HSSC11-05.4B

Paper for Consideration by HSSC

Preliminary report on Future of the Paper Nautical Chart

Submitted by:	NCWG
Executive Summary:	-
Related Documents:	HSSC5-INF7, HSSC6-08INF1, CSPCWG11-09.6A, CSPCWG11-13.1A, NCWG2-13.1A
Related Projects:	-

Background and Introduction

The idea for writing a paper on the Future of the Paper Nautical Chart 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.

Over the span of five years, three working group chairs, and several working group members volunteering to help write a paper. This task is 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.'"

The NCWG preliminary report (Annex 1) on the Future of the Paper Nautical Chart has been prepared by a sub working group led by Colby Harmon (USA). The report presents some preliminary findings in the executive summary, but no final recommendations are being made at this time.

Discussion

Sales and use of paper nautical charts is declining while use of electronic navigational charts (ENCs) is increasing. The effort required to maintain paper and associated digital raster chart formats is now becoming disproportionate to the benefit gained by the use of paper charts.

Hydrographic offices are now exploring different ways to reduce the burden of raster chart production, such as decreasing the number of charts in their suite of raster chart products, or developing simplified raster chart products that are easier to produce. Some efforts are also being made to make use of ENCs, or products derived from ENCs, more attractive to mariners and recreational boaters.

This report has prepared to give an overview of significant issues related to the "Future of the Paper Nautical Chart". It is not an exhaustive study of global paper nautical chart production, distribution, and usage practices. Many of the sections are presented from the perspective of only one or just a few Hydrographic Offices. Although many of these experiences are considered typical, the conditions and practices in other nations may differ. This report is intended 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 for the IHO to consider are presented, although it is expected that further exploration and discussion of these issues will also be needed to help hydrographic offices, chart distributors, and chart users better prepare for what lies ahead. These findings and recommendations are based on the experiences, observations and impressions of NCWG members and their Hydrographic Offices; and general research into paper chart production costs, usage and sales occurring after the mandated use of ECDIS by SOLAS vessels.

In order gather further information from IHO Member States NCWG has prepared a survey (see Annex 2).

This information will provide greater insight into the challenges faced by paper chart producing agencies throughout the world. This report will be updated with an analysis of the results after the survey responses are received. The survey will be sent to IHO MS by mid-June through a CL. The CL will also include this preliminary report with any changes resulting from HSSC comments.

The final report will be presented at HSSC-12. It will include a summary of the survey results, any changes in the report text resulting from new insights gained from the survey, and final recommendations as determined by the NCWG

Way forward

NCWG has drafted the following way forward:

10 Apr 2019	**NCWG submits FPNC Paper to HSSC-11** Paper includes draft of Preliminary Report and draft survey questions for IHO Member States.
6-9 May 2019	**NCWG presents FPNC Paper and survey at HSSC-11**
10-23 May 2019	**HSSC comments on preliminary report and survey to NCWG** Send comments to colby.harmon@noaa.gov, cc mikko.hovi@traficom.fi.
10-27 May 2019	**NCWG incorporates HSSC comments into FPNC preliminary report and survey and forwards them to IHO Secretariat**
By 10 June 2019	**IHO Secretariat sends circular letter to IHO Member States** CL transmits Preliminary FPNC Report and survey to MS. MS are asked to respond to the survey.
31 August 2019	**Deadline for receipt of MS FPNC survey responses**
1-30 Sep 2019	**NCWG analysis of MS survey results**
1-31 Oct 2019	**NCWG edits Final FPNC Report via correspondance**
5-8 Nov 2019	**Complete Final FPNC Report & recommendations at NCWG-5**
11-14 May 2020	**NCWG presents Final FPNC Report at HSSC-12**

Action Required of HSSC
The HSSC is invited to:

a. note the preliminary report, and provide any comments it sees appropriate by 23 May 2019
b. note the draft survey, and provide any comments or additional questions it sees appropriate by 23 May 2019
c. endorse the way forward for finalizing the report.

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

**** Preliminary Report for review at HSSC 11 ****
10 April 2019

Executive Summary

Background

The Nautical Cartography Working Group (NCWG) of the International Hydrographic Organization (IHO) has prepared this overview of significant issues related to the "Future of the Paper Nautical Chart". This paper is not an exhaustive study of global paper nautical chart production, distribution, and usage practices. Many of the sections are presented from the perspective of only one or just a few Hydrographic Offices. Although many of these experiences are considered typical, the conditions and practices in other nations may differ. This report is intended 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 for the IHO to consider are presented, although it is expected that further exploration and discussion of these issues will also be needed to help hydrographic offices, chart distributors, and chart users better prepare for what lies ahead. These findings and recommendations are based on the experiences, observations and impressions of NCWG members and their Hydrographic Offices; and general research into paper chart production costs, usage and sales occurring after the mandated use of ECDIS by SOLAS vessels.

Information that will be gathered through a survey of IHO Member States (Annex B) will provide greater insight into the challenges faced by paper chart producing agencies throughout the world. This report will be updated with an analysis of the results after the survey responses are received.

Key Finding

Sales and use of paper nautical charts is declining while use of electronic navigational charts (ENCs) has increased four or five fold in some areas. The effort required to maintain paper and associated digital raster chart formats is now becoming disproportionate when compared to the growing use of ENCs.

Hydrographic offices are now exploring different ways to reduce the burden of paper chart production, such as decreasing the number of charts in their suite of paper/raster chart products, or developing simplified paper/raster chart products that are easier to produce. Some efforts are also being made to make use of ENCs, or products derived from ENCs, more attractive to mariners and recreational boaters.

Regulations Related to the use of Paper and Electronic Charts

The International Convention for the Safety of Life at Sea (SOLAS), Chapter V, Regulation 19, "Carriage requirements for shipborne navigational systems and equipment," specifies that "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."

In July 2018, the International Maritime Organization (IMO) mandated requirement for most commercial vessels on international voyages to use an Electronic Chart Display and Information System (ECDIS) with Electronic Navigational Charts (ENCs) came into full effect. Some national maritime authorities now also allow commercial ships on domestic voyages to navigate entirely with ENCs. Many recreational boaters have also embraced the use of electronic charts. Although many of these users still keep some paper charts as a back-up, the sales of paper charts has diminished significantly over the past decade while use of ENCs has increased significantly.

The United Nations Convention on the Law of the Sea (UNCLOS) defines various maritime limits, over which coastal states have certain rights, such as Territorial Seas, Contiguous Zones, Exclusive Economic Zones, and the Continental Shelf. The convention states the need to publish these limits on charts and deposit them with the United Nations, but the convention does not specify whether the charts are to be paper or electronic. It may be time for more nations to start publishing their maritime limits on ENCs and deposit them with UN using the new S-121 format. This would also support the greater use of GIS technology to share information and identify inconsistencies.

Nautical Chart Users

In addition to conventional nautical chart users, such as professional mariners on international or domestic voyages; and recreational boaters plying lakes, rivers, bays and coastal waters, there are a number of other users of nautical chart data that are more difficult to categorize or account for. In fact, it is even difficult to determine the proportion of chart sales attributed to professional mariners verses recreational boaters, much less others using charts for any number of purposes, such as vessel traffic safety, defence, environmental planning, maritime and ice-related delimitations, tourism planning, fisheries management and other non-navigational purposes.

Single Source Chart Production Database

Several hydrographic offices have made a transition to a single nautical chart production database, which is used to produce both ENC and paper nautical chart products. This is sometimes accompanied by a transition in the relative proportion of production skills required. More cartographers are involved in database operations, compilation and ENC encoding work, while fewer are supporting paper nautical chart product generation and distribution.

Changes in the Chart Product Suite

ENC data can take some time for the initial data encoding, but can easily be published from a production database with little additional effort. Paper chart products usually require additional, manual cartographic "finishing" operations before they can be published.

Some hydrographic offices are considering the development of a simplified version of standard paper nautical charts that would reduce the need for chart "finishing." These simplified products would be intended primarily as a back-up for electronic navigational systems. There may be a role for the IHO to help develop a specification, or at least guidelines, for a simplified raster chart product for back-up.

Some hydrographic offices are also cancelling some paper charts while maintaining the corresponding ENCs or creating new, larger scale ENC coverage without creating equivalent paper charts.

The difficulty of electronic navigational systems in providing a "big picture" overview of a large area may be mitigated by the introduction of larger display screens aboard ships. In the meantime, there is some evidence that the need for small-scale general and sailing charts may persist. The sales of all scales of paper charts is falling, but sales of smaller scale charts are decreasing at a slower pace.

International (INT) Charts

The original intent of the IHO international (INT) chart concept was to facilitate the provision of charts suitable for international shipping and consistent compliance with international specifications. INT charts also enable IHO member states who provide charts outside their own national waters to print facsimile charts with only minor modifications. However, an increasing number of hydrographic offices are now reluctant to produce INT charts and maintain INT schemes, preferring that their national charts be adopted in lieu of INT charts as long as they are already produced in accordance with

S-4 specifications. The situation is very different from one charting region to another and the future of the INT chart concept itself is now in question, especially given that larger SOLAS vessels are now required to navigate with ECDIS and ENCs.

Print on Demand

Several hydrographic offices are now using a mix of traditional printing (usually offset lithography) and "print on demand" (PoD) methods. Many have completely transitioned to PoD. Traditional printing methods require warehousing large numbers of pre-printed charts that need to have corrections applied when they are sold. For hydrographic offices that maintain critical (Notice to Mariners) corrections on the PoD version of charts in-between new numbered editions of nautical charts, the PoD process prints and immediately distributes fully updated charts as each user orders one – even in the middle of new chart editions. PoD makes chart distribution more efficient, but it is still tied to traditional paper chart production. Chart (or Product) on Demand has the potential to create customized paper charts directly from a database.

"Chart on Demand" / Printing Paper Charts from ENC Data

A few hydrographic offices are developing an alternative to traditional paper chart production that enables users to specify the extent, scale, and paper size of their own customized paper chart product. Any "chart on demand" product would necessarily look different than a standard chart. A primary difference is that chart layouts look more like the standardized designs used on a national topographic maps series. Some methods currently create a ready-for-printing raster product from ENC data using the IHO S-52 presentation library (symbology specified for use in ECDIS), because there are already rules in S-52 for mapping ENC feature/attribute values to standard symbology. There are also efforts to provide a more traditional (INT1 symbology based) rendering, but there are difficulties to overcome, as discussed in the next section.

Portrayal of Raster Charts with S-57 Attributed Data

Some efforts have been made to use S-57 attributed data to automatically apply INT1 symbology and legends on raster chart products, but there is not yet a universal method of undertaking this process. Each of these efforts must currently be undertaken by individual hydrographic offices. Some useful future research and development efforts that could facilitate sharing resources to expedite this process could include:

- Creation of a standard naming convention for all INT1 symbols.
- Adaptation of S-52 look-up tables to point to paper chart symbols enumerated in an INT1 symbol catalogue.
- Creation of precise (engineering quality) symbol shape, size, and colour specifications for INT1 symbols.
- Creation of a standard library of digital symbol graphic files for INT1 paper chart symbols, perhaps in the same Scalable Vector Graphics (SVG) format used for the new S-101 ENC product.

This could also make it easier for S-101 development efforts to prototype using more paper chart symbols for the portrayal of ENCs, something that many ECDIS users have shown a preference for. Ongoing development of the S-101 ENC Product Specification should also keep in mind that in addition to supporting the portrayal of ENC data in ECDIS, consideration should be given to how ENC encoding can be optimized to support the symbolization and printing of paper nautical charts from ENC encoded data.

Raster Navigational Chart Production

Raster Navigational Charts (RNCs) – digital images of traditional paper nautical charts – were once used as an alternate data source in ECDIS for areas in which no ENCs existed. Complete ENC coverage is now widely available, so the need for RNC data in ECDIS is no longer a significant factor for hydrographic offices to consider. Some hydrographic offices have ceased RNC production altogether, others continue to produce RNC data or RNC based raster tiles to provide digital base map data for other

non-ECDIS navigational systems. Production of an RNC in any given area requires the same initial effort needed to create a traditional "paper chart" image.

Raster Tile Products

Some hydrographic offices produce tiled raster chart data that can be used with GPS enabled electronic chart systems or other chart plotter display systems to provide real-time vessel positioning. Tiles are also being used on third party nautical data integration websites. At least one hydrographic office is experimenting with generating tiled raster chart data directly from its production database without creating the corresponding full paper chart image and associated marginalia, etc. Thus, ENC and tiled raster chart products are produced, but not the corresponding paper chart.

Recommendations

This is a preliminary report. Recommendations will be provided in Section 7.0 of the final version.

1 Introduction

1.1 The Dynamic Nature of the Nautical Chart

Portolans (nautical charts covered with a rhumbline network) started to appear in Europe in the late 13th century. This innovation took advantage of the new practical use of the magnetic compass for marine navigation. Portolans exemplify how the form of one navigational tool can be 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 notability, moving from paper media to the digital form of Electronic Navigational Charts (ENC).

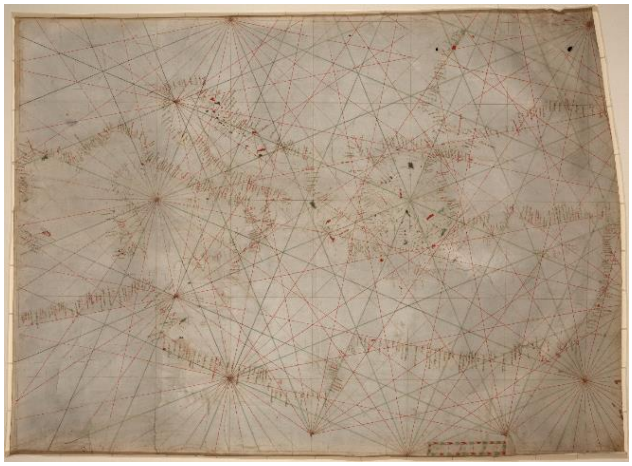


Fig. 1. Portolan chart of the Mediterranean Sea ca. 1320 to 1350

1.2 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 paper 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 Nautical Cartography Working Group of the International Hydrographic Organization has prepared this overview of the most significant issues related to the "Future of the Paper Nautical Chart," which also 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.

1.3 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."

1.4 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)[1] 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. Many of the sections are presented from the perspective of only one or just a few Hydrographic offices. Although these experiences are considered typical, the conditions and practices in other nations could differ. This report is intended 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 additional IHO nautical cartographic guidance.

[1] 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].

1.5 Terms Used in this Paper

ECDIS (Electronic Chart Display and Information System) A navigation information system which with adequate back-up arrangements can be accepted as complying with the up-to-date chart required by regulations V/19 and V/27 of the 1974 SOLAS Convention, as amended. Use of ECDIS is now mandatory by most SOLAS vessels on international voyages.

ENC (Electronic Navigational Chart) The data base, standardized as to content, structure and format, issued for use with ECDIS on the authority of government authorized hydrographic offices. The ENC contains all the chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart (e.g. sailing directions) which may be considered necessary for safe navigation. The format and encoding of ENC data is specified by the S-57 *IHO Transfer Standard for Digital Hydrographic Data*. The recently developed S-101 *ENC Product Specification* will eventually be phased in to replace S-57 based ENCs.

INT1 symbology The chart symbols defined in IHO S-4 for use on paper nautical charts.

Paper Nautical Chart or Paper Chart A printed chart specifically designed to meet the requirements of marine navigation, showing the depth of water, nature of bottom, elevations, configuration and characteristics of coast, dangers and aids to navigation.

In this report, Paper Nautical Chart or Paper Chart are the terms most often used. the terms most often used are

> In this report, the more awkward term "Raster/Paper Nautical Chart" is not used; "Paper Nautical Chart" or "Paper Chart" are preferred. Although not explicitly stated, most of the discussions in individual sections about "Paper Nautical Charts" also applies to the digital raster versions of the paper chart as well.

POD (Print on Demand) A means of duplicating and distributing paper charts (or other hardcopy materials) in which single copies or small quantities of charts are printed as an order for a particular chart is received. Replication is usually by digital printers or plotters as opposed to offset lithography which is used to make large numbers of copies at a time, which are then warehoused for subsequent distribution. Distribution is either directly from a retail nautical supply store or chart agent facility in which a customer walks in to buy a chart; or by mail to satisfy orders placed on-line.

Raster Chart A printed paper nautical chart, a scanned image of a paper chart, the digital image from which a paper chart is made, or other digital representations of a "traditional" nautical chart stored as rows and columns of colour pixels. That is, raster chart, unless otherwise stated, generally includes paper charts and digital charts that use a raster format, such as Raster Navigational Charts.

RNC (Raster Navigational Chart) A digital facsimile of a paper chart originated by, or distributed on the authority of, a government-authorized hydrographic office. It is either a single chart or a collection of charts. RNCs may be used in ECDIS (in Raster Chart Display System mode) where ENCs are not available at all or are not of an appropriate scale for the planning and display of the ship's voyage plan.

1.6 Related Documents

1974 NOV	SOLAS, International Convention for the Safety of Life at Sea
2013 NOV	HSSC5-INF7, Future demand for Paper Nautical Charts
2014 MAY	The International Hydrographic Review, Next Generation Paper Chart
2015 APR	CSPCWG11-09.6A, The Future of S-4 as the IHO Chart Specification
2015 APR	CSPCWG11-13.1A, The Future of the Paper Chart
2016 APR	NCWG2-13.1A, Future of Paper Charts
2014 NOV	HSSC6-08INF1, Australian experiences in deriving paper charts from ENC

2 Current Environment

The IMO carriage requirements mandate the use of ECDIS for the majority of shipping as primary source for navigation, although paper charts may be used as a backup. Some mariners – who are not

subject to the mandate – continue to use paper nautical charts exclusively. However, there is a growing mix of users who navigate with both paper and digital charts, or who plan voyages and navigate entirely with digital charts (even using redundant digital systems as their only back-up). This section describes how paper charts continue to be used in this mixed environment of venerable age-old methods and advanced modern means 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. Crew members 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 of Regulation 19 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.

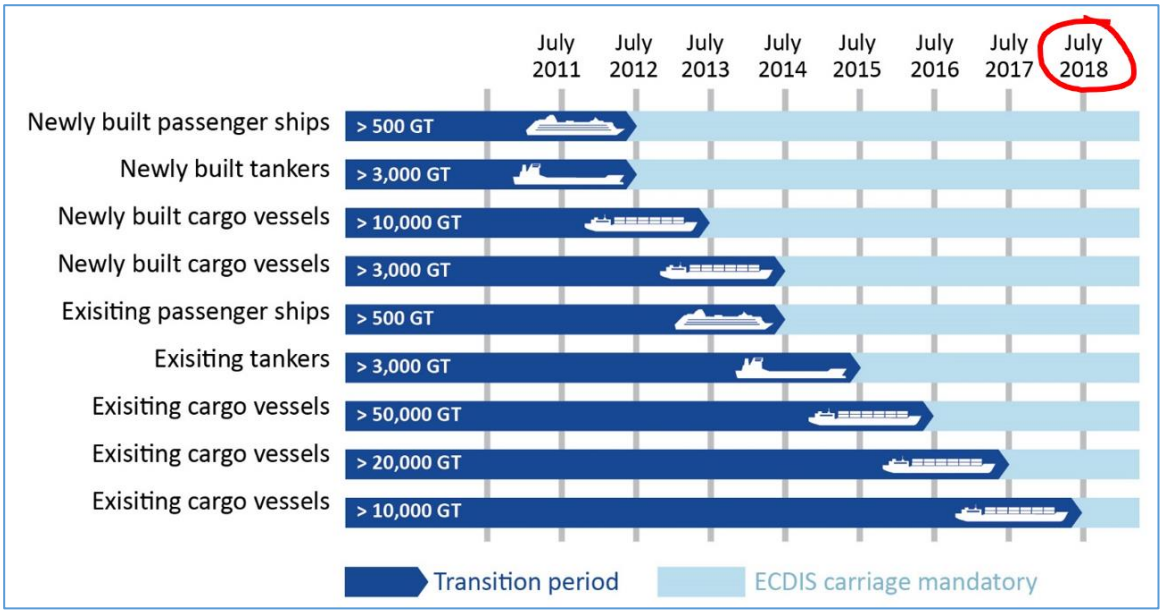


Fig. 3. ECDIS Implementation Schedule for Vessels on International Voyages

Paragraph 2.1.5 of Regulation 19 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.
More 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.

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.
Although IHO Circular Letter CL61/2015 requested that IHO Member States provide updates to this information annually, it is likely that outdated information persists on the IHO "Backup Paper Charts" webpage.

b. Paper Chart Carriage Requirements for other Regulated Commercial Vessels[2]

Table 1 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 requirements 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 by the national authority.

National Chart Carriage Requirements for other Regulated Commercial Vessels[1]						
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			X			X
Sweden						
Turkey						
United Kingdom						
United States			X			X

Table 1. National Chart Carriage Requirements for Commercial Vessels on Domestic Voyages

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

[2] Commercial vessels not subject to the IMO mandate to use ECDIS.

c. United Nations Convention on the Law of the Sea (UNCLOS)[3]

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 the 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. 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.

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."[4]

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 first Edition of S-121 is expected to be released for implementation and testing purposes in mid-2019. Ultimately, S-121 may provide another option for publicizing maritime boundaries, other than through paper or electronic charts.

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 > ENCs, ECDIS&S-100 > ENC Availability > Backup Paper Charts (link)

[3] 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

[4] 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

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

It is important to highlight that the use of Backup Charts for ECDIS Navigation would only be required in an emergency situation (ECDIS failure) and as such 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 the ECDIS is back in working order or other external support is received (for example, pilot assistance).

Considering it is unlikely that HOs are looking to increase their chart portfolios to accommodate a new product (except for S-101) this paper focuses on the following two options. Each option 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 fulfil the IMO chart back-up requirements ('Reduce by adapting' strategy).

Option B: Developing a new IHO S-10x Product Specification to standardize and facilitate the generation of a paper chart from published ENCs by mariners or chart agents ('Stop by delegating' strategy).

Option A - Backup Charts for ECDIS Navigation produced by HOs using existing IHO Standards

- 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 ENCs.
- 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 plot the ship route, monitor their position and safely take them to the nearest:
  - Suitable 'waiting area' until the system can be repaired; or
  - 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.

- 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 'backup' 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

- A practical example on the use of this strategy is given in Annex B.
- A preliminary list containing the minimum type of features to be present in Backup Charts for ECDIS Navigation is given in Annex A.
- The HOs would continue the production and distribution of these charts as per current practices.

Option B - Backup Charts for ECDIS Navigation produced from latest published ENCs using a new IHO S-10x product specification

- 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 ENCs. 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.).
- Portrayal could look more S-52 than INT-1.
- 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 standardize and simplify the output and support and facilitate chart carriage compliance inspections conducted by Port State control officers.
- With time, HOs 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 essentially be "delegated" to private enterprise/industry or the end user.
- 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 depending on countries' laws and regulations. In many instances, although charts are highly recommended to be carried on board, they are not required by the local authorities.

The use of web services and tools already developed by some companies (for example, Esri – see the US NOAA Custom Chart web application) could be used by non-SOLAS vessels to produce a paper version of the ENCs covering the area of interest. They could print and carry them on board if desired; or are requested to carry some kind of physical chart backup based on official data.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about any existing or planed, simplified, "fit for purpose" paper chart products to be used as an on board back-up for digital charts.

b. Small Scale Planning Charts

Even if the general need for paper charts might be declining, is there still a need for small-scale paper chart coverage for overview and route planning purposes? Recent market research, reported by the UKHO, reveals that small-scale planning charts are still being used by mariners and other types of chart users at a steady rate with slightly less decline than larger scale charts.

At the IHO Nautical Cartography Working Group (NCWG) meeting in November 2018, it was suggested that research and development was going into displaying ECDIS on larger format screens, as opposed to the current smaller, Type-Approved screens. Working with manufactures, the UKHO confirms that many are looking to fulfil this user requirement in the near future for back-of-bridge and route planning purposes.

The ability to display ENCs on larger screens may diminish one of the key factors cited by users that distinguishes paper charts from their corresponding digital versions – the previously held notion of the superiority of the paper chart's use for planning purposes and other back-of-bridge operations. However, larger ENC display formats alone may not bring about the end of paper chart use for passage planning. Larger screens may be impractical or too expensive for smaller ships or non-ECDIS users, and there may still be other changes to the content and portrayal of ENC data needed to draw some users away from paper charts.

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

When determining the impact of the use or non-use of paper nautical charts by non-navigational users, we need to establish who these potential users affected by the discontinuation of paper charts are. Following the "e-Navigation[5]" concept, Annex 2 to the publication, MSC 85/26/Add.1 Annex 20, *"Strategy for the Development and Implementation of e-Navigation",* lists the potential users, as shown in Table 2, below.

[5] e-Navigation is defined as "the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment." e-Navigation is intended to meet present and future user needs through harmonization of marine navigation systems and supporting shore services. The development and implementation of the concept is coordinated by the International Maritime Organization in accordance with the "Strategy for the development and implementation of e-Navigation" adopted in 2009 by the Maritime Safety Committee (MSC).

Shore-based e-Navigation Users	
– Ship owners and operators, safety managers – VTM organizations – VTS centres – Pilot organizations – Coastguard organizations – Law enforcement organizations – National administrations – Coastal administrations – Port authorities – Security organizations – Port State control authorities – Incident managers – Counter pollution organizations – Military organizations – Fairway maintenance organizations – AtoN organizations – Meteorological organizations – Hydrographic Offices/Agencies[6]	– Ship owners and operators, logistics managers – News organizations – Coastal management authorities – Marine accident investigators – Health and safety organizations – Insurance and financial organizations – National, regional and local governments and administration – Port authorities (strategic) – Ministries – Marine environment managers – Fisheries management – Tourism agencies (logistics) – Energy providers – Ocean research institutes – Training organizations – Equipment and system manufacturers and maintainers

Table 2. Shore-Based Paper Nautical Chart Users

These shore-based users are responsible for the safety of maritime traffic and defence, environmental planning, maritime and ice-related delimitations, tourism planning, fisheries management, military organizations and many other issues. These demand modern, proven and efficient tools optimized for good decision making to maximize reliability and ease of use in maritime navigation and communications. In many cases, this determination was based on paper charts themselves, but some organizations have been able to optimize and evolve to use other formats, adapting to new technologies and related tools resulting in error minimization. Many have adapted to Electronic Navigation via the Electronic Navigational Chart (ENC) and the Raster Navigational Chart (RNC) on an Electronic Chart Display and Information System (ECDIS), or its military version the Warfare- Electronic Chart Display and Information System (WECDIS), as well as other GIS technology systems or WEB Services. Some System Implementations Include:

- ENC / RNC on ECDIS or WECDIS, or other ECS (Electronic Chart Systems), is as problem-free as purchasing and installing the relevant system.
- Web services and tools already developed, such as the Spanish ISD IHM web application, SHOM DATA ISD, are used instead of paper charts. These web services can be implemented using standard OGC protocols like Catalogue Service Web (CSW), Web Map Service (WMS), Web Feature Service (WFS), Web Coordinate Transformation Service (WCTS) and Web Processing Service (WPS).

Nevertheless, current technological developments should be properly employed to avoid the risk of putting future development of maritime navigation systems in danger due to a lack of proper standardization. Consequently, the following should be guaranteed:

- Identification of potential users and their requirements, regardless of the specific maritime shore-based aspect to be managed, planned, etc.
- That any adopted technological development will further maritime safety and environmental protection, taking into account the required global implementation.

[6] In regard to planning, not ENC & RNC production.

- Proper implementation of computer applications to provide the maritime transportation sector and others with better access to the information.
- That the new application was designed and produced taking into account the requirements, capabilities and skills of all users.
- Proper cost-benefit analysis and risk assessment.
- Required training.
- Required adaptation of organizations and regulations.
- Improved regulation of maritime traffic and associated shore-based services due to better data provision, coordination and exchange using formats easier to read and used by shore-based operators involved in supporting operations related to ship safety and efficiency.
- Infrastructure to improve continuous authorized information on-board, between vessels, from vessel to shore, and among shore authorities and others, which will prove advantageous.

2.4 Production Issues

a. Systems/databases used for both paper chart and ENC production

As is the case with many HOs, the Swedish Maritime Administration (SMA) has seen a decrease in demand for paper chart products since the introduction of the Electronic Navigational Chart (ENC). The lessening demand was projected early on and has influenced both ENC and paper chart production. With a greater demand for ENCs, it was deemed an inefficient use of resources to focus on producing a less demanded product.

SMA currently maintains approximately 580 ENC cells in five navigational purposes as well as a variety of cartographic products. These include paper nautical charts (roughly 117 nautical charts as well as passage planning charts and pilot examination charts), small craft charts (16 A3-sized booklets), tiled raster data and advertising products. Since the introduction of the ENC, SMA has implemented a unique chain of production in which one database stores all object data required for the production of all SMA products. This has been achieved by categorizing objects by usage band and then subsequently by whether the object is a source feature or a cartographic feature. Where possible, ENC objects are rendered with INT1 presentation, otherwise a cartographic object is created and linked to the ENC object in order to provide the correct presentation in paper chart products. Data from neighbouring countries is maintained and updated based upon foreign ENCs. Figure 4 below depicts the database structure.

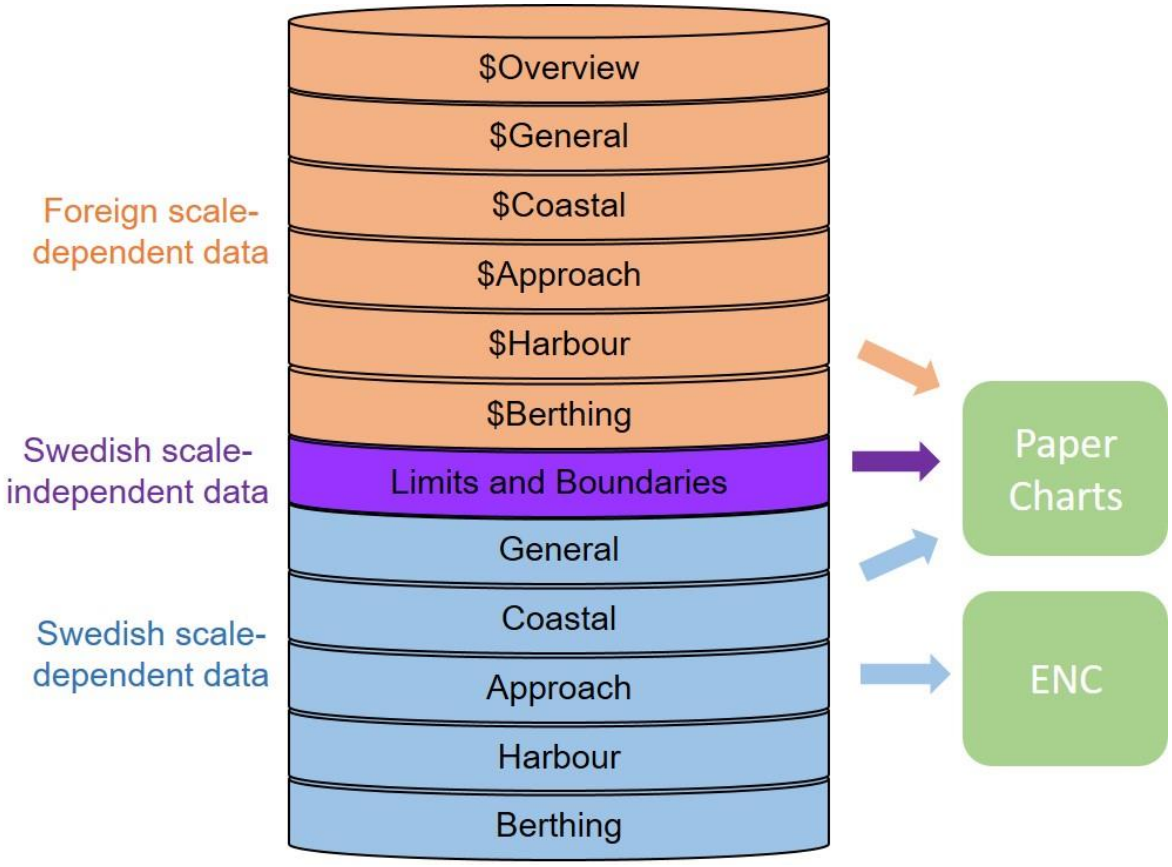


Fig. 4. Structure of SMA chart-production database

This schema enables database operators to apply updates to ENC and cartographic products simultaneously, thus creating a simplified workflow (Fig. 5). Many paper chart products produced by SMA overlap in some way. By having cartographic and source feature data within the same database, it allows cartography to be recycled after the initial update to the database. This means that with every new edition of paper chart, paper chart generators need simply import any changes made in the database between editions as opposed to recreating cartography for each individual product. Once this step is complete, cartographers working with product generation can focus on chart specific features such as grids and graticules, scale bars and product specific texts.

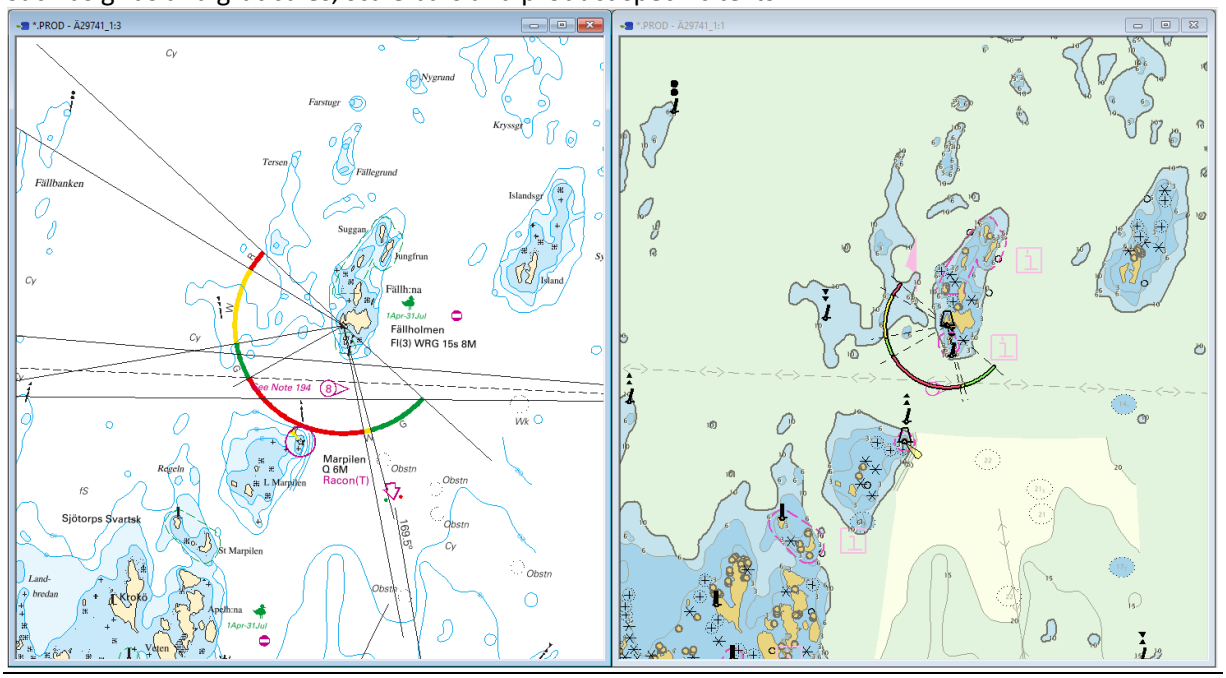


Fig. 5. Simultaneously Updating Raster and ENC products

In addition to paper charts, SMA creates tiled raster data, which provide essential background data for web mapping services used both in house and distributed to customers. Using a single database, it is possible to create seamless raster tiles with the same cartography and presentation as their nautical paper charts.

Moreover, a single database production chain can also aide other areas of the organization. If there is a change in the database that requires a Notice to Mariners (NtM), the database operator will send a tiff image of the new cartographic representation to the NtM office. This image is then published along with the NtM in order to clarify updates to those using paper nautical charts.

The coverage for ENC cells and paper chart products are relatively similar. The majority of cells in SMA's ENC library have been derived from paper charts at similar scales. There are, however, always exceptions to the rule. Additional larger scale ENC cells have been created along Furusundsleden after mariners requested a more detailed depiction of the fairway. These are not produced in paper chart form.

Finally, single database maintenance has influenced how resources are distributed along the chain of production. There are currently 20 cartographers within SMA working as database operators, updating ENC and compiling cartography, while only four cartographers focus on paper chart generation. Structuring the organization in this way means resources are focused on keeping the contents of the database, and consequently our products, as up to date as possible.

Some Views Offered at the November 2018 NCWG Meeting:

During a discussion of the future of paper charts at NCWG-4, representatives from many hydrographic offices stated that they still have an obligation to produce paper charts in some or all of their areas of responsibility. Many of the countries represented are using a single database to produce both paper and digital products. Of those countries using a single database, all stated that producing ENCs was less effort as the database is updated and validated. Finished ENCs can be swiftly published from the database, but the paper products need further augmentation before they can be published. It was also noted that some hydrographic databases are being enhanced to support high-density ENCs, which makes deriving paper products more difficult.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about use of a single source production database.

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

Several hydrographic offices are using, or moving toward the use of, a single database from which to produce both electronic and paper nautical chart products. Some efforts have been made to use S-57 attributed data to automatically apply INT1 symbology and legends for paper chart products, but there is not yet a universal method of undertaking this process. This is partially due to the many national deviations from standard INT1 symbols that are in use by hydrographic offices. Thus, any effort to automate symbolization necessitates developing a unique solution for each agency.

Even if every chart producing agency were to strictly adopt all of S-4's INT1 symbols, there are other reasons that hinder the development of symbolization automation methods that could produce consistent, repeatable results from any ENC data. Two obstacles stand out:

- Lack of engineering quality paper chart symbol specifications; and
- Lack of a standard S-57 feature to INT1 symbol mapping.

Lack of standard paper chart symbol specifications:

Sample symbol images are usually provided, but precise specifications explicitly defining symbol characteristics, such as line weights, symbol dimensions, and colours are generally not provided in S-4. The final depiction of each standard symbol is left to the discretion of each chart producer. There are even variations of symbol depictions amongst the three "official IHO" INT1 documents produced by France, Germany, and Spain. S-52, the specification that defines the portrayal of ENC data in ECDIS, provides engineering drawings of each ECDIS symbol as well as a digital "Symbol Library" that ECDIS manufactures may take advantage of. There are no analogous drawings or digital symbol files for S-4.

Lack of standard S-57 feature to INT1 symbol mapping:
There is no standard mapping of S-57 features and attributes to INT1 symbols and legends, as there is in the S-52 Specification, which provides symbol look-up tables for most S-52 symbols and Conditional Symbology Procedures (CSPs) in Unified Modelling Language (UML) flow diagrams for more complicated feature portrayals. This is further complicated by some minor variations in ENC data encoding practices between some data producers, which would require variations in a “standard” mapping of S-57 to INT1 symbols from producer to producer. Some hydrographic offices have developed their own mapping, but there is no widely available, consistent mapping that could be shared amongst chart production system developers.
S-4 was not intended to map S-57 encoded ENC data to symbols on a paper chart, but use of this type of workflow is increasing. Some experimentation is being done to take advantage of the existing S-57 feature to ECDIS symbol mapping in S-52. In this case, a paper chart is produced using ECDIS (S-52) symbols. Although, this is a valid first step, users have expressed a preference for INT1 paper chart symbols on paper charts and there are other problems associated with the use of ECDIS symbols on paper charts. However, some adaptation of this approach, tailored to the needs of paper and digital raster charts, could accelerate the ability to automate paper chart generation using ENCs or other S-57 attributed data.
Although the S-101 ENC Product Specification has many improvements S-57, there is no reason not to go ahead with developing an S-57 to INT1 mapping at this time. The S-57 and S-101 Product Specifications share a significant degree of similarity in ENC encoding guidance. The eventual adaption of an S-101 to INT1 mapping from an S-57 based solution will benefit from the ability to test the S-57 mapping on the wide variety of S-57 ENC data the is currently available.
Some useful future research and development efforts that could facilitate sharing resources to facilitate this process include:

i. Creating a standard naming convention (a symbol catalogue) for all INT1 symbols. INT1 documents that many nations produce to provide a "legend" for their chart symbology do not show all instances of paper chart symbols and therefore do not provide a complete naming convention for all INT1 symbols.
ii. Adaptation of S-52 look-up tables to point to paper chart symbols enumerated in the symbol catalogue discussed in i above.
iii. Creation of precise symbol shape, size, and colour specifications for INT1 symbols in S-4.
iv. In addition to – or possibly instead of – creating the specifications in iii above, creation of a standard paper chart symbol library of digital symbol graphic files. The S-52 library uses an old pen-based format; the new S-101 ENC product specification uses the Scalable Vector Graphics (SVG) format. There may be other more universal vector or raster graphic formats that are more useful for printing purposes.
v. Ongoing development of the S-101 ENC product specification should also keep in mind that in addition to supporting the portrayal of ENC data in ECDIS, consideration should be given to how ENC encoding can be optimized to support the symbolization and printing of paper nautical charts for ENC encoded data.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about their portrayal of paper charts with S-57 attributed data.

c. Print on Demand (PoD)

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 is aimed at:

- Re-positioning charts from local datums to WGS84 with the publication of a New edition of the traditional paper nautical chart (as S-4 requires in section 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. 6).

Off-set lithographic printing

(Discontinued by Italian Hydrographic Institute)

Digital printing

(In use at Italian Hydrographic Institute)

Fig. 6.

HOs' production strategies have been deeply affected by recent developments in print-on-demand (POD) 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 (or a single production database from which ENCs are derived) now also provide the primary source data for paper charts. Much of paper chart production has become an automatic process through the conversion of ENCs or S-57 encoded data from a single database. The human work is focused in clarifying the presentation and increasing the paper chart's readability. Sometimes these "chart finishing" activities can still take a significant amount of effort.
For example, the essential steps of paper chart production workflows of the Italian Hydrographic Institute are shown in Figures 7 through 10, 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 from the corresponding ENCs through the process shown in Figure 7:

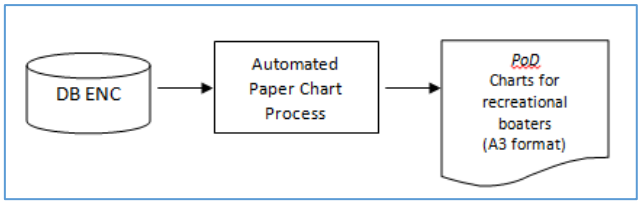


Fig. 7. ENC to recreational boating charts workflow

These charts are updated every 2 weeks, in accordance with the Italian Notices to Mariners (NtM) booklet and their release is synchronized with revisions to 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 Figure 8, 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 process.

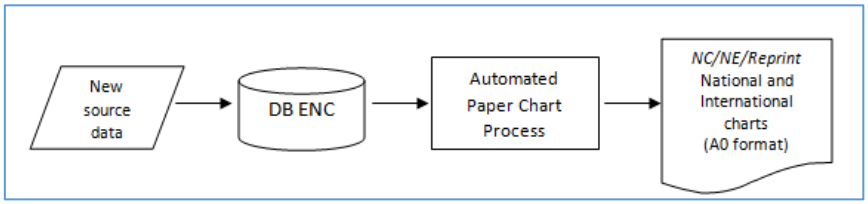


Fig. 8. ENC to paper nautical chart workflow

The Italian Hydrographic Institute now uses the workflow in Figure 8 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 either a new chart (NC), new edition (NE), or reprint is required, based on the following:

- New data that covers an area too large to be updated with an NtM block;
- A large number of routine and critical NtM 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 ENCs (Figure 9).

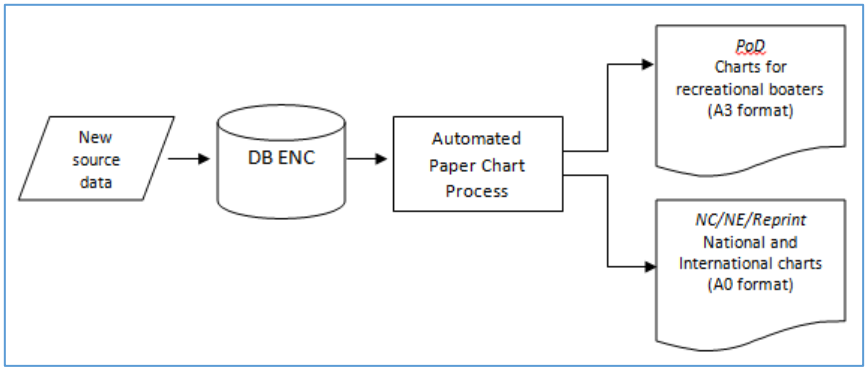


Fig.9. Combined ENC to paper nautical chart workflow

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 (Figure 10). These will eventually be replaced by the modern, efficient production processes and software to take advantage of the PoD workflow (Figure 9).

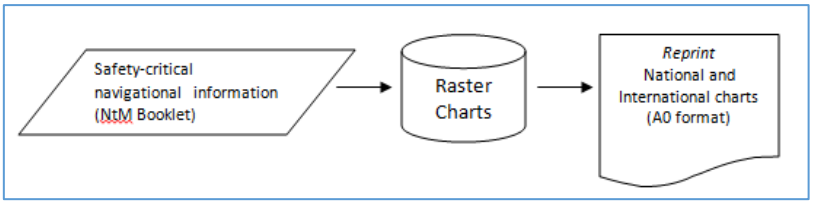


Fig.10 Raster to paper nautical chart workflow

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 process 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 HOs, which allows updated products to 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, the nautical and navigation community are waiting for the complete transition to ECDIS in order to assess the impact and consequences on production and sales of paper charts.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about use of print-on-demand chart distribution.

2.5 Paper Chart Sales and Product Usage

a. Declining demand for paper charts

There has been an expectation that as mandatory use of ECDIS increases, demand for paper charts will diminish. This was discussed in the paper, HSSC5-INF7, "Future demand for Paper Nautical Charts", submitted to the IHO Hydrographic Services and Standards Committee (HSSC) by the Australian Hydrographic Service in 2013, shortly after the first ship types were required to implement ECDIS technology.
In fact, for at least three hydrographic offices (Spain, UK, and US), this decline started even earlier. The sales of paper nautical charts appear to have now levelled off somewhat. Continued sales of paper charts are likely to be from recreational boaters, back-up charts for ECDIS users, and other commercial vessels for which use of ECDIS is not required (as well as framed copies of charts hung in beach houses and restaurants). It is unclear at this time whether these customer communities will persist in purchasing paper charts and for how long. As the price of chart plotters and other ENC display equipment decreases and the ease of use of ENCs increases, more customers may make the switch to digital charts. Demand for paper charts might not ever drop to zero, but there may be a "tipping point" at which the small volume of paper chart sales make continued production increasingly tenuous.
The graphs below show paper nautical chart sales for these three hydrographic offices. These charts also show the implementation of print-on-demand chart production and distribution methods, in which small quantities or single copies of charts are printed (or plotted) as individual charts are ordered. This is a growing trend, as discussed in section 2.4.c., "Print on Demand (PoD)" above. PoD has, or is about to replace traditional printing methods for several hydrographic offices, where large quantities of new editions of paper charts were printed (usually using offset lithographic printing presses) and warehoused for subsequent distribution.

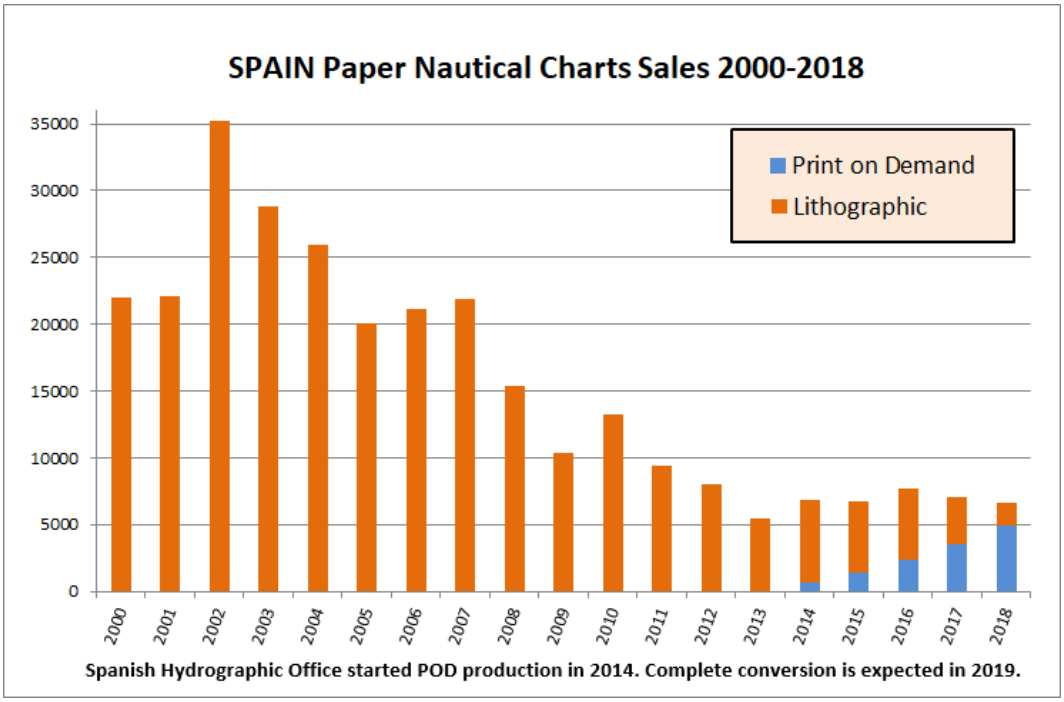


Fig. 11. Spanish lithographic and print-on-demand annual nautical chart sales

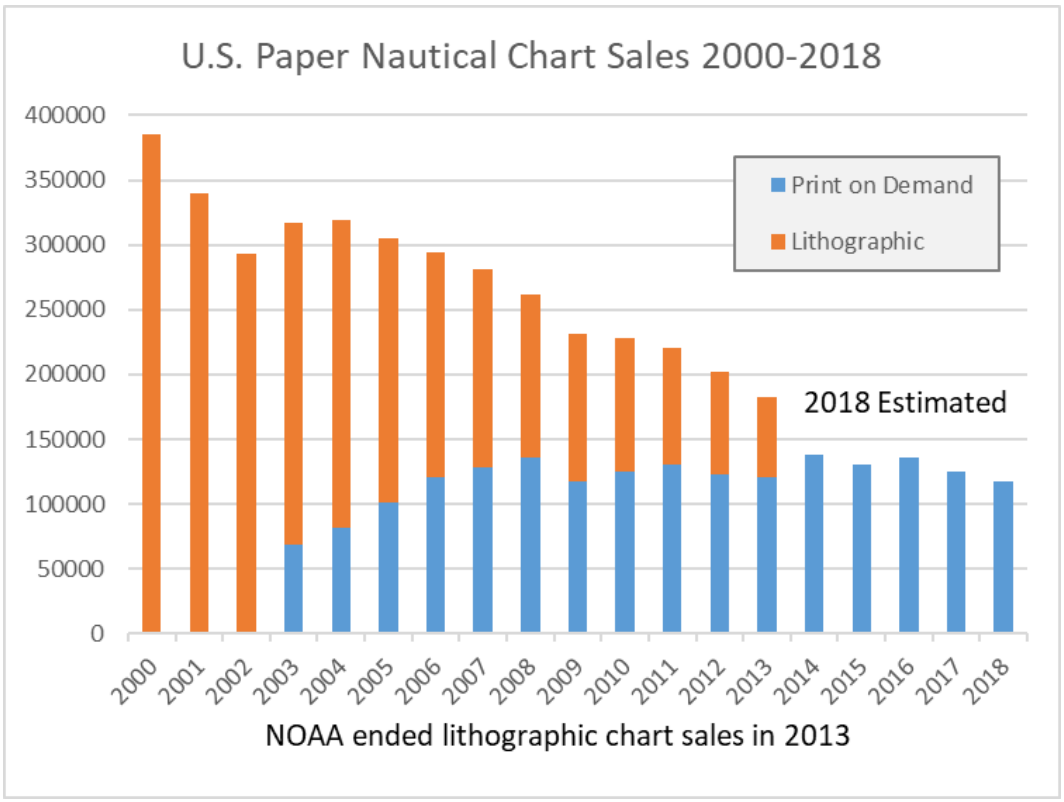


Fig 12. US lithographic and print-on-demand annual nautical chart sales

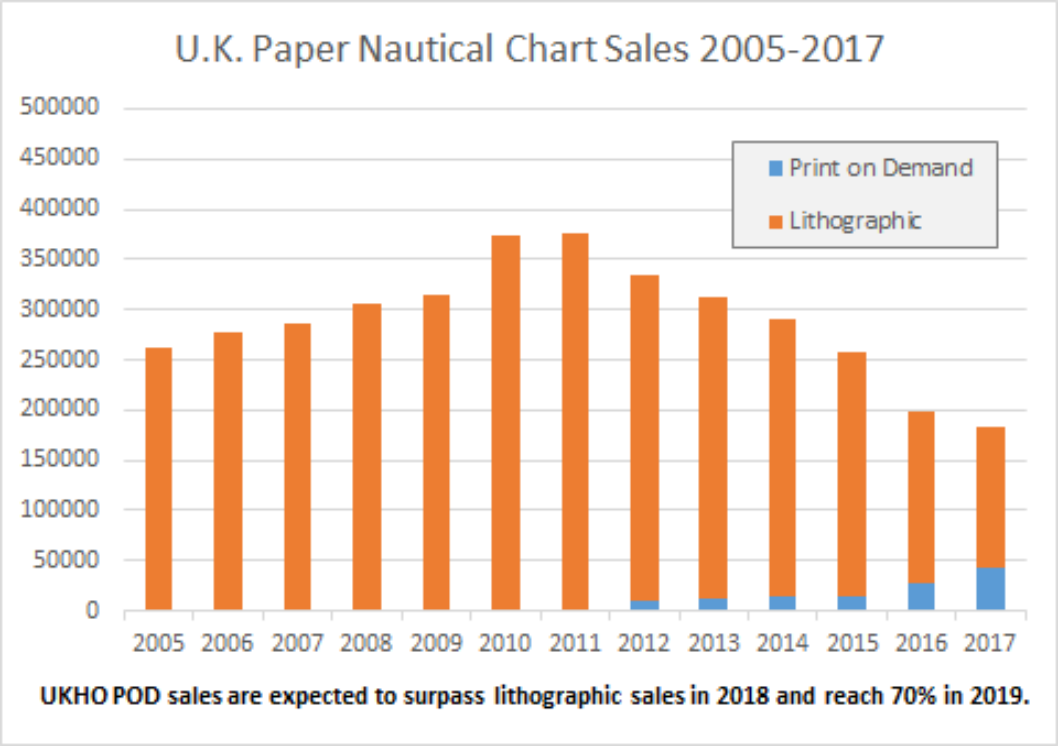


Fig 13. UK lithographic and print-on-demand annual nautical chart sales

Member States are invited to complete the "Future of the Paper Nautical Chart 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 ENCs

The demand for Electronic Navigational Charts has steadily increased since their introduction in the 1990s. Although ENCs were founded on the paper chart experience, they are now increasingly diverging from the original paper nautical chart product. This is especially the case areas where ENC coverage has been reschemed into a gridded layout without regard to the original paper chart footprints. Some HOs, such as the US, are creating larger scale ENC coverage without creating the corresponding paper chart product, further differentiating the two product suites. Some of the factors that make ENCs 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 ENCs will increase in popularity as their ability to interoperate with other navigationally important datasets, such as S-100 based products, is enabled. ENCs 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 ENCs from their paper chart legacy. Some stakeholders are convinced that the only way to realize ENC's full potential is to get rid of paper charts altogether. However, HOs 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 ENCs 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 ENCs will likely continue to tip the scales in favour of increasing ENC use and diminishing paper chart use.

The graphs below show substantial increases in the sale of ENCs by Spain and the UK.

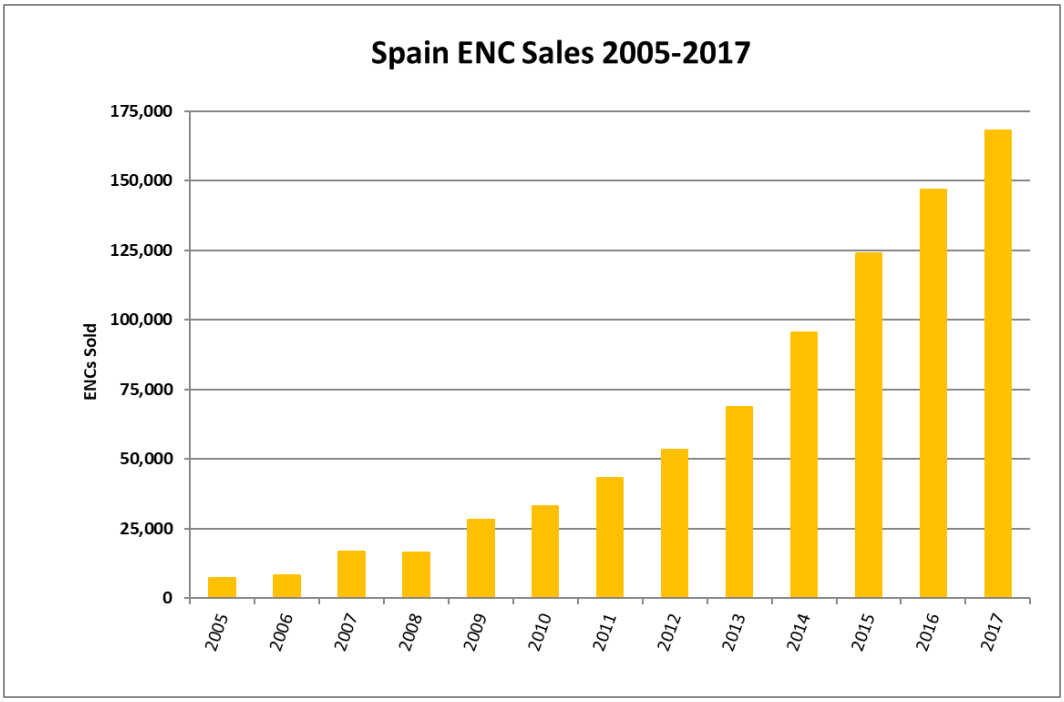


Fig 14. Spain ENC sales

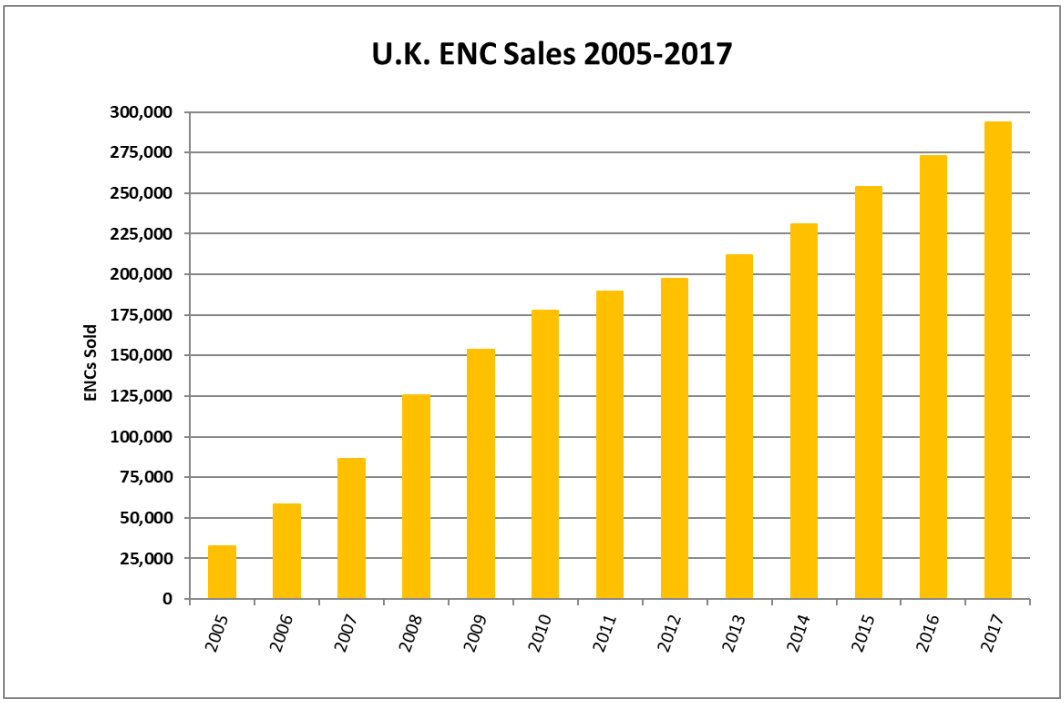


Fig 15. UK ENC sales

Member States are invited to complete the "Future of the Paper Nautical Chart 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.

Many areas of the world now have complete ENC coverage. This is the case for the US, which nonetheless, still produces RNC data for use by recreational boaters; as well as for Australia, which stopped RNC production several years ago. Other HOs are also planning on ceasing RNC production.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about the production of RNCs and other nautical products `in their national waters.

d. Recreational boaters' use of paper and digital charts

The means of meeting the needs of recreational boaters varies from place to place. Many hydrographic offices provide chart products specially tailored for recreational boaters or other small craft. However, recreational boaters also purchase many standard paper nautical charts, either out of preference or because they are the only chart format available in a particular area. Conversely, professional mariners sometimes purchase small craft charts created for recreational boaters, especially if they provide larger scale coverage of a waterway. Thus, it is difficult to measure or predict the impact of paper chart sales from recreational boaters.

It is equally difficult to get an accurate understanding of recreational boaters' use of digital charts – either official ENCs and RNCs, or more commonly, third party digital charts. Sales data for commercially available digital charts is usually treated as sensitive proprietary information.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide any information about their strategies to provide nautical chart products to recreational boaters.

3 Future Environment

3.1 Product Coverage

a. International (INT) charts

In January 2016[7], the IHO commissioned a new web service named INToGIS providing the necessary on line tools for the IHO Member States and the Charting Region Coordinators to review and maintain INT chart schemes; and monitor the production of INT charts. This web service superseded the paper version of the IHO Publication S-11 Part B – *Catalogue of INT Charts*, and is now fully operational. This major step forward in the monitoring of INT schemes and INT chart production was also followed in 2018; by the adoption[8] of Edition 3.1.0 of S-11 Part A - *Guidance for the Preparation and Maintenance of International (INT) Chart and ENC Schemes*; and the associated deletion of IHO Resolution 1/1992 – *Monitoring of INT Charts*.

Notwithstanding these recent improvements, an increasing number of IHO Member States are now becoming reluctant to produce INT charts and maintain INT schemes, alternatively choosing the adoption of their national charts in lieu of INT charts as long as they are already produced in accordance with S-4 regulations. Noting, however, that the situation is very different from one charting region to another (See Table 3.1.a.1 below), the future of the INT chart concept itself is now in question.

Region	Coordinator	Commission	Scheduled	New publications reported in 2017	Published Total	Regional Database Version
A	USA/NOAA	USCHC	15	0	15	3.0.0
B	USA/NOAA	MACHC	82	2	49	3.0.1
C1	Brazil	SWAtHC	51	1	36	3.0.2
C2	Chile	SEPRHC	44	0	7	3.0.0
D	UK	NSHC	217	2	217	3.0.5
E	Finland	BSHC	302	2	292	3.0.8

[7] See IHO CL 89/2015 dated 17 December 2015.
[8] See IHO CL 11/2018 dated 2 February 2018.

Region	Coordinator	Commission	Scheduled	New publications reported in 2017	Published Total	Regional Database Version
F	France	MBSHC	248	4	172	3.0.3
G	France	EAtHC	172	1	141	3.0.3
H	South Africa	SAIHC	125	6	99	3.0.4
I	Iran	RSAHC	143	0	100	3.0.1
J	India	NIOHC	172	2	144	3.0.2
K	Japan	EAHC	294	0	240	3.0.0
L	Australia	SWPHC	67	6	62	3.0.2
M	UK	HCA	117	4	84	3.0.4
N	Norway	ARHC	12	1	9	3.0.1
1:10 Million	IHO Sec.		25	0	24	3.0.0

Table 3. INT chart production by charting region

What is the INT chart concept all about?

When looking to the future, one should not forget the past…

"The International Hydrographic Organization (IHO) was formed in 1921 as the result of a desire for greater standardization of nautical charts and associated publications and consequently for greater safety of mariners. It was felt that this standardization could be achieved in such a way that language and symbol differences would be minimized and that a chart produced by one country would be perfectly comprehensible to a navigator from another country." (S-11 Part A, Preface, Paragraph 1).

Following on, the INT chart concept was finally established and proposed in 1967, "…instead of several different hydrographic offices each producing different charts of the same ocean area, often with differing data, scales and limits, it would be both more economic and safer if one hydrographic office would compile and produce an original chart to internationally agreed specifications. Other hydrographic offices would then be able to print the chart, using the basic reproductive material provided by the original producer nation but substituting their own language, if they wished." (S-11 Part A, Preface, Paragraph 2).

From 1982, the concept of small-scale INT chart schemes and series was further extended to medium and large scales covering international shipping areas, including approach and harbour charts. This concept was applied quite extensively in and across several charting regions … until the dawn of global ENC production. Thanks to the INT chart noble and efficient concept, similar principles were implicitly adopted on a regional basis for the development of coordinated ENC scheme production and maintenance, in support of the Worldwide ENC Database (WEND) Principles. These principles are now in force in Edition 3.1.0 of S-11 Part A.

It is recognized that the intention of INT charts was also to ensure the safety of navigation in international waters. With respect to this purpose, regardless of the custodian nation, exactly the same scheme and symbology were used for the production of INT charts. Maintaining this high level of standardization is still appreciated as it prevents any confusion and/or misinterpretation of the information on the charts used by both merchant and defence Navies around the world. It is well known that there is no such well-established consensus among the IHO Member States as to the symbology used within national chart series. Even nations responsible of producing both national and INT charts often use different schemes and symbology for each.

Another positive contribution of INT chart production to the community that is worth mentioning is the opportunity it provides to the nations that are neighbouring each other or the same sea, to work together in the production and even in the surveying, thus to share the responsibility, as well. The single drawback pronounced concerning the production of INT Charts is the extra work power it demands, which will become less and less of an issue as technological and relevant software improvements continue.

What is going on?

The INT chart concept was implemented with some success due also to the fact that it was supported by IHO Resolution 7/1919 - *Hydrographic Office arrangements for the exchange and reproduction of nautical products* - it is worth noting that that this Resolution is still in force, 100 years after its adoption.

There is no such imperative need for exchanging repromats and even S-57 data between HOs nowadays, in particular for safety of navigation, since ENCs have become the primary "fuel" for ECDIS navigation, at least for international shipping. Indeed, ENCs can now be schemed, produced and maintained in accordance with the principles given in S-11 Part A, without any need to be derived from INT paper charts (schemed or produced).

As a consequence, some HOs are now choosing to produce national charts only (large scale in particular), hopefully still S-4 compliant, out of existing INT schemes. Others, concerned by the dual maintenance of INT charts and ENCs in a timely and consistent manner, are contemplating not producing INT charts at all. This means *de facto* that there is no longer a recognized need for HOs to provide mariners with a full worldwide and functional[9] set of INT paper charts for international shipping (large, medium and small scales), even for ECDIS back-up arrangements[10].

One could argue that the relative success of the INT chart concept (a single set of INT standardized charts covering the world) is because the IHO community has been unable to establish a one-stop-shop for mariners to easily obtain charts. This has been partially achieved by the world-wide coverage of Admiralty charts, but not all of the INT charts produced around the world have been adopted in the Catalogue of Admiralty charts.

The INT chart system has proven to be very helpful though, for printer nations who chart more than their home waters. Very often, the chart coverage consist of adopted INT charts whose production and update is much easier and faster than the production and update of recompiled charts. But if national charts only (without INT number) are produced in accordance with S-4, one could argue that it is also possible to adopt these charts, without problems to the printers chart portfolio.

Over the years, the concept has become less attractive because there were only a few HOs, having international maritime ambitions, which have acted as printer nations. So national chart schemes without INT chart numbers still exist. As a consequence, the double management by one HO, of INT charts schemes together with its own national scheme, has become quite challenging and more complicated than in the past, this feeling being intensified by the search of an optimal solution for the co-production of ENCs.

Requirements

Whether it is for sailing, or even for route planning and back-of-bridge functions, it appears that the demand for INT charts (or the demand for paper charts meeting INT charts standards; that is S-4 compliant), seems to have decreased significantly. This fact could also be worded as follows: Is there still a need for a single HO, let's say in Europe, to produce reprints of INT charts covering the coasts of the Republic of Korea, the USA or Australia? And vice-versa? Is the situation different within one charting region? For mariners who do not use ECDIS, ECS or digital navigation chart plotters as primary tools for navigation, is it sufficient to know that, as long as national paper charts exist, they can be produced on demand, and when printed, they meet S-4 regulations using international portrayal symbols and abbreviations? Is it sufficient to know that they are easily available on the market; and therefore mariners requirements for safe navigation can be met? In other words, is it sufficient to make sure that any mariner can get access to a distributors' network of paper charts (national or INT), from which they will be able to order the paper charts needed to cover their voyage?

[9] Small, medium, and large scales, providing adequate coverage for international shipping.

[10] Even though it is still planned in the IMO MSC.1/Circ.1503 dated 24 July 2015 – ECDIS Guidance on Good Practice in its Annex A, paragraph 8 which states: « IHO provides an online chart catalogue that details the coverage of ENCs together with references to coastal State guidance on any requirements for paper charts (where this has been provided). The catalogue also provides links to IHO Member States' websites where additional information may be found. The IHO online chart catalogue can be accessed from the IHO website at: www.iho.int."...but noting that there is no requirement for these back-up charts to be INT charts.

Furthermore, if the INT chart coverage was used as the "metric" for defining and assessing the *adequate* ENC coverage when ECDIS carriage became mandatory for SOLAS-type vessels[11], this is not the case anymore. The IHO, the Regional Hydrographic Commissions and the ENC Producers have much better tools at their disposal to adapt their ENC scheming and production plans than to refer to and directly replicate INT chart coverage.

What's next?

The INT chart world-wide coverage at all scales has reached a very good level of maturity (See Figure 16 below).

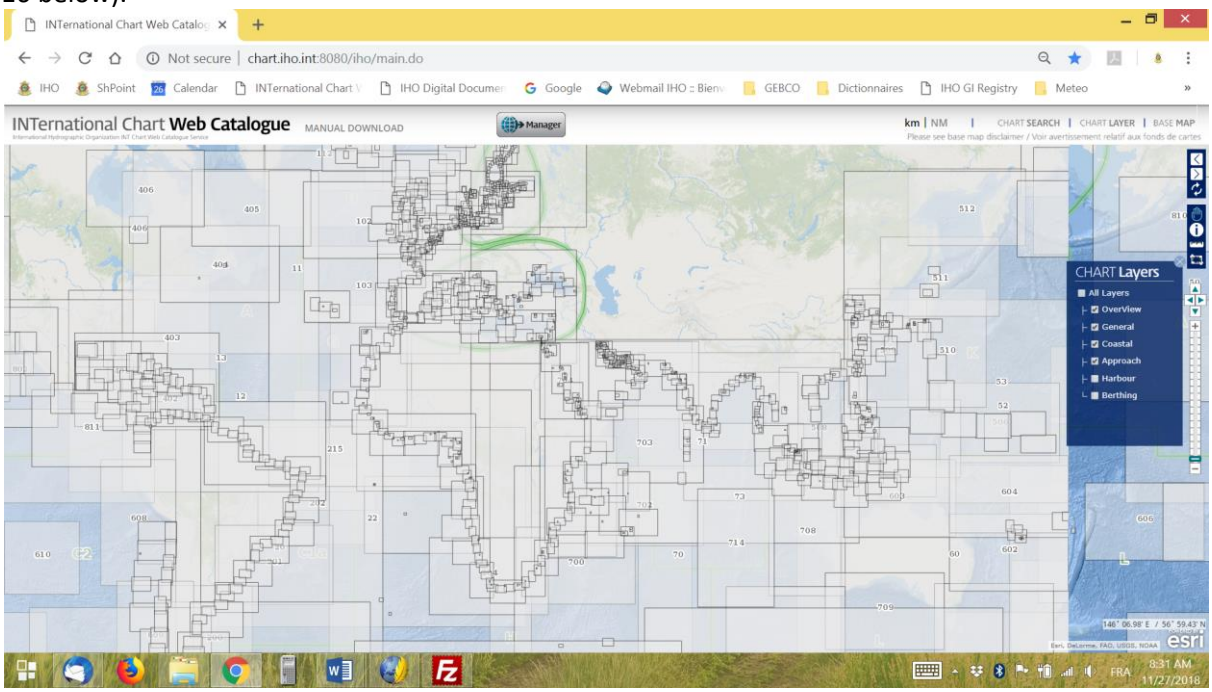


Fig. 16. Global INT chart coverage (overview, general coastal, and approach)

The production of new INT charts appears to have stabilized. At the end of 2017, in S-11 Part B - *Catalogue of INT charts* - there was a total of 1691 INT charts produced, out of a total of 2086 INT charts schemed. With the exception of 2017, the production of new INT Charts seems to have declined slowly (See Figure 17,)[12].

[11] From 1 July 2008 for High-Speed Craft, then beginning on 1 July 2012 onwards for SOLAS vessels (depending on the ship type, size, and construction date).

[12] These figures, as of Nov. 2018, may differ from those provided in previous IHO annual reports. This is due to a change in the accounting methodology, thanks to the use of INToGIS which now allows the generation of statistics with consolidated figures even when they are obtained for previous years.

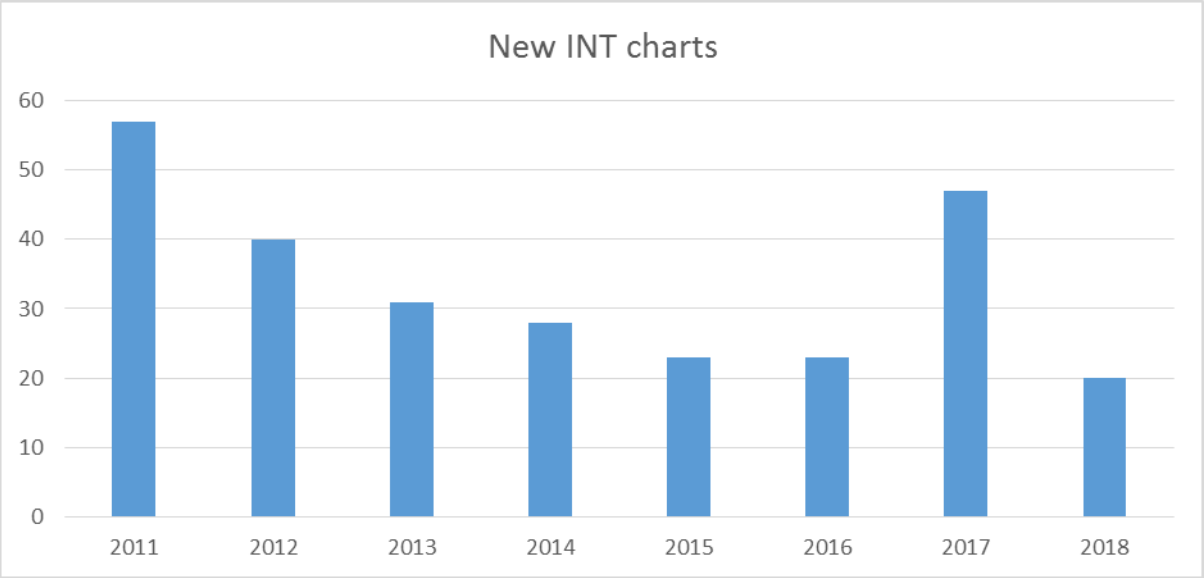


Fig. 17. INT chart production figures, 2011-2018

This trend is quite significant and puts the whole INT concept at stake. With the possibilities offered by new technologies (exchange of subsets of chart content databases, digital repromats, print-on-demand), the so-called *printing* nations of INT charts are able to establish new or revise existing bilateral arrangements with HOs producing charts, irrespective of the existence of the INT chart concept. However, with the exception of the UK, there are actually very few *printing* nations left (DE, ES, FR, IT…) for small numbers of INT charts, confirming that one of the core functions of the INT chart concept of 1967 – the smooth bilingual reprint of charts for foreign sea areas for a national fleet – is no longer a core strategic component of the IHO Member States activities.

The adoption of INT charts of a foreign partner for bilingual reprint might not be attractive any longer, but the second part of INT standardization – namely conformance to S-4 – remains of relevance. Likewise the INT scheme maintains burden sharing; prevents duplication of efforts; and encourages regional cooperation. All these are good arguments from the IHO perspective to keep the overarching INT concept alive.

So, what are the necessary and sufficient conditions for amending the INT chart concept to retain its *possible recommendations?*

This paragraph offers a set of proposals for the future of INT charts and the INT chart concept. These proposals need to be discussed and refined. Their possible impact needs to be assessed. Once finalized, they will need to be endorsed by the appropriate Working Groups and Committees.

They are:

a. HOs still willing to produce or re-print INT charts, or even other national paper charts, are encouraged to establish appropriate arrangements in accordance with IHO Resolution 7/1919 as amended.
b. HOs still willing to produce or re-print INT charts, or even other national paper charts, must comply with S-4 regulations (portrayal international standards, INT-1, etc.).
c. HOs still willing to produce or re-print INT charts, or even other national paper charts, from a single chart content database, must maintain the procedures (such as NtMs) to ensure that the final product is kept up-to-date and consistent, in content, to the ENCs in force; covering the same area (see also h).
d. IHO Working Groups and Committees are invited to prepare a transition plan (standard bilateral arrangements, minimum technical requirements, portal depicting distribution network of paper charts, etc.), to be approved at the Assembly in 2026 (A-4), aiming to amend the INT chart concept but ensuring the continuing possibility for IHO Member States to remain interoperable when they wish to produce or re-print national paper charts.

e. From 2023, the IHO Secretariat will be invited to approach the IMO in order to propose the implementation of amendments to the relevant IMO Circulars (Safety of Navigation) dealing with back-up arrangements, nautical charts and publications [13], etc.
f. Subsequently, IHO Working Groups, Committees will be tasked to delete or amend the relevant standards and publications accordingly.
g. For risk mitigation, and in parallel of the proposals listed above, it is suggested that IHO Working Groups, Committees, Regional Hydrographic Commissions pursue the monitoring of INT charts schemes and production, taking advantage of the INToGIS web services, until 2026 (A-4).
h. Taking this a step further, and in the interests of a possible "print-from-ENC" Product Specification that could fulfil IMO Carriage Requirements, consideration should be given to adapting the current INT chart concept and the regulations in S-4 so as to better align with ENC production and modern data transmission and product distribution processes (perhaps using the WEND Principles and the RENCs one-stop-shop-distribution coordination mechanisms as a starting point.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide any information about their production of INT charts.

b. Rescheming paper chart coverage.

<<< Text will be added to this section to discuss hydrographic office plans for raster chart rescheming, including the reduction of redundant coverage, use of fewer compilation scales, easier synchronization with ENCs, etc. >>>

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide any information about plans to re-scheming raster charts to be more compatible with ENC coverage or for other purposes.

c. ENC-only coverage

In 2018, the US National Oceanographic and Atmospheric Administration (NOAA) made the decision to stop making any new (first edition) paper nautical charts. Where new chart coverage or larger scale coverage is required, only new first edition ENCs are created. Much of the new "ENC-only" coverage is in remote areas (the Chukchi Plateau, Yukon River, Etolin Strait, and Hoonah Harbor – all in Alaska). However, there is now a new ENC cell along the Merrimack River – about 60 km north of Boston, and another covering the only deep-water petroleum loading/unloading platform on the US East Coast – in Long Island Sound. There will be no corresponding paper chart coverage produced for these areas.

The US is also in the very early stages of rescheming its entire ENC suite. A new regular, gridded layout of ENC cells will eventually replace the existing irregular, paper-chart based ENC cells. Many of the new ENCs will be at a larger scale than the existing cells within each of the six ENC usage bands. Some corresponding smaller scale paper chart coverage will eventually be cancelled in order to devote limited chart production resources to maintaining the expanding stock of more detailed ENCs. Thus, as new, larger scale ENC coverage is produced and the corresponding paper chart coverage is either not created or cancelled, there will be an increasing supply of improved ENC coverage and a diminishing supply of paper charts. If equivalent paper charts were required for all new, larger scale ENC coverage, it would not be possible to produce either of these larger scale products with NOAA's existing production resources.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about plans to create new ENC-only coverage or to reduce existing paper chart coverage.

[13] SOLAS Chap V, Regulations 2 and 9 if appropriate.

d. RNC-Tile Service

The US NOAA has created a Raster Navigational Chart Tile Service comprised of 15 million individual chart tile images. Each of NOAA's 1,000 full RNC image files is cut into thousands of smaller “tiles” that display much faster than full RNC images. The tile service provides geo-referenced, nautical chart tile sets for the public that comply with several web map and map tile standards, such as Web Map Tile Specifications (WMTS) and the Tile Map Service Specification (TMS).

NOAA RNC tiles can be used with GPS enabled electronic chart systems or other chart plotter display systems to provide real-time vessel positioning. Tiles are also being used on third party nautical data integration websites. Although the NOAA RNC tile service data does not meet IMO or US Coast Guard chart carriage requirements for commercial vessels, it is a useful alternative for recreational boaters.

RNC-Tiles-Only Coverage

Up until recently, all of the US RNC Tile data was derived from full RNC chart images (RNC chart images are generated by the same process that creates NOAA paper chart images). That is, there is a full standard RNC and a standard paper nautical chart available for each set of corresponding RNC Tiles. However, NOAA has recently started experimenting with generating RNC Tile data directly from NOAA's chart production database without creating the corresponding full RNC or POD chart image data first. This process requires fewer resources to produce than a standard full RNC chart image, which requires creation of a grid, source diagram, and other marginalia. The first instance of this covers the Merrimack River – the same area discussed in the ENC-only section, above. Thus, this area is really "ENC and RNC Tile only" coverage without the usual paper chart.

This approach may provide a "bridge" for users considering a move away from paper charts, but would still prefer a more "paper-chart-like" display on their digital device. Other national charting authorities may have other non-traditional raster-based products that require fewer resources to produce.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about plans to create new RNCs (or other non-ENC digital chart data) without any corresponding paper chart.

3.2 Alternative Methods of Paper Chart Provision

a. Printing paper charts from ENCs

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 INT1 symbols, and no need to have them heavily reviewed for cartographic accuracy.
- The simplification or elimination of hand corrections (notices to mariners). 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 paper chart 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, 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 scale coverage within the cell.
- Cartographic finishing: Cartographers perform many tasks to improve the readability of a chart, such as positioning to text. Some of these tasks are either not performed well in S-52, or are not performed at all. There are also elements of paper charts that are not included in ENC, such as chart border and marginalia, grid, title and construction notes, and scale bar.
- Environmental variables: The S-52 uses not just the ENC data, but also variables set by ECDIS user in its visualisation rules.

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 INT1 symbology.
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 INT1 symbology.
- Improve accuracy and consistency across paper products by clearly defining the relationship between S-57 encoding and INT1 symbology, 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 INT1 symbology specification and its accompanying technology.
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.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about printing paper charts from ENCs.

b. Product on Demand / Chart on 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 US 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 HOs are exploring 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 option for users to define their custom product and have one of the US commercial printing partners plot the large format chart and ship it to them.

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 ENC navigational purpose (harbour, 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., 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. The intelligent placement of text associated with charted features, such as place names and light characteristics will also pose a challenge.
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 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 trade-offs. 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 INT1 symbology 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.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide information about use of chart-on-demand /product-on-demand technology.

c. Enhancing the portrayal of 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 INT1 symbology as specified in S-4 maximizes readability.

The greatest advantage of S-52 is that it is data-driven, entirely determined by ENC encoding. Thus, its use ensures a consistent visualization, irrespective of the agency producing the data. INT1 symbology 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 INT1 symbology have perfected the craft of generating navigational products that maximize readability. Some aspects of paper 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 specifications (the S-101 ENC Product Specification and others) or the development of requirements for more "cartographically intelligent" software.

A move to harmonize the INT1 symbology of 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 the 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 Subworking Group has been formed primarily of members of the ENCWG and S100WG. NCWG may need to engage more proactively with other IHO 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 the IHO website are:

www.iho.int > ENCs & ECDIS > E-navigational Documents

www.iho.int > IHO Council, Committees & Working Groups > Nautical Information Provision Working Group (NIPWG) > e-Navigation and Maritime Service Portfolios

<<< Text will be added to this section to discuss the effect on the future of paper nautical charts that e-Navigation and IMO Maritime Service Portfolios will have; or alternatively, discuss the difficulty in addressing paper chart/e-Navigation related issues while the concept is still evolving. >>>

4 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.

Member States are invited to complete the "Future of the Paper Nautical Chart Survey" to provide their assessment of the potential impacts of a world without paper nautical charts.

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	*	*	*	*	*

Table 4. (* 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 the Paper Nautical Chart 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 charts. 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 gaps in ENC coverage to support safe navigation. HOs would all need to regard the ENC as the primary navigation tool, for example, in areas where HOs have "blued-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 producing authorities contributing to world ENC coverage, plus individual differences in 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 source 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. This has been identified by the IHO as a key issue with the use of ENCs and Producing Authorities have been requested to provide “meaningful” values for CATZOC in areas where it has been assigned as "Unassessed."

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 by SOLAS vessels being fully implemented in 2018, 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

<<< Text will be added to this section to discuss what new user requirements might arise if paper chart production were to end. This might include items, such as:

- *"Chart-on-Demand" – possibly not so much as a backup for ECDIS, but as a means to provide small scale paper "overview" charts.*
- *Non-SOLAS mariners: ECS market – a different product or could this just be ENCs? Perhaps an argument for a raster product? >>>*

e. IHO Standards and Specifications

<<< Text will be added to this section to discuss changes to IHO standards and specifications that should or could be made to accommodate a navigational environment without paper charts. This might include items, such as:

- *S-4: Will need to evolve more toward the nautical cartography requirements for the compilation and use of ENCs in ECDIS, rather than the traditional terrestrial paper chart navigation methods. Refer to paper CSPCWG11-09.6A.*
- *S-11 Part A: Need to see if there can be (or needs to be) any adaptation of the INT Chart concept to ENC scheming.*
- *Development of an ENC Feature to INT1 Symbolization Mapping Specification, INT1 Symbol Library, and/or other artefacts to enable the consistent printing of paper charts from ENC encoded data.*
- *Development of a Minimum Mandatory Content for Paper Backup Charts for ECDIS Navigation Product Specification >>>*

f. IHO Working Groups

<<< Text will be added to this section to discuss what changes to the terms of references of the Nautical Cartography and other IHO working groups would be appropriate or necessary, as well as any changes that would be appropriate in the general working group structure of the IHO. >>>

5 *NCWG Recommendations for:*

<<< This section will be completed after responses from the IHO Member States Survey on the Future of the Paper Nautical Chart have been received. >>>

5.1 IHO

5.2 National hydrographic offices and IHO member states

5.3 ECDIS, ECS, and other "chart plotter" manufacturers

5.4 Production software developers

5.5 Other stakeholders organizations, such as IMO, UNCLOS

5.6 Professional Mariners

5.7 Recreational boaters

5.8 Other stakeholders, such as GIS and other non-navigational users

6 *Other remarks and recommendations from IHO member states and other stakeholders*

<<< This section will be completed after responses from the IHO Member States Survey on the Future of the Paper Nautical Chart have been received. >>>

Member States and other Stakeholders are invited to complete the "Future of the Paper Nautical Chart Survey" to provide any additional remarks and recommendations.

7 *Actions to be considered by:*

7.1 HSSC

Note the paper.

Discuss whether the paper is comprehensive in addressing issues related to the Future of the Paper Nautical Chart;

Discuss further steps and provide guidance to NCWG on finalizing this report.

7.2 NCWG

Conduct a survey of IHO Member States to gather additional information regarding the state of production and use of paper nautical charts;

Update this preliminary report based on the survey results, and other recommendations from the IHO Member States and the HSSC;

Submit the final version the Future of the Paper Nautical Chart report to HSSC-12.

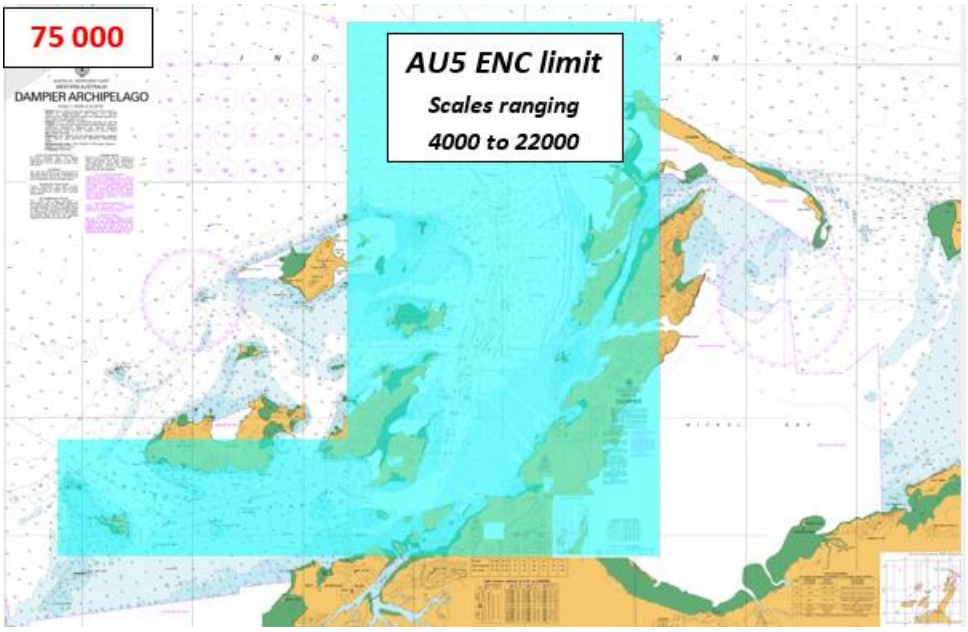
Annex A – Minimum Mandatory Content for Backup Charts for ECDIS Navigation

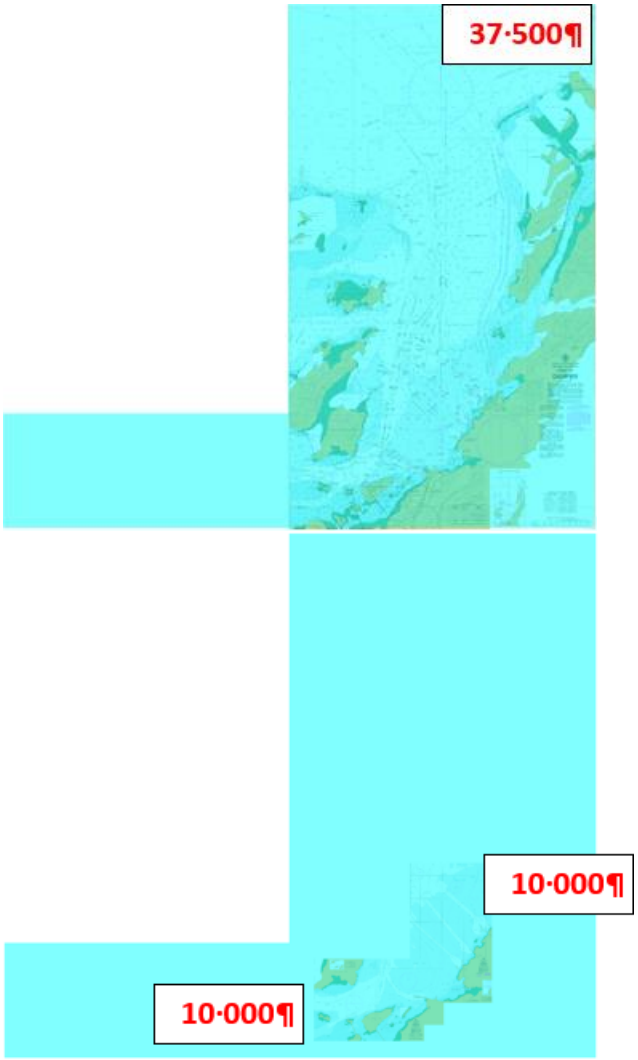
Must Have
Anchorages and anchorage areas
Pilot boarding places
Obstructions to navigation (rocks, wrecks, etc.) - In depths under 30/50 meters only
Selection of aids to navigation with corresponding light description
Depth band colours based on a ship's safety settings (Blue and Light blue)
Depth contours 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 Backup Chart for ECDIS Navigation 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.




37·500¶
10·000¶
10·000¶

Future of Paper Nautical Chart Survey

**** Draft ****
10 April 2019

Survey Accompanying the Future of the Paper Nautical Chart (FPNC) report from the IHO Nautical Cartography Working Group.

Survey Submitter Information

Information about the submitting IHO Member State and the associated Point of Contact

1. First name of person submitting this survey response

2. Last name of person submitting this survey response

3. E-mail of person submitting this survey response

4. Which IHO Member State is this survey response from?

Algeria Argentina Australia Bahrain Bangladesh Belgium Brazil Brunei Darussalam Bulgaria Cameroon Canada Chile China Colombia Croatia Cuba Cyprus Denmark Dominican Republic Ecuador Egypt Estonia Fiji Finland France Germany Greece Georgia Guatemala Iceland India Indonesia Iran Ireland Italy Jamaica Japan Korea, Democratic People's Republic of Korea, Republic of Kuwait Latvia Malaysia Malta Mauritius Mexico Monaco Montenegro Morocco Mozambique Myanmar Netherlands New Zealand Nigeria Norway Oman Pakistan Papua New Guinea Peru Philippines Poland Portugal Qatar Romania Russian Federation Saudi Arabia Seychelles Singapore Slovenia South Africa Spain Sri Lanka Suriname Sweden Thailand Tonga Trinidad and Tobago Tunisia Turkey Future of Paper Nautical Chart Survey Ukraine United Arab Emirates United Kingdom United States Uruguay Vanuatu Venezuela Viet Nam

National Regulatory Information

Information about your national maritime regulations for commercial vessels on domestic voyages. (Ref FPNC 2.2.b)

5. Primary - What type of nautical charts does your national maritime authority require commercial vessels to carry on domestic voyages? [Check one]

Only Paper Charts

Only ENCs

Either Paper Charts or ENCs

Other:

6. Backup - What type of nautical charts does your national maritime authority allow commercial vessels to carry on domestic voyages as a backup for the primary chart type? [Check all that apply]

Paper Charts

ENCs

RNCs

No Backup required

Other:

Backup Chart Development

Backup Charts

Information about any existing or development plans for a "fit for purpose" paper chart to be used as a backup. (Ref FPNC 2.3.a)

7. What actions or plans has your agency made to provide a simplified paper nautical chart specifically for use as a backup for electronic navigational systems (ECDIS, ECS, chartplotters, etc.)? [Check all that apply]

We have no plans to create a simplified paper chart product other than standard nautical charts.

We recently started considering the possibility of creating a new, simplified paper chart for back-up.

We are actively developing policies and/or specifications for a new, simplified paper chart for backup.

We have prototyped a new, simplified paper chart for backup.

We are producing and distributing a new, simplified paper chart for backup.

We explored producing a simplified paper chart for backup, but have now stopped this effort.

8. Is your agency doing any other activities related to development of any product to be used as a backup for electronic navigational systems?

Chart Production System

Information about the use of a single production system for maintaining both ENC and paper chart nautical products.

9. Is your agency using, or moving toward the use, of a single production database that stores data to maintain both ENC and paper charts? (Ref FPNC 2.4.a) [Check the closest answer]

Our ENC and paper charts are produced from a single database.

Our ENC and paper charts are produced from separate databases.

Our ENC and paper charts are produced from separate databases, but we are actively migrating toward use of a single production database.

Our ENC and paper charts are produced from separate databases, but we are considering a move toward use of a single production database.

Other:

10. Is your agency using S-57 encoded data to produce S-4 based symbolization on raster chart products? (Ref FPNC 2.4.b) [Check the closest answer]

Yes. The symbolization of raster charts totally automated.

Yes. The symbolization of raster charts nearly automated, but some manual "finishing" is required to completely symbolize the chart.

No. We use S-57 encoded data to create raster charts, but raster symbolization is generated from additional (non-S-57) attribution.

No. Our raster charts are not created from S-57 encoded data.

Distribution of Paper Nautical Charts

Paper Nautical Chart Sales

Information about sales of paper nautical charts between 2008 and 2018. This section first asks about pre-printed stocking of paper nautical charts and then about Print-on-Demand distribution methods. Please report sales numbers for each separately.

11. What methods do you use for stocking and distributing your paper nautical charts? (Ref FPNC 2.4.c) [Check all that apply]

Large stocks of charts are printed in advance and stored for distribution.

Single charts, or small quantities, of charts are printed or plotted as orders are received.

Other:

Please provide the number of your agency's standard, pre-printed, paper nautical charts sold in each of the calendar years below. (Ref FPNC 25.a)

These are charts printed in large batches, usually by offset lithography, and then warehoused for subsequent distribution to customers.

12. 2008	15. 2011	18. 2014	21. 2017
13. 2009	16. 2012	19. 2015	22. 2018
14. 2010	17. 2013	20. 2016	

Please provide the number of your agency's standard, Print-on-Demand, paper nautical charts sold in each of the calendar years below. (Ref FPNC 25.a)

These are charts printed one or a few at a time as they are ordered by customers.

23. 2008	26. 2011	29. 2014	32. 2017
24. 2009	27. 2012	30. 2015	33. 2018
25. 2010	28. 2013	31. 2016	

Distribution of Electronic Navigational Charts (ENCs)

34. ENC usage can be counted in several ways. Please indicate the method that you are using to report ENC sales. [Check one]

If an ENC is sold or licensed for use in any part of a year, it is counted as 1 sale in that year.

If an ENC is licensed for use for a portion of a year, the count for that ENC is pro-rated. For example, if a particular ENC is licensed for a ship's use for 6 months, it is counted as 0.5 sale for that year.

Other:

ENC Sales

Information about sales of ENC cells between 2008 and 2018.

Please provide the number of your agency's ENCs sold in each of the calendar years below. (Ref FPNC 25.b)

35. 2008	38. 2011	41. 2014	44. 2017
36. 2009	39. 2012	42. 2015	45. 2018
37. 2010	40. 2013	43. 2016	

Nautical Chart Formats

Information about the relationship between your paper chart products, Raster Navigational Charts (RNCs), and Electronic Navigational Charts (ENCs) (Ref FPNC 25.c)

46. Which of the following nautical chart formats does your agency produce. [Check all that apply]

Standard paper nautical charts

Special paper charts for recreational boaters

Raster Navigational Charts (RNC)

Electronic Navigational Charts (ENC)

Other:

47. What products or services does your agency provide for specifically for recreational boaters? (Ref FPNC 25.d)

Future Products

48. How many new (first edition) paper INT charts does your agency expect to create in the next three years? (Ref FPNC 3.1.a)

49. Do you plan on a general rescheming of the layouts of your paper nautical charts in the near future? (Ref FPNC 3.1.b) [Check one]

Yes

No

50. If rescheming paper nautical charts is planned, please explain the rational for re-scheming (to better align with ENC coverage and scales, reduction in raster chart coverage, etc.) (Ref FPNC 3.1.b)

51. Do you have corresponding paper nautical chart coverage for your ENCs? (Ref FPNC 3.1.c) [Check the closest answer]

Nearly every one of our ENCs have a corresponding paper chart covering the same area.

About 75% of our ENCs have a corresponding paper chart covering the same area.

About 50% of our ENCs have a corresponding paper chart covering the same area.

About 25% of our ENCs have a corresponding paper chart covering the same area.

None of our ENCs have a corresponding paper chart covering the same area.

52. When you create new or larger scale coverage in an area, what nautical chart products do you produce? (Ref FPNC 3.1.c-d) [Check all that apply]

Standard paper nautical chart

ENC

RNC

Raster titled data

Vector tiled data

Other:

53. Are you using or planning to use any technology that would print paper charts directly from ENC data? (Ref FPNC 3.2.a) [Check the closest answer]

Yes, we are use a mostly automated process to do this.

Yes, we are use a semi-automated process to do this.

Yes, we are use a mostly manual process to do this.

No, but we are exploring ways in which this might be done.

No. We have no plans on doing this.

54. Are you using, or planning to use, any technology that enables users to define their own paper chart extent and scale to output their own customized chart? (Ref FPNC 3.2.b) [Check the closest answer]

Yes, we already provide this service to our customers?

Yes, we are prototyping technology that could provide this service.

Yes, we are considering the possibility of developing this service.

No. We have no plans for providing this type of service.

Impact of Change

Assessment of the potential impacts of a world without paper nautical charts.

55. What is your perception of the impact of a world without paper nautical charts would have on the following five areas? That is, what degree of changes would be needed to accommodate paperless navigation or would result from paperless navigation? (Ref FPNC 4.) [Check one level for each row]

International Regulation	High	Med	Low
National Regulations	High	Med	Low
User Requirements	High	Med	Low
Nautical Product Production	High	Med	Low
Sales Revenue	High	Med	Low

56. What types of changes in your maritime national regulations would be required to enable the disuse of paper nautical charts? (Ref FPNC 4.1.a)

Additional Comments

57. Are there any other comments that you would like to add regarding the future of the paper nautical chart?