of IMO compliant ECDIS have entered the market of navigation equipment. Although their compliance have been tested according to the same requirements, i.e. the IMO Performance Standards for ECDIS, IHO S-57, IHO S-52 and the IEC 61174 test standard, some of the systems behave differently in providing basic functions of data display. Users have reported being irritated by virtually differing strategies from one make of ECDIS to another for three functions:

- (1) To load and display ENCs for specific display scales
- (2) The clutter caused by displayed information not being thinned out as the scale is reduced'
- (3) For the indication of an 'overscale' state

This study - requested at the 9th TSMAD Meeting, IHB Monaco, October 2002 - explains the back-ground of the observed effects, discusses alternative suggestions to overcome detected deficiencies and suggests future common rules for both ENC producing agencies and ECDIS manufacturers.

ENC Navigational Purposes

In the ideal case an ECDIS could display ENC data based on large scale source material at arbitrary display scales. During zoom out the ECDIS would then perform automatic generalisation for

areas and contours. Unfortunately the problem of automatic generalisation is not solved sufficiently yet. As a result there is not 'the one' ENC compiled from a specific scale which serves for virtually the whole range of display scales, e.g. 1/5,000 to 1/1,000,000. Instead, Hydrographic Offices produce several ENCs which cover identical sea areas but of different scale. Depending on the navigational task at hand, ECDIS could select and display the most appropriate ENC for the operational area. Considering this, the 'ENC product specification' (S-57 Appendix B.1) requires that each ENC must be assigned to a 'Navigational Purpose'. Clause 2.1 of ENC product specification specifies six different navigational purposes:

1 <i>Overview</i>	2 <i>General</i>
3 <i>Coastal</i>	4 <i>Approach</i>
5 <i>Harbour</i>	6 <i>Berthing</i>

By assigning an ENC or cell to a navigational purpose, the cartographer conveys to the mariner for which navigational purpose the ENC was compiled. The navigational purposes are not dedicated to distinct ranges of scales. Instead, the HOs are free to assign their ENCs to a navigational purpose which they feel appropriate for the applied generalisation and the precision of the source material. Today

there is a huge variety between the compilation scales of ENC's that are assigned to the same navigational purpose by different national HOs.

One might think that, while zooming between display scales, ECDIS would select the particular ENC most appropriate for the intended navigational purpose. However, S-57 no longer connects navigational purposes and scales together, and there are no rules defined in S-52 or within the IMO Performance standards for ECDIS stating the scale range of ENC's from which the ENC must be selected for a given display scale. Consequently, ECDIS manufacturers may construct devices which may allow the mariner to zoom in to a scale of 1:1,000 on an ENC that has been classified for 'overview' purpose, or he can zoom out to 1:1,000,000 on a cell that was assigned to the 'berthing' navigational purpose. Of course, in reality the strategies to load and display ENC's of existing ECDIS systems are more sophisticated. Generally speaking the loading policy individually developed by manufacturers is a combination of

- The display scale selected
 - The compilation scale of the ENC's in view
 - The potential underscale situation of ENC's in view
 - The potential overscale situation of the ENC's in view
 - The navigational purpose of the ENC's in view
- With regard to navigational purpose, the manufac-

turer reintroduced assigned scale bands individually. These individual scale bands as well as the specific loading mechanisms differ between manufacturers with the result that ECDIS of different types may display ENC's differently at any given display scale.

Compilation Scale and Navigational Purposes

Today ENC's are still primarily compiled from existing paper charts. The encoded compilation scale of most ENC's available is generally set to a value twice or equal to the scale of the paper source used¹, but there are no common rules for the assignment of compilation scale agreed between the Hydrographic Services. The use of the ENC scale for the display of the data content on an ECDIS should provide the most precise information for the mariner. However, it is one of the main benefits of the ECDIS concept to zoom between different display scales in order to adapt the presentation of a sea area to the mariner's task at hand.

In practice, the first indicator for an ECDIS to load an ENC is given by the navigational purpose. The navigational purpose of an ENC is coded in the file name and therefore easily accessible for a calling routine. Additional indications for a suitable display scale are given by the compilation scale coded in the CSCL entry within the cell header and the meta

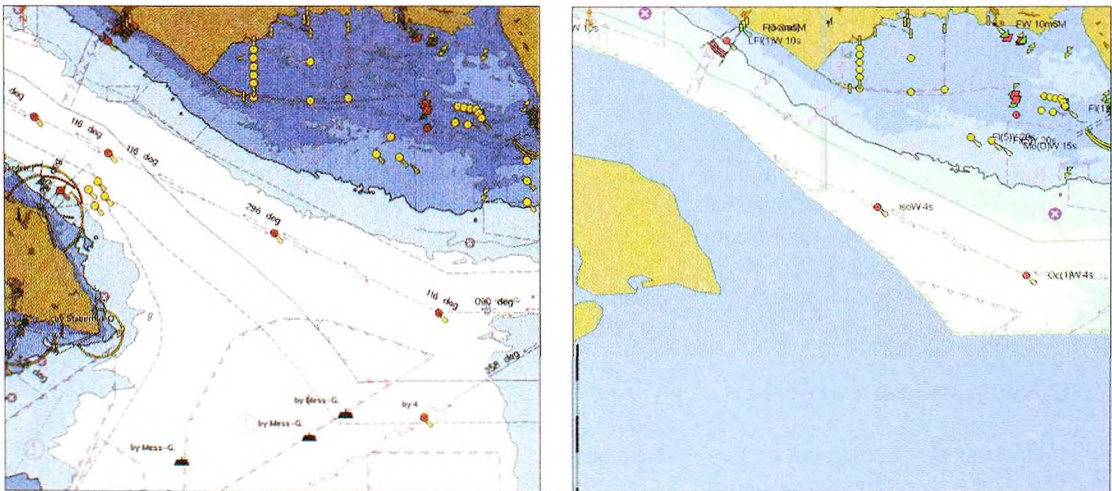


Figure 1: deviating display of identical sea area on different ECDIS operating identical ENC's

¹ As an example of 'twice the scale': $2 \times 1/20,000 = 1/10,000$

object M_CSCL as part of the ENC data. This information is only accessible if the ECDIS system has already 'opened' the ENC. Taking both information navigational purpose and compilation scale as base information for a loading strategy, the manufacturer can match these two indicators: assign individually defined scale ranges to the navigational purposes and, build up a list of all compilation scales of all cells converted to SENCs. In the same way as for the determination of the compilation scale, there are no common rules among the Hydrographic Offices for a relationship between the compilation scale of an particular ENC and the assignment of this ENC to a particular navigational purpose.

From the cartographer's point of view the optimum presentation of an ENC on an ECDIS screen could theoretically be reached using the compilation scale for the display. But in reality there are only a few ECDIS systems on which the navigational purpose of an ENC determines the selection of the display scale. This mode of ECDIS operation might be desirable from the hydrographers' standpoint but the majority of existing ECDIS behave in quite the opposite way: it is the user who pre-selects a preferred cartographic scale or a nautical mile range (as known from the radar world) that fits the particular navigation task. It is then up to the ECDIS software to search for ENCs fitting well to the pre-selected scale/radar range. This user pre-selected scale of course fits exactly to the compilation scales of the available ENCs only in rare cases. Consequently ENCs are mostly displayed in scales different from their compilation scale, but

ideally 'within' their intended navigational purpose – whatever this means. Different zoom steps should consequently make use of different ENCs – belonging to the navigational purpose best fitting the pre-selected scale. To maintain the latter, sufficient coverage of navigation areas with ENCs through all navigational purposes is needed. The ENC coverage currently available is unfortunately still a world-wide patchwork by areas and by navigational purposes with big holes in it. To overcome this situation in the interim, many ECDISes also load up ENCs for display when their navigational purposes are actually 'outside' the selected display scale.

The SCAMIN Attribute

As already stated, the display scale of an ENC is not restricted to its compilation scale – although the original concept was to display each ENC only 'within' its navigational purpose. If an ENC is shown at a far smaller scale than the compilation scale, displayed chart details are virtually merged together, forming clusters. In this case, the resulting clutter can only be avoided by the suppression of charted details. For this purpose each object class of the S-57 Object Catalogue that is symbolised by the Presentation Library for ECDIS has available to it a 'Minimum Scale' attribute, abbreviated as SCAMIN. This attribute provides the means to control a kind of 'an ECDIS. It is obvious that the use of this attribute has a significant slow down affect on both the presentation of a chart and its drawing speed.



Figure 2: Effects of SCAMIN: in 24 N.M. range: scale < SCAMIN = detailed information suppressed
In 6 N.M. range: scale >= SCAMIN = detailed information displayed

In S-57, APPENDIX B.1, Annex A – ‘Use of the Object Catalogue for ENC’ it is stated:

2.2.7 Display instructions - Attributes SCAMIN and SCAMAX

The SCAMIN of an object determines the display scale below which the object must no longer be displayed, in order to reduce clutter. In setting this level, the producer should consider both clutter and the scale at which the object is no longer likely to be necessary for navigation.

Remarks: The use of the attribute SCAMAX is prohibited. If SCAMIN is missing the object must be displayed at all scales.

SCAMIN exists to reduce clutter on the screen of an ECDIS. In other words, if the SCAMIN attribute of an object is, 50,000 the object will disappear from the ECDIS screen at the moment the navigator zooms out, and reduces the scale below 1:50,000.

It is a fact that SCAMIN is a powerful tool to control an ENC’s ‘behaviour while zooming in and out on the ECDIS screen, but it is a lot of work as well to set SCAMIN individually for each object and it requires a lot of experience to populate the appropriate objects with a proper and meaningful value for SCAMIN. This may be the reason why today only a few of the Hydrographic Offices make use of SCAMIN in their data production. Those who do it, do it individually, because there are no common

rules within S-57 how far from the compilation scale, SCAMIN attributes should be set. However, populating the SCAMIN attribute would be much easier and would require much less work if there were more generally accepted guidelines how to apply SCAMIN. But even the simply use of SCAMIN would greatly enhance the quality of ENCs, and it would make it much easier for ECDIS manufacturers to correctly handle ENCs. Indeed, harmonised rules for SCAMIN might be a final aim for the future – the ECDIS technology would benefit in due course if more Hydrographic Services made use of SCAMIN today. Those Hydrographic Services should apply the same basic assumption as is applied in deciding navigational purpose - that the values for SCAMIN should be set in relation to a scale band related to a particular ENC navigational purpose. The setting of a common definition of scale bands is as sorely missed for SCAMIN as it is missed now for setting navigational purpose.

Overscale

The SCAMIN effects discussed earlier occurs at ‘zoom out’ from an ENC whereas the topic of ‘overscale’ occurs at ‘zoom in’ of an ENC. If an ENC is ‘overzoomed’ to a display scale larger than compilation scale, the IMO requires that the user be warned of this by a so called ‘Overscale Indication’. If the mariner deliberately overscales the display by zooming in, the IMO Performance Standard for ECDIS requires that an overscale indi-

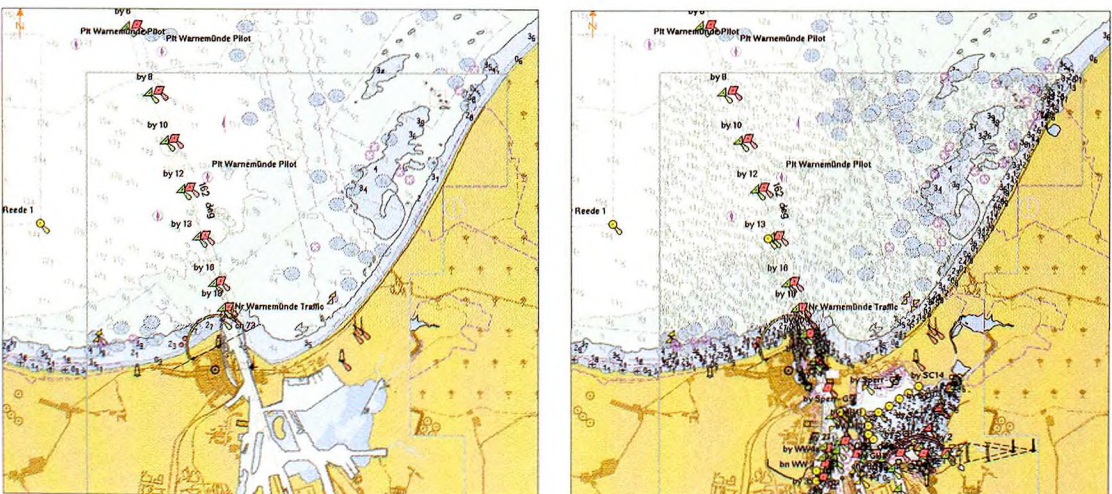


Figure 3: Alternative display of identical sea area at identical display scale, one with and the other without SCAMIN attributes encoded.

cation should be written on the display (as 'Display Base') and give the overscale factor. This 'Overscale' indication (described in detail in S-52, App.2, Annex A, Par. 4.1) is usually a text string which pops up somewhere in the user interface area.

Section 4.2 of S-52, App.2, Annex A deals with the case, when the display is made up of information from ENC's of different navigational purposes. It requires the overscale pattern ('prison bars') to be used to identify areas drawn from ENC's of less detailed navigational purposes, which are enlarged more than twice their compilation scale in order to bring them to the display scale. The overscale pattern is part of 'Standard Display' and stands for 'grossly overscaled'. Within the 'standard display', the viewing group 'Chart data coverage' controls the display of the overscale pattern.

However, it seems that some ECDIS manufacturers and type approval authorities have misinterpreted the overscale pattern to be dependent on only the compilation scale, without any connection to the display of ENC's from different navigational purposes. Consequently some ECDIS may put the overscale pattern on top of each ENC that is 'grossly overscaled'.

Furthermore, it seems that some ECDIS manufacturers and type approval authorities misinterpreted the designation of the 'prison bars' to 'standard display', i.e. that they forgot that the mariner is

allowed to switch off parts of 'standard display' intentionally. Consequently some ECDIS do not provide the mariner with the option to intentionally remove the display of the overscale pattern.

It was never intended that the prison bars should be applied to the ENC on which the ship is located, no matter how large the overscaling factor is. If the ship moves into one of the smaller scale ENC's of a multiple-ENC display, the overscale factor of the overscale indication should change to reflect the larger degree of overscaling, but the 'Prison Bars' overscale pattern was intended to disappear. But indeed, this intention was not documented in S-52 at all. In addition, the disappearance of the 'prison bar pattern' from the display at the very moment when the ship enters the affected ENC might be technically hard to control and may confuse the user as well.

Independent from these noted misinterpretations and technical problems, the setting of a common definition of scale bands could also be taken as an opportunity to reconsider the definition of 'grossly overscaled' as an enlargement by 2 or more times their compilation scale. The rules could potentially be changed in a way that the 'grossly overscale' case does not occur as long as a cell is displayed 'within' the scale band of its navigational purpose. In addition, consideration could be given to the ratio of 2 for enlargement interpreted as 'grossly overscaled' and a larger value may be more appropriate.

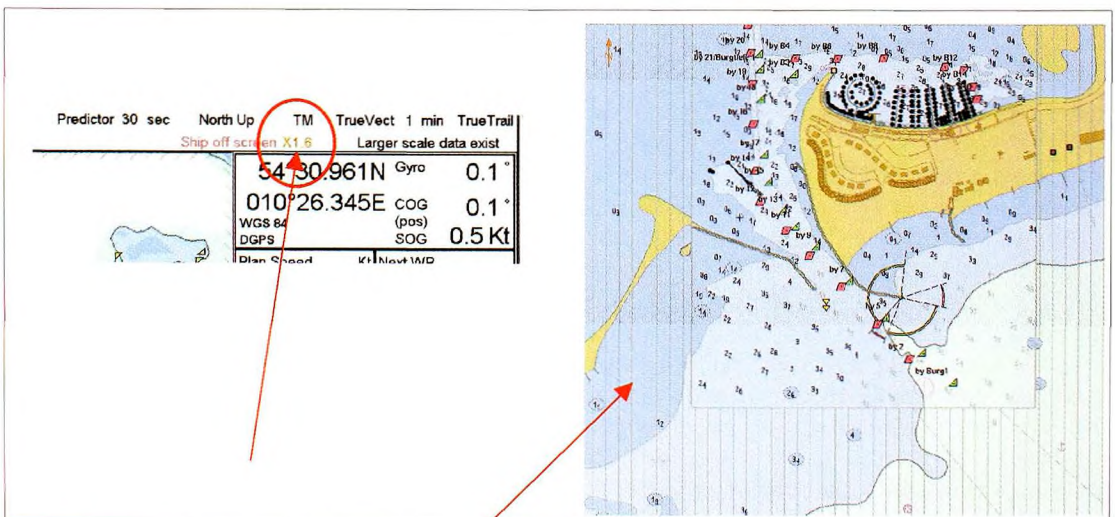


Figure 4: Overscale indication and 'grossly overscaled' pattern

Relationships between Navigational Purposes, Compilation Scales and SCAMIN

The assignment of ENC to navigational purposes, their compilation scale, the application of SCAMIN and the indication of the overscale state, are not technically linked to each other in the first place. However, due to the individual ECDIS strategies to load cells in relation to the display scale selected by the user, all four items affect each other: The following examples of ENC loading strategies which are used by a number of different ECDIS manufacturers, showing the effects of varying processing methods in dealing with the SCAMIN attributes and the 'overscale' indication, make the need for harmonised rules obvious.

Chart Data Selection for Display

Basically, there are two common philosophies to control the extent of the chart view: Either the mariner selects a display scale, or a – radar like – display range. Potentially there is a third option: the user selects a distinct navigational purpose and the system loads the ENC at the of the location of the ship using its compilation scale. This strategy would of course lead to a number of ECDIS problems, e.g. adjacent ENCs of different compilation scales near the ships location, different compilation scales in one cell using the meta object M_CSCL and so forth. Consequently today there is no ECDIS on the market that operates in this way and therefore this case is not considered in this paper any further.

Scale Oriented Display

Selecting a display scale in ECDIS usually means choosing from a list of fixed scales, for example 1:500,000, 1:250,000, 1:100,000, 1:75,000, 1:50,000, 1:25,000, and 1:10,000. In order to load an ENC of navigational purpose 3 'coastal' and compilation scale 1:180,000 the manufacturer may assign the ENC internally to both 1:250,000 and 1:100,000 display scale but this ENC will never be displayed at its actual compilation scale. Thus, SCAMIN attributes should in practice have values with regard to the list of selectable display scales, and which are smaller (or numerically larger) than the actual compilation

scale. For example, if the default SCAMIN is set to 1:250,000, all affected objects would be suppressed on the 1:250,000 fixed display scale.

This example demonstrates that a standardised list of display scales for ECDIS user interfaces would support the cartographer choose appropriate SCAMIN values for scale oriented ECDIS display modes.

Range Oriented Display

Mariners prefer to think in ranges, because they are used to RADAR. About half of the approved ECDIS systems world-wide offer a list of ranges from which the mariner can select the range most appropriate for the situation. The range orientation is currently going to get more importance due to the appearance of radar devices of the so called 'Chart Radar' class. The applicable standard was finalised by the International Electrotechnical Commission (IEC) (IEC 60936-4) in 2002 and the first approved chart radars will enter the market soon. This new class of radar combines the radar image with the display of ENCs as background and is strictly range orientated by its nature of being a radar.

Range oriented ECDIS as well as the chart radar, share the problem of assigning ENCs of different navigational purposes to their ranges. The IMO ECDIS Performance standards requirement a minimum 270 mm x 270 mm chart area, together with the resolution requirements usually results in the use of 21" CRT-monitors/19" flat panels with 1280 x 1024 pixel resolution for ECDIS installations. The application of radar ranges to those types of monitors results in a list of scale ranges (see figure 5, 1st and 2nd columns). The scales that result from ranges are seldom traditionally rounded numbers. This makes it difficult to match a standard scale list with ranges.

However, a list of standardised display scales adapted to radar ranges would also be very welcome in this case. The steps in between the scales in this list should be small enough that odd scales of display ranges do not grossly deviate from the closest rounded scale value. The resulting standard scale list therefore should not differ more than ten percent from the original scales resulting from ranges on a 21" monitor/19" flat panel (see

Selectable range	Fitting scale on 21" Monitor 1280x1024 Resolution	Standard scales (rounded)
200 NM	1:2,744,000	1:3,000,000
96 NM	1:1,320,00	1:1,500,00
48 NM	1:659,000	1:700,000
24 NM	1:330,000	1:350,000
12 NM	1:165,000	1:180,000
6 NM	1:82,000	1:90,000
3 NM	1:41,000	1:45,000
1.5 NM	1:21,000	1:22,000
0.75	1:10,500	1:12,000
0.5 NM	1:6,900	1:8,000

Figure 5: Relationship between Radar ranges and standard scales on 21" monitors

Selectable range	Fitting scale on 21" Monitor 1280x1024 Resolution	Assigned Navigational purpose	Available ENC/Compilation scale on position to be loaded
200 NM	1:2,744,000	Overview	XX1xxxx.000 CS: 1:1,500,000
96 NM	1:1,320,00	General	XX2xxxx.000 CS: 1:850,000
48 NM	1:659,000	Coastal	XX3xxxx.000 CS: 1:150,000
24 NM	1:330,000		XX4xxxx.000 CS: 1:50,000
12 NM	1:165,000	Approach	XX5xxxx.000 CS: 1:20,000
6 NM	1:82,000	Harbour	XX6xxxx.000 CS: 1:5,000
3 NM	1:41,000		
1.5 NM	1:21,000		
0.75	1:10,500		
0.5 NM	1:6,900		

Figure 6: Loading strategy for 'Coastal' ENCs are available

Selectable range	Fitting scale on 21" Monitor 1280x1024 Resolution	Assigned Navigational purpose	Available ENC/Compilation scale on position to be loaded
200 NM	1:2.744,000	Overview	XX1xxxx.000 CS: 1:1.500,000
96 NM	1:1.320,00	General	XX2xxxx.000 CS: 1:850,000
48 NM	1:659,000	Coastal	
24 NM	1:330,000		
12 NM	1:165,000	Approach	XX4xxxx.000 CS: 1:50,000
6 NM	1:82,000	Harbour	XX5xxxx.000 CS: 1:20,000
3 NM	1:41,000		
1.5 NM	1:21,000	Berthing	
0.75	1:10,500		XX6xxxx.000 CS: 1:5,000
0.5 NM	1:6,900		

Figure 7: Loading strategy if no 'Coastal' but 'Approach' ENC's are available

figure 5, 3rd column). Note that the scales in the standard scales column are always smaller or equal to the numerical scale that results from the selectable range:

However, the assignment of radar ranges to a list of standard scales is not helpful today because of two reasons:

- Navigational purposes are not defined in relation to distinct scale bands
- A selection of fixed compilation scales as potential standard scales are not harmonised between HOs

As a result the above recommended list of standardised display scales is related to existing IHO standards. For the implementation of ECDIS, the individual ECDIS manufacturers are now forced to assign ENC navigational purposes to their own versions of scale ranges: In practice they reintroduce navigational purpose scale bands assigned to radar ranges and establish an ENC loading policy which is mainly based on their individual scale band definition. This policy is also influenced by the fact that the current ENC coverage for sea

areas in general, but particularly for the variety of navigational purposes, is still poor. In this difficult situation for commercial success, the ECDIS manufacturers developed different strategies to display ENC's – if there are any – useful for navigation for a wide range of scales/ranges. The following example (Figure 6), showing the loading strategy of an approved ECDIS of a prominent manufacturer, illustrates the general behaviour of range oriented ECDISes:

Figure 6 shows the assignment of navigational purposes to ranges and – as an example – applicable ENC's through all of the navigational purposes. Assuming that the user selects 12 NM range for display, the ENC XX3xxxx.000 / CS: 1:150,000 of navigational purpose 'Coastal' will be displayed.

Figure 7 shows how this ECDIS behaves if there is no appropriate cell of 'coastal' navigational purpose available for this sea area: the ENC of the next more detailed navigational purpose 'approach' is loaded. Assuming that SCAMIN for some objects is at half the compilation scale (say 1:100,000), then those objects would be suppressed on the display at 12 NM range.

Selectable range	Fitting scale on 21" Monitor 1280x1024 Resolution	Assigned Navigational purpose	Available ENC/Compilation scale on position to be loaded
200 NM	1:2.744,000	Overview	XX1xxxx.000 CS: 1:1.500,000
96 NM	1:1.320,00	General	XX2xxxx.000 CS: 1:850,000 Grossly Overscaled
48 NM	1:659,000		
24 NM	1:330,000	Coastal	
12 NM	1:165,000		
6 NM	1:82,000	Approach	
3 NM	1:41,000	Harbour	XX5xxxx.000 CS: 1:20,000
1.5 NM	1:21,000		
0.75	1:10,500	Berthing	XX6xxxx.000 CS: 1:5,000
0.5 NM	1:6,900		

Figure 8: Loading strategy if no 'Coastal', no 'Approach' but 'General' ENCs are available

Selectable range	Fitting scale on 21" Monitor 1280x1024 Resolution	Assigned Navigational purpose	Available ENC/Compilation scale on position to be loaded
200 NM	1:2,744,000	Overview	XX1xxxx.000 CS: 1:1,500,000
96 NM	1:1,320,00	General	XX2xxxx.000 CS: 1:850,000
48 NM	1:659,000		
24 NM	1:330,000	Coastal	XX3xxxx.000 CS: 1:150,000
12 NM	1:165,000		
6 NM	1:82,000	Approach	XX4xxxx.000 CS: 1:50,000
3 NM	1:41,000	Harbour	XX5xxxx.000 CS: 1:20,000
1.5 NM	1:21,000		
0.75	1:10,500	Berthing	XX6xxxx.000 CS: 1:5,000
0.5 NM	1:6,900		

Figure 9: Loading strategy if during zoom in, both 'Approach' and 'Harbour' ENCs are available

If it is further assumed that an 'approach' ENC for the operating area is also not available, the ENC of the next less detailed navigational purpose – in this case of navigational purpose 'general' is loaded. This ENC is dramatically 'grossly oversized' but only marked with the 'prison bar' pattern (see Figure 8) if adjoined by 'coastal' or larger scale cells and as long as this ENC is not occupied by the ship.

These examples of ENC loading only describe the general principles, not the complete behaviour of the different loading strategies of the individual ECDIS manufacturers. There are of course some special cases, such as 'harbour' ENCs which should not be displayed beyond 12 NM range and 'Overview' ENCs should be limited to being displayed down to the 48 NM range. Again we must stress that these strategies have been developed as an interim measure, mainly due to the lack of S-57 coverage in general and through the navigational purposes. A general conclusion made for different loading strategies is as follows:

- ENCs of more detailed navigation purposes have priority over ENCs of less detailed navigation purposes
- Loading order starts from navigational purpose 'harbour' and continues upwards until 'overview'. The loading is complete when the whole display screen is filled with ENCs qualified best for the selected display scale, by its compilation scale/navigational purpose
- If there are no qualified ENCs for the selected scale available 'underscaled' ENCs have precedence over 'overscaled' ENCs, taking the availability of SCAMIN within the 'underscaled' ENCs into account



Figure 10:
Display of
'harbour' ENC
overlaid on
'approach'
ENC

Another example derived from practical experience is the multiple loading of ENCs to be displayed at the same time: imagine a vessel sailing in coastal waters approaching an estuary. The mariner operates his ECDIS at 6 NM range but during his approach to more congested waters he switches to 3 NM range. The ECDIS will now load the 'harbour' ENC and overlay it to the 'approach' ENC which is already loaded and still displayed (see Figure 10). Figure 9 explains a possible effect of SCAMIN setting: assuming the SCAMIN is set to half the compilation scale, that is to 1:40,000, affected objects are suppressed on 3 NM range display because the actual display scale of 1:41,000 is just the fraction of 1,000 smaller.

How Should an Optimised ECDIS Behave?

As shown in the course of this paper, there are unfortunately some differences between the originally intended and the 'real' behaviour of existing ECDIS. The problems highlighted previously make it quite clear, that it is not yet possible to demand an ECDIS which provides all data dependent capabilities in an optimum way. Quite a number of the problems result from the availability of ENCs, their characteristics and their representation. But what are the prerequisites for an 'optimised' ECDIS from the data perspective? There are basically three different areas of potential optimisation: ENC coverage/attribution/designation, ENC processing, and ENC display.

ENC Coverage/Attribution/Designation

One of the main reasons for the problems with ENCs described earlier is the fact that (in contrast to private vector data) ENCs have a variety of originators – the different national HOs. All of the ENCs available are basically produced according to the IHO data exchange standard S57 but they differ slightly from HO to HO. One could say that all of them make use of the same 'language' but using it in slightly deviating 'dialects'. Obviously it is complicated for ECDIS manufacturers to adjust their systems to allow for all of those 'dialects' in a consistent manner. On the other hand not all of the variety of ENC processing methods of the different ECDIS manufacturers make optimal use of all of the ENC characteristics available.

Conclusion:

It seems that Version 3.1 of S57 gives the data-producers too much freedom for data production. There is a need to harmonise the application of S57 for ENC production without changes to S57, Edition 3.1 itself nor the Use of the Object Catalogue (UOC), Edition 2.1.

As already mentioned, reliable algorithms for online automatic generalisation of one ENC for different display scales are not available today, therefore an ECDIS uses different ENCs for different scales. In the ENC world these different levels of generalisation are called navigational purposes or navigational purposes. In the ideal case there should be a smooth non-detectable transition between ENCs of different navigational purposes. This goal could be reached if the following conditions are fulfilled:

- All navigational purposes applicable to the particular sea area are covered by ENCs
- The SCAMIN attribute is set for point and area objects ideally to agreed guidelines, and these SCAMIN values are again harmonised with scale bands designed to the navigational purpose of the particular ENC

The setting of SCAMIN attributes is a mechanism of ENC generalisation which has no model in the paper chart world. By evaluation of the individual SCAMIN attribute values, ECDIS can remotely decide to display an object dependent from the selected display scale. In the paper-chart world the matter of generalisation is in responsibility of the individual HO who issues the chart and this is true for the setting of SCAMIN in the ENC world as well. This setting must remain with the sole responsibility of the national HO, however, from the ENC processing and display point of view, harmonised guidelines between the different national HOs would be desirable.

A potential agreement about harmonised SCAMIN setting procedures must consider the direct relationship with the loading strategy of an ECDIS. It is vital to decide if SCAMIN values should only be used within one navigational purpose or across several navigational purposes. Assuming there will be full ENC coverage through all navigational purposes, the ECDIS could potentially switch from one navigational purpose to the next navigational purpose while zooming out and SCAMIN values of an

ENC would have to fit only to the assigned navigational purpose. But if a navigational purpose is missing (e.g. there is only harbour and coastal and no approach) ENCs from the better navigational purpose may remain displayed at smaller scales while zooming out. For this case SCAMIN settings must get values beyond the range of their assigned ENC navigational purpose. This of course leads to a lot of extra work on the ENC production side. Indeed, this time consuming and laborious task might be redundant one day if scale bands for navigational purposes and loading strategies are better harmonised and ENC coverage through the navigational purposes are more complete: in this case SCAMIN settings could be restricted to the value of the smallest scale of the particular navigational purpose band.

The potential introduction of harmonised procedures of SCAMIN settings is inseparably combined with the need for a commonly agreed definition of scale bands assigned to the different navigational purposes/navigational purposes. Version 2 of the S57 originally included such scale bands and it seems to be desirable to reintroduce comparable arrangements for current data production again.

Conclusion:

Besides the need for enhancement of data production for all navigational purposes affected in distinct sea areas, the introduction of agreed procedures for the setting of SCAMIN and the reintroduction of navigational purpose scale bands are the vital requirements in this area. The setting of values for the compilation scale feeds to purposes here: It gives directions to which navigational purpose (scale band) the particular ENC belongs to, and represents a base setting from which all of the individual SCAMIN values will be derived.

ENC Processing

While zooming in or out, ECDIS ideally always loads the ENC belonging to the navigational purpose most appropriate to the selected display scale. This of course needs sufficient coverage for the operational area in general and through the navigational purposes as well. Many national HOs have already started the production of ENCs and the amount of available ENCs increases continuously from year to year. But for the foreseeable future, a

full coverage will only be available in areas with busy harbours and near the main shipping routes regularly surveyed by the more advanced HOs. The world-wide ENC coverage will remain patchy for a long duration, and therefore existing ECDISes must have functions to allow the systems to accommodate situations where there is a limited amount of ENCs available, e.g. only one navigational purpose or where a navigational purpose is missing and the system has to jump over that gap, e.g. directly from coastal to harbour. As long as this situation exists, a simple loading strategy of the most appropriate ENCs for the selected display scale is not applicable.

Conclusion:

For the interim some commonly agreed recommendations how an ENC loading strategy should work would be desirable. Common rules for SCAMIN settings and reintroduced navigational purpose scale bands would definitely form the ideal basis for such recommendations.

ENC Display

In theory an ECDIS should provide a presentation which is clear and unambiguous under all ambient light conditions and operational circumstances. But modern ECDIS combine charted information based on ENCs overlaid with operational information such as own ships symbol, Variable Range marker (VRM) and Electronic Bearing Lines (EBL), planned and monitored routes, radar overlay, ARPA and AIS targets. Some manufacturers may add area information for weather routing and other useful add-ons. An enormous variety of information is going to enter a screen of restricted size and a restricted number of colour and symbol combinations. The danger of misinterpretation because of information overload is a vital one and each form of clutter that can be intentionally suppressed should be encoded to provide for this. For the operational information overlay, the mariner is fed with options to configure their display by switching on an off features he may need for the task at hand. For the charted information the situation is different: it would be laborious for the mariner to switch classes of chart objects on and off individually. Therefore SCAMIN is an essential feature here. Provided that the ENCs in use carry this attribute, for display scales where the density of the data is so high that the screen will be cluttered, less

important chart objects will be thinned out by the use of SCAMIN very effectively. Experiences from practice have evidently shown the advantages of SCAMIN settings and their automatic processing.

Conclusion:

A special function that allows the mariner to switch the use of SCAMIN on and off on his request, combined with appropriate training, could improve the ECDIS operation and could encourage HO's to apply SCAMIN settings as well.

When the display scale gets larger than the compilation scale, the overscale indication may still be acceptable, however the setting of the compilation scale should take care of corresponding radar ranges. The event when a 'grossly overscaled' pattern is triggered, should only occur if an ENC is displayed outside the possibly reintroduced scale bands for navigational purposes. Moreover, this pattern should remain on the display for the case when the ship's symbol enters the ENC displayed as 'grossly overscaled' in order not to confuse the mariner.

What Is To Be Done?

The preceding section contains general action items in italics which can help to optimise the ECDIS currently installed and encourage the future improvement of new ECDIS generations. Most of the activities proposed below can be performed by the ENC producers without any violation of the S57 standard in force. At the same time the work of the C&SMWG for the improvement of the display standard S52 may benefit from these suggestions.

More Prescriptive S57 Standard

S57, Edition 3.1 and the applying UOC, Edition 2.1 are frozen. For future editions of S57, like the envisioned edition 4.0, a more prescriptive coding regulations might be considered and the UOC may then be adapted appropriately. However, this doesn't help for Edition 3.1 which is in place for the foreseeable future. Improvements can be made here by making efficient use of the proposed ENC bulletin board for 'good coding practice' on the IHB-server. The TSMAD working group of the IHO has already used these means to recommend procedures and encoding hints.

Availability of Data

This problem can of course not be solved by optimised application of the standards. The IHO and the advanced HOs should still continue to support enhancements of ENC production and distribution mechanisms.

Setting of Compilation Scale

The ENC header field CSCL gives basic direction to which display scale an ENC belongs and when it is loaded by the different ECDIS. If the scale of the paper chart on which the production of the ENC was based is used as CSCL, the ENC is usually loaded too early. In addition to this, while zooming into the data the overscale warning is triggered too early compared to the resolution of a computer screen.

- Good experiences have been made by a number of national HOs (reported by Germany, Poland, Portugal, Spain, Sweden) to set the CSCL to approximately twice the scale of the paper chart on which the ENC is based². This practice of setting CSCL to double the paper chart scale value is recommended herewith as a general agreement
- One alternative solution for an HO would be to display the ENC at chart scale on an ECDIS. If the display is cluttered, the scale is increased until the display is uncluttered. The HO then asks the question, 'is the ENC safe to use at that scale'? If the answer is yes, that scale becomes the value of CSCL
- Another alternative would be for the encoder only to include a selection of the data that appears on the paper chart to prevent clutter at paper chart scale. However, one could argue that this goes against S-52. 3.1 (b), which states that the ENC should contain 'all information relevant to navigation at present depicted on the paper chart'

If in the future more source data is directly used for ENC production, individual compilation scales using CSCL in the header, or more individually encoded by using M_CSCL still has to be provided by the cartographer. For his decision he should keep in mind, that this ENC will be displayed with

the limited resolution of a computer screen and not on printed paper. The second option noted above might then be a useful interim approach until more experience is gained.

SCAMIN Settings in Relation to Navigational Purposes and Scales

SCAMIN is of overwhelming importance for a useful ENC representation. HOs should be encouraged to use it in general, i.e. the IHO should make it mandatory to use SCAMIN. Even if SCAMIN is only used in a non-harmonised way, this is far better than not using it at all.

Because of the inseparable nature of the settings of SCAMIN and scale bands assigned to navigational purposes the following example explains the current handling at ENC data production for German waters done by BSH (Federal Maritime and Hydrographic Agency of Germany)³.

This procedure described below constitutes a combination of arrangements for two topics which are proposed for wider acceptance herewith:

- Designation of scale bands to distinct navigational purposes/navigational purposes
- Guidelines to set SCAMIN values for different object classes of ENCs, dependent on their assignment of navigational purposes

For the matter of SCAMIN setting procedures the German approach is only given as one 'how to' example which might be too laborious for HOs who provide larger ENC coverage.

Scale Bands Assigned to Navigational Purposes

The assignment of scale bands to navigational purposes by BSH resulted from the accuracy and the scales of the digitised paper chart sources. In addition to these basic arrangements for ENC production at BSH, figure 11 contains a reference to radar ranges relating to the display scale. Although basically not intended, the assignment of scale bands and the values of SCAMIN seem to fit quite well with the usual radar ranges.

² As an example of 'twice the scale': $2 \times 1/20,000 = 1/10,000$

³ Based on: H. Fasterding, Guideline for the use of SCAMIN, Edition 1.2, BSH Rostock, August 2002

SCAMIN Settings

For the matter of SCAMIN settings it should be noted that this guideline does not necessarily substitute individual SCAMIN settings due to the individual circumstances of sea areas contained in ENC's. Well founded exemptions are permitted at any time. First positive experiences with the procedures described below have been gained with the application of these procedures for ENC production at BSH.

Each object gets a virtual scale band. This means that the cartographer decides for each individual object down to which scale band it should be displayed. The common rules for generalising navigational charts are used as criteria to be applied. This means that all objects which are shown in small scale navigational purpose must be shown in all larger-scaled navigational purpose as well. The setting of SCAMIN across navigational purposes leads to positive effects in the current situation of incomplete ENC coverage through navigational purposes.

(1) Group 1- and meta objects do not get any SCAMIN (S57, Use of object catalogue Ed. 2.1)

(2) Fixed values for SCAMIN

The following objects get SCAMIN-value 1,000 00

ACHARE	ADMARE	BUAARE ^{CATBUA 1}	CBLSUB	COALNE
CONZNE	DEPCNT	DEPAREline	DWRTCL	DWRTPT
EXEZNE	FSHZNE	ISTZNE	MIPARE	RCRTCL
RECTRC	RCTLPT	SLCONSI ^{line *4}	TESARE	TSELNE
TSEZNE	TSSBND	TSSLPT		

(3) SCAMIN-values depending on navigational purpose-band down to which the object should be displayed:

When the compilation scale is in the vicinity of two scale bands, the cartographer decides which navigational purpose will be assigned to the cell

The rules for setting SCAMIN values refer to only those objects which are displayed within the assigned scale band.

Navigational purpose	SCAMIN value	Assigned scale band	Selectable radar ranges	Fitting scale on 21" monitors
Berthing	12,499	> 1.5,000	0.5 NM	1:6,000
Harbour	24,999 49,999	1:2,000 – 1:10,000 1:10,000 – 1:20,000	0.5 NM 0.75 NM 1.5 NM	1:8,000 1:10,500 1:21,000
Approach	99,999	1:20,000 – 50,000	3 NM	1:41,000
Coastal	299,999	1:50,000 – 1:150,000	6 NM	1:82,000
General	799,999	1:150,000 – 1:400,000	12 NM 24 NM	1:165,000 1:330,000

Figure 11: Designation of SCAMIN values to navigational purpose bands for German ENC production practice

(4) Exceptions

- Cases which do not get a proper result using Figure 11:

In such cases the cartographer can use the following approximation:

Compilation-scale multiplied by 4 minus 1.
Example: compilation scale 1:6,000 x 4 = 1:24,000 – 1 = 1:23,999

Note! The larger the scale the smaller the displayed area, allowing SCAMIN to be handled more individually. However, at a small scale, objects covering large areas certainly require uniform handling of SCAMIN.

- Areas covered with M_CSCL-object

In such cases the cartographer decides if the values contained in Figure 11 are suitable, otherwise the above approximation is used to evaluate the SCAMIN value for those objects that are to be displayed only within the threshold of the CSCALE attribute value

- Piles (S-57 object PILPNT):

The approximation 'compilation scale multiplied by 2 minus 1' can be used. Avoidance of

clutter at smaller scales leads to the individual handling of the SCAMIN values of these objects. It is recommended that a uniform value be used within one ENC

(5) Example

The attached example shows a SCAMIN-setting based on an existing paper-chart.

The following SCAMIN-values were encoded:
- 299,999 for objects to be displayed down to the navigational purpose 'coastal' and shown on the

⁴ bordering land-areas

⁵ According to the SCAMIN-Philosophy below it should be 1:24,999.



Figure 12: Inlet Warnemünde main chart compilation-scale in ENC 1:2,500

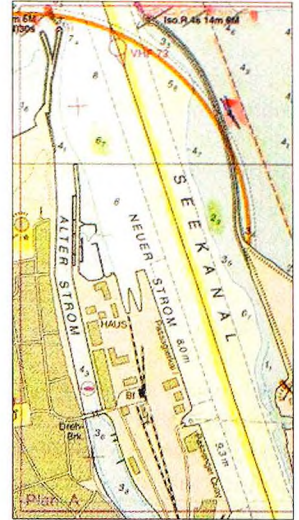


Figure 13: Rostock harbour main chart compilation scale in ENC 1:6,250

- corresponding paper-chart (marked yellow)
- 99,999 for objects to be displayed down to the navigational purpose 'approach' (marked red)
- 49,999 for objects to be displayed in the navigational purpose 'harbour' but down to smaller scale-ranges (marked green)
- 25,000⁵ for objects to be displayed in the navigational purpose 'harbour' but only when zooming into larger scale-ranges. In this example showing 'Warnemünde' inlet, the objects within the inlet which also appear in the main-chart, are marked (orange) (compare Figure 12 and Figure 13)
- 12,999 for objects in the inlet, which are to be displayed only on a zoom-scale corresponding to the compilation scale of the inlet

Unified Loading Policy

Basics of unified loading policy recommendations:

- (1) The loading mechanism uses the navigational purpose as a first priority, then the ENC header value of CSCL as the second priority, then the attribute values of the meta object M_CSCL as a third priority.
- (2) ENCs of more detailed navigation purposes have priority over ENCs of less detailed navigation purposes.
- (3) Loading order generally starts from navigational purpose 'harbour' and continuous upwards until 'overview'. The loading is complete when the whole of the displayed screen is filled with ENCs qualified best for the selected display scale by

its navigational purpose as a first priority and its compilation scale as a second priority.

- (4) If there are no qualified ENCs for the selected scale available 'underscaled' ENCs have precedence against 'overscaled' ENCs taking the availability of SCAMIN within the 'underscaled' ENCs into account.
- (5) If ENCs are already loaded for the selected display range/scale and the user zooms into a more detailed range/scale equal to 6 NM or smaller (i.e. 5 NM), more detailed available ENCs may be loaded in addition and overlay to the less detailed ENCs already loaded.

Notes:

- This unified loading policy should be interpreted as recommendations in the sense that they are not mandatory nor will they reach this status within the foreseeable future
- It is up to the individual manufacturers to optimise their display engine until more practical experience has been gained and more complex requirements may be agreed
- The unified loading strategy would be supported by ENCs consisting of full world coverage at 1:10,000,000 officially issued by IHO

Unified Handling of 'Overscale' Indications

Basics for handling 'overscale' indications

- (1) No 'grossly overscale' pattern is to be displayed as long as the selected display scale is

inside navigational purpose of the ENC's displayed – assuming navigational purpose scale bands will be reintroduced

- (2) If ENC's of different navigational purposes cover the screen and some of them do not belong to the navigational purpose of the selected display scale, those overscaled ENC's shall be indicated with the 'overscale' pattern
- (3) If an ENC is marked with the overscale pattern, this pattern shall remain displayed under all operational circumstances in order not to confuse the user
- (4) The extended use of M_CSCL meta object for a huge variety of compilation scales within one ENC should be avoided to suppress ever changing overscale indicated parts of the display if the mariner zooms in and out within an ENC

Resulting Actions of International Bodies

The following suggestions for action at the international level may help to define common rules and strategies in order to optimise current and future ECDIS generations. The following list indicates possible activities for international organisations affected:

- (1) Agreed tentative definition of scale bands for navigational purposes and introduction of harmonised rules for SCAMIN setting:
 - Discussion on technical level (e.g. TEWG of IC-ENC) of different RENCs, i.e. IC-ENC and PRIMAR
 - provisional implementation by ENC producing RENC member states
 - Report of experiences to TSMAD meeting
 - Adoption by TSMAD to be published within the S-57 bulletin of 'good coding practice' at IHB server
 - Consideration by CHRIS
- (2) Agreed recommendation of loading policy for ENC's to be developed by C&SMWG:
 - Discussion on technical level in close cooperation with industry at C&SMWG meeting
 - Forwarded to future S-52, Ed. 3.3 and/or future S-52 bulletin at IHB-Server
 - Consideration by CHRIS

- (3) Amended requirements for overscale warning for future S-52, Ed. 3.3

- Discussion on technical level in close cooperation with industry at C&SMWG meeting
- Forwarded to future S-52, Ed. 3.3 and/or future S-52 bulletin at IHB-Server
- Consideration by CHRIS/IEC/IMO

Biography

Dr Mathias Jonas, is presently responsible for the performance of legal type approval of Electronic Chart Systems, Integrated Navigation Systems, Voyage Data Recorder, Satellite Navigation receiver at Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency). After passing examination for nautical officers at the Maritime Academy of Rostock-Warnemünde in 1986. Employed as scientific assistant at the Maritime Academy from 1987 to 1991. Promoted about theoretical problems of manoeuvre prediction for ships at the University of Rostock in 1992. Involved in the SHOPSY project at ISSUS, Hamburg from 1991 to 1993. Since 1994 employed at BSH, Hamburg.

Johannes Melles joined the Federal Maritime and Hydrographic Agency (BSH) in 1986, having obtained a Master of Science degree in geophysics from the University of Hamburg.

During his first year at the BSH he worked on the development of a small GIS system for German research vessels. From 1987 to 1989 he worked as a marine geophysicist for the German company Preussag in the Circum-Pacific region.

In 1989 he rejoined the BSH and started his work in the hydrographic department. Among other activities he was responsible for the first German ECDIS projects and was heavily involved in the development of the IHO data exchange standard (S57). Currently he is working on the development and introduction of the new BSH production system NAUTHIS (Nautical Hydrographic Information System).

He is also chairman of the IHO working group SNPWG (Standardization of Nautical Publications Working Group), which works on the integration of nautical publications into ECDIS.

E-mail: mathias.jona@bsh.de, johannes.melles@bsh.de