

**4th NCWG MEETING
The Hague, The Netherlands, 6 - 9 Nov. 2018**

**Paper for Consideration by NCWG
Future of the Paper Chart**

Submitted by:	United States (NOAA)
Executive Summary:	Status of drafting the "Future of the Paper Chart" document and summary of the work that still needs to be done to complete it.
Related Documents:	None
Related Projects:	None

Introduction / Background

The idea for writing a paper about paper charts originated at the ninth meeting of the Chart Standardization and Paper Chart Working Group (CSPCWG) in 2012. During the meeting, a discussion about the relevance of the INT chart concept expanded to consider the future of the paper chart generally. It was opined that, while ENC's are particularly useful for navigation at larger scales, paper charts at smaller scales are still very useful for planning and overview and it was suggested that a paper could be drafted on this subject.

Over the span of five years, three working group chairs, and several working group members volunteering to help write a paper, less than complete success was achieved in finishing the task. It remains in the work plan of the Nautical Cartography Working Group (NCWG) as high-priority Item A16, "Consideration of the 'future of the paper chart.'"

Analysis / Discussion

Thanks go to the mighty group of a handful of individuals who have contributed to this effort already. Their draft text has been edited and compiled into the draft "The Future of the Paper Nautical Chart" document that is attached herein. Some progress has been made, but much still remains to be done. It is hoped that we can revitalize the effort and complete the document in time to submit it to HSSC next May.

This can be accomplished if we follow the schedule shown below.

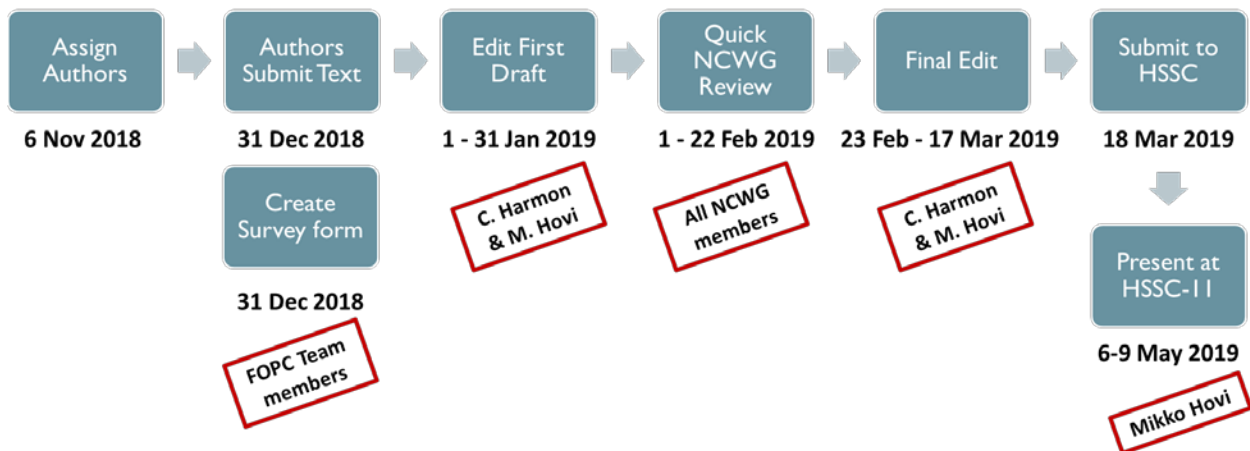


Figure 1.

It is important that a number of *dedicated* and *responsive* authors be identified to write the remaining sections. This recruitment is planned for the first day of the NCWG4 meeting.

The status of each section is provided in [NCWG4-06.1B](#)

Also during the meeting, we want to validate the need for any surveys that we want to conduct either before or after the document is presented to the HSSC.

Conclusions

NCWG has a short time to complete the FOPC document, but much has already been done. We need motivated volunteers to finish the job.

Recommendations

- Recruit volunteers to finish writing the unfinished sections.
- Validate any needs for surveys and develop a strategy for administering the surveys.
- Follow the schedule in Figure 1

Action required of NCWG

The NCWG is invited to:

- a.) Follow the recommendations stated above
- b.) Submit writing assignments on or before the due date of 31 December 2018
- c.) Encourage their agencies to submit any survey requests in a timely manner

The Future of the Paper Nautical Chart

An Overview of Issues and Recommendations Regarding
Paper Nautical Charts in the Current and Future Marine Environment
by the International Hydrographic Organization – Nautical Cartography Working Group

- - Working Draft - - 12 October 2018 - -

Executive Summary

<<<This section is to be written after the paper is completed>>>

Introduction

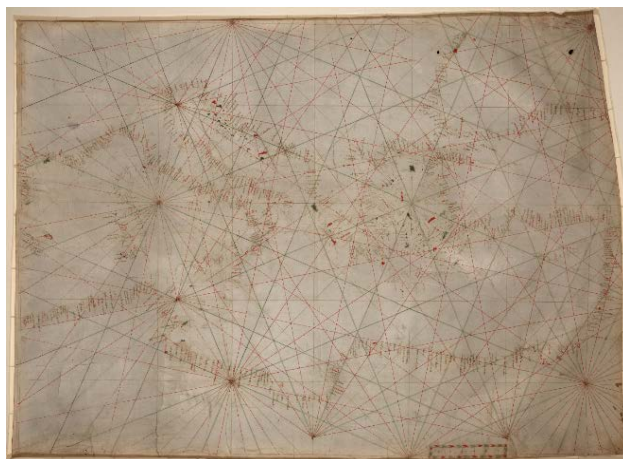


Fig. 1. Portolan chart of the Mediterranean Sea ca. 1320 to 1350

Portolans, nautical charts covered with a rhumbline network, started to appear in Europe in the late 13th century. This innovation took advantage of the recent practical use of the magnetic compass for marine navigation. Portolans exemplify how the form of one navigational tool can be heavily influenced by the advent of another. The invention of radio direction finding in the 1930s, which eventually led to the addition of LORAN lattices on nautical charts, is another example. The creation of the Global Positioning System (GPS) and development of Electronic Chart Display and Information Systems (ECDIS) in the 1990s changed the form of

nautical charts in a radical way; most notably, moving from paper media to the digital form of Electronic Navigational Charts (ENC).

1.1 Purpose

While paper and raster nautical charts have coexisted with the vector ENC for nearly three decades, the advent of GPS, ENCs, and ECDIS is now having an increasing influence on the way raster charts are made and used. The content, format, distribution, and even the continued existence of the paper chart, are topics that are now commonly discussed by professional mariners, recreational boaters, regulatory authorities, national hydrographic offices, and other stakeholders. To prepare adequately for the future, the International Hydrographic Organization - Nautical Cartography Working Group has prepared this overview of the most significant issues related to the “Future of the Paper Nautical Chart,” and offers some recommendations to be considered by the IHO. It is hoped that further exploration and discussion of these issues will help official chart producers, paper chart makers, and chart users better prepare for what may lie ahead.

1.2 Background

The idea for writing this paper originated at the ninth meeting of the Chart Standardization and Paper Chart Working Group (CSPCWG) in 2012. During the meeting, a discussion about the relevance of the INT chart concept expanded to consider the future of the paper chart generally. It was opined that,

while ENCs are particularly useful for navigation at larger scales, paper charts at smaller scales are still very useful for planning and overview and it was suggested that a paper could be drafted on this subject.

Over the span of five years, three working group chairs, and several working group members volunteering to help write a paper, less than complete success has been achieved in finishing this task. It remains in the work plan of the Nautical Cartography Working Group (NCWG) (the former CSPCWG) as high-priority Item A16, “Consideration of the ‘future of the paper chart.’”

1.3 Scope

With the goal of finally completing the task of writing a paper on the “Future of the Paper Nautical Chart” in mind, the scope of this study has intentionally been designed to be an overview with the understanding that digging deeper into some topics may be desired in the future. That is, to identify issues that may affect the future production and use of paper national and international (INT)* nautical charts and to discuss the most important aspects of those topics in a timely manner. The information presented is intended to stimulate additional discussion and ultimately prompt a desire to delve deeper into the ramifications of specific topics that are introduced here. This paper is not an exhaustive study of global paper nautical chart production, distribution, and usage practices. It is meant only to introduce important paper chart related issues that may require the IHO, individual hydrographic offices, regulatory organizations, mariners, and other stakeholders to think about paper charts differently and to take appropriate actions to prepare for the future of the paper chart. Some preliminary recommendations are provided for further consideration and the possible development of more practical IHO guidelines.

1.4 Related Documents

- 2013 NOV [HSSC5-INF7](#), Future demand for Paper Nautical Charts
- 2014 MAY [The International Hydrographic Review](#), Next Generation Paper Chart
- 2014 NOV [HSSC6-08INF1](#), Australian experiences in deriving paper charts from ENC
- 2015 APR [CSPCWG11-13.1A](#), The Future of the Paper Chart
- 2016 APR [NCWG2-13.1A](#), Future of Paper Charts

<<< This list of references will be expanded >>>

* The IHO developed the international chart concept to facilitate the provision of minimum sets of charts suitable for the navigational requirements of international (foreign-going) shipping. These charts are intended to enable those IHO Member States who provide, or wish to provide, charts outside their own national waters, to print by facsimile reproduction with only superficial modifications, selected modern charts under the terms of a bilateral arrangement between the Member States [Technical Resolution 7/1919 as amended refers].

Current Environment

The most recent edition of the *American Practical Navigator* (Bowditch) succinctly summed up the current state of marine navigation.

With the advent of automated position fixing and electronic charts, modern navigation has become an almost completely electronic process. The mariner is constantly tempted to rely solely on electronic systems. But electronic navigation systems are always subject to potential failure, and the professional mariner must never forget that the safety of their ship and crew may depend on skills that differ little from those practiced generations ago. Proficiency in conventional piloting and celestial navigation remains essential.¹

This section describes how paper charts continue to be used in this mixed environment of venerable age-old and advanced modern methods of navigation.

2.1 Traditional Role of Paper Charts



Fig. 2 Use of paper and electronic charts

Paper charts, pencils, dividers, parallel rules, and protractors, as well as Notices to Mariners and chart correction templates, are still used to chart courses while planning voyages and to plot positions while underway. Crewmember's ordinarily fix their ship's position every ten minutes or less often in open ocean.

Calculating a position with a sextant, by taking bearings with a bridge wing alidade, or by dead reckoning can take several minutes. Even when paper charts are being used, some mariners have taken to obtaining ship positions from ECDIS and then recording progress on the corresponding paper chart.

2.2 International and National Regulations

a. IMO ECDIS and Paper Chart Carriage Requirements

The International Convention for the Safety of Life at Sea (SOLAS) was first adopted in 1914, has been amended many times since then. SOLAS Chapter V, Regulation 19, Carriage requirements for shipborne navigational systems and equipment," paragraph 2.1.4 specifies:

All ships, irrespective of size, shall have nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements of this subparagraph. Ships to which paragraph 2.10 applies shall comply with the carriage requirements for ECDIS detailed therein.

Paragraph 2.10 provides a schedule for mandatory adoption of ECDIS by certain types and sizes of ships as their primary means of navigation, as depicted in Figure 3 below. As of July 2018, the transition period to ECDIS has now been completed.

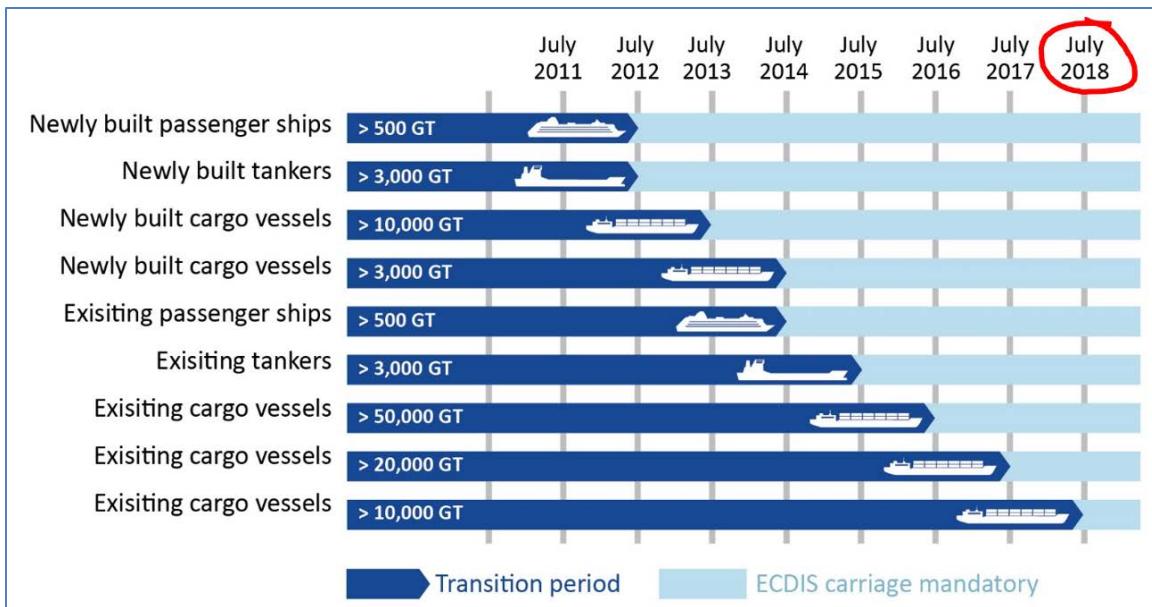


Figure 3, ECDIS Implementation Schedule for Vessels on International Voyages

Paragraph 2.1.5 specifies the need for a back-up. It states:

All ships, irrespective of size, shall have: back-up arrangements to meet the functional requirements of [paragraph 2.1.4], if this function is partly or fully fulfilled by electronic means.

An associated note states:

An appropriate folio of paper nautical charts may be used as a back-up arrangement for ECDIS. Other back-up arrangements for ECDIS are acceptable.

Back-up requirements in case of an ECDIS failure are specified in IMO Resolution MSC.232(82), "Revised Performance Standards for ECDIS," Appendix 6.

Concisely:

- All ships are required to carry nautical charts to display their intended route and monitor their position.
- Use of an ECDIS meets this requirement.
- Most ships undertaking international voyages must use an ECDIS.
- Regardless of whether ECDIS is required or not, if "electronic means" are being used to meet chart carriage requirements, then a back-up must be in place.
- An appropriate folio of paper nautical charts may be used as a back-up for ECDIS.
- Other types of back-up for ECDIS are acceptable
- General functionality of an appropriate ECDIS back-up is specified in IMO Resolution MSC.232(82).
- The IMO resolution does not explicitly state so, but a secondary ECDIS system with a separate independent source for power and GPS feed would meet the requirements for a back-up to the primary ECDIS.

<<< Discuss the trade-offs for ships with dual ECDIS vs ECDIS with paper charts for back-up? What are the costs for Dual ECDIS with ENC vs maintaining suites of both ENCs and paper charts, which require manual corrections? What proportion of SOLAS ships are currently using paper chart back-up and what is

the trend for the future? Is there any expectation that the IMO will drop the option for ECDIS back-up with paper charts? >>>

Information about the availability of paper charts for ECDIS back-up was collected by the IHO in 2007. Data provided by many countries is available at https://www.iho.int/srv1/index.php?option=com_content&view=article&id=394&Itemid=427&lang=en, but it is not clear if this ten-year-old information is still valid.

b. Paper Chart Carriage Requirements for other Regulated (non-SOLAS) Vessels

<<< <<< Discuss any IMO or other national requirements to carry paper charts as the primary means of navigation. Also, discuss how requirements for domestic commercial vessels, which are not part of the IMO mandate, may be changing. For example, USCG no longer requires use of paper charts for U.S. commercial and other regulated (non-SOLAS) vessels.

The table below shows a summary of the carriage requirements for vessels on domestic voyages as enforced by national regulatory agencies. This table is meant to reflect a nation’s general requirements, not to document all the distinctions and exceptions that are usually found in maritime regulations.

Mariners should not use this table to determine carriage requirement in their nation’s waters. Refer to official local and national regulations for the most specific and up-to-date carriage requirement information.

As a general guide to those providing information for this table, it may be assumed that the requirements for paper chart or ENC carriage apply to “most vessels” with lengths of 10 meters or greater. If distinctions for different types of vessels are thought to be important, these may be made with multiple entries and indicated parenthetically.

Note that this table includes possible requirements for use of ENCs, but not the type of system that may be required for the display and use of the ENCs, which could be ECDIS or other non-ECDIS systems as specified the national authority.

National Chart Carriage Requirements for Commercial Vessels on Domestic Voyages						
Member State (Recent NCWG participants shown)	Required for Primary Navigation			Required for Back-up		
	Only Paper Chart	Only ENC	Either Paper Chart or ENC	Only Paper Chart	Only ENC	Either Paper Chart or ENC
Canada						
Denmark						
Finland						
Italy						
Japan						
Netherlands						
Norway						
Spain						
Sweden						
Turkey						
United Kingdom						
United States			X			X

Member States are invited to complete the "Future of Nautical Charting Survey" to provide information about carriage requirements for ENCs and paper nautical charts for domestic voyages.

c. United Nations Convention on the Law of the Sea (UNCLOS)²

The United Nations Convention on the Law of the Sea (UNCLOS) is an international treaty that defines states' rights and responsibilities regarding the oceans, such as navigational rights, territorial sea limits, economic jurisdiction, legal status of resources on the seabed beyond the limits of national jurisdiction, passage of ships through narrow straits, conservation and management of living marine resources, protection of the marine environment. There are currently 168 state parties to the convention, which came into force in 1994. States are individually responsible for the discharge of their own obligations to international conventions and treaties.

The convention defines various zones and their limits, over which a coastal state has certain rights. Under the convention coastal states can claim jurisdiction over a Territorial Sea, a Contiguous Zone, an Exclusive Economic Zone, and Continental Shelf.

In the convention, various references are made to charts, the need to publish certain features on charts, and deposit of those charts with the United Nations. The need for publicity of baselines, limits and boundaries supports the effective and appropriate application of jurisdiction, rights and responsibilities of users and coastal States.

UNCLOS Articles that reference charts are:

- Article 5 Normal Baseline
- Article 6 Reefs
- Article 16 Charts and lists of geographical coordinates – Territorial sea
- Article 22 Sea lanes and traffic separation schemes in the Territorial Sea
- Article 43 Sea lanes and traffic separation schemes in Straits used for international navigation
- Article 47 Archipelagic Baselines
- Article 53 Right of Archipelagic Sea Lane Passage
- Article 75 Charts and lists of geographical coordinates – EEZ
- Article 76 Definition of Continental Shelf
- Article 84 Charts and lists of geographical coordinates – Continental Shelf
- Article 94 Duties of the Flag State
- Article 134 Scope of this part – The Area

As long as required features can be publicised on appropriate scales of charts, the convention does not specify whether the chart must be electronic or paper.

Special non-navigational UKHO charts

UK defines straight and fixed baselines for UK and overseas territories where applicable by statutory instrument. UKHO produces several straight baseline charts of UK and overseas territories that are updated *ad-hoc* and are not to be used for navigation. The charts are referenced in the statutory instruments that declare the straight baselines. These special charts exist, because UKHO does not show straight baselines on standard navigational charts. If these paper charts were to be removed, straight baseline data would need to be either included on the electronic navigational chart series or submitted as list of coordinates to the Secretary-General of the United Nations (by *note verbale*), and the statutory instruments would need to be amended.

IHO S-121 Maritime Limits and Boundaries Product Specification

S-121 establishes a framework for digitally communicating the geographic extents of marine areas and the associated rights and restrictions that apply to them. The product specification is being developed

by the S-121 Project Team (S121PT), which was established as a subsidiary of the IHO S-100 Working Group in December 2015. However, calls for such a development go back at least a decade earlier.

For example, United Nations General Assembly resolution 59/24 of 17 November 2004 seeks, "to improve the existing Geographic Information System for the deposit by States of charts and geographical coordinates concerning maritime zones, including lines of delimitation, submitted in compliance with the [UNCLOS] Convention, and to give due publicity thereto, in particular by implementing, in cooperation with relevant international organizations, such as the International Hydrographic Organization, the technical standards for the collection, storage and dissemination of the information deposited, in order to ensure compatibility among the Geographic Information System, electronic nautical charts and other systems developed by these organizations."³

The S121PT terms of reference state that the team's objective is to develop the IHO S-121 Maritime Limits and Boundaries Product Specification, which takes the following into account:

- Defining a proposed data model;
- Create an S-100 conformant product specification for Maritime Limits and Boundaries to support coastal States' depository obligations in accordance with the Convention;
- Determine if S-100 needs to be extended to facilitate the implementation of the deposit obligation of coastal States' under the Convention.

A draft standard is intended for review and trial by December 2018.

If there is a change away from the UNCLOS requirement of deposit and publicity of charts for maritime baselines, outer limits of zones and maritime boundaries then there will need to be significant legislative development. It is highly unlikely that UNCLOS would be re-opened, instead an additional implementing agreements may be considered: this is a major international conference and negotiation which could take several years. The alternative may be for informal compliance outside treaty obligations. That would leave UNCLOS in place with its legal and ratified requirement for chart publicising maritime baselines, limits and boundaries.

2.3 User Requirements

- a. "Fit for Purpose" Paper Charts for use as a Back-up to ECDIS and other Systems

Reference: www.iho.int > ENC's, ECDIS&S-100 > ENC Availability > Backup Paper Charts ([link](#))

This section looks into some strategies the IHO may explore to:

- justify and accelerate ENC production and ECDIS navigation
- help reduce HO's paper chart portfolios
- provide SOLAS vessels a non-ECDIS alternative as an adequate back-up for navigation in case their main navigation system malfunctions.

At the moment of writing this paper the IMO mandatory ECDIS carriage requirement is in force for all SOLAS vessels and the recreational and non-SOLAS market has been using ECS (loaded with official and non-official charts) for an extended period of time. The number and diversity of navigational products HO's are expected to offer has now reached a point where is not sustainable due to staff issues. At the moment mariners can opt between paper and S-57 ENC's but soon they will also ask for S-101 ENC's. Quality over quantity will lead HO's to remove options from the 'products menu' and paper charts look like the most reasonable candidate to start with. It is now time for HO's to educate and prepare mariners for e-Navigation times.

It is important to highlight that the use of BUCEN (Back Up Charts for ECDIS Navigation) would only be required in an emergency situation (ECDIS failure) and therefore a reasonable expectation that the ship may not be able to continue her trip as planned exists. A ship may need to temporarily deviate to a safe waiting place (anchorage or open sea) until ECDIS is back in working order or other external support is received (e.g., pilot assistance).

Considering that it is unlikely HOs are looking to increase their chart portfolios to accommodate a new product (except for S-101) this paper will focus on the following two main options. Each of them aims to lower HOs' workload by either reducing or completely stopping the production of paper charts.

Option A - Identifying a subset of existing charts in the current portfolio and 'adapting' them to fulfill the IMO back-up requirements. – 'Reduce by adapting' strategy.

Option B - Developing a new IHO S-10x product specification to standardise and facilitate the generation of a paper chart from published ENC's by mariners or chart agents. – 'Stop by delegating' strategy.

Option A - BUCEN produced by HOs using existing IHO Standards

1. Full ENC coverage based on the existing paper chart portfolio must be achieved first. This would allow HOs to retire some paper charts while retaining coverage and detail in their ENC's.
2. The aim is to reduce the existing paper chart portfolio to the minimum number of charts required to provide adequate ECDIS backup (SOLAS Chapter V – 2.1.5) in the country's charting area of responsibility. In simple terms this means charts that would allow mariners to draw the ship route, monitor their position and safely take them to the nearest:
 - a) suitable 'waiting area' until the system can be repaired; or
 - b) pilot boarding place from which it can be assisted to berth safely.

The limits of any larger scale ENC with no paper chart equivalent should be added to these charts.

3. The first step would be for HOs to identify the smallest scale charts suitable to serve as back-up in case of ECDIS malfunction. The first areas to analyse should be port approaches followed by the areas used for coastal transit between ports and lastly the link with offshore territories or neighbouring countries (open sea navigation). Depending on the area in question the following scale ranges may be considered suitable to select the largest scale 'back-up' chart:
 - Port approaches: 75 000 to 150 000
 - Coastal (restricted): 150 000 to 350 000
 - Coastal (not restricted): 500 000 to 1 500 000
 - Open sea transit: 3 500 000 or smaller
4. A practical example on the use of this strategy is given in Annex B.

5. A preliminary list containing the minimum type of features to be present in a BUCEN is given in Annex A.
6. The HO's would continue the production and distribution of these charts as per current practices.

Option B - BUCEN Produced from latest published ENC's using a new IHO S-10x product specification

7. This option is about developing a new IHO S-10x product specification aimed to generate, on demand, a paper product from the latest published and up to date ENC's. A dedicated software should allow mariners to generate a POD file that could be printed on shore (before departure) or on board (in a dedicated plotter) with minimum input (limits, scales, planned route, etc.).
8. Portrayal could look more S-52 than INT-1.
9. This new product specification must define all the key features and construction parameters required by a paper product aimed to serve as ECDIS back-up only. It should standardise and simplify the output and support and facilitate chart carriage compliance inspections conducted by Port State control officers.
10. With time, HO's could stop producing paper charts and focus all their energy on enhancing and extending their ENC (S-57 and S-101) portfolios. The production of paper chart products would be 'delegated' to the user.

Note that this discussion does not provide a comprehensive and detailed analysis for each option. The intention is to present the key ideas behind each alternative in order to promote further discussions and analysis.

Carriage requirements for non SOLAS vessels vary a lot depending on countries' legislations. In many instances, although charts are highly recommended to be carried on board, they are not enforced by the local authorities.

The use of web services and tools already developed by some companies (e.g., ESRI – see the US [NOAA Custom Chart](#) web application) could be used by non SOLAS vessels to produce a paper version of the ENC's covering the area of interest. They could print and carry them on board in case they either want or are requested to carry some kind of physical chart backup based on official data.

b. Small Scale Planning Charts

<<< If the general need for paper charts ends, would the need for small scale paper chart coverage remain for overview and route planning purposes? How would charts be selected for this purpose? Could this need be accommodated by a different product-on-demand format? >>>

c. Remarks and recommendations from other stakeholders

<< Other wisdom from hydrographic offices, mariners, and other paper chart stakeholders. >>>

Member States are invited to complete the "Future of Nautical Charting Survey" to provide any additional remarks and recommendations.

d. Impacts on non-navigational users of paper nautical charts

<< Who are the other users of paper charts? Can they easily transition to use RNC or ENC charts? >>

2.4 Production Issues

a. Systems/databases used for both raster and vector chart production

<<< Discuss HO's experiences producing both raster and ENC products with either one or more than one production system. Is there still a rough correspondence between raster and ENC product footprints?

b. Portrayal of raster charts with S-57 attributed data

<<< Discuss the challenges of symbolizing raster products from data encoded to support ENC production. Comment on what is "lost in translation" or what is made easier by using S-57 encoded data. What will become easier or more difficult to symbolize after the transition to S-101 encoding? >>>

c. Print on Demand (PoD)

<<< Discuss HO's current print on demand capabilities. Is the release of POD charts synchronized with the comparable ENC? If not, which product is usually released first? How often are new PODs released, weekly, monthly? Do all PODs contain all newly applied source data (such as routine application of hydrographic surveys, etc.) in addition to critical corrections, or do only "New Editions" have routine (non-critical) data added? >>>

The current paper chart's production workflows have certainly been influenced by the continuous increase in use of ENCs and by the technological developments related to printing processes.

Over the past two decades, many HOs have focused on producing an ENC portfolio derived from existing paper charts and consistent with their content.

Now, many HOs have reversed the process and shifted to an "ENC first" based workflow where nautical paper charts are derived directly from ENCs or from the same database used to produce ENCs. This process was aimed at:

- re-positioning charts from local datums to WGS84 with the publication of a New edition of the traditional chart (as S-4 required at B-201.3);
- populating a coherent digital database from which to derive and update two independent official products: paper charts and ENCs.
- resolving inconsistencies between overlapping paper charts

Moreover, many HOs have replaced complex lithographic printing presses with modern, efficient digital printers (Fig.4).



Off-set lithographic printing
(Discontinued by Italian Hydrographic Institute)

Digital printing
(In use at Italian Hydrographic Institute)

Fig. 4

HOs' production strategies have been deeply affected by recent developments in print on demand technology, which eliminates the need for warehousing or correcting charts sold long after their printing dates. PoD technology allows HOs to print and release more frequently updated charts, better meeting chart users' needs and expectations.

For many HOs, the ENC now provides the primary source data and the paper chart's production has become an automatic process through the conversion of ENCs. The human work is focused in clarifying the presentation and increasing the paper chart's readability.

For example, the essential steps of paper chart production workflows of Italian Hydrographic Institute are shown in figures five through eight, below. Over the years they have been revised, modified and improved, in order to better exploit the potential of PoD technology.

In 2006, a whole portfolio of charts for recreational boaters was created directly by the ENCs through the process shown in fig.5:

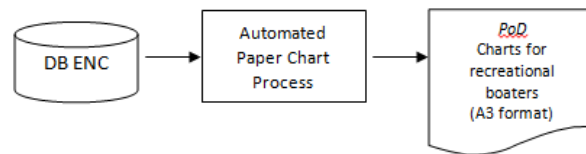


Fig. 5

These charts are updated every 2 weeks, in accordance with the Italian NtM booklet and their release is synchronized with the comparable ENC.

The good results achieved with this process led to the adoption of a very similar workflow in 2010 for creating, updating and printing National/International paper charts in A0 format. This process, as shown in Fig.6, starts with the ENC database which is updated with both new source data and further corrections derived from a critical revision of products already published. This guarantees a complete coherence among paper charts, ENCs, and nautical publications. This workflow was made possible only through the use of the digital printing in A0 format and the abandonment of the traditional off-set printing.

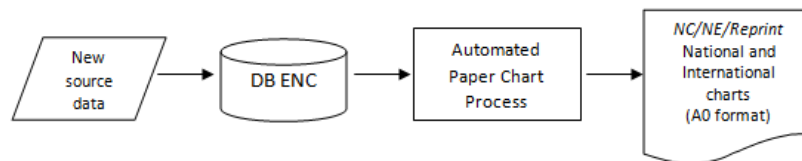


Fig. 6

The Italian Hydrographic Institute now uses the workflow in Fig. 6 for about 65% of its national and international charts (the process for the other 35% is described later in this section). Unlike the PoD process used for recreational charts, which have new regular updates available as often as every two weeks to reflect ENC changes and application of NtMs, these national and international charts are only printed when a new chart (NC), new edition (NE), or reprint are required, based on the following:

- availability of new data that covers an area too large to be updated with an NM block;
- a large number of routine and critical NM updates have been applied to the chart.

Obviously, the process of producing and printing charts for recreational boaters also benefits from this newer workflow, since both products are derived from updated ENC's (fig.7).

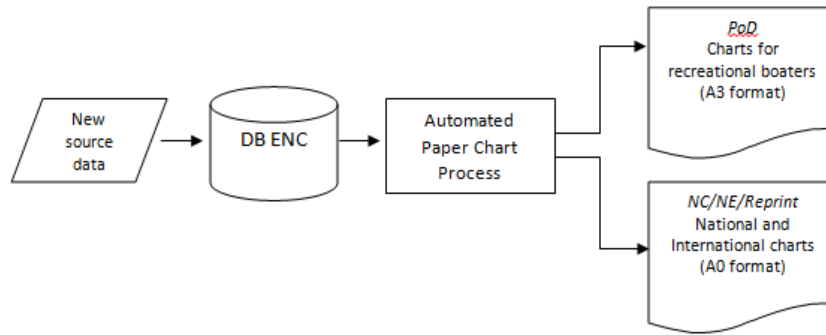


Fig.7

Approximately 35% of the Italian Hydrographic Institute portfolio is in raster format with edition dates prior to 1990. These charts are updated through obsolete software and workflows, used only to produce reprints or reproduce foreign charts (Fig.8). These will eventually be replaced by the modern, efficient software to take advantage of the PoD workflow.

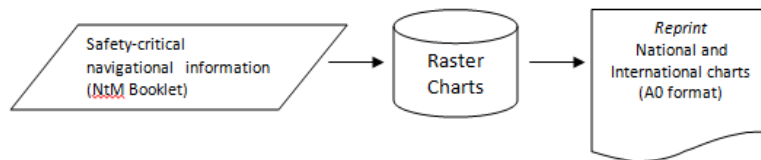


Fig.8

Great effort has been devoted to build systems that allow both the ENC and the paper chart to be updated in parallel. Even though the PoD has increased efficiency, the efforts demanded of HOs to produce and update paper charts have not decreased. The maintenance of two official products remains a challenge, because of the limited availability of human resources and time needed to output both products (including the extra portrayal finishing required for paper charts).

The advantages of PoD are not to be underestimated. PoD printing has become a common technology used by most of HOs, which allows updated products reach mariners much faster. Nevertheless, in a world that is rapidly changing in technology, PoD should be considered a "transitional strategy" due to the fact that paper charts remain expensive and time consuming to make. It is also a product that is increasingly disregarded by the incoming digital generation. In a short while PoD might make way for a more flexible and already feasible second generation of paper charts made by *Product on demand*.

In the meantime, nautical and navigation community are waiting for the complete transition to ECDIS in order to assess impact and consequences on production and sales of paper charts.

2.5 Paper Chart Sales and Product Usage

a. Declining demand for paper charts

<<< Discuss various HOs' experience with chart sales. Which customer segments have had the greatest change in sales? (see [HSSC5-INF7](#), "Future demand for Paper Nautical Charts"). The trend for US sales is shown below. What are the trends in other countries? Are paper charts sales statistics a valid measure of the need for paper charts (are there some important chart customer segments who will never be able to transition to ENC's with an ECDIS or ECS?) >>>

The trend for US lithographic and Print-on-Demand nautical chart sales is shown below.

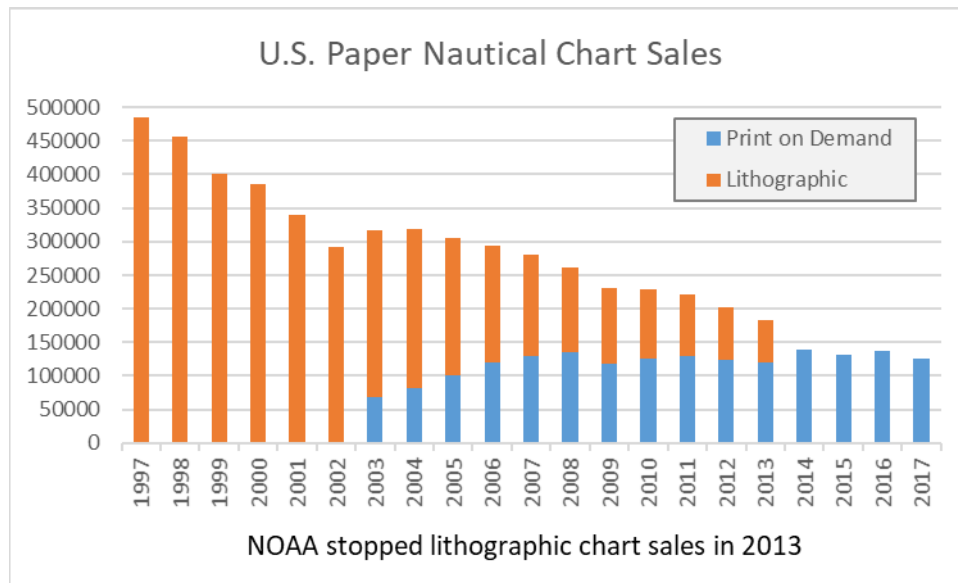


Figure 3, U.S. Lithographic and Print-on-Demand Annual Nautical Chart Sales

Member States are invited to complete the "Future of Nautical Charting Survey" to provide information about the sales and distribution of their paper nautical charts (both lithographic and print-on-demand) between 2000 and 2018.

b. Increasing demand for ENC's

<<< Discuss various HO's' or the RENC's experience with ENC sales. Which customer segments have had the greatest change in sales? >>>

In the last decade the demand for Electronic Navigational Charts has increased. Although ENC's were founded on the paper chart experience, they are now becoming more and more independent and diverging from the original raster product. Some of the factors that make ENC's so appealing to the customer are also contributing to the obsolescence of paper charts, such as the ease of distributing updates. It is anticipated that ENC's will increase in popularity as their ability to interoperate with other navigationally important datasets, such as S-100 based products, is enabled. ENC's will be a core component of the evolving e-Navigation concept, as well as part of applications required by many different kinds of users.

The challenge for the hydrographic community will be the continuing detachment of ENC's from their paper chart legacy. Some stakeholders are convinced that the only way to realize ENC's full potential is to get rid of the paper charts altogether. However, HO's must realize that paper charts are part of navigational history and the end of paper charts are unlikely to occur in the short term future. Once any dependencies which ENC's and paper charts have with each other are illuminated, each product will be able to reach its own natural level of acceptance and use.

The full IMO mandate for the use of ECDIS, as well as continuing improvements in the content and format of ENC data, and the applications used for the display and use of ENC's will likely continue to tip the scales in favor of increasing ENC use and diminishing paper chart use

Member States are invited to complete the "Future of Nautical Charting Survey" to provide information about the sales and distribution of their ENC products between 2000 and 2018.

c. Diminishing need for RNCs for ECDIS

Most, if not all RNC production is tied to parallel production of paper charts from the same chart images. When there is a high demand for RNCs, the “extra” effort to produce paper charts is small. If the need for RNCs decreases, then the rationale for continuing paper chart production must be based more on the trade-offs related to the costs of producing paper charts on their own.

<<< Discuss how some hydrographic offices now have complete ENC coverage, thus RNC charts are no longer required in these areas. Australia still produces paper charts, but stopped RNC production. Have other HOs halted RNC production (or never had any RNC production)? The US Coast Guard does not recognize RNCs as meeting carriage requirements, as the US has a complete ENC suite. Non-SOLAS, regulated vessels must use either ENCs or paper charts in US waters. >>>

d. Recreational Boaters’ Contribution to Paper Chart Sales

<<< How many recreational boaters are active in different nations? How many operate in coastal waters (as opposed to “non-IMO” lakes and rivers)? What percentage of HOs’ paper chart sales is attributable to recreational boaters? What, if any, public relations messages do HOs want to convey to recreational boaters regarding the transition to digital products and the possible end of paper nautical chart production? >>>

e. Recreational Boaters’ use of Digital Charts

<<< Discuss how boaters are now using ENCs, RNCs, and third-party products derived from ENCs and RNCs. What are the advantages and disadvantages of this? Discuss the concern over third-party products not being updated as often as their “source” national HO products. >>>

Future Environment

3.1 Product Coverage

a. International (INT) Charts

<<< Discuss the need, if any, for continuing the production of INT charts. Is the need greater in certain areas and less (or not needed at all) in other areas? Why are so many IHO Member States now so reluctant to produce INT charts, even when their national charts continue to be produced in accordance with S-4? Is there a strong recommendation to end INT chart concept and the associated IHO resolutions? >>>

b. Rescheming paper chart coverage.

<<< Discuss benefits and challenges of standardizing the layout of paper chart coverage for hydrographic offices, including the reduction of redundant coverage, use of fewer compilation scales, easier synchronization with ENCs. (This is an important topic in the US, which has over 2000 chart panels presented in 130 different scales. There is less of a need for this in other countries, such as Finland, which has 1294 chart panels (including leisure charts) with only 13 unique scales. >>>

c. ENC-only coverage

<<< Discuss HOs’ experience with ENC only coverage. What percentage of charts is ENC-only? What circumstances make the most sense for ENC-only coverage? Have any problems related to ENC-only coverage occurred? >>>

d. RNC-only coverage

<<< Discuss HOs’ experience with RNC only coverage (production of an RNC or raster tile service product, without release of the corresponding paper product). The US has just produced its first RNC-only coverage (it is actually ENC & RNC-only, with no paper POD). Do any other HOs have RNC-only or

ENC/RNC-only charts? What circumstances make the most sense for RNC-only coverage? Have any problems related to RNC-only coverage occurred? >>>

3.2 Alternative Methods of Paper Chart Provision

a. Printing paper charts from ENCs

<<< Discuss benefits and challenges of printing paper copies of ENC cells, including symbolization, whether to and how to maintain printed ENCs with hand corrections, what traditional paper chart items (such as source diagrams, tide tables, etc.) if any, would need to be added to the “paper ENC.” Would printed ENCs meet carriage requirements for paper charts or as a back-up to ECDIS? Would a printed ENC chart specification be required? If so, should it be incorporated into S-4, or be separate? Should printed ENCs use the S-52 symbol set, the raster INT1 symbol set, or some other combination of symbols? Should a “Printed ENC symbol set” be added to the S-100 Hydro Portrayal Registry? There is a distinction between printing a paper nautical product using ENC data as a source, versus printing an actual paper representation of an ENC cell. This difference should be discussed, as well as the advantages and disadvantages of each. >>>

There are some potential alternatives to traditional paper charts that could improve efficiency while also attempting to mitigate the impacts to existing paper products. One of the potential alternatives to traditional paper charts is to directly render ENC datasets using the S-52 presentation library.

Since S-52 is automatically applied to an ENC, there are some key advantages to this approach, including:

- The automatic application of symbology. Because the charted content is now rendered using ENC data directly, there is no need to perform a translation from ENC to a different vector or raster format, no need to translate data to S-4 symbols, and no need to have them heavily reviewed for cartographic accuracy.
- The simplification or elimination of hand corrections (Notices). Since the data encoding is intrinsically tied to the presentation library, the instant an update (ER) is applied, the charted content is updated accordingly. Data updates are synonymous with symbology updates, mitigating the need to publish hand corrections, as well as the lag between ENC and raster updates.

Since most existing paper chart plans are not perfect reflections of their ENC counterparts, this approach is not as simple as just swapping out an ENC for a chart plan. There are a few issues to evaluate when considering this approach.

- Data coverage. There are often differences between the data coverage, both in extent and in scale, between the ENC and the paper chart.
- Generalization. In some cases, missing data at smaller scales is filled by cartographically generalizing larger scaled data. This may not be reflected in the ENC, which could have an M_CSCL (compilation scale) area of larger coverage within the cell.
- Cartographic finishing. Cartographers perform many tasks to improve the readability of a chart, which are either not performed well in S-52, or are not performed at all.

In addition to leveraging S-52, another potential alternative to traditional paper charts would be to combine using ENCs as a data source with a new data-driven version of S-4.

This approach would allow hydrographic offices to:

- Continue making traditional paper charts, without the pushback that would accompany the utilization of S-52 symbology as a replacement for S-4.
- Improve accuracy and consistency across paper products by clearly defining the relationship between S-57 encoding and S-4, rather than being accomplished manually by a human or automatically by a program that was built on inferring this relationship.
- Improve efficiency in production as the application of the symbology to the data would be automatic, and without need for comprehensive review.

Another benefit of this approach is that there is little impact to the end user. The impact, which could be significant, would be predominantly felt by the NCWG, hydrographic offices, and software vendors in creating, managing, and implementing a data-driven S-4 specification and its accompanying technology.

Although providing a mapping of ENC encoding to S-4 would seemingly allow for much more streamlined chart production with minimal impact on the status quo, it is limited in addressing the issues that more broadly affect maritime visualization standards. It does not address ECDIS display concerns, such as those raised by France in [NCWG3-08.8A](#), and it does not serve to harmonize paper and electronic symbology.

Also, since the source would be an ENC, it would also suffer from the same issues - data coverage, generalization, and a lack of cartographic refinement - that would be encountered in using S-52.

b. Product on Demand / Chart of Demand

Product on Demand or Chart on Demand technology enables a user to create a customized chart from a database by selecting a centre point, scale and paper size. Some implementations may allow users to select the symbology set to use (INT1, Traditional S-52, Simplified S-52, etc.) and other options, such as depth units in meters or feet. The U.S. is prototyping this technology, called [NOAA Custom Chart](#), using its suite of over 1,200 ENCs as the database from which customized paper charts can be created. Other HO's are perusing similar capabilities. At the moment, the user may download and print the custom chart on their own for free. In the future, there may be an additional option for the users to define their custom product and have one of the U.S. commercial printing partners plot the large format chart and ship it to the user.

This technology works best when the underlying data is "seamless." Therefore, having ENC data (or data in another database) that is compiled at the same or similar scales, for each navigational purpose (Harbor, Approach, Coastal, etc.) will result in "custom chart" output without any discontinuities from large changes in scale. The creation and placement of some chart elements, such as compass roses, notes, source/ZOC diagrams, graphic scales, tide tables, etc., that will require special handling. Working out which of these elements will be required on a custom chart and how to accommodate their placement on a chart is an ongoing avenue of research.

Chart on Demand technology has several potential advantages when compared to traditional chart production. Chart on Demand can:

- Reduce the cost associated with paper chart production. Since this type of system uses S-57 ENC data directly, and uses the S-52 presentation library, the application of symbols and legends is automatic and standardized.
- Eliminate the lag between ENC and paper chart updates. An updated Chart on Demand product can be created as soon as an ENC update (ER) is published.

- Make rescheming irrelevant to charts. Since the user defines their own chart extent, an agency can scheme their data holdings to maximize their own internal operational efficiency, without concern for pre-existing paper chart footprints.
- Harmonize paper and ECDIS visualization. Leveraging the same visualization across both paper and electronic navigational products would mean that mariners do not need to understand two disparate symbology specifications.

In achieving these benefits, Chart on Demand technology is not without tradeoffs. Because consistency is the key to automation, there are several aspects of traditional paper charting that would likely become victims of such a revolution. Some of the known impacts to implementing Chart on Demand as a replacement for traditional paper products are:

- Standardized layouts. The adoption of a layout with a single plan per chart improves the viability of automation. There are legitimate legacy reasons that drive some of the unique layouts and scales found in traditional paper charts. These issues may not be mitigated with an On-Demand approach, sometimes requiring two plots to cover the same area once covered by a single chart.
- Marginalia. Scale bars, titles blocks, explanatory notes, ZOC diagrams, and other chart information need to be placed in specific locations outside of the charted area. Currently, this information is placed inside the charted area - typically on land or over some other area deemed insignificant to navigation. This practice ensures that all charts must be hand-touched, as the space available for such features varies from chart to chart.
- Explanatory Notes. Some notes are found on every chart, and it is therefore easy to enforce consistent placement in the marginalia. However, there are some notes that only appear on a chart if certain local conditions are met, or if the chart contains a specific type of feature. This can be accomplished automatically, but it may be achieved differently by various software solutions.
- Source Diagrams. Since Category of Zone of Confidence (CATZOC) information is captured in the ENC, ZOC diagrams can be generated automatically with relative simplicity, but need to be placed in a specific location in the chart marginalia. Source Diagrams often require data sources other than the ENC. Although any data source can be consumed by an On-Demand application, it is important to note that having a data source is crucial to complete chart automation.
- Resistance to Change. Even if the NCWG works with the appropriate working groups to ensure the correct cartographic attributes are present in S-101, and the cartographic conventions that built S-4 are applied via a machine-readable technique, it is unlikely the automated output will provide the precise quality that can be achieved by a skilled human cartographer. This could result in both internal and external resistance to adopting a new type of product.

Chart on Demand is just one example of what is possible with technological innovation. To what degree and how quickly these innovations might be adopted remains to be discovered. The pace will likely depend in part on how closely the changing technology meets the needs of the maritime community.

c. Enhancing the portrayal of S-57 ENCs

The two predominant international display specifications in maritime navigation, S-52 and S-4, each have advantages. S-52 is automatic and repeatable, while S-4 (also called INT1 symbology) maximizes readability.

The greatest advantage of S-52 is that it is data-driven, entirely determined by ENC encoding. This, its use ensures a consistent visualization, irrespective of the agency producing the data. S-4 is not machine-readable and consequently cannot be directly applied to portray a data source.

A weakness of an S-52 driven display is that it lacks many basic cartographic conventions that minimize clutter and otherwise make a chart easier to read. Some of these issues are outlined in [NCWG3-08.8A](#). Nautical cartographers using S-4 symbology have perfected the craft of generating navigational products that maximize readability. Some aspects of raster chart compilation should be considered for enhancing the S-52 based experience for ENC users (ECDIS or in other systems), which could include the need for additional "cartographic attributions" in S-100 based product specification (the S-101 ENC Spec. and others) or the development of requirements for more "cartographically intelligent" software.

A move to harmonize the S-4 and S-52 symbology in S-100 could produce a machine-readable portrayal solution that would also be more human-readable. Some of the benefits include:

- Improve the feasibility of full paper chart automation
- Improve the readability of ECDIS through inclusion of cartographic rules
- Provide a single set of symbols for navigators to learn, regardless of navigational product
- Maintain a single visualization standard for all maritime products

Harmonizing these specifications will also provide a stronger role for NCWG in managing digital symbology specifications, the maintenance of which was once undertaken by the now disbanded Digital Information Portrayal Working Group (DIPWG). Although now included in the NCWG terms of reference, the working group is still primarily dealing with paper chart issues, while an ENC Display Sub-working Group has been formed primarily of members of the ENCWG and S100WG. NCWG may need to more proactively engage with other working groups to ensure that cartographic concepts are reflected in the development of S-100 based product specifications and the systems that display them.

3.3 e-Navigation

Useful links on www.who.int > ENCs, ECDIS&S-100 ([link](#)) and NIPWG > e-Navigation and Maritime Service Portfolios ([link](#))

<<< Is there a useful, generally accepted definition of what "e-Navigation" is? If so, discuss paper nautical chart issues related to e-Navigation and IMO Maritime Service Portfolios. If not, discuss the difficulty in addressing paper chart/e-Navigation related issues while the concept is still evolving. >>>

Changes a Future without Paper Charts Would Require

This section does not advocate for the end of paper charts, it merely serves to identify some of the changes that would have to take place to enable a complete transition away from paper and raster charts, if that is what the future holds. This discussion will help to illustrate how easy or difficult, and realistic or unrealistic, a paperless future would be. Some changes are more important for commercial mariners, others are more relevant for recreational boaters.

<<< This section will help provide a "reality check" for those who predict the extinction of paper charts within a certain number of years or those who claim that the need for paper charts will go on indefinitely. This section should list the different actions against criteria (for instance, regulations, international, national, production, sales revenues, user requirements >>>

Summary of Impact of a World without Paper Charts					
Impact on...	International regulations	National regulations	User requirements	Production	Sales revenues

Member State Perspective	*	*	*	*	*
NCWG Perspective	*	*	*	*	*

* These table cells are to be marked High, Medium, Low, or None

4.1 Regulatory and Standards Changes

a. IMO and other International Regulations, and National Regulations

No change is required to specific regulations to enable a Future without Paper Charts, as SOLAS Chapter V and national laws are written at a sufficiently high level to avoid mentioning specific products.

However, changes would be required to IMO recommendations and national guidelines for all sizes of vessels where specifics are currently mentioned. That is, where paper or raster charts are specifically cited, as opposed to the more generic terms "chart" or "nautical chart," which are used in some regulations and are commonly understood to include both paper and digital (raster and vector) nautical charts. Adapting these existing regulations and guidance for use on ENCs will require action from national maritime administrations, which are often distinct from Hydrographic Offices.

Member States are invited to complete the "Future of Nautical Charting Survey" to provide information about any changes to their national regulations that would be required to enable the disuse of paper nautical charts.

b. Chart Producing Agency Production Process

From the aspect of safety, there is a preference to have a level of paper back-up in cases such as GPS denial. Traditional celestial and paper navigation continues to be taught at Navy colleges due to the threat of GPS denial.

There is also a requirement to consider the other users of nautical charts, such as deep sea mining, oil and gas industry, shore based activities, etc., who are currently using paper. In some cases, other digital data may be more appropriate than a generalised chart/ENC. Shore based activity would also need appropriate products, which are not necessarily paper charts.

As a whole, ENC quality and coverage would need to improve to remove holes to support safe navigation. HOs would all need to regard the ENC as the primary navigation tool e.g. in areas where HOs have blue-out the ENC with a message 'see paper chart'. Achieving this on a global scale is not a simple process due to the number of individual contributors to world ENC coverage, plus individual capacity and capabilities.

Many ENCs have hydrographic survey data attributed with a CATZOC (category of zone of confidence) of "unassessed." Paper chart equivalents will usually carry a Source diagram, which is likely to convey more information to the mariner regarding data age and quality. Although a large undertaking for some hydrographic offices, conveying the same degree of quality metadata on an ENC as is now shown on most paper charts would require populating the CATZOC attribute with more meaningful data quality values.

c. Chart Sales Revenue

A significant number of vessels are now required to carry ECDIS. However, there will be ongoing residual paper chart sales from vessels that are not required to carry ECDIS or that use paper charts as a back-up to ECDIS.

As a result of the mandatory use of ECDIS roll-out completing this year, it is anticipated that the growth in ENC sales and corresponding decline in paper chart sales may level-out.

Residual paper chart sales to ECDIS mandated vessels are expected to continue until the next major refit of the vessel (when a second ECDIS for back-up could be installed) or the vessel is retired. New builds will likely be sufficiently equipped to not require purchasing suites of paper charts for back-up.

Where vessels are not required to carry ECDIS, a mix of paper charts and ECS is likely to be used. Larger vessels in this category (>500gt) are likely to move to ECDIS, but the take-up will probably be slow. The use of ECS with ENCs on smaller vessels may further diminish the use of paper charts where a full suite of paper charts is not required.

At present, the size of the residual paper chart market is difficult to establish or predict.

d. User Requirements

<<< If paper chart production were to end, what new user requirements might arise? >>>

e. IHO Standards and Specifications

<<< What changes to IHO standards and specifications should or could be made to accommodate a navigational environment without paper charts? >>>

f. IHO Working Groups

<<< What changes to the terms of references of the Nautical Cartography and other IHO working groups would be appropriate or necessary? Would any change in the general working group structure be appropriate? >>>

Recommendations for:

- 5.1 IHO
- 5.2 National hydrographic offices, IHO Member States
- 5.3 ECDIS, ECS, and other “chart plotter” manufacturers
- 5.4 Other stakeholders organizations, such as IMO, UNCLOS
- 5.5 Mariners
- 5.6 Recreational boaters
- 5.7 Other stakeholders, such as GIS and other non-navigational users

Actions to be considered by:

- 6.1 NCWG
- 6.2 HSSC

Annex A – Minimum Mandatory Content for BUCEN

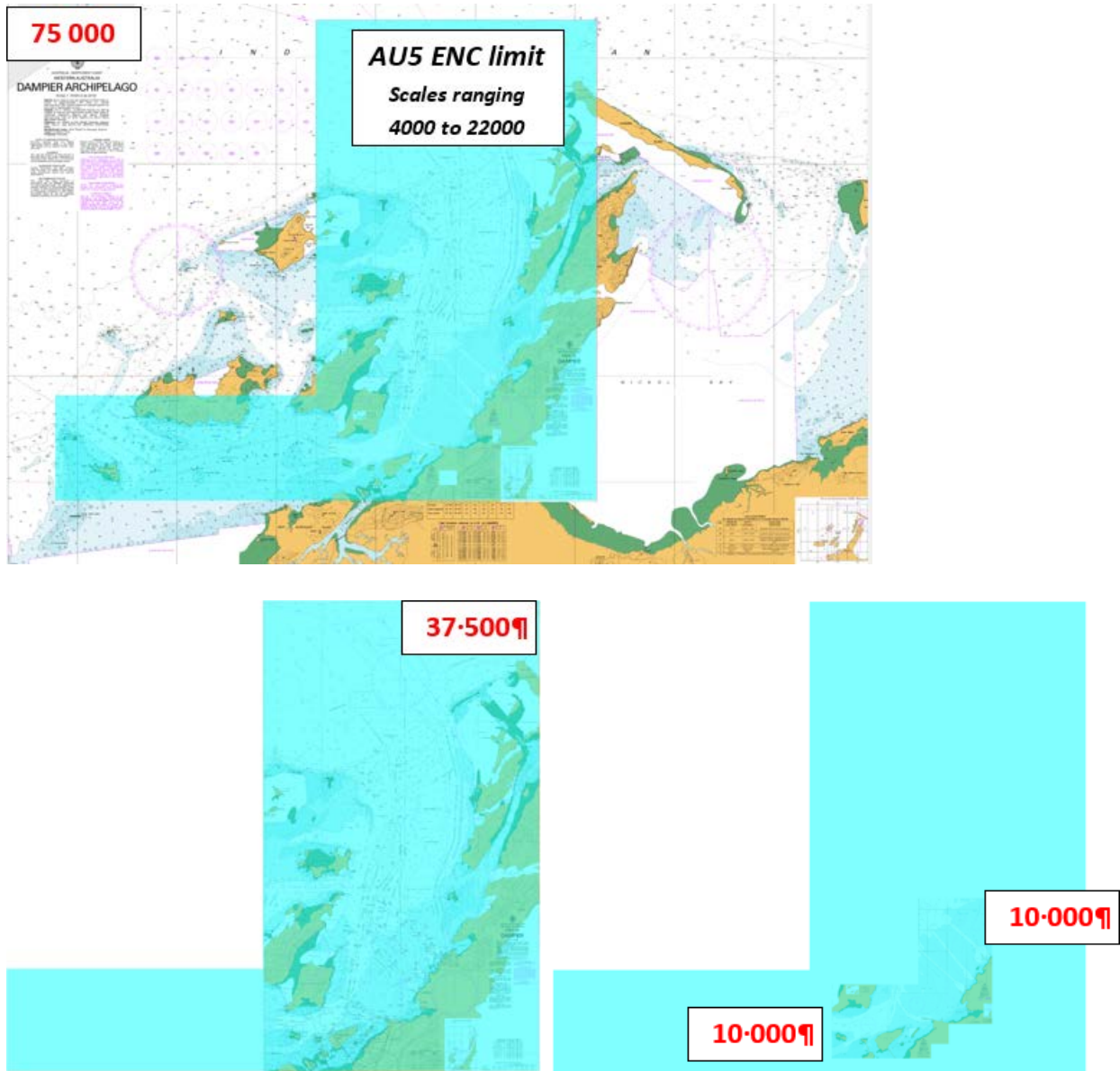
Must Have
Anchorage and anchorage areas
Pilot boarding places
Obstructions to navigation (rocks, wrecks, etc.) - In depths under 30/50 meters only
Selection of aids to navigation with corresponding light description
Depth band colours based on a ship's safety settings (Blue and Light blue)
Depth contours and contour value
Soundings
SBDARE areas; NATSUR= coral or rock
Entry Restricted and/or prohibited areas
All chart notes linked to any of the objects in this list
Pipelines and cables - In depths under 30/50 meters only
Reporting points
Land areas (COALNE, SLCONS)
Unsurveyed areas
Conspicuous landmarks
Spot heights
Dredged areas
Compass rose
Scale bar
WGS 84 - graticule and graduation
Bridges over navigable water (including vertical clearances)
Overhead cables over navigable water (including vertical clearances)
Dolphins
Posts
Floating Docks
Areas being reclaimed
Hulk
Floating barriers
Tidal levels table
Tidal streams and currents (H40 to H46)
Tidal streams panel
Swept areas
Sand waves
ZOC diagram
Routeing measures (Two-Way routes, recommended tracks)
Limits of Ice

Desirable
Ships planned route
Magnetic legend
Harbour limit

Not Needed
Elevation curves
Non conspicuous features
ADMAREs
Vegetation
Built up areas and buildings
Foul areas

Annex B – Example of Reduce and Adapt strategy Port Approaches - Port of Dampier (Western Australia)

Retain 75 000 chart as BUCEN showing AU5 ENC limit and withdraw three larger scale paper charts from the portfolio, one 1:37 500 scale charts and two 1:10 000 scale charts.



End Notes

¹ American Practical Navigator, available at

https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0002

² United Nations, "United Nations Convention on the Law of the Sea," 10 December 1982, at

http://www.un.org/depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm

³ United Nations, "Resolution 59/24 Oceans and the Law of the Sea," page 4, at

http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_59_24.pdf