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A REVIEW OF THE RELATIONSHIP OF THE ENC AND DNC HYDROGRAPHIC VECTOR DATA PRODUCTS

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Abstract

This document discusses the level of harmonization between the S-57 and DIGEST standards and the relationship between the ENC and DNC products. It is shown that the military and regulated commercial navigation have different needs, and that it is natural to have two different standards. However, in those areas where the needs overlap the standards should be equivalent. Commercial navigation requires "official" data whereas the military require a broad range of the "best available data". These needs are complementary. At the content level ENC data can be a pure subset of DNC data, however additional harmonization is required to achieve this.

1. INTRODUCTION

The International Hydrographic Organization (IHO) and the NATO based Digital Geographic Information Working Group (DGIWG) have both been working toward the development of data interchange standards for geographic information, tailored particularly to their fields of endeavor. Both have produced data products for hydrographic charts: the IHO Electronic Nautical Chart (ENC) product specification and the DGIWG Digital Nautical Chart (DNC) product format. The needs addressed by these

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two product formats are quite different, yet because they address the same area there is a potential conflict. This document will address the relationship, both perceived and real, between the two data products and propose a strategy for handling these products. Both the ENC and DNC hydrographic chart vector data products can and should exist, but the relationship between the products and their areas of application should be clearly set out. However compliance with the international maritime conventions for safe navigation requires observance of additional specifications for an Electronic Chart Display Information System (ECDIS). The study of how ECDIS requirements can be supported on military vessels is currently understudy in NATO. Both the military requirements for access to all available relevant data and the International Maritime Organization (IMO) requirements for the consistent presentation of official data must be accommodated.

1.1 Background of S-57

The International Hydrographic Organization (IHO) has been actively pursuing the interchange of electronic chart information for over a decade. At first the intent was to assist in automated cartography by defining a standardized method of exchanging digital charting information between Hydrographic Offices. IHO issued a specification in 1987 (called DX 87) and then subsequently a significantly revised version in 1990 (called DX 90). Both of these specifications concentrated on the exchange of data between Hydrographic Offices. There were few implementations of these standards for many reasons, the primary reason being that there were virtually no software tools for handling the data. Few tools existed since exchange was only one of a large number of other compatibility problems, and there was not much market for a partial solution.

Different Hydrographic Offices had organized their digital cartography in various manners appropriate to their internal organizations and there was little compatibility between nations. Having a standard to exchange data only solves part of the problem. Once the data has been communicated from one Hydrographic Office to another, it is still necessary for the second Hydrographic Office to integrate the data into its internal system to be able to use the data for chart production. The primary barrier to the integration of data was the fact that there was no common definition of hydrographic features (objects).

By 1991 the goal of simply exchanging hydrographic data was extended to include the exchange of "official" electronic chart data to manufacturers to assist in the provision of data sets for the emerging Electronic Chart Display Information Systems (ECDIS). Although this is a much broader goal, it has been more achievable, because it forced the standardization of other aspects of digital hydrography beyond the simple exchange of data. The most important aspect of this additional standardization has been the development of the IHO S-57 Object Catalogue. With common standards for the description of hydrographic features using the Object Catalogue, georeferencing, and metadata it became possible to exchange a hydrographic data set that could be used effectively by another Hydrographic Office.

The development of IHO S-57 edition 2 incorporated the object catalogue, a general data model, metadata, georeferencing and all of the information necessary to

effect unambiguous interchange. It did not, however, solve the problem of standardizing the "official" hydrographic product. To do that it was necessary to have a well defined product specification. Canada and France developed a product specification for S-57 edition 2, but the IHO as a whole waited until issuing S-57 edition 3 in November 1996 with an internationally agreed product specification for the Electronic Nautical Chart (ENC). Edition 3 also contained a better specified data model, and a transactional update mechanism. This allowed S-57 to earn the International Maritime Organization approval as part of the approval for the Performance Standards for ECDIS of November 1995. This means that navigation is permitted, under the Law of the Sea, using "official" ENC data when the data is maintained using the S-57 update mechanism.

Achieving IMO approval has been a significant accomplishment. The controversial part of moving from S-57 edition 2 to edition 3 has been the large number of changes that were introduced in the Object Catalogue. This caused significant delays in production schedules and the re-working of much data in those countries that had committed to S-57 edition 2.

The production of ENC data has been slow. A significant amount of work is required to produce ENC product specification compliant data sets. In part this is due to the fact that the existing paper chart base data and, where it exists, "electronic cartography" level digital data may not always be up to the level of quality needed in an Electronic Chart product. This complicates the production of ENCs with the general revision of the base chart catalogue, slowing the production of ENC data sets. The major threat to the use of ENC in the market place is the unavailability of "official" produced ENC data sets.

1.1.1 What is an ENC

To answer the question "What is an ENC" it is necessary to first answer the question of "What is a Chart". This may seem an obvious question, but the answer is not simple. Navigation at sea is a regulated activity in order to ensure safety of navigation. A whole body of law has developed over centuries that regulate navigation. Each nation is responsible for managing navigation within its waters, and must identify hazards and safe navigation routes. A mariner is informed of hazards and safe navigation routes through a chart. This is analogous to the equivalent air corridors in an aeronautical chart or the road signs on the side of the road for land navigation. A chart is a legal document that is the official description of the permitted safe routes, and hazards which may be encountered.

The legality of the chart is very important. It means that the country that issues the chart takes liability if the chart is in error. This is equivalent to the liability that the highway department takes if it mis-signs an intersection or the civilian air authority takes with respect to the regulation of air travel. If a highway department allowed a traffic light to go green in all four directions, and this caused an accident, it might be sued. This is equivalent to a Hydrographic Office committing an error in the production of a chart, and taking the liability.

An ENC is an electronic equivalent to the "official" chart. It therefore must contain all of the information that the responsible government agency considers is required for safe navigation in its waters. What is "official" is really defined by what the responsible government agency is willing to take liability for. Of course the technical facilities must be present to support the "official" ENC data. That is why the IMO approval and the International Electrotechnical Committee approval of systems is needed. However, assuming these facilities are available, then the liability issue dominates.

1.1.2 Separation of Carrier and Content

An electronic chart data set consists of two parts. The first, and most important is the "content" and the second is the exchange format used to convey this content. The format effects the message, but it is not the message.

Consider human language as an analogy. A particular message, such as the time of the next high tide, can be stated in English as "High tide is at noon" or in French as "La marée haute arrivera à midi". The message is the same regardless of the language. There may be no technical term for tides in K'wa, the language of the Bushmen of the Kalahari desert, so this language does not provide the technical facilities to carry the message.

There are a number of different ways of handling digital geographic information. The same information can be stored on computer disks, communicated over telecommunications channels or stored in databases. All of these correspond to different technical languages. As long as the technical facilities are available to handle the data then there is no loss of the information content.

The International Organization for Standardization (ISO) defines an architecture for Open Systems Interchange (OSI). It structures a communication or other information system into seven distinct layers that separate the application structure from the encoding from the communications channel, or media. This methodology permits the same message to be carried over many different media. The same concept of the separation of carrier from content applies to hydrographic data in the form of an electronic chart. What is important is the defined information content in an ENC, not the particular means of encoding.

The ENC product specification, as it is interpreted in a particular country, defines the "official" electronic chart content for that country. The S-57 standard is a carrier of that content. Other carriers may also exist to support the official content. For example, if a manufacturer of a certified ECDIS reads official ENC data into his system, it is transformed into the internal format of that ECDIS (a system ENC format or SENC). The data still remains official even though it is no longer in the S-57 exchange format. To ensure that the "official" data is not corrupted in the process of conversion to an SENC, the International Electrotechnical Committee (IEC) provides a certification mechanism.

The S-57 standard itself currently only supports one encoding, that of the ISO 8211 standard. ISO 8211 was designed as a "data descriptive interchange format"; that is, it contains a description of the meaning of all data elements along with their content. Other exchange standards such as the ISO 8824 ASN.1 telecommunications format or the ISO Standard Generalized Markup Language (SGML/XML) may also be used to encode the data in different circumstances without altering the "official" content.

1.1.3 The IHO Suite of Standards

S-57 is one of a suite of standards for the support of ECDIS. It contains the all important ENC product specification that defines the content of an "official" hydrographic chart. It also contains the format for encoding the data. S-52 is a sister standard to S-57. It contains performance specifications for an ECDIS together with a definition of the presentation library. The presentation library describes exactly what is to be displayed on the screen of an ECDIS for each feature and set of conditions. It is a rule based "expert system" for presentation, developed to ensure that a mariner sees a consistent display of ENC data. The last standard of the suite is the International Electrotechnical Committee conformance specification for an ECDIS system. The IEC type certifies that an ECDIS from a particular manufacturer meets the IHO and IMO requirements.

The IHO suite of standards specify everything from the data through to the final presentation on a display screen. This is to ensure that "paper chart equivalency" is obtained, not just in the data, but in what the mariner sees before him.

1.2 Background of DIGEST

The DGIWG DIGEST standard also has a long history. Work began on the DIGEST standard in 1982 for the purpose of sharing and exchanging digital mapping data between NATO nations. The initial intent was similar to that of S-57, and concentrated on the exchange of data between agencies, in this case the military mapping agencies of NATO nations. There are many parallels to the evolution of the S-57 standard, including the choice of the ISO 8211 encoding standard for the exchange of "bulk or archival" data between agencies.

The scope of application of the DIGEST standard is much broader than that of S-57. Military needs include Land, Sea and Air requirements and the joint operations of Land, Sea and Airforces as well as strategic planning. This means that data from a broad range of sources must be possible to be displayed simultaneously. It is impossible for the military to develop custom data products for all applications, so it is necessary to be able to easily construct custom data sets from a broad range of sources and pre-defined generic products.

An important application of DIGEST is in joint military operations, such as UN peace keeping operations, where all nations involved will need to work from the same data sets. This means that data produced by, for example France, should be usable in a Canadian operation in Africa. This "plug and play" capability requires the standardization of software tools as well as data products.

Navigation, on land, sea and air, is an important component of DIGEST usage. But it is not the only requirement. The combination of several data sources may be required in a particular operation.

DIGEST is actually a suite of standard consisting of a general specification together with a set of defined products. DIGEST products are based on co-production agreements between NATO nations. These highly specified data products serve as the base for creating custom views to address operational requirements. For example some aspects of land and sea data can be combined for a coastal operation.

1.2.1 DIGEST Multiple Encodings

The DIGEST standard was extended in 1990 to accommodate Multiple Interchange Media. This permitted the support of the ISO 8824 telecommunications encoding and the Vector Relational Form (VRF) encoding as parts of DIGEST edition 1.1 in 1992. The DIGEST Annex B encoding for raster data was added in 1997 to align with ISO JTC1 SC24 committee on Image Processing standard for raster data.

The DIGEST standard consists of several parts. Part 1 is a general description and overview. The main body of part 2 provides a general specification, with detailed descriptions of different encapsulations in annexes of Part 2. Part 3 describes the codes and tables used in the standard and part 4 describes the Feature and Attribute Coding catalogue. Each of the encapsulations described in the annexes of DIGEST Part 2 describes DIGEST using a different encoding specification for use with a different type of data or over a differ communications media.

DIGEST A - makes use of the ISO 8211 "data descriptive" encoding technique and is intended for Archival and Bulk interchange between military mapping agencies. ISO 8211 encodes the description of all data elements along with their value, making the encoding format useful for "blind" interchange where the two communicating parties don't know the entire exchange context, but is inefficient for small messages.

DIGEST B - makes use of the ISO 8824/ ISO 8825 telecommunications encoding technique which is intended for efficient telecommunications interchange. ISO 8824 describes data "in context" requiring additional processing to parse the data, but is very efficient for telecommunications, especially for transactional dialogues and shorter messages.

DIGEST C VRF - makes use of a simple relational table encoding technique intended for direct use of the data from a CD-ROM or computer file structure. It is a simple flat file data base description of geographic data. Since it is a relational database form it includes relational database constraints. However, in the latest edition of DIGEST (2.0), mechanisms have been introduced to support all of the

capabilities of the other formats of DIGEST within the relational paradigm.

DIGEST D - makes use of the ISO JTC1 SC24 BIIF encoding technique for raster data. This encoding is intended to align DIGEST with the ISO standards for image communication for handling raster data.

Although DIGEST data products have primarily been developed using DIGEST C (VRF), there has been some use of DIGEST A for context independent interchange. The use of DIGEST B for telecommunications is just developing, and DIGEST D for raster data is new. However, the DIGEST content is independent of the carrier, and it is possible, for example, to communicate part of a DIGEST data set that was originally encoded using DIGEST C VRF over a telecommunications link using DIGEST B (the telecommunications form). The same data could also be expressed in DIGEST A archival form.

1.2.2 DIGEST Products

The real strength of DIGEST lies in its broad set of data products. The original DIGEST data product was the Digital Chart of the World (DCW), a land mapping product for strategic purposes at the 1:1,000,000 scale. This has been supplemented by the Vector Smart Map (VMap) series at 1:1,000,000, 1:250,000, 1:50,000 and urban scales. The VMap level 0 (1:1,000,000) and the DCW have been made public domain data sets, which has greatly increased the level of implementation of the DIGEST standard.

Other DIGEST compatible data sets include:

Arc Digital Raster Graphic	(ADRG)
Arc Standard Raster Product	(ASRP)
Compressed ADRG	(CADRG)
Controlled Image Base	(CIB)
Digital Flight Information Product	(DFLIP)
Digital Gazetteer	
Digital Nautical Chart	(DNC)
Digital Terrain Elevation Data	(DTED)
Digital Topographic Data	(DTOP)
Feature Foundation Data	(FFD)
Harbor, Approach and Coastal DNC Product	(HAC)
Interim Terrain Data / Planning Interim Terrain Data	(ITD/PITD)
Littoral Warfare Data	(LWD)
Transportation and Logistics Data	(TLD)
UTM Standard Raster Product	(USRP)
Vector Product Interim Terrain Data	(VITD)
Vector Smart Map Level 0	(VMap0)
Vector Smart Map Level 1	(VMap1)
Vector Smart Map Level 2	(VMap 2)
Vector Smart Map Urban VMap	(UVMap)

Vector Vertical Obstruction Data	(VVOD)
World Vector Shoreline	(WVS)
World Vector Shoreline Plus	(WVS+)

The content from any of these data sets can be used alone or in combination. The DIGEST viewing software tools allow data to be extracted from any of the data sets and combined with data from other data sets to address operational requirements.

DIGEST compatible data sets are not necessarily NATO products. Many are developed based on co-production agreements between NATO nations. This is the case for the Digital Nautical Chart product.

1.2.3 DNC

The Digital Nautical Chart product (DNC) is a DIGEST compatible product designed to address the maritime requirements of NATO military services. According to the DIGEST specification in the scope statement its purpose is: " The DNC is a general purpose global database designed to support marine navigation and Geographic Information System (GIS) applications."

DNC data sets are organized in a similar manner to the other DIGEST data sets in terms of Libraries (Geo-Datasets) and Coverages. There are four basic types of DNC data. These are HARBOR, APPROACH, COASTAL and GENERAL libraries. A BROWSE library is also included, which provides a global overview of the DNC coverage. The data sets are also tiled to form continuous seamless coverages (where data is available). DNC tiles align with the tiling systems of other DIGEST data products. The Digital Nautical Chart is organized into a number of distinct Thematic layers these include:

GENERAL, HARBOR, APPROACH, and COASTAL library thematic layers	Coverage name
Cultural Landmarks	CUL
Earth Cover	ECR
Environment	ENV
Hydrography	HYD
Inland Waterways	IWY
Land Cover	LCR
Limits	LIM
Aids to Navigation	NAV
Obstructions	OBS
Port Facilities	POR
Relief	REL
Data Quality	DQY

BROWSE library Thematic layers	Coverage name
Coastline/Countries	COA
Library Boundaries	LIB

In addition there are several classified layers of information that may be used together with the DNC; for example Mine Warfare information.

The DNC product is encapsulated using the DIGEST Annex C Vector Relational Form (VRF) encoding. The encoding consists of a set of relational database tables structured so that they may be stored in a simple computer file structure. This permits the data to be stored on a CD-ROM for direct use using the same tools available for all other DIGEST data sets.

The DNC product makes use of the same Feature and Attribute Coding Catalogue (FACC) that is defined for the use in the rest of DIGEST. This permits portions of other DIGEST data sets to be integrated with DNC data. For example, information extracted from the VMap series of topographic map products could be used to replace or augment Cultural Landmark or other such DNC data.

The DIGEST suite of standards and tools also contains a presentation mechanism for the definition of a rule based symbolization. This is analogous but not identical to that used in S-52 compliant ECDIS systems.

1.3 Overlapping Requirements

There is a significant overlap between the DNC and ENC data products. Both address nautical charting, but both have different secondary purposes. At the very high level one can arm wave and say that ENC and DNC are the same. At the detail level they are very different for important reasons.

Because of the overlap there is an implied conflict between proponents of ENC and those of DNC. This should not occur. Both ENC and DNC exist for different reasons, and their area of overlap is an area of potential cooperation rather than conflict.

The principal behind the IHO Electronic Nautical Chart (ENC) is that of "**Safety of Navigation**". Although safety is important it has a different meaning in a military environment. The principal behind the suite of DIGEST data products, and the Digital Nautical Chart (DNC) in particular, is "**Best Available Data**".

The "official" ENC data products in a particular country are legal documents that define the rules for safe navigation under the maritime SOLAS (Safety Of Life At Sea) conventions. For this reason the suite of IHO standards and certification requirements ensure that the "official" data is displayed before the mariner. If a mariner were to select additional items to display in addition to those required, then he might clutter the screen. In that, and many other cases, the ECDIS equipment is required to warn the mariner that he is not operating in certified ECDIS mode.

The military is not obliged to follow the SOLAS conventions, but endeavours to do so when possible. In search and rescue situations or in response to hostilities, the military may have to venture into waters not normally considered safe. In addition, a military ship requires more information about the land, sea and air conditions around it.

The DNC is the nautical charting part of this broader military requirement. A common set of data may be available on a warship that is used for many different purposes. The navigator and helmsman may need navigational data, augmented as needed for additional military hazards. Others on the ship may make use of the same database selecting other information for their operational purposes. An aircraft carrier will obviously also require aeronautical chart information, and a submarine will require detailed bathymetric data.

It is desirable for a DIGEST compatible display system to be able to display "official" hydrographic data but it must be able to display more. In this sense the ECDIS requirement is a subset of the military requirement.

2. COMPARISON OF THE RELATIONSHIP OF ENC/DNC

Most comparisons of the ENC and DNC data products concentrate on the supporting technical standards. Although there is value in comparing and aligning the S-57 and DIGEST standards, it is not the answer for comparing ENC and DNC.

ENC and DNC are product specifications, and as such are content specifications. The content stands independently from the format standard in which it is encoded.

Provided that the technical facilities are available, and for the most sakes they are, then ENC data can be encoded using DIGEST and DNC data can be encoded using S-57. Either technical format can be used to hold the information content.

There is a practical reason for wanting to encode ENC data content in DIGEST (possibly as the core of a future revised DNC data specification to support "official" data), but there seems to be little practical reason to encode the current DNC data in S-57 other than for conformance testing. The IEC 61174 test standard makes use of the IHO ENC Test Data Set which is in S-57. QA software developed by a number of sources may be used on data in the S-57 form. There also may be a desire to convert some DNC products into ENC to help in the production process.

The data content of DNC and ENC were reviewed as part of the DIGEST / S-57 Interface Control Document. The differences are in the areas of:

- terminology
- metadata
- data model
- feature catalogue

Terminology: Both the DNC and ENC and their supporting format standards have different terminology. Although this leads to many misunderstandings, it is not a critical problem.

Metadata: There are two types of metadata in the S-57 based ENC and the DIGEST based DNC. These are:

- structural metadata (about the format)
- metadata about the data content

Much of the content based metadata is equivalent between the two products due to the fact that the underlying DIGEST and S-57 standards have been largely aligned with respect to most important areas of metadata. Both standards have been harmonized with respect to sounding datums, hydrographic datums, and other aspects of georeferencing. Data Set Identification information is either identical or directly derivable. Data Set History Information is also identical or directly derivable. The area of major misalignment in metadata is the specification of quality. The fundamental concepts for handling quality are similar, with DNC providing a quality coverage that in general corresponds to the ENC Zones of Quality concepts. However the details of the quality specification are sufficiently different that it is not clear whether one could be derived from the other.

Spatial Data Model: One of the major early achievements of the harmonization work between DIGEST and S-57 was the harmonization of the spatial data models. Both formats support the same four spatial schema, (Spaghetti, Chain Node, Planar Graph and Planar Graph with Faces - sometimes termed Full Topology). However the ENC and DNC products use different levels of topology. The DNC product claims to be fully topologically integrated. This means that it uses Planar Graph with Faces topology whenever an area type features exist. It uses progressively lower levels of topology for coverages that do not include Area, or those that do not include Areas or Linear features. The ENC product specification states that ENC data must be encoded using Chain-Node Topology. This difference in the level choice of use of topology is not a major concern, because topology can always be derived from the geometry of the spatial data. However, this requires work in the conversion or in the ECDIS.

An ECDIS would need to use a higher level of topology to calculate spatial operations such as "Within". To calculate whether a point is within an area, such as whether a ship has crossed a safety contour and is in a danger area, requires a complex point in polygon calculation to derive it from the geometry as would be needed for ENC data. It is a very simple operation in a fully topologically integrated data set. such as that in DNC. Therefore it is likely that an ECDIS manufacturer would read an ENC into an ECDIS system and then generate the full planar graph with faces topology to speed-up the operation of the ECDIS. The System ENC (SENC) used within the ECDIS is comparable to the DNC topological structure. With respect to the data model the **DNC is equivalent to an SENC**.

One advantage of using the lower level of Chain Node topology for the ENC data set is that it reduces the complexity of updating. This will be addressed later in the sub-section on updating.

Feature Model: A second part of the data model, sometimes called the Feature Model, is the manner by which features are organized in layers or groups. The ENC product specification defines two distinct data groups: Group 1 (Skin of the Earth)

and Group 2 (all other objects). Group 1 contains a small number of objects types that form a complete coverage of the area of the chart. That is, it describes the earth or sea bottom. All other objects exist over this skin of the earth.

The DNC product specification chooses a completely different way to organize feature data. DNC consists of a number of layers (coverages), each associated with a different theme. (see 1.2.3 above). Each layer is topologically integrated, but there is no layer to layer topology. In fact some features have to be repeated between layers since they are needed to complete the geometry of that layer. For example, the coastline may be the boundary of the ocean, the political boundary of a country and be the 0 contour.

There are advantages and disadvantages to both ways of organizing the data. Topological integration, as per DNC, provides speed for direct use, but it limits the complexity of a Group/Layer to maintain manageable topological complexes. In addition the need for DNC data to be used together with other DIGEST data products requires that there be a general structuring of the data into many layers so that selective layers may be combined.

The definition of two simple groups, as per ENC, provides advantages within the limited context of electronic charting, especially for updating. However, it may require a more complex conversion to produce an SENC within an ECDIS. Because so much of the structure of a data set is built on the basic grouping/layering of data, the organization of data into many layers in DNC and two groups in ENC is one of the most difficult practical issues. A Feature/Object type may be valid for both the "Skin of the Earth" or the other group in ENC which may affect how it is converted to DNC. Alternately a Feature Object type may exist in more than one layer in DNC.

Feature Catalogue: By far the major differences between the ENC and the DNC are the differences in the feature/object and associated attribute catalogues. A significant effort was placed on the alignment and conversion of these catalogues in the DIGEST/S-57 Interface Control Document. [Reference: Interface Control Document Version 2, September 1997]. Both the IHO and DGIWG have been working on alignment of these catalogues, and significant progress has been achieved. After the DGIWG FACC meeting of December 1997 all but a few Objects and about 200 Object Attribute combinations do not have direct preferred mappings. Mappings exist but there may be a loss of information such as assigning an Object Attribute combination to an "other" attribute category within FACC.

There remains additional work that needs to be done to improve the overall S-57 Object/Attribute to DIGEST Feature/Attribute mapping.

Both the ENC product specification and the DNC product specification use only a subset of their respective catalogues. This is both a benefit and a difficulty. The benefit is that many of the Object/Attributes that have not yet been mapped are obscure ones that are not used in ENC or DNC. The difficulty is that some of the conversions between the S-57 Objects/Attributes used in ENC have been mapped to Feature/Attributes that are not used in DNC. A section of the Interface Control Document (ICD) addressed this issue. This is not a serious issue, but an annoying one,

because it could have been avoided. Additional work is also needed on this part of the ICD with the goal of having a complete and good match for all of the Object/Attributes and Feature/Attributes used in the respective products. Note that an easy solution in a future version of DNC would be to add some additional existing FACC features to the allowed DNC repertoire. Vigilance is also required in both the IHO TSMAD Working Group in the maintenance of S-57 and in the DGIWG FACC Working Group to ensure that any changes to the IHO catalogue or to FACC are coordinated and are also reflected in the ICD. The misalignment of products could be minimized in a future version of the ICD by addressing products as well as the base catalogues.

2.1 Technical Issues

There are a number of other technical issues of alignment between an ENC and DNC data set that must be addressed. These are discussed below:

- Both the DIGEST standard and the S-57 standard support multi-lingual alphabets. Place names and other information can be expressed in any language in the world. The ENC product specification requires that all information be available in the English language as well as in any other national language. This is similar to the requirement for the mandatory use of English in air traffic control, and provides a base language. The DIGEST standard (in all of its encapsulations including VRF) supports this capability, however the DNC product makes use of only the US subset of DIGEST VRF (called the Vector Product Format - VPF). This sub-set encapsulation does not include the full capability for the support of accented characters available in DIGEST. In addition the DNC product specification limits the use of characters to level 0 (ASCII). This only supports the English language. By default the S-57 ENC product specification uses level 1 character encoding corresponding to the Latin 1 alphabet (ISO 8859-1 including French accents). The standards match, but DNC has made a choice that is lower than ENC. This is an important issue for Canada, much of Europe and other nations. A future version of DNC should be extended to include the language support capabilities already available in DIGEST, so that multi-lingual charts may be developed.

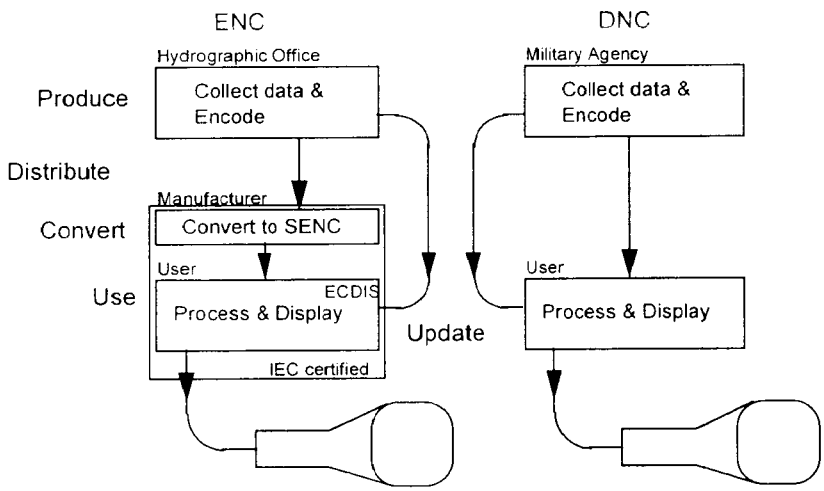
- DNC limits its point connectivity so that no connected nodes represent point features. This makes the table structure in VPF simpler (slightly). However it means that it is not possible to represent certain structures that are perfectly legal in ENC data. For example a Lighthouse point feature that is coincident with the end of a Pier line feature requires the coincidence of a point feature and a connected node. The Light house would have to be moved slightly to avoid the connected node. One could convert from a DNC to an ENC but there would need to be low level editing required to go the other way. The restriction is in the DNC specification not in DIGEST. A future version of DNC could easily provide the capability of supporting this situation with complete backward compatibility.

- DNC does not support multiple (repeating) attributes of the same type. For example, there could not be two transmitting frequencies for a radio tower. In DNC this would be handled by creating two coincident Radio Tower features with different attributes. This restriction was identified in the ICD study, and has been corrected in DIGEST edition 2, but it is not in the current DNC specification.

The previous list is not exhaustive. There are numerous small technical inconsistencies that trouble the translation process. Many if not all of the problems have been addressed and solved at the level of the base exchange formats of S-57 to DIGEST, but the choices of the use of these formats at the product specification level causes translation difficulties. Since the translation process is primarily from the S-57 ENC to the DIGEST encoded DNC, most of the responsibility for solving these conversion problems lies on the DIGEST side. A future version of the DNC product specification could be developed that made use of the new facilities placed in DIGEST edition 2 for alignment with S-57. From the point of view of the format and structure this could be done in such a way so that there is complete backward compatibility with the existing production of DNC data.

2.2 Steps in the Creation/Use of Data

The following diagram gives a general outline of the steps in the production and use of hydrographic chart data. Note that there is one additional step in the IHO ECDIS process; that is, the conversion of S-57 to an SENC format. This is consistent with the IEC certification of ECDIS equipment. Differences in the type of update are given in the type of update discussed in section 3.



The following table presents the same structure in a more descriptive form. There are other incompatibilities that are evident in this table, such as the different grouping into coverages or groups and the tiling.

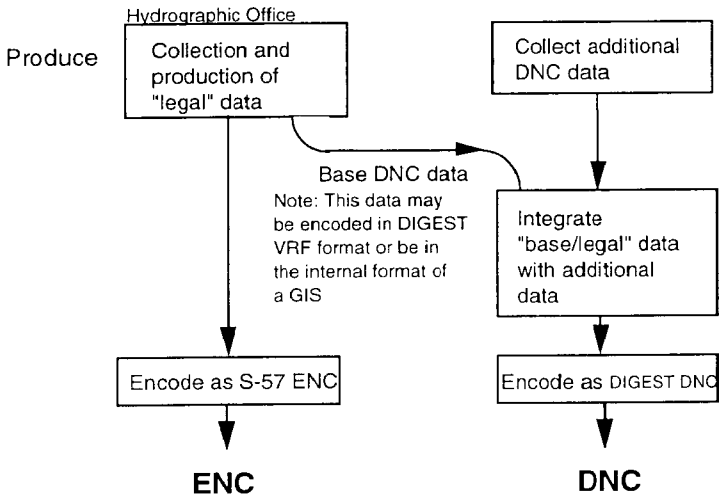
STEP	ENC	DNC
Collect data according to collection rules	ENC Annex A Use of Object Catalogue + National rules on what is considered legal by the national Hydrographic Office	DNC Collection Rules Document
Encode Feature/Objects	Use S-57 Object Catalogue per ENC product specification	Use DIGEST FACC per DNC product specification
Organize Data	Structure into ENC Group 0 or 1	Group into ENC coverages, and tile according to tiling plan
Encode in Exchange format	Encode into S-57	Encode into DIGEST VRF tables
Distribute Product		
Decode for use	Convert to SENC Manufacturer dependent form	DNC already in direct use form
Updates	Incorporate updates received as transactional messages	Replace sets of tables altered in update
Presentation	Display according to S-52 presentation library, possibly together with radar or other well specified additional information.	Display selected coverages and features using predefined views and symbolization, possibly together with other DIGEST data products

The production of a DNC and an ENC data product goes through very similar steps; however, there are a number of important differences. The primary difference is that the DNC is distributed in a direct use form. This means that it essentially corresponds to the SENC level of the ENC process. The claim is that the DNC is at the SENC level, not that it is equivalent to the SENC in IHO terms. To be a complete SENC it would have to be combined with a DIGEST VRF viewer software and symbolization set. The important thing to remember is that DNC is a direct use product in DIGEST Vector Relational Form (VRF) and this most closely corresponds to the SENC level.

If an appropriate conversion was used in the production process to generate DIGEST encoded DNC data from the S-57 ENC data collected, without loss of information, then the DNC data would correspond to the "legal" electronic chart data. The Hydrographic Office defines what is the legal hydrographic data in its jurisdiction, in accordance with IHO and IMO regulations. This can be represented in DNC.

The "legal" data is just part of the data that is normally required in a DNC. This "legal" data forms a "base" DNC that can then be augmented to meet the additional DNC data collection requirements. A "base DNC" is the complete set of Hydrographic

Office approved data, corresponding to the ENC product specification, represented in DIGEST VRF form. To match the DNC product specification additional data needs to be included.



Since DNC data corresponds to an SENC data set, it should be possible to certify a system that displays DNC data as an E CDIS system. Such a certification would require the faithful representation of all of the "base" DNC data in accordance with the rules for ECDIS performance and in accordance with the S-52 presentation library rules. If additional DNC data beyond the scope of the "legal" requirements were displayed, it may, dependent upon the type of this additional data, be necessary for the ECDIS equipment to indicate that the system was not operating in ECDIS compliant mode.

2.2.1 Different Military Needs

A common sense principal applies to the comparison of ENC and DNC. If one starts with the same source data, one should get the same results, as long as the two exchange formats or other parts of the system do not lose any data.

There has been significant effort over the past four years expended on ensuring that DIGEST can be converted into S-57 without losing any information. A minor amount of additional work is required, but this problem is essentially solved. The parameters of conversion have to be expanded to include the ENC and DNC product specifications. This will require the acknowledgment that there will have to be a future DNC product specification that will be totally backward compatible with the existing DNC product specification, but which includes additional information to fully support the "base/legal" DNC data without loss of information.

The other fact that needs to be acknowledged is that a DIGEST based system can be a compliant ECDIS. The issue is one of the true presentation of the legal content of a chart and the associated operation of an ECDIS.

There has been a significant amount of misunderstanding over the past number of years that has led to potential conflict. There are underling differences between the military requirements and those of regulated civilian navigation. ENC data is deliberately narrowly defined to ensure consistency and to provide safety margins within which safe navigation is possible. The military normally wishes to comply with these conventions, but needs additional data in order to address extraordinary circumstances. The official data from a Hydrographic Office should be well identified and be a clean sub-set of the data available for use in a military environment.

One option, that is sometimes discussed, is to build a system that is capable of reading and using both S-57 ENC data and DIGEST DNC data. One could switch from a fully compliant S-57 ECDIS mode to a DIGEST mode. Unfortunately this does not satisfy the important requirement to be able to integrate both data sets. If a military vessel were displaying the coastal zone information, it would want both the Hydrographic Office data and the additional data at the same time. It is necessary to be able to build upon the Hydrographic Office data, and therefore it must be converted into the DIGEST VRF product form. To integrate the data, all of the issues of compatibility that have been discussed above must be addressed.

2.2.2 WECDIS

NATO has begun the study of the development of a Warship Electronic Chart Display Information System (WECDIS). This study group is in its initial study phase, but it has already identified that it needs to be able to present both official S-57 ENC data and DIGEST DNC data as well as many other data sources, such as raster data products. To do this properly it will not be sufficient to have just a "multi fuel" approach. Providing multiple sets of non-integrated data to the operator of such a system on a ship will place the burden on the operator to be able to integrate the data. It may be permissible to be able to choose between different raster formats, because only one raster data set may be displayed at one time, but vector data sets may be integrated, and may also be combined with raster data.

True compatibility requires integration of the content. This means that there needs to continue harmonization of the ENC and DNC products. It also means that ENC data should be able to be represented as a base component of DNC data. The integration task should be taken on by the military mapping agency on behalf of its Navy.

The WECDIS forum should become the forum in which the alignment of content is specified in terms of requirements to the IHO TSMAD committee and the DGIWG.

2.2.3 Presentation

Presentation issues under DIGEST are different from those under S-52. The DIGEST software tools provide a capability to define rule based symbols for the representation of Features and attributes. This is very similar to the ECDIS requirements as described in the presentation library in IHO S-52. However, the DIGEST requirements are broader because there is a wider variability of possible feature types. Under the ENC product specification there is a very tight binding between S-57 Objects and attributes and the corresponding presentation rules. There exist a number of horizontal presentation rules, where the presentation of one object may affect the presentation of an adjacent object.

2.2.4 Requirements

An important issue is whether the military wants to be able to display official Hydrographic Office data or to have a certified ECDIS (possibly as a WECDIS). To display official data requires that the "base" DNC data produced by the Hydrographic Office correspond to the same content as the hydrographic data also published by the Hydrographic Office as an "official" S-57 ENC product. That is the harmonization should be brought to the level so that there is no information loss.

To achieve a certified ECDIS status based on DNC data will impose additional constraints. It will be necessary for the compliant ECDIS to be able to support all of the presentation and performance rules for an ECDIS, in addition to having sufficient flexibility to be able to accommodate additional military data from other DIGEST data sources. There may be a reflection back on the ECDIS performance specifications to ensure that this is possible.

A future DNC product specification could be made to be much closer to the current ENC product specification. This could lead to DNC being accepted as a DIGEST relational form implementation of ENC at the SENC level. To achieve this would require a shift in thinking in both organizations. A DNC would effectively become a DGIWG standardized SENC of the S-57 ENC product specification using the DIGEST VRF encoding. This is a preferred outcome over continued misunderstanding and potential conflict.

3. UPDATING

One of the most important parts of a navigation system is the maintenance of the currency of the data. This is equally true for all forms of navigation, but the frequency of the required updates differ.

The IHO has developed an update mechanism for S-57 data that is based on a transaction oriented approach. This suits the needs of large vessels that can obtain update information over communications means while still at sea. It is assumed that

smaller vessels that frequent a single port or a small number of ports will be able to obtain update information for the ports and waters of interest while at port.

The IHO updating mechanism communicates messages to add, modify or delete objects and attributes in a data set. Updating in ENC is based on the fact that there are few "layers" or groups and that data is at a low level of topology. Replacing an object has few links to other objects, and therefore an object by object based replacement is possible.

A comparable updating mechanism exists for the DIGEST VRF based products; however, this updating mechanism is based on table replacement not object replacement. DIGEST compatible products such as DNC operate at a higher level of topology (because they are direct use products more akin to an SENC). This means that there are more side effects to an update that must also be communicated. If a feature is changed there are implications in a number of tables linked to that feature. All of the tables that are changed are transmitted. This is much more than the ENC update, but it works well for the higher level of topology supported by DNC.

The two systems are not incompatible, they are complementary. A transactional update mechanism can, over time, degrade a data set, if there is a possibility for compounding errors due to missed update messages or corrupted data. IHO has provided facilities to minimize such possible errors, but the possibility always exists. A replacement update mechanism is less efficient, but potentially more rugged. It is also required when the volume of data is greater in an update message, as is the case for DNC.

When a transactional update message is received by an ECDIS system it must be converted into the required modifications to the SENC format for that system. This means that the topological relationships and consistency checks must be calculated. If a transactional update message were sent to a DIGEST display information system, the same topological relations and consistency checks would have to be calculated. It is theoretically possible to use a transactional update method for DNC. The calculations that would have to be done are equivalent to those that would have to be done in an S-57 based ECDIS in converting to the EDCIS internal SENC format.

A common generic update message is theoretically possible that could be used to generate both ENC and DNC updates, if the two data sets are identical in content. This is only possible if there is no information loss in producing one from the other. It would also require unique IDs as defined in S-57 ENC to also be included in the DNC data.

DIGEST VRF currently supports relative "IDs" for each table. Some research work currently going on by Laser-Scan Corporation for the US NIMA has proposed unique "IDs" for VRF relational tables, to build an Object/Relational database structure. If that structure were available it would certainly be useful; however, an additional attribute as a secondary key could serve in the current DNC structure to support a unique ID.

A transactional update mechanism, based on the DIGEST B telecommunications encoding, could be developed for DNC that paralleled the IHO S-57 transactional update mechanism. This new update mechanism could be generalized to support both S-57 and DIGEST. If the content of the update messages are the same and the unique "IDs" are the same then one update mechanism could be used to serve both data formats. The only additional data that would have to be transmitted is the S-57 Object code and the FACC code for each modified object/feature.

4. TC211 IMPLICATIONS

The International Organization for Standardization (ISO) is currently developing a suite of base geographic information standards. Both DIGEST and S-57 have been identified as "functional standards" for which profiles can be developed of the base standards. This will drive future versions of DIGEST and S-57 closer together. DGIWG has already indicated that the next edition of DIGEST will be based on TC211 components, as long as TC211 accommodates all of the requirements of DIGEST.

TC211 may provide important opportunities for technical alignment between the base DIGEST and S-57 standards. It will also, through its International Standardized Profiles (ISP) process provide the mechanism to align products such as ENC and DNC.

TC211 is developing a suite of 20 standards. Some of these standards, are of great importance to both IHO and DGIWG. The standards of primary interest are the TC211 Reference Model, the Feature Model as part of the rules for Application Schema and the Spatial Schema standard. Also, TC211 is developing a comprehensive metadata catalogue and rules for the establishment of Feature and Attribute Catalogues.

IHO and DGIWG representatives have worked through the TC211 committees to ensure that these TC211 base standards are compatible with S-57 and DIGEST. Other groups such as the database standards group JTC1 SC32 SQL/MM and the Open GIS Consortium are also cooperating toward harmonized standards. It is greatly to the benefit of IHO and DGIWG to align themselves with this effort.

The introduction of the TC211 base standards provides an important, and unique opportunity to further align S-57 and DIGEST, and especially the ENC and DNC products.

5. PROPOSED STRATEGY FOR HYDROGRAPHIC OFFICES

One of the barriers in the past to the introduction of ECDIS was the high volatility of the standards. This is why the IHO froze S-57 for four years after it was released in October 1996 and then extended this freeze to an additional two years.

What has been indicated in the previous sections of this report implies change, and change is bad for stability. It is important for the industry to realize that all change will be evolutionary. Stability is of great importance. Hydrographic Offices should not change their current production plans for S-57 ENC data.

5.1 Official Data for DNC

A Hydrographic Office for a country, defines what the legal content of navigational charts are for that country. The relationship between the Hydrographic Office and the military mapping agency varies from country to country. In some countries, such as France, they are one in the same agency. In some countries, such as Canada, there are separate agencies. In countries such as the United States the military mapping agency is a IHO member agency in its own right. The production of official DNC data would vary from country to country.

All of the legal data content should be included in a "base" DNC. There should be no arbitrary pre-filtering. If the military agency wishes to filter the data to meet the current DNC product specification, then it can make that choice. However, the full complement of the official data should be available for future use. The "base" DNC should include all of the information in the released ENC.

Since the "base" DNC is not the final DNC product, it does not have to comply exactly with the existing DNC specification. It does not meet that specification anyway because some information is missing. It is suggested that some additional supplementary attributes be carried in the "base" DNC. It is proposed that these include:

- S-57 Object ID and Attribute ID - So that in the future as the conversion between the DIGEST FACC and the S-57 Object catalogue improves, the base data could be used to produce a better match to a FACC feature and attribute. It is also desirable to carry the data so that a user who is familiar with only the IHO catalogue could retrieve those attributes from a DIGEST viewer. The NOTES related attribute table in DIGEST VRF could be used to carry this information.

- S-57 Unique ID - updates of ENCs should not require that a DNC be recompiled from the "base" data and the other auxiliary data sources. If the unique IDs were preserved as attributes of the "base" DNC then it is possible to use them to process an ENC update message and to generate a DNC table oriented update message. The process cannot be made automatic if the unique IDs are lost. This information will also be useful for future work on developing a common update mechanism.

- Accented Characters - If any accented characters are used as part of the official data, in NINFORM, as place names or elsewhere, then these accented characters should be retained in the "base" DNC data.

- Geometric Integrity - No modifications should be made to the geometric integrity of the data to conform to the current DNC specification. The facilities of DIGEST 2.0 VRF that were introduced to support S-57 should be used. The current DNC product specification is of 1993 vintage, and does not use all of the capabilities of DIGEST. Any filtering should be done at the last stage in DNC production. There must be the capability to support point features that are coincident with connected nodes. This facility is available in DIGEST VRF, but not used in the current DNC specification.

- List Attributes - S-57 supports list attributes. Although they are used infrequently they are important. VRF in DIGEST edition 2 introduced a Relational Attribute Table and Join Table to support them, when they are required. They should be represented as repeating attributes in the "base" DNC data.

All of the data in the ENC product should be included in the "base" DNC. This means that one can claim that the basis for the DNC products are the official charts. Once there is any filtering that removes data, the DNC stops being a bearer of official data. The last filtering stage should make it plainly obvious where there are problems with the current DNC specification.

5.2 Standards Influence

The current DIGEST and S-57 standards are close, but there remain a number of incompatibilities that require further harmonization. If the goal is to eliminate the potential conflict between the Digital Nautical Chart and the Electronic Nautical Chart products, then it is necessary that further harmonization continue.

Significant harmonization occurred during the production of the DIGEST/S-57 Interface Control Document and during the production of S-57 edition 3 and DIGEST edition 2. The majority of the work was the creation of a conversion of almost all of the S-57 Objects and Attributes to equivalent DIGEST FACC Features and Attributes. Currently the alignment is at the standards level, not at the product specification level.

-For all practical purposes the data models match. ENC uses level 1 (connectivity only) topology, where DNC uses level 3 (planar graph plus faces) topology. Level 1 is a pure subset of level 3., but it takes some work to build the more complex level 3 topology. Most GIS systems already provide this capability.

-The translation between the S-57 Object catalogue and the FACC is not perfect. We have a 100% conversion; that is, every S-57 object has a translation to a FACC feature attribute combination. But some of these conversions are not very good. Converting specific attributes to an "other" category is a conversion, but information is lost. The S-52 presentation library manager depends upon some attributes that are lost, so perfect S-52 rendering is not straight forward.

-The DGIWG FACC Working Party meeting in December 1997 improved the translation for many S-57 objects by adding new attributes to FACC, but all of the recommendations from the ICD were not accepted. There were some conflicts with other proposals to modify FACC. DNC does not align perfectly with FACC. To get DNC and ENC to really align there will have to be another round of work on catalogue alignment.

The biggest differences are at the product specification level and the collection criteria level, where there are numerous minor problems which impact compatibility. The following list identifies the major areas of misalignment encountered during the production process. This analysis is the result of actual dual product production from ENC to DNC. The problem areas can be classified into three main areas: Uncollected data, difficult conversions, and keying updates. If certain data was not collected by a Hydrographic Office to produce an ENC or paper chart, but it is required in the DNC specification, there is little that can be done. One can't generate data out of thin air. In some cases if the field sheets are available it is possible to generate the additional data, but this is not the usual case. Some aspects of converting from S-57 ENC to DIGEST encoded DNC are difficult to perform but are entirely achievable. The higher level of topology and the cross tile edge pointers needed in DIGEST VRF can be calculated automatically from the S-57 data because the data models have been harmonized. The S-57 unique identifiers need to be preserved in DNC data to be able to apply update messages derived from ENC update messages. That is, the military mapping agency would have to maintain a master DNC with the unique IDs in place in order to process ENC type update messages and then produce VRF table replacement type update messages.

- **Cross-Tile topology and edge matching:**
  A DNC database may contain libraries of 4 types, Harbour, Approach, Coastal and General. A single library can contain many charts. The S-57 ENC definition specifies six applications, Berthing, Harbour, Approach, Coastal, General and World. Manual selection is required to assign S-57 charts to the DNC categories. The tiling scheme and «grouping» or «layering» differ between DNC and ENC. Automated and semi-automated tools exist to assist in the topology rebuild process.

- **ENC to DNC Bathymetric Conversion:**
  S-57 depth areas are chosen by the Hydrographic Offices with respect to the individual products and the "safety" factor (possibly 2, 5, 10, 15m,...). DNC has fixed ranges e.g. 10-20-30m.

DNC depth areas (0-10m) start at the HWL (coastline) to the 10m, extending over the drying line (0m in S-57). The HWL in S-57 is actually +x m for chart datum (not 0m).

This is a case where the data required for DNC was not captured to produce ENC.

- **ENC to DNC Content Discrepancies:**
  Based on test data conversions it was found that the majority of the mappings in the ICD are correct; minor errors still existed in at the attribution level. Refinement work at the catalogue harmonization level will need to be completed as a result of actual mapping exercises; these will have to be reflected in the ICD (Interface Control Document).

- **ENC to DNC Attribute Dependency Handling:**
  If a particular DNC attribute is populated with a certain value, then one or more other attributes may also have to be populated in a particular dependent fashion. ENC have similar dependency characteristics identified as "mandatory attributes". When transferring attribution from ENC to DNC, the attribute dependency rules must be upheld. In most cases, the feature mapping conversion table can populate these correctly. Additional conversion rules are required in the ICD to respect dependencies.

- **Data Quality Attribute Mismatches:**
  A discreet feature mapping can be done between various S-57 Meta-data "Quality" Objects and the DNC DQAREA Object. However, the source S-57 file does have the appropriate information to populate these attributes

- **DNC Format Specific issues -Polygon Overlaps and Universal polygons:**
  S-57 allows overlapping polygons of all types except for the "Skin of the Earth".

  DNC area objects are defined in each of the coverages. Coverages are restricted to planar topology which does not allow overlapping polygons. The Universal polygon defines the area in each coverage which is not populated with feature area types. The DNC specification permits multiple features to share the same geometry. This can implement the planar graph representation of the S-57 objects in DNC. The DNC product specification does allow the use of join tables to allow multiple features to share the same geometry (although some of the DIGEST product specifications don't permit the use of this DIGEST facility). A conversion procedure needs to be documented so that the conversion of one topology to another is done consistently.

To achieve ENC/DNC compatibility will require continued support of the harmonization process. The focus should shift to achieving a complete conversion of those S-57 Objects and Attributes used in ENC to the FACC codes used in DNC.

Metadata alignment has not been addressed since edition 1.2 of DIGEST and edition 2 of S-57. There are few problems with metadata, other than with the representation of quality, but these issues should be addressed.

Future efforts should work toward a new DNC product specification, that makes use of the new capabilities in DIGEST edition 2 (and which is fully backward compatible). Also work should be done on a common transaction oriented update mechanism so that S-57 ENC updates can also be used directly with DNCs.