Recommendations for IHO Guidance on ENC conversion

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EXECUTIVE SUMMARY

Approach

1. In November 2023, the IHO-Singapore Innovation and Technology Laboratory (IHO-SG Lab) and IIC Technologies jointly facilitated the S-57 to S-101 ENC Conversion Workshop in Singapore. The IHO-SG Lab is a joint initiative between the IHO and the Maritime and Port Authority of Singapore (MPA). The Conversion Workshop was generously funded by the IC-ENC.

2. The ENC conversion workshop was held with the main aim of testing the S-65 Annex B (ENC conversion guidance document Edition 1.1.0) and most of the lessons learnt derived from the training conducted and feedback from member States in attendance. The workshop was focused on a practical approach with data producers bringing their own data and third-party software tool manufacturers supplying their respective software for testing and use by the participants.

3. Over 20 professionals from 20 IHO member States spanning North and South America, the Middle East, Europe, and Asia and Oceania gathered to enhance their skills across various software tools.

4. Recognising the experience level of the participants, the workshop began with an initial training session covering the relevant parts of S-100, the structure of S-101 and the main differences producers face between S-57 and S-101. Participants learned about the fundamentals of data conversion, via the mappings of S-57 objects to S-101 features.

5. With a common level of understanding established, S-65 Annex B was used as the basis for practical exercises conducted throughout the latter half of the workshop. These exercises progressed from simple S-57 conversion to more complex mappings described in S-65 Annex B, involving validation and verification of object/feature mappings in the converted data. The exercises encompassed all parts of S-65 Annex B and utilised various third-party software tools.

6. This report examines how the current IHO guidance on ENC conversion, particularly IHO S-65 Annex B and could be improved, and how well it worked when tested in a real-world environment. It includes an annex (Annex A) providing background information on the setup and execution of the workshop.

Overall Conclusion

7. S-65 Annex B is a sound vehicle for describing the IHO's preferred mappings between S-57 and S-101 and provides a foundational reference for both data producers and software tool implementers. No factual errors were found during the course of the workshop, and some suggestions for improvement to the text and inclusion of diagrams is included in the subsequent sections.

8. S-65 Annex B, however, could usefully be enhanced to provide:

    a. Normative descriptions of all conversions, preferably in a machine readable form;

    b. More detailed categorisation of the manual effort required by data producers, such as data preparation (and readiness checks), validation of outputs and verification against source cells. This could usefully be subdivided into whether explicit data edits are required, whether manual verification is required pre/post conversion, Checks for use of certain attribute values and others.

The “manual input” area is one of the most critical for data producers, so providing as much detail and categorisation as possible would significantly enhance S-65 Annex B;

c. A linked, HTML version with direct references to the S-101 FCEG and S-57 UOC for ease of access by data producers; and

d. An exhaustive test dataset for educational and practical testing for both data producers and software tool manufacturers.

9. Training is an essential part of the support given to data producers in the period before the dual fuel transition period begins. Training should recognise the complexity inherent in the conversion technologies and the dual fuel environment for data producers. It is significantly more complex to maintain a dual fuel service, requiring additional verification and validation. Producers will likely need time to assimilate the S-100 (and S-101) aspects and new software tooling they will inevitably require.

10. Some gaps were identified in the S-100 ecosystem and these were:

    a. There is a lack of an approved validation standard for S-101,S-100 or pre-conversion checks. This led to a proliferation of tests by different manufacturers and producers which can (at worst) contradict each other or (at best) be mutually incomplete;

    b. The relatively new impact on production processes of the complex versioning of catalogues, and software tools was confusing for end users and led to a systemic complexity which made it difficult to integrate disparate software tools together; and

    c. There is a lack of systematic verification tools capable of verifying the “correct” application of the mappings defined in S-65 Annex B (or modifications thereof defined by the data producer themselves). Additionally, the ability to verify a “source” S-57 ENC with its “dual fuel production” equivalent is another area where verification tools will be required in the longer term.

11. Data Producers benefited greatly from the experience of working together. Workshops which combine training with exercises could be held to spread knowledge and existing experiences of ENC conversion. Also, open meetings where data producers could gather to collectively address common issues such as:

    a. Validation of produced data (both S-101 and S-57 intended for dual fuel);

    b. Construction of production systems for dual fuel services; and

    c. Verification of data between S-57 and S-101.

USING THE WORKSHOP OUTCOMES TO FACILITATE THE REVIEW OF THE GUIDANCE DOCUMENT

Importance and Challenges of Training

1. Some challenges of presenting such a workshop as a training session found were:

    a. It was difficult to communicate the complexity of the source matter unless participants are reasonably skilled up to the level before. It would be overly demanding to expect participants to take on board S-101, and thereafter, conversion. This would be challenging if they have limited familiarity of how the IHO approaches conversion (through mappings, pre-validation, editing, S-65 etc.);

    b. Workshop/educational settings struggled to replicate the environment of an operational HO environment. There are essential principles which can be communicated but a full database driven dual fuel production system might be out of scope for most educational settings. Therefore, a set of essential concepts should be defined which could then be taught, such as mappings, validation/verification and pre-conversion testing;

    c. Conversion is intrinsically linked to software availability, versioning, and many other concepts. These would need to be approached together; and

    d. We recognised that until producers understand the broader S-100 background thoroughly, and how it is reflected in S-101, there is little chance they would understand the finer points and nuances of how ENC conversion is supposed to work. This could pose a big challenge. Using software tools proved to be immensely beneficial as it actively engaged everyone– and provided practical application, which was more effective than learning through listening.

Participants' Feedback on Conversion

2. An assortment of general feedback from participants during the workshop is described in this section. These are reproduced exactly from the questions asked in various Q&A sessions. Some of which are discussed elsewhere in this report but it is useful to have a record of the areas where it is felt further effort either in IHO guidance, or conversion tool behaviour.

    a. "We converted the same cell with three converters, and validated it and got different validation results."

    b. "Unicode characters in attribute strings sometimes aren't understood properly or converted."

    c. "Default values set by converters are sometimes different in datasets causing different portrayals."

    d. "We weren't aware some features would be dropped, e.g. SORIND."

    e. "Sometimes the data coverage is not being cut with M_CSCL."

    f. "It is really noticeable the difference between conversion via editing environments and via file to file conversion."

g. "It would be useful to link Validation results with possible remedies. This could also work in verification testing as well."

h. "How will the migration of v1.1 to v1.2 of S-101 work in practice?"

i. "Conversion of features with primitives excluded by UOC – these cases aren't allowed but converters don't necessarily exclude them – this raises the question whether a converter test dataset should include all dropped information (to make sure it's dropped), i.e. everything allowed in S-57 (what if you did a universal S-57 dataset, all features with all attributes."

j. "We don't know how to change mappings. Or whether we should. Or the implications of doing so."

S-65 Annex B Outputs

3. Some specific aspects of S-65 Annex B noted during the workshop are presented in this section.

a. A question was raised about what LNDMRK, CATLMK=19 [Area] converts to. This is being pursued with the conversion sub working group and the latest edition of S-65 Annex B.

b. There were issues with names not displaying in data after conversion using one of the software tools, but were displayed in data converted using other tools. This specifically relates to the display Name sub-attribute not being set to an appropriate value in the feature Name complex attribute during conversion. The remodeling of feature name means these attributes will now be encoded differently. The root cause appears to be the original mapping files had not set sub-attributes in accordance with the feature catalogue.

c. A question was raised by a participant over the mapping of M_CSCL feature and the construction of associated Data Coverage features created. This is a complex conversion to achieve as it involves the creation of new geometry. The converter in question had not created the geometry correctly, with the replacement DataCoverage (replacing the M_CSCL) overlapping the main DataCoverage feature. Additionally, the scale settings were incorrect for the new feature. The guidance on scales has since changed significantly, with the introduction of optimumDIsplaySCale, and indeed further modifications are likely. S-65 Annex B refers to "cookie cutting" geometry where holes are to be cut which could be clarified and reinforced with manual checking messages to ensure data producers have the correct scales and geometry resulting from a M_CSCL conversion.

d. Some participants in the workshop spent time examining bridge conversions, an area where a number of changes have taken place in the modelling in S-101. The creation of a bridge now requires geometry to be added (as in the previous example) with the bridge having the geometry of the component features. The S-65 Annex B description does not detail how the geometry is formed (it is assumed it is the perimeter of the component features (assuming they are all connected spatially). A simple diagram, similar to the S-101 DCEG diagram detailing bridges would be informative in this respect.

e. S-65 Annex B makes no reference to pre-conversion readiness checks, although the working group spent some time identifying them and contributors to the working group have developed their own definitive list of checks to be run on data prior to conversion. It was noted by several

participants that no standardised set of readiness checks are defined in S-65 Annex B. This can be partly addressed by better defining the object conversions requiring manual intervention and those where mappings have been dropped from S-101 but requires further discussion in the working group to come to any firm conclusions on how to take them forward.

Detailed Feedback on S-65 Annex B

4. Due to the duration of the workshop and activities, only few in-depth insights or detailed technical observations on S-65 Annex B's content were received. Those received have been provided as feedback to the relevant IHO working group (and noted in the previous section). Overall, it was noted that S-65 Annex B has considerable value both for data producers (who use it primarily as a source of normative information on conversion details) and for implementers of software and production systems. This could lead to the S-65 Annex B evolving in different directions in order to cater for the distinct needs of these two user groups.

5. One of the reasons why feedback on S-65 Annex B is difficult to define is because the end users attending the workshop have not directly experienced S-65 Annex B itself. Participants view the effects of S-65 Annex B as implemented by software tool manufacturers and implementers. Most ENC encoders use validation software tools to assess whether their data is "correct" and S-57 has a well evolved system under S-58 of these tests. Unfortunately, no "S-65 tests" currently exist, as no verification of conversion using the mappings defined by S-65 Annex B has been put in place. It was only when workshop participants looked at their own data, either with an S-101 viewer or through the lens of a verification tool, that they saw where misalignments existed between the S-57 and S-101 data. Thus, most feedback gained from the workshop relates to the use of software tools, data validation and strategies for production rather than specific observations on S-65 Annex B itself. These observations, however, reflect on S-65 Annex B as the central IHO document and suggest certain actions the IHO community could take to better support data producers transitioning to S-101.

6. S-65 Annex B serves a dual purpose, catering to two very distinct user groups. It provides information for both data producers and implementers of software tools, and this duality should be recognised as having an effect on its content. It was noted that S-65 Annex B's nature is as a guidance, rather than a normative, document within the IHO ecosystem. IHO is not in a position to mandate conversion between different S-57 and S-101 features, but the mappings which S-65 Annex B encapsulate are likely to be interpreted, largely, as mandatory.

7. Currently, there is no straightforward "S-65 valid" conversion as it is not a simple matter of two datasets conforming to the content in S-65 Annex B. However, there could be a middle ground, involving some form of assurance that S-65 Annex B has been adhered to with certain listed (and possibly data producer specific) exceptions. Even if this approach was applied to simple or1-to-1 mappings, it would help considerably in terms of clarity for end user data producers and provides a fixed reference for software tool manufacturers to focus on.

8. As many data producers are likely to consider the content of S-65 Annex B as normative, and given the enormous importance of its contents, making it as user accessible as possible should be a priority for IHO and the working groups concerned. The community should explicitly acknowledge that S-65 Annex B delivers this blend of normative/informative advice.

9. The primary difficulty with S-65 Annex B is its nature as a document. In order to gain the maximum benefit users must read it alongside the S-101 DCEG, and the S-57 UOC. The workshop participants

were mainly ENC encoders and were relatively unfamiliar with the intricacies of many of the IHO working groups. Therefore, S-65 Annex B (effectively a normative specification) presented a challenge in terms of its ease of use due to the complexity of cross-referencing all the documents together. This could be alleviated by making more accessible versions of the information available through an interlinked HTML version.

S-65 Annex B has Enormous Value for Both Producers and Implementers

10. S-65 Annex B provides the following values:

    a. A list of feature->feature mappings (although no attribute->attribute mapping is explicitly defined). Industry partners would value a (preferably machine-readable) list of object/feature and attribute/attribute mappings even if S-65 Annex B then overrides some with its complex mappings. Mappings of associations are also required if possible. These are less vital as they are little used by end user systems and only a small number are required in S-101 encodings.

    b. A broad category of where "manual input is required", i.e. where a straight mapping from S-57 to S-101 is not possible for any reason. The columns in the tables break this down to some degree but a more structured breakdown would be useful.

    c. The structure following the S-57 UOC is extremely useful as the vast majority of implementers and encoders are familiar with the S57 UOC or S-101 DCEG. This was a remark made by several participants.

    d. From the industry point of view, the situation is also challenging. Industry tool providers implement software production systems, mainly for S-57 and S-100 products – and conversion systems. Most implement data conversion in a generic or framework-based manner, which then allows for multiple customisation. They, therefore, implement the provisions of S-65 Annex B and most have to do this manually, by interpreting the wording within the IHO PDF document. This is laborious, time consuming and error-prone (many require several iterations to correctly implement its provisions). A machine-readable version of the conversions documented in S-65 Annex B would provide a valuable resource for implementers of software tools, including production and validation. This would be a considerable effort by the sub working group however, and some intermediate solutions should be sought.

Recommendations on S-65 Annex B

11. A HTML version of S-65 Annex B with links between documents spanning the S-57 UOC, S-101 DCEG and S-65 Annex B would be a valuable addition to the IHO resources for implementing data producers.

12. Machine readable mappings (even just for the simple mappings) would be valuable for software implementers. By providing a definitive list, it is then easier to work out where mappings need to be adjusted between versions.

13. Enhancements to the tables to more clearly state the nature of the manual effort required (these are often the more valuable part of the document and the entry point for many producers) would be beneficial. Where manual intervention is required, it could be sub-divided into:

    a. Verification either pre or post conversion;

b. Those requiring explicit data edits for particular values;
c. INFORM based mappings;

d. Other, more complex mappings; and

e. Restricted values (these are currently defined).

14. An exhaustive (or as exhaustive as possible) test dataset containing all the “special cases” within S-65 Annex B. This has been prototyped already and could be further expanded. It would be an invaluable training resource and would help implementers. This could include all source data values relevant to ENC conversion, including INFORM mappings, relationships and the more complex mappings. The partial one used during the workshop will be supplied to the IHO working groups as a starting point, and it is hoped it can be kept up to date as S-65 Annex B and S-101 PS develop further during 2024.

15. Inclusion of Pre-readiness checks in S-65 Annex B. There is no standard set of pre-readiness checks and this should be considered by the working group. The existence of readiness checks provides a good level of assurance (although it should be noted that they are no guarantee of valid data following conversion).

16. Default values, nulls and unknowns in some areas require clarification. Default values of all attributes defined during conversion should be checked to ensure they are exp[licit or possibilities detailed.

17. Some simple diagrams to illustrate geometry operations, e.g. cookie-cutting and creation of geometry for bridges would enhance those sections.

18. Clearer text about purpose and use, and status (i.e. guidance vs normative standard). This is a difficult area but it could be more clearly explained for the benefits of the document’s end users. These could then extend to the clarification of mandatory setting of attributes, for example, and effect required.

19. The difference between Initial conversion versus the requirement and management of ongoing production systems was not fully appreciated by many participants. The challenges of constructing a dual-fuel production system and the place of ENC conversion in them should be contextualised in the IHO guidance documents.

OTHER OBSERVATIONS AND OUTPUTS

Conclusions on Reverse Conversion

1. The technology for producing the reverse conversion seems to be in a state of advanced prototype. The mapping processes used are robust but the mapping files, and the cells they produce still require work and input to generate consistently valid cells. The cells created contained many validation errors, mainly composed of topology/geometry errors and errors in object/attribute validation. This created a lot of discussions, particularly with the software manufacturers who attended the workshop.

2. Many issues were fixed but some remained – an additional observation was that, as with the S-57 to S-101 conversion, different validation errors were seen when using different tools. From the short time the workshop focused on this topic, the conclusion seems to be that the mappings, rather than the technology, need time to develop to achieve better results and more alignment with the exacting standards demanded by S-58 and S-57.

3. The short time available for S-101 to S-57 conversion did not allow much time for detailed feedback. Notwithstanding, discussions with participants reinforced that with some future production systems, the reverse conversion will be carried out for the duration of the transition period. and is therefore an essential component of a future production system. IHO guidance is therefore essential, as documented in S-65 Annex C, and long-term support is likely to be required for it. The comments addressed to S-65 Annex B in terms of making precise statements of the mappings would also apply to S-65 Annex C as well.

Guidance on Production Systems

4. A topic of discussion during the workshop when working on the reverse conversion of S-101 to S-57 was how future dual-fuel capable production systems would be structured. Although it is difficult to make any firm conclusions (due to all data producers having different approaches to dual fuel production) the workshop discussed the merits of:

    a. A purely file-based approach to production systems, using parallel updating processes; and

    b. The database approach, for those already with databases of source information, which will either convert S-101 outputs to S-57, or using an enhanced database which would directly convert content to S-57 on export.

5. This represents a consensus view of the group. Those with existing file based production systems are likely to use parallel updating methods and parallel production systems for S-57 and S-101. They have a strong requirement for verification tools which can automate the vast majority of the conversions present in ENCs of both types.

6. Those with database systems face design decisions in their future production systems, choosing between conversion from exported S-101 directly to S-57, or converting S-101 database content which can be partially enhanced to support a broader range of S-57 data. This approach is a continuum with some participants focusing on directly converting the S-101 back to conformant S-57 (using manual processes where necessary) and others developing hybrid database schemas to support dual fuel production. There is no fixed method for doing this, and S-65 Annex B can better support processes by defining the mappings required explicitly. How the remaining data content is defined (i.e. whether

all the missing information is “put back in”) and how S-58 validation can be achieved with “reverse converted” cells is not currently addressed by any IHO guidance. Whether this is required will probably emerge as more data producers look at the reality of supporting dual fuel systems in the coming months.

Topics Raised during Industry Panel

7. During the workshop, an industry panel was held, and this allowed participants to ask questions of industry representatives in attendance. This was a valuable session. For some, the practical benefits of working with conversion tools are enhanced when more background and contextual input are gained through discussions.

8. The questions asked at the industry panel were:

    a. “How can we do this again? How can industry offer licenses to data producers to help them explore and begin production in advance of the main drive for S-101?”;

    b. “All stakeholders need to understand the time lag in implementations by industry. Once OEM software is delivered, if changes to standards occur then it needs to be changed again and release cycles are long for tool manufacturers. There still remains an outstanding problem of versioning with S-100 at a generic level which is now reflected in the various implementations.”;

    c. “Versioning is still a major obstacle to consistent conversion experiences, and user perception of the process. Software tools often do not feature prominently versioning information and the knowledge of which feature catalogues and portrayal catalogues are compatible with each other is not generally well known. This is an area requiring clarity within the working groups currently though and more concrete information would be available to share with groups attempting conversion. The time lag introduced by the requirement to update from one version to the next (e.g. v1.1 to v1.2 to v2.0) including datasets and software tools (including mapping files) can make this complex to navigate for end users and innovative ways of visualising and managing such compatibility must be considered.”;

    d. “How we go from v1.1 to v1.2 (of S-101) is simply not well defined nor demonstrable at the moment. S-100 is silent on how these things should be implemented so there is little assistance for OEMs in practical terms outside publications like S-65 Annex B?”; and

    e. “Validation checks. In the absence of a published validation standard for S-101 different approaches have been implemented:

        i. No validation;
        ii. Validation based on S-58 extrapolated;
        iii. Pre-readiness checks;
        iv. Written by IC-ENC;
        v. Written by others; and
        vi. Based on S-65 Annex B.

    f. “This is “This is ok but a fragmentation of how things should be. The ideal is that the IHO publishes official validation standards and pre-readiness checks for data. A consistent baseline helps all

stakeholders speak with a common language when describing the effectiveness of conversion, validation, verification and production system capabilities."

g. "Versioning. As mentioned above there is a lack of awareness, and an ongoing confusion/ ambiguity with versioning in a more generic sense. Software, and data are sometimes not explicit about the versions being used and compatibility between them. It will take time to get a point of maturity in all these areas."

h. "WG meetings only last a week, and many production staff don't go to them – these tools are immensely valuable for staff to gain experience and go through the clicks to make the data and create S-101 versions of their own cells."

i. 'S-100 is infinitely flexible, but it won't tell you how to implement it, that is up to you. This is the difficulty. This is one of the core issues faced by industry participants, in that S-100 is merely a standards framework with a large degree of variability and the exact nature of what to implement has never been set out formally. Therefore, some areas require more detail which can only be found through experimentation and practical research and development. This underlines why such workshops are valuable in that they offer an opportunity to bring together real-world ENC data with state-of-the-art software tools to test IHO standards in an open forum."

Designing Exercises

9. The workshop presented many exercises and provided materials to support their execution. As the participants were from a broad spectrum of backgrounds, the exercises were scaled to allow all participants to work at a level suitable for them.

10. Some experience gained from doing the exercises at the workshop are listed below. These may be useful for others designing/hosting similar workshops:

    a. Start with simple exercises testing understanding and move onto more complex ones. Have a variety of exercises for different users according to where they feel they are in their development of s-100 / S-101 knowledge and associated production systems;

    b. Many participants require a lot of discussion so always supplement training with lots of Q&A and advice on how to setup and configure ENC conversion (i.e. the bigger picture of how ENC conversion training fits into production system);

    c. Be as vendor neutral as possible, looking at data itself, rather than the production systems. This helps as it keeps discussions focused on how data is being converted, rather than the particular processes used. It also helps develop core understanding of conversion technologies;

    d. Make sure they have some experience, at least up to UOC level;

    e. Focus exercises on own data where possible as participants are familiar with it and can isolate/focus on cases most useful to them. Many of the complex mappings are in isolated cases within existing cells and participants know where these can be allocated., and also how their encoding practices may differ from those defined in the UOC; and

    f. Steadily increase complexity – a suggested ramping up of exercise content is given below:

i. Simple conversion – convert and examine simple ENCs;
ii. Examine mappings and verify simple mappings;
iii. Validation of output and verification of objects/features between source and converted data. Introduce concept of some data being dropped;
iv. Focus on complex modelling, mainly bridges and AtoNs (if possible, bring in relationships as well);
v. Pre-conversion validation tests including data editing and verification of the results;
vi. Look at complex mappings using INFORM. Show simple examples;
vii. Other Complex mappings – using S-65 descriptions. Focus on how manual effort may be required prior to conversion. Use standardised test datasets to show many explicit examples;
viii. More detailed Validation;
ix. More detailed Verification against Source ENC;
x. Move onto S-101 to S-57 reverse conversion (including how to design production systems);
xi. Validation and Verification of reverse converted cells, including verification of dual fuel S-57 with the source S-57 created;
xii. Changing mappings and seeing the results. Preferably link to individual producer encoding guides, and how they can create their own mappings to better meet the requirements of S-65; and
xiii. Database customisation and its applications in making dual fuel production systems and how this relates to ongoing verification of dual fuel outputs.

ANNEX A

Background

1. The dual fuel approach proposed by the IHO for the management of the transition period from S-57 to S-101 is designed to enable the ECDIS implementation community to phase in the introduction of S-100 ECDIS into the existing S-57-only market. This is alongside the revision of the relevant IMO documentation and associated regulations, and it enables a gradual transition by data producers to S-101 over a number of years. It requires close collaboration between software manufacturers, data producers, the IHO and the OEM/IMO community.

2. The requirement for IHO member states to produce both S-57 and S-101 data during the transition period substantially complicates their responsibilities. The ability to migrate production systems from S-57 production to dual fuel production is thus a common problem faced by all member states at the current time. Conversion technologies are aimed at the following objectives:

    a. Conversion of existing data holdings (those which produce existing S-57 only services) to new data holdings capable of producing S-101.

    b. The use of the converted data holdings for the production of both S-57 and S-101 and their respective updates during the transition period.

3. ENC conversion has been a central element in the IHO's strategy and a focused working group was setup by IHO to assist member states in preparation for conversion. The working group has met consistently and has produced documents detailing how conversion should be approached by member states, collectively S-65 Annex B and C. These explain S-57 to S-101 conversion and the reverse conversion (used in Dual Fuel production systems for legacy S-57 cells).

4. The IHO sub working group meets periodically to discuss topics relevant to the conversion questions, and therefore, S-65 Annex B holds much significance. It is used by both data producers and software tool implementers as a normative reference when developing conversion technologies.

Introduction

5. This project aims to both educate and experiment with the various forms of Electronic Navigational Chart (ENC) conversion available, and to explicitly test the current support available through the International Hydrographic Organization (IHO) working group ecosystem. The project, initially planned as a 6-month conversion test-bedding, was later reshaped into a single-week workshop due to resourcing constraints.

6. The workshop had the following objectives:

    a. To provide tangible feedback on the IHO's conversion guidance document S-65 Annex B, testing it using real-world ENCs and a range of up-to-date software tools from multiple industry partners.

    b. To enable education through using software tools for ENC conversion, combined with a short background training session.

    c. To explore ideas of dual fuel production systems, and how ongoing maintenance of ENCs is to be accomplished during the transition period.

7. The conversion workshop was thus designed to test S-65 Annex B and C through a technical deep dive using member states' own data and a variety of third-party software tools. As a first foray into such workshops, it was combined with a training element enabling a broad variety of attendees to gain benefit from the material presented. The workshop was facilitated by IIC Technologies and a collection of training materials and practical exercises designed.

8. The workshop also supplied logistical and technical support for the participants. A number of dedicated laptops were made available for participants who either did not have access to hardware for the exercises, or who were unable to install software packages on hardware issued to them by their organisations. This allowed all participants a choice of software tools to use, in addition to a breadth of tools available which represents the current state of the art in all dimensions of ENC conversion[1].

9. The software tools available to the participants were:

    a. 7Cs Analyzer (for validation of both S-57 and S-101 data).

    b. Caris Composer v4.1 (S-100 enabled, S-57 to S-101 and vice versa).

    c. ESRI ArcPro Beta v4 (newly released – supports S-100 and S-57 to S-101 conversion).

    d. dKart converter (converts between S-57 and S-101 and S-101 to S-57).

    e. IIC ENCTools v0.0.7 – verification of S-57 and S-101 data.

    f. NIWC ENC viewer and ShoreECDIS for viewing of S-101 data.

    g. 7Cs SeeMyENC for viewing of S-57 data.

10. The objective of the various software was to provide tools for conversion, analysis, editing and viewing of ENC data in both S-57 and S-101. The IIC Technologies supplied tool (i.e. IIC ENCTools v0.07) allowed side by side verification of feature content, drawing together results from the conversion packages.

11. Each participant was asked to supply their respective data in advance for the workshop to ensure the data was "representative" of their holdings. The objective of supplying the data in advance was to pre-prepare pre-conversion checks to be run which provided material for some of the intermediate level exercises. This data was used to extract INFORM values and "missing information" attribution for analysis by the participants.

Workshop Programme

12. The programme of the workshop aimed to cover:

    a. Conversion of ENC data from its existing content to S-101.

[1] No preference was given to any particular software package and the workshop was vendor and tool-neutral. The selected tools (and functions of tools described) in no way reflects any preference, nor describes their functionality in totality.

b. Establishment of a dual fuel capability (how difficult is it to produce S-57 from S-101, or from a hybrid database).

c. How to produce ongoing updates once the initial dual fuel capability is established.

13. A background to S-65 Annex B was given, explaining its origin and how it is meant to be used, alongside an explanation of its relationship to the S-57 UOC and the S-101 DCEG.

14. The training session then discussed the fundamental concept of a "mapping", a way of relating a concept in S-57 to a corresponding one in S-101. This was then used to define more concrete examples of mappings in general, using these simple ideas of a mapping between features (objects), their attribution and geometry and showed how they are aggregated together to form ENCs of each type. The concept of mappings is familiar to anyone involved with ENC conversion and has also been adopted by software manufacturers.

15. The mapping idea was the central training concept and was elaborated to discuss more complex mappings and then the more S-65 Annex B specific ones, such as INFORM-based conversion and the more complex conversions (and data topics) described in S-65 Annex B, for example:

> Data Producers are advised to evaluate their data holdings to ensure that any encoded **CTRPNT** objects that may be used as a navigational fixing mark are encoded as **CTRPNT** with CATCTR = *1* or *5*, or re-encode as a **LNDMRK** object, prior to conversion.

16. More complex mappings were introduced, including those based on INFORM values and those requiring either user validation or manual intervention. All these mirrors the content within S-65 Annex B and were familiar to those who have already experienced ENC conversion.

Workshop Materials

17. Much of the workshop's materials are in MS PowerPoint™ slides which were presented and subsequently provided to the IHO-SG Lab and the workshop participants. These are split into two distinct sections:

a. Training slides, including an introduction to the basics of S-100;

b. Exercises, to guide practical activities during the workshop.

18. The practical exercises were designed to accommodate multiple different levels of S-100 knowledge and S-101 experience. It was noted that having wide variety of skill levels at the workshop placed a challenge for the training aspects, but generated good interaction between different participants – this is discussed further in the next section.

Training

19. Training was restricted to only the knowledge required for ENC conversion. The training element of the workshop placed challenges in that some participants were very experienced, and others had little experience either of S-100 or S-101. Future workshops should consider to either ensure participants have a minimum skill level or provide prior S-100/S-101 basic training to prepare participants for the complexities of conversion.

20. The opening session described the objectives on the workshop, and the expected outputs.

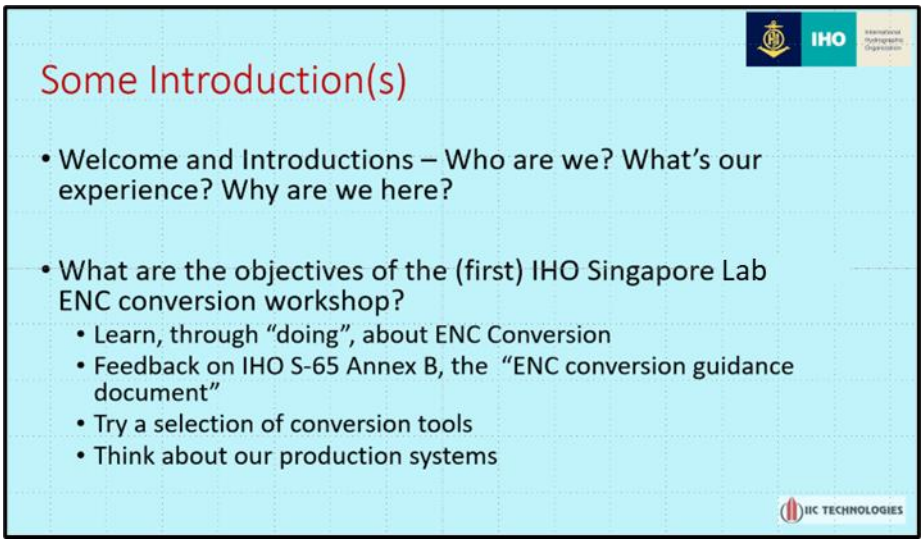


Figure 1: Introductory slide

21. This was followed by the initial training session aimed at those in the workshop with little or no experience of S-101 (or S-100).

22. A cross-section of the abilities within the workshop is illustrated as such:

I am ready (S-101/S-57).
I know what I'm doing but I've not started any S-101.
I am confident of S-57, I know S-101 a bit, it's easy isn't it?
S-57 can be challenging, I'm not sure about S-100? What's a feature catalogue?

23. This illustrates the hierarchy of knowledge in respect of ENC conversion. There were a number of data producers represented who have accomplished several stages on the road to S-101 production, whilst some were only knowledgeable in S-57. In order to engage with the complexity introduced by the concepts of conversion it is necessary to be in the top one or two levels. The workshop catered for participants of all skill levels, which allowed them to work together and assist each other in understanding the training materials. This worked well during the time allotted but it limited, in some ways, the feedback required on S-65 Annex B as one of the objectives.

24. The training developed was restricted to:

    a. A basic grounding in S-100, only insofar as it relates to S-101 and S-10 encoding. Thus, little mention is made of the General Feature Model (only in passing), or other product specifications such as S-102, S-104 or S-12X navigational publications.

    b. A focus on the differences between S-101 and S57 – described using names/terms and definitions rather than the detailed concepts. This culminated in definitions of complex attribution and relationships as well as the concept of "catalogue" and what it means.

    c. An accessible introduction to the data structures in S-101, features/information types, and their "bindings" to attributes/sub-attributes and the types defined for attribution.

25. This provided a streamlined path through the bulk of S-100, enabling a common language for description of S-101 concepts. The workshop itself was software-neutral and non-proprietary so it is paramount to establish a language for communication of ENC and data concepts without requiring reference to individual software packages. For example, the workshop slides adopt a common visual notation for ENC features, shown below:

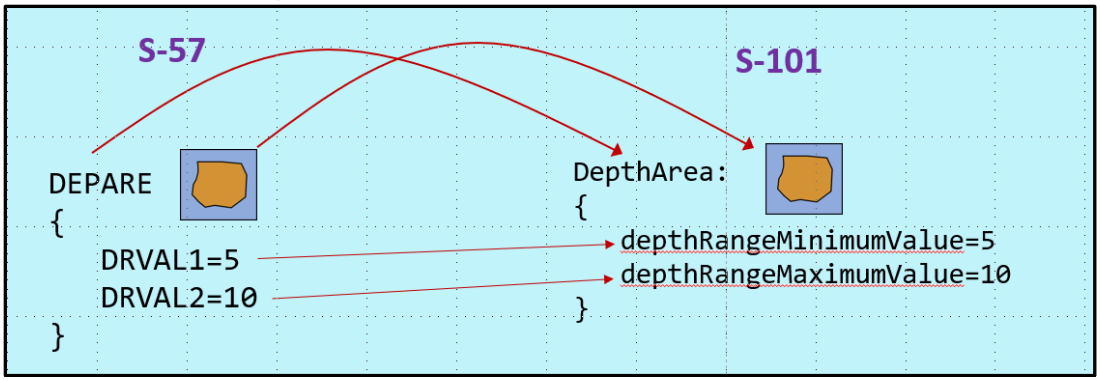


Figure 2: An example of notation used to communicate conversion mappings

Complex Mappings

26. The reason why ENC conversion is not a deterministic one-to-one process is because of the existence of complex mappings. Many of these are defined using INFORM values in S-65 Annex B. There are specific sections and examples/exercises in the workshop for this crucial category of mappings.

27. These are described in a visual language, with the corresponding textual element of S-65 Annex B included for reference. For example:

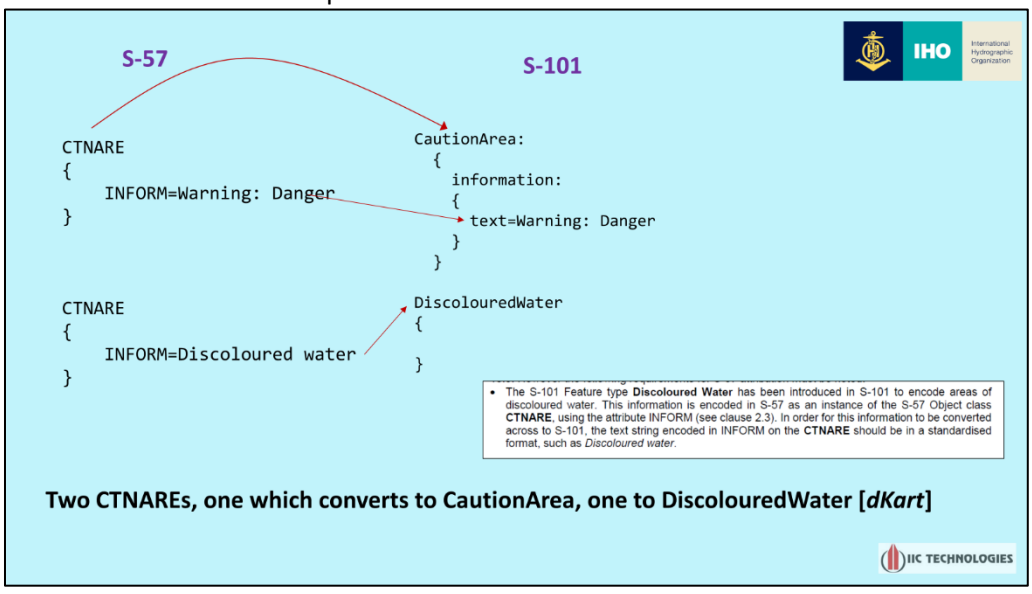


Figure 3: Examples of INFORM-driven complex mappings

28. These complex mappings are reasonably easy to understand and provide an excellent foundation for appreciating many of the subtleties of ENC conversion. They also provide a good foundation for understanding the relevance of Pre-conversion Readiness checks.

Pre-conversion Readiness Checks

29. The concept of pre-conversion readiness checks were also introduced and it is shown how to iteratively experiment with different mappings to improve S-101 data, as well as the importance of preparing S-57 data prior to conversion. The workshop had a set of readiness checks received from IC-ENC for use during the workshop exercises. These were supplemented by a set of readiness checks run on the participants' data and supplied to them for use in the exercises. These simple readiness checks illustrated data which would be dropped under ENC conversion. This simple exercise allowed participants to examine data, and results of checks, and then to assess and edit prior to conversion, noting the differences in the converted data.

30. This led to a simplified picture of an iterative process of ENC conversion which was used as a model for the activities in the S-57 -> S-101 conversion section of the exercises:

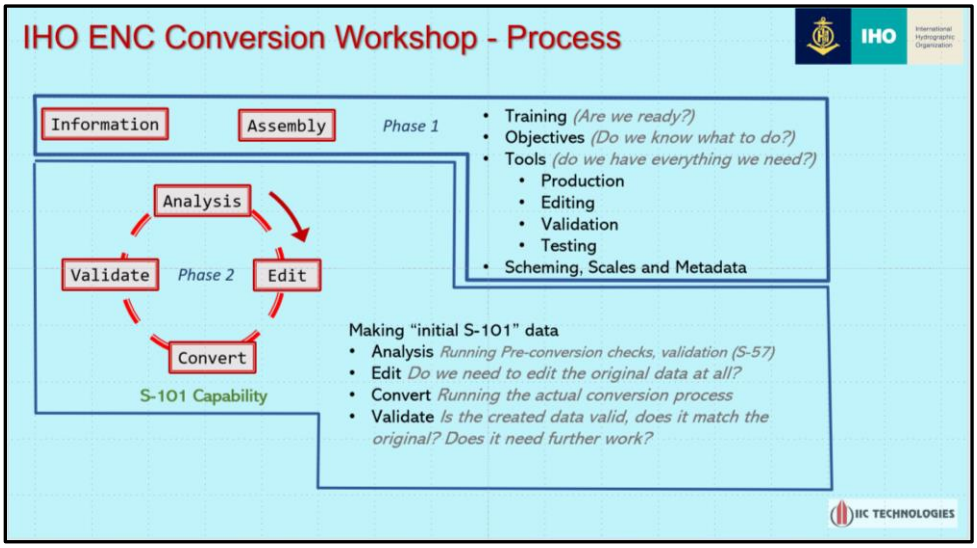


Figure 4: Process of conversion. From Assessment to Verification

31. The process illustrated is a simple, iterative one which shows how the training feeds into practical activities, assessing, checking, converting, validating (and verifying) data. This process was what the workshop exercises were based on. This process laid the foundation for the exercises which then take up the rest of the workshop. Once the basic concepts were established, the exercises were used to build experience of working with them. The basic concepts, in summary, are:

    a. What ENC conversion is, and why it is done. The differences between conversion of initial source and ongoing conversion to support dual fuel.

    b. S-65 Annex B and its role in assisting in data preparation as well as conversion references.

    c. Simple Mappings.

    d. INFORM and complex mappings.

    e. The importance of preparation, and iterative conversion matched with validation and verification of content against original data holdings.

Exercises

32. This section describes the exercises given to workshop participants. Data was supplied to those without it, and all tools were made available to all participants. Participants were encouraged to ensure they had tools for data manipulation, analysis, viewing (portrayal) and validation. Example:

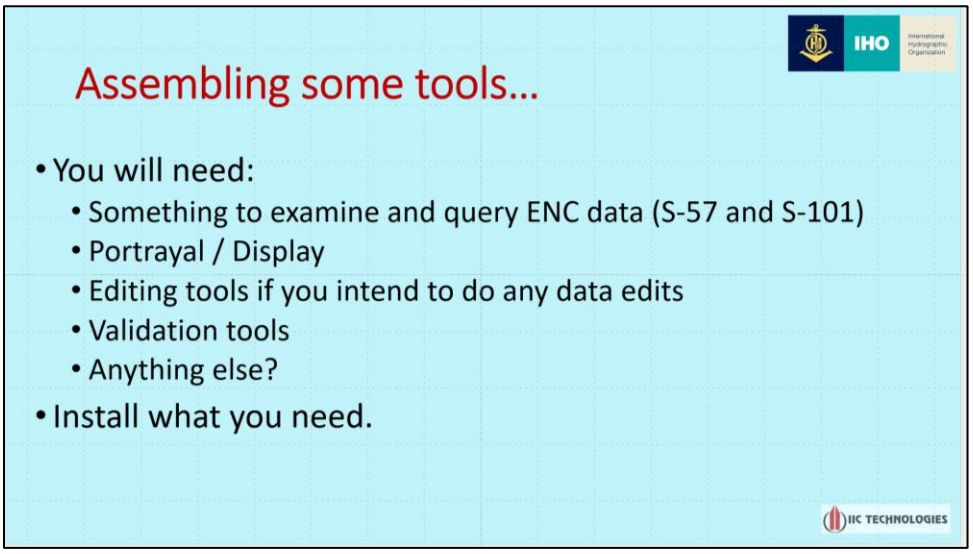


Figure 5: Exercise preparation

33. The conversion exercises were structured as follows (progressively more complex):

Exercise 1	Simple conversion
Exercise 2	Exploring mappings between cells. Searching for INFORM or complex modelling examples.
Exercise 3	Using readiness checks to look at data prior to conversion, and to understand the importance of preparing data for conversion.
Exercise 4	Analysis / validation checking of data post conversion.
Exercise 5	Using different tools and comparing results obtained from them.
Exercise 6	Conversion of a specific test dataset with many of the special cases within it. Conversion of dataset with different tools and comparison of the results.
Exercise 7	Manipulation of mapping files, changing mappings for specific reasons and examining the differences between the data obtained.
Exercise 8	Reverse conversion from S-101 to S-57, validation of S-57 and comparison between original and new (DF) S-57. How this relates to the construction of production systems by data producers.
Exercise 9	Complex Conversion – specific S-65 Annex B test cases.

34. Exercises 1 to 4 were reasonably straightforward and reinforced the training given. Exercises 5 to6 were more intermediate. Exercises 7 to9 tested more complex concepts and provided more valuable (and scarce) feedback.

35. The exercises were designed to cater to different ability levels and were suitable for a broad range of participants. Generally, most participants focused on exercises they could achieve and progressed onto

more challenging ones once confident. While few participants finished all the exercises, everyone gained some value from their accomplishments.

36. These activities led inevitably to a discussion on how dual fuel production systems should be designed and the popular models for dual fuel production, for example:

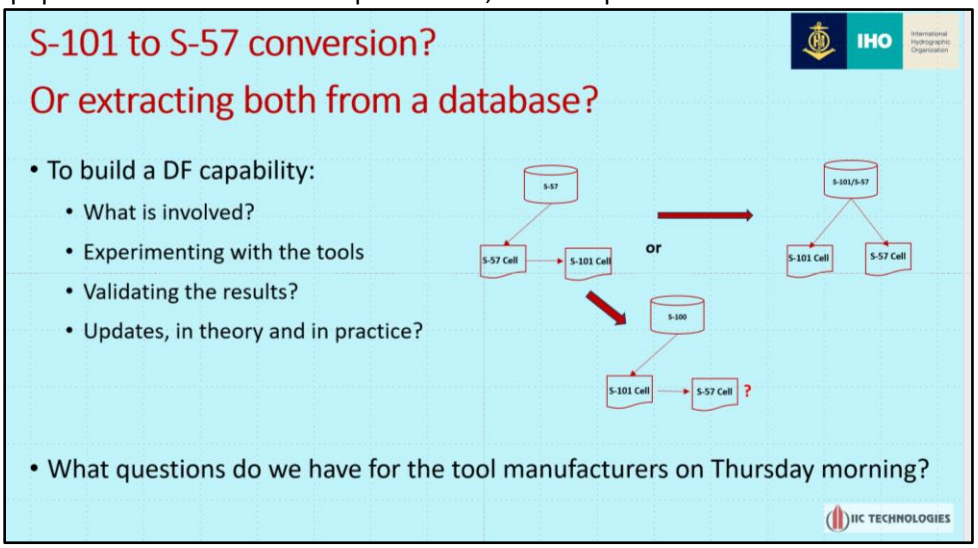


Figure 6: Dual Fuel production system discussion

37. This discussion, and the feedback from it, focused on S-65 Annex B is described in the next section of this report.

38. During the workshop exercises, question-and-answer sessions were periodically held to share experiences, as well as the opportunity to work in groups. It was noted that this happened naturally, with many of the more experienced participants willingly assisted those who had less experience with ENC Conversion.

Reverse (S-101 to S-57) conversion and production systems

39. This discussion, and the feedback from it, focused on S-65 Annex B is described in the next section of this report.

40. The workshop dedicated some time examining “reverse conversion”, from S-101 to S-57. This is normally discussed in the context of production systems providing S-57 data for legacy (non-S-100) ECDIS, which is a direct consequence of the dual-fuel mode approach defined by the IHO.

41. Commercial-off-the-shelf (COTS) tools were used to reverse convert a number of S-101 datasets back into S-57, followed by validation of the resultant datasets using 7Cs Analyzer. Effectively, this step replicated the process presented at the start of the workshop, i.e.:

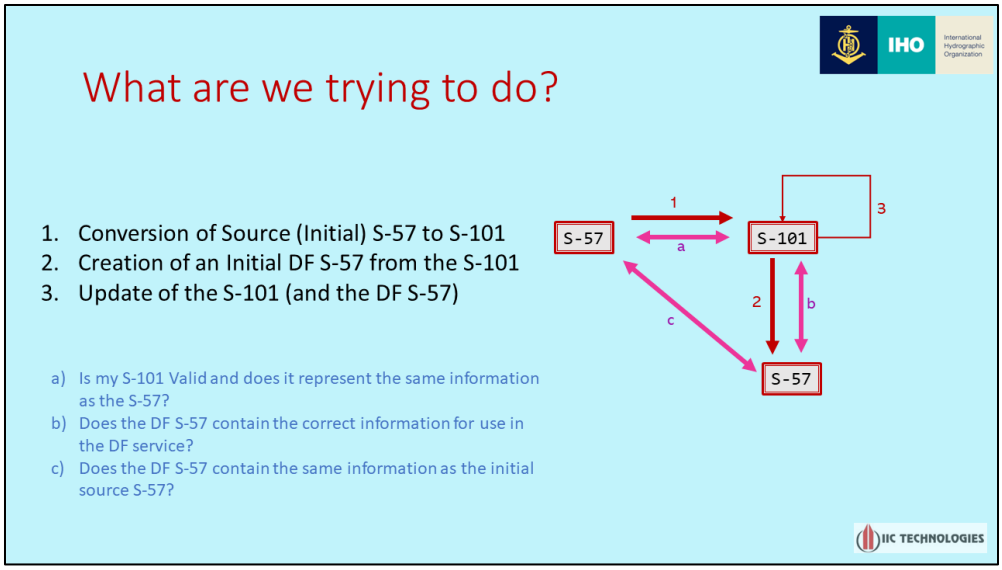


Figure 7: Overall process and aims/phases of the workshop

42. The reverse conversion section of the workshop covered the background and rationale for its inclusion. This was done because the reverse conversion of S-101 to S-57 has not received nearly as much attention as the initial source conversion for production systems. However, because the reverse conversion mappings are likely to govern ongoing dual fuel data production (as shown in Figure 7), this element is of paramount importance (and one where manual intervention has a far greater through life cost to the organisation). The workshop focused on the COTS tools capable of supporting reverse conversion, and how such processes contribute to the dual fuel production process for those with hybrid ENC databases.

43. The ongoing need for S-57 has led many producers to a production system design where the legacy S-57 is derived from a common database with the S-101 data. In reality this is not a hard choice between straight “conversion” or hybrid databases but a combination of both where certain features (normally those with 1-to-1 mappings) can be converted without issue from an S-100 based data store, whereas more complex mappings, or missing information can be drawn from bespoke data modelled and held alongside the S-101-native features in the database. The mappings from S-101 to S-57 are used to do the conversion. The untested part of this process, largely, is the complexity of doing so, the nature of bespoke mappings (that may be different for all data producers) and whether the resultant cells meet the rigorous S-58 validation defined in the ENC world.

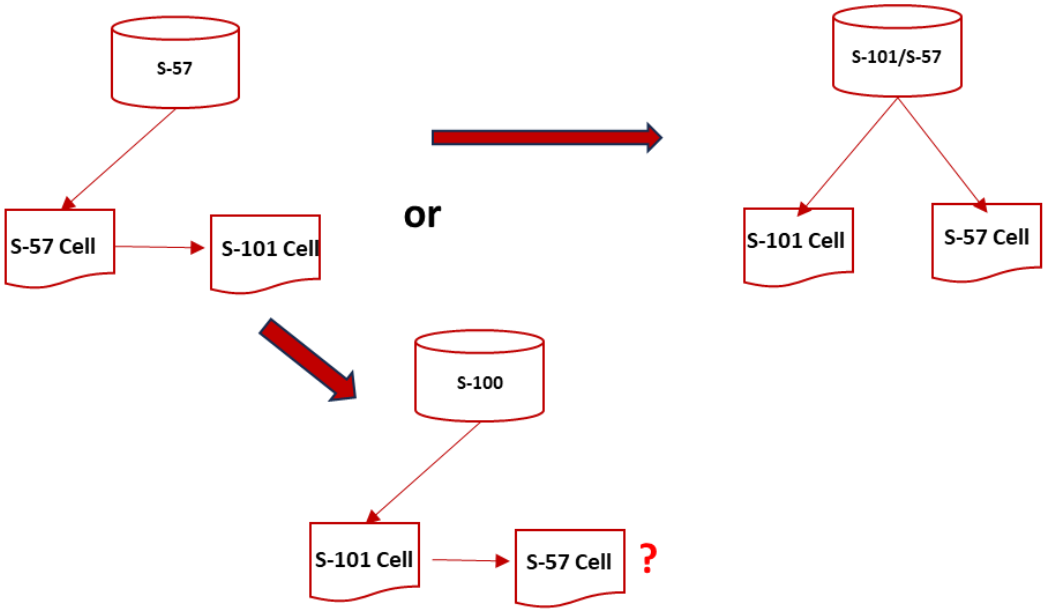


Figure 8: Conversion models vs a common database

44. In such a system, producers aim to "edit S-100", and therefore there is an implicit mapping of S-100 features to S-57 features in the output. This is slightly different to the situation when doing an "initial conversion" of S-57 to S-101 but is essentially the same thing, conversion of a database representation of S-101 data, to an S-57 cell. The workshop considered the reverse conversion question over several exercises, mainly concentrating on creating S-57 data from a new S-101 cell, then validating it using 7Cs Analyzer. A prototype verification between the created S-57 and original S-57 was also performed, alongside verification between the source S-101 and the produced S-57.

45. As reverse conversion is described (in S-65 Annex C) using the same terms and technologies (e.g. mappings, arranged in the S-101 DCEG order) there is little extra to add as background for reverse conversion, other than the contextual information on how it is applied. It is slightly harder to apply as it relates to ongoing use of conversion technologies rather than the initial source conversion but in a practical setting this could be less important.

46. Figure 8 shows how initial source S-57 is converted to S-101, followed by reverse conversion used on an ongoing basis for DF production. The verification steps are also shown. This diagram also shows the challenges of reverse conversion to some degree. The S-101 created has no formal validation "status". having been converted from S-57. Thus, residual validation errors in the S-101 (and any non-conformities to the S-101 DCEG) could, potentially, be magnified by the reverse conversion back to S-101. Just as S-57 to S-101 conversion requires a stable, valid base for the data, encapsulated by S-58, so does the reverse conversion. But the formal validation standard for S-101 is not currently available so a certain amount of uncertainty in the assessment of the created data should be expected.

47. The other difficulty with the workshop in approaching reverse conversion was the time and learning curve aspects. A workshop which focuses partly on education is further complicating matters by attempting to have an in-depth session on reverse conversion. The added complexity and appreciation of the significance of the topic limits the amount of useful feedback possible, as well as specific areas of focus on IHO publications and subgroups. A more dedicated space for rigorous testing and discussion on these topics would be needed to extract more value.

48. The workshop was able to execute the process, and perform the necessary validation, comparing the results (in the diagram above) with each other. A dedicated verification process evaluating S-57 cells against each other is another gap identified (some tools exist but few at the level of reliability and thoroughness required by such a migration process).

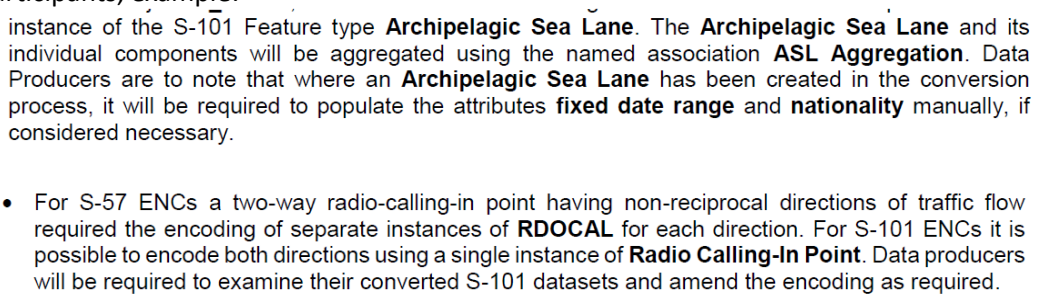
Areas not examined

49. There were some areas which could not be examined in detail.

More complex cases

50. The conversion workshop delivered a lot of value from the small amount of time available but it also limited some of the more complex and ambitious outcomes.

51. The programme had little time to deal with more complex cases of conversion. Future workshops could focus on the more complex cases, Particularly those where mappings are not simply 1-to-1or purely INFORM value driven. There are around 30 of these within S-65 Annex B and these were shown to participants, example:



instance of the S-101 Feature type **Archipelagic Sea Lane**. The **Archipelagic Sea Lane** and its individual components will be aggregated using the named association **ASL Aggregation**. Data Producers are to note that where an **Archipelagic Sea Lane** has been created in the conversion process, it will be required to populate the attributes **fixed date range** and **nationality** manually, if considered necessary.

- For S-57 ENCs a two-way radio-calling-in point having non-reciprocal directions of traffic flow required the encoding of separate instances of **RDOCAL** for each direction. For S-101 ENCs it is possible to encode both directions using a single instance of **Radio Calling-In Point**. Data producers will be required to examine their converted S-101 datasets and amend the encoding as required.

Figure 9: Examples of more complex cases of conversion

52. In many cases they require more in-depth manual inspection, verification and management but often focus on areas with few data instances and sometimes may require specialist compilation expertise or knowledge and experience. Not all of these were examined. A comprehensive test dataset could address many of these cases and provide a forum for discussion and experimentation. This will be presented to the relevant IHO working group for consideration.

Associations

53. Associations were given sufficient focus. This area of S-101 encoding demands a deep understanding to fully appreciate, as it requires complex verification. Production software and conversion techniques may gloss over the details.

54. More focused exercises could be done to concentrate on creating the correct relationships between destination S-101 features from S-57 objects (and S-57 aggregations/associations where possible). It is also an area where validation tools set against baselined standards will help locate issues enormously. While some focus on AtoNs and Bridges was done, this should be supplemented with specific exercises to ensure that correct relationships are in place in the destination datasets.

S-100 Training

55. The workshop only allocated just over a day for training on S-100 and S-101. Ideally, several days, plus time for consolidation would have been necessary for many participants in order to adequately

prepare them for understanding how ENC conversion and future production systems should be constructed. This is an area that may require further development, and one where IHO may consider providing foundational S-100 training as a separate activity to ENC conversion.

Industry Support

56. The support from industry, for provision of software licences for the duration of the workshop was extremely valuable. The workshop simply would not have been possible without the support of the software vendors providing their tools to use for educational and research purposes. The bringing together of industry and member state representatives, to work on genuine ENC data is invaluable and mutually beneficial as it allows for the examination of and work on real-world use cases. Creating such opportunities should be a matter of priority for the IHO working groups concerned.