The Future of the Paper Nautical Chart
Final Report

28 August 2020

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

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 report 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 typical for many hydrographic offices, the conditions and practices in other offices could differ. A survey conducted by the NCWG provided an opportunity for all IHO member states to share their individual circumstances.

This report introduces 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. The report makes recommendations for further consideration and for the possible development of additional IHO nautical cartographic guidance.

Key Finding

Sales and use of paper nautical charts has declined by about half from 2008 to 2018, while use of electronic navigational charts (ENCs) has increased about seven fold during the same period. 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 ways to create raster chart products directly from ENC data. 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." Regulation 19 also states that "An appropriate folio of paper nautical charts [still] may be used as a back-up arrangement for ECDIS."

In July 2018, the International Maritime Organization (IMO) mandated requirement for most commercial vessels on international voyages to be fitted with an Electronic Chart Display and Information System (ECDIS) came into full effect. Some national maritime authorities now also allow commercial ships on domestic voyages to navigate entirely with ENCs. It is noteworthy that only seven member states of the

48 responding to the NCWG survey indicated that only paper charts will meet carriage requirements. Most indicated that either ENCs or paper charts were acceptable.

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 or to comply with local regulations, the sales of paper charts has diminished over the past decade while use of ENCs has increased significantly. This, however, varies by country.

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 reporting their maritime limits on ENCs. 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 also cancelling some paper charts while maintaining the corresponding ENCs or creating new, larger scale ENC coverage without creating equivalent paper charts. A few hydrographic offices are planning for the eventual cancelation of *all* of their raster chart products.

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 many 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 (IHO S-4 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 ENCs or other S-57 attributed data to automatically apply IHO S-4 (also called 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 precise symbol shape, size, and colour specifications (engineering drawings) for S-4 symbols.
- Creation of a naming convention for and a standard library of digital symbol graphic files for S-4 paper chart symbols, perhaps in the same Scalable Vector Graphics (SVG) format used for the symbols for the new S-101 ENC product.
- Adaptation of S-52 look-up tables to point to paper chart symbols enumerated in an S-4 symbol catalogue.

This could also make it easier for S-101 development efforts to prototype using more paper-chart-like 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.

Paper Charts for Back-up

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. Although there is not strong support among NCWG or IHO member states in general at this time, 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 sometime in the future.

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.

Recommendations

Recommendations are provided in Section 5.0 of this report.

1 Introduction

1.1 The Dynamic Nature of the Nautical Chart

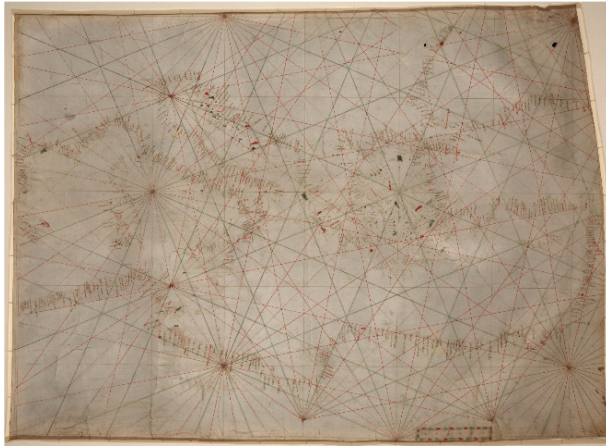Portolans (nautical charts covered with a rhumbline network) started to appear in Europe in the late 13th century. This innovation took advantage of the new practical use of the magnetic compass for marine navigation. Portolans exemplify how the form of one navigational tool can be influenced by the 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 typical for many hydrographic offices, the conditions and practices in other offices could differ. A survey conducted by the NCWG provided an opportunity for all IHO member states to share their individual circumstances. 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. The report makes recommendations for further consideration and for the possible development of additional IHO nautical cartographic guidance.

1.5   Survey of IHO Member States

In addition to the narrative sections of this report, written by a handful of hydrographic offices, a broader perspective on the current and future state of paper nautical chart production is provided in the results of an extensive survey of IHO member states that are reported here. Survey responses were received from 52 of the 89 IHO member states[2], shown in Table 1 and Figure 2.

Argentina	Ecuador	Korea (Rep of)	Saudi Arabia[2]
Australia	Estonia	Malaysia	Singapore
Bahrain	Denmark	Malta	South Africa
Bangladesh	Finland	Mauritius	Spain
Belgium	France	Mexico	Suriname
Brazil	Germany	Netherlands	Sweden
Canada	Greece	Norway	Thailand
Chile	Iceland	Oman	Tunisia
China[1]	India	Peru	Turkey
Colombia	Indonesia	Poland	Ukraine
Croatia	Iran	Portugal	United Kingdom
Cuba	Italy	Romania	United States
Cyprus	Japan	Russian Federation	Venezuela

Table 1, IHO member states responding to the future of the paper chart survey.

[1] China did not respond to the survey directly, but did provide the paper titled, "Discussion on the Future of the Paper Nautical Chart from another perspective," to the 5th meeting of the IHO Nautical Cartography Working Group (Nov 2019).
[2] Saudi Arabia responded to IHO Circular Letter 29/2019, but abstained from submitting a survey questionnaire.

---

[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].
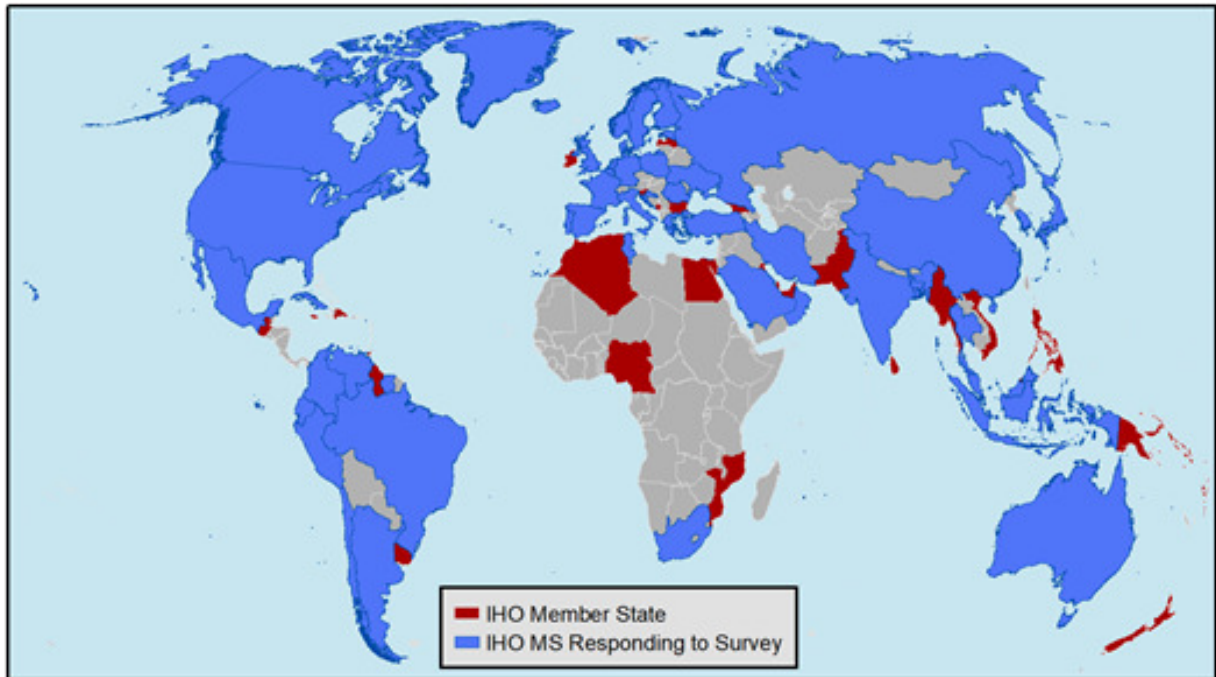[2] Memberships of four additional states are currently suspended. More information about IHO member states is at https://iho.int/en/map-of-member-states.

Figure 2, IHO member states responding to the future of the paper chart survey.

Summaries of survey responses by IHO member states are shown after this "Survey Results."

1.6   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.

ECS (Electronic Chart System)   A navigation information system that electronically displays vessel position and relevant nautical chart data and information from the ECS data base on a display screen, but does not meet all IMO requirements for ECDIS, and does not satisfy SOLAS Chapter V requirement to carry a navigational chart.

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.

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, the ungainly 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 apply 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 that 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. IHO S-61, [Product Specification for Raster Navigational Charts (RNC)](January 1999) defines the product format.

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[1] of ECDIS for the majority of shipping as the primary source for navigation, although paper charts may be used as a back-up. 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.

---

[1] Although this report in some instances refers to '*mandatory use of* ECDIS', it is noted that the precise wording in SOLAS V/19.2.10 is 'Ships engaged on international voyages *shall be fitted with* an Electronic Chart Display and Information System (ECDIS)[…]'.

2.1   Traditional Role of Paper Charts

Fig. 3. 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), 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 4 below. As of July 2018, the transition period to ECDIS has now been completed.
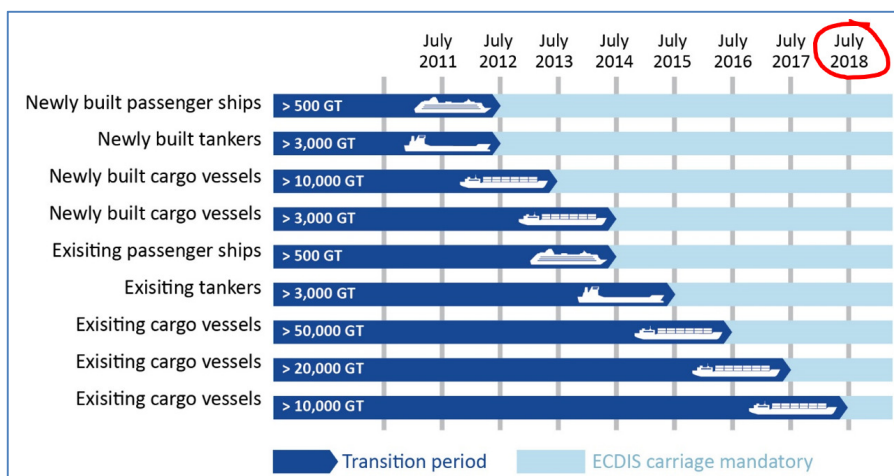

Fig. 4. ECDIS Implementation Schedule for Vessels on International Voyages

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.

b. Paper Chart Carriage Requirements for other Regulated Commercial Vessels[1]

- SURVEY RESULTS

Figure 5 shows a summary of the primary and back-up carriage requirements, reported by IHO member states, for vessels on domestic voyages as enforced by national regulatory agencies. This is meant to reflect a nation's general requirements, not to document all the distinctions and exceptions that are usually found in maritime regulations. It is noteworthy that only seven member states of the 48 responding to this survey question indicated that only paper charts will meet carriage requirements.

This figure includes 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.

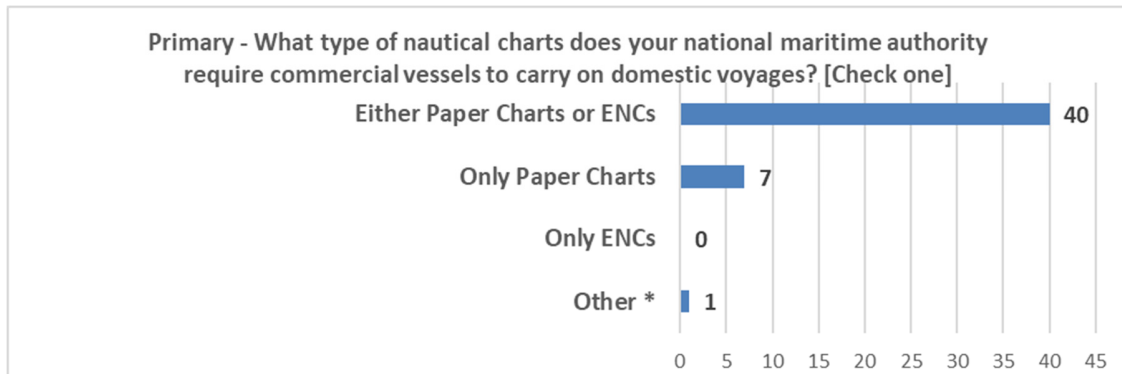[1] Commercial vessels not subject to the IMO mandate to use ECDIS.

Figure 5. National Primary Chart Carriage Requirement for Commercial Vessels on Domestic Voyages
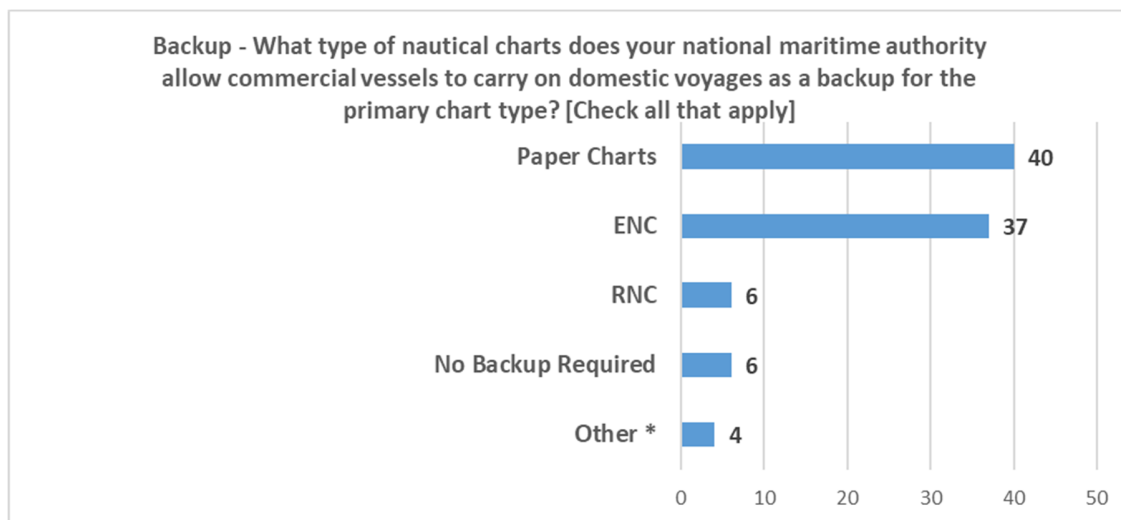* One member state responded "ENCs and Paper Charts."

Figure 6. National Back-up Chart Carriage Requirement for Commercial Vessels on Domestic Voyages
* Four member states provided the additional "Other" chart types accepted as back-ups or other remarks, shown in Table 2.

Member State	"Other" item in addition to the chart options identified as acceptable back-ups
Croatia	No back-up required if use Paper Charts as primary chart type. If use ENCs then it can be other independent ECDIS or Appropriate Paper Charts (APC)
Malaysia	[Also] Electronic Chart System (ECS) - Driven Product
Mauritius	When ECDIS is being used, can be either paper chart or another independent electronic system.
Portugal	IAW SOLAS Chapter V/19 and IMO resolutions MSC. 232(82)/MSC.64(67) annex 5 and MSC.86(70)

Table 2.

c. United Nations Convention on the Law of the Sea (UNCLOS)[1]

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,

---

[1] 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

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."[1]

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.

The first edition of S-121, *Maritime Limits and Boundaries* was published in Oct 2019 for implementation and test purposes. Ultimately, S-121 may provide another option for publicizing maritime boundaries, other than through paper or electronic charts.

---

[1] 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

2.3 User Requirements

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

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 most 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 for some HOs. 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 Back-up 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.

Reduce by adapting strategy: Identifying a subset of existing charts in the current portfolio and 'adapting' them to fulfil the IMO chart back-up requirements.

Stop by delegating strategy: 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.

Each of these options/strategies is described in more detail below.

Reduce by adapting strategy - Back-up 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 back-up (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:
  o Suitable 'waiting area' until the system can be repaired; or
  o 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 'back-up' chart:
  - Port approaches: 75 000 to 150 000
  - Coastal (restricted): 150 000 to 350 000
  - Coastal (not restricted): 500 000 to 1 500 000
  - Open sea transit: 3 500 000 or smaller

- 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 Back-up Charts for ECDIS Navigation is given in Annex A.

- The HOs would continue the production and distribution of these charts as per current practices.

Stop by delegating strategy - Back-up 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 Print-on-Demand (POD) file that could be printed on shore (before departure) or on board (on a dedicated plotter) with minimum input (limits, scales, planned route, etc.).

- Portrayal could look more like S-52 than INT-1. This would be more useful for (often younger) crew members who may be more familiar with the use of ECDIS than paper charts.

- 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 each country's 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 (such as the [NOAA Custom Chart](#) web application being used by the US) 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 back-up based on official data.

Of the 50 IHO member states providing responses to the NCWG survey, 38 stated that they have no plans to create a simplified or specific back-up chart format, while 14 stated that they were or were exploring some aspect of creating simplified charts.
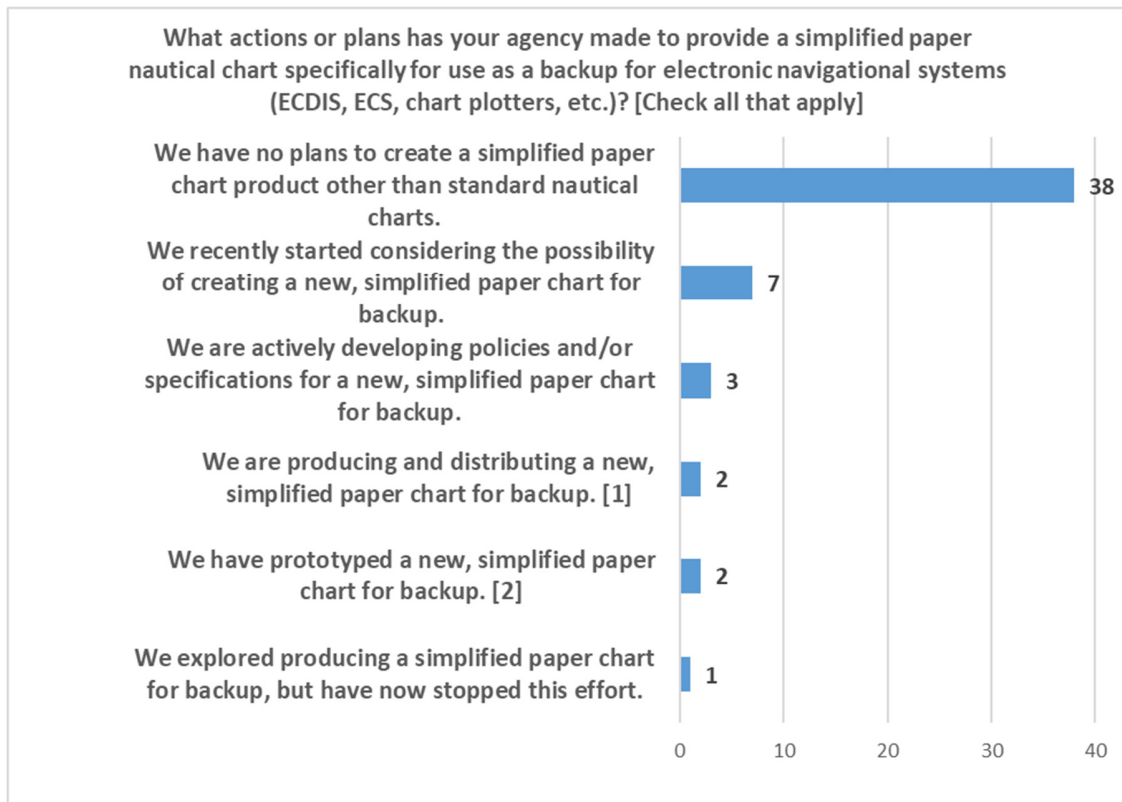
Figure 7.
[1] Columbia, Germany
[2] Canada, United States

Is your agency doing any other activities related to development of any product to be used as a back-up for electronic navigational systems?	

Australia	a) We suggested a new definition for 'back-up chart'. Refer to paper HSSC11-05.4F.
	b) To assist in the burden of paper chart production and maintenance the AHO has initiated a review process intended to permanently cancel excess paper charts in ports and coastal areas where the Electronic Navigation Charts (ENC) provide detailed coverage at a larger scale. The review process is based upon:
	  - Overall demand for ENC is five times greater than for paper charts, with that difference increasing annually.
	  - Paper charts used as a back-up for ECDIS equipped vessels should provide sufficient coverage and detail to enable a vessel to proceed to an anchorage or pilot boarding ground for subsequent guidance into port.
	  - Vessels not subject to pilotage requirements, such as domestic commercial vessels, do not require the same level of large scale detail as larger vessels, but still benefit from charts of adequate scale covering the overall pilotage area.
	  - This involves retaining the smaller scale chart product but migrating key information not previously displayed at that scale level and referring to areas covered at larger scale by ENCs only (use of a Chart note and associated reference on the face of the chart).
	c) We are looking into NOAA's online 'Chart on demand' solution (by ESRI) as a possible solution to support non-commercial vessels

Canada	Yes, the concept of Paper Chart 2.0
Croatia	Not at the moment, but we are aware of the situation (indication in the national regulations and IHO activities regarding their views on the future of paper charts). Being aware is an initial phase for further consideration and corresponding activities.
Malta	In respect of paper charts and nautical obligations, we meet our obligations through a bilateral agreement with UKHO.
Suriname	If ENC is considered as primary, the paper chart should be the back-up.
United Kingdom	UKHO had developed a get-you-home folio which could be used as back-up for ECDIS failing, this has not been actively pursued since the prototype was proposed. It could not be confirmed if this concept would adequately meet the user requirement.

Table 3

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

To determine the impact of the use or non-use of paper nautical charts by non-navigational users, one must establish who these potential users affected by the discontinuation of paper charts are. Following the "e-Navigation[1]" 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 4.

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[2]	– 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 4. 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

---

[1] 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).

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

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 considered:

- 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.
- Proper implementation of computer applications to provide the maritime transportation sector and others with better access to the information.
- The new application is designed and produced to take the requirements, capabilities and skills of all users into account.
- 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 8 depicts the database structure.
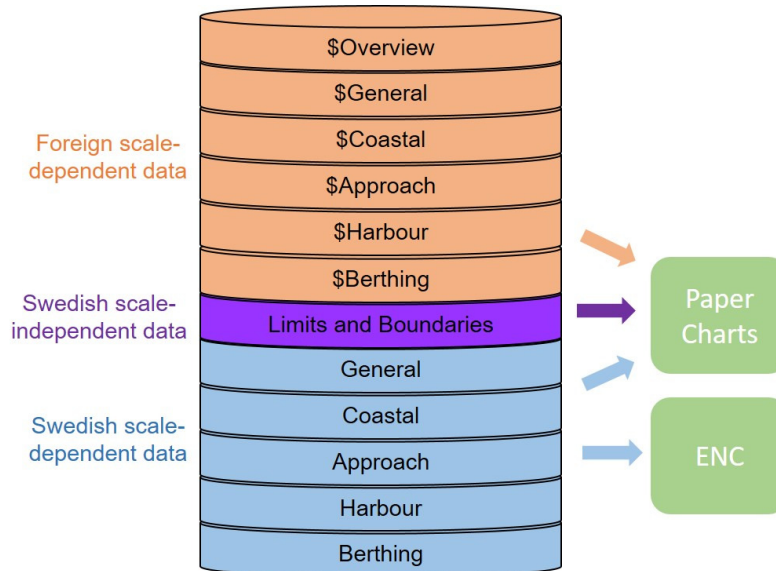

Fig.8. Structure of SMA chart-production database

This schema enables database operators to apply updates to ENC and cartographic products simultaneously, thus creating a simplified workflow (Fig. 9). 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.
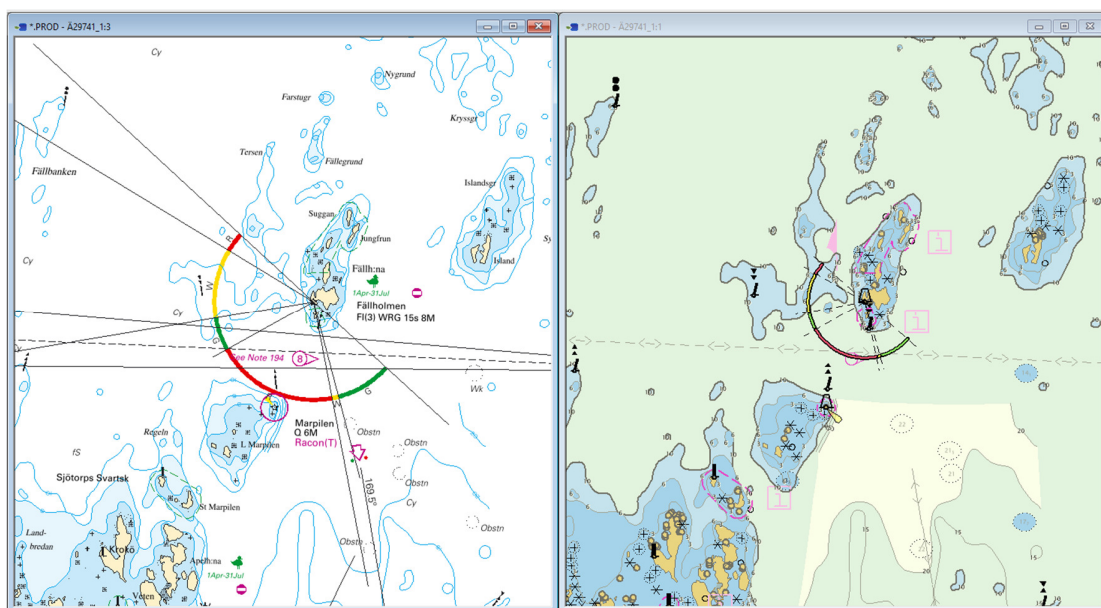

Fig. 9. Simultaneously Updating Raster and ENC products

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-4 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.

Figure 10.
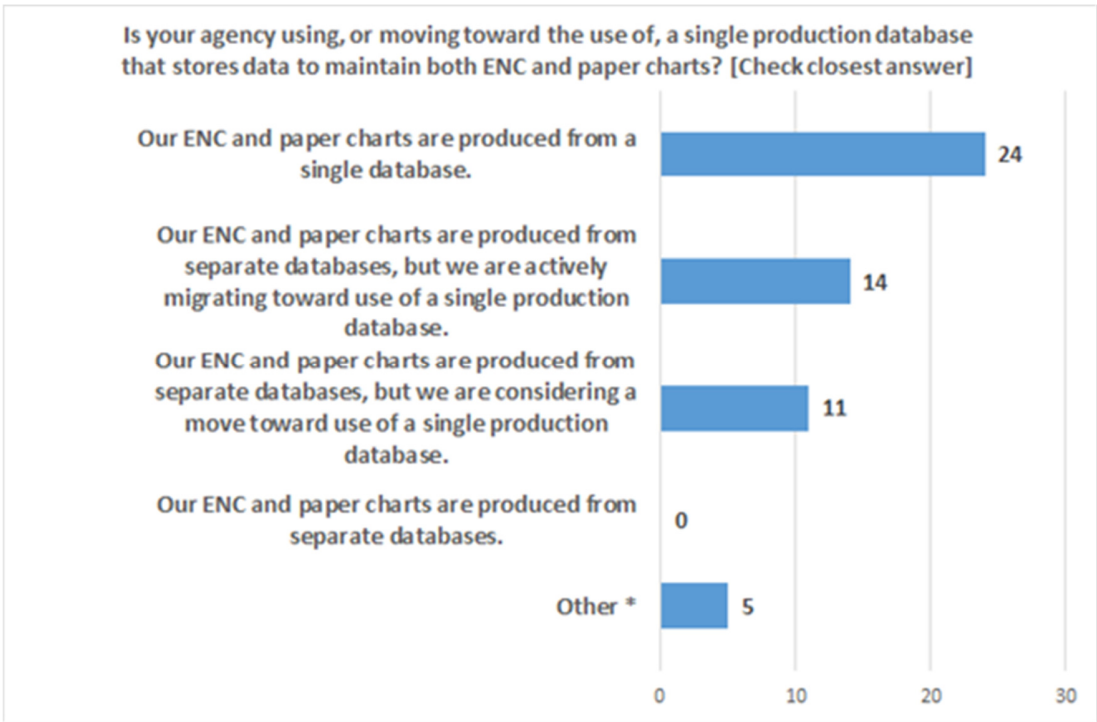* Four member states provided the "Other" responses shown in Table 5.

Brazil	Currently, some ENC cells and paper charts are produced from a single database, while others are still based on single files. Brazil is still migrating towards the use of a single production database. [Also tallied among the 14 "… actively migrating toward …" in Figure 10.]
Cyprus	Our nautical publications are produced by UKHO. In the future we intend to produce both ENCs and charts from a single database [Also tallied among the 11 "… considering a move toward …" in Figure 10.]
Denmark	We are in the process of moving to a single database for both paper and ENC. [Also tallied among the 14 "… actively migrating toward …" in Figure 10.]
Malta	Malta HO has only ENC production and maintenance capabilities.
United Kingdom	Our ENC and paper charts are produced from a single database, for all home waters and areas of primary responsibility. [Also tallied among the 24 "… produced from a single database …" in Figure 10.]

Table 5.

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 (see Figure 11.). Some efforts have been made to use S-57 attributed data to automatically apply S-4 (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 S-4 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 S-4 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. 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 S-4 symbol mapping:
There is no standard mapping of S-57 features and attributes to S-4 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 S-4 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 S-4 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 over the current S-57, there is no reason not to go ahead with developing an S-57 to S-4 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 S-4 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 S-4 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 S-4 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 S-4 symbols.

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.

.   - S U R V E Y   R E S U L T S
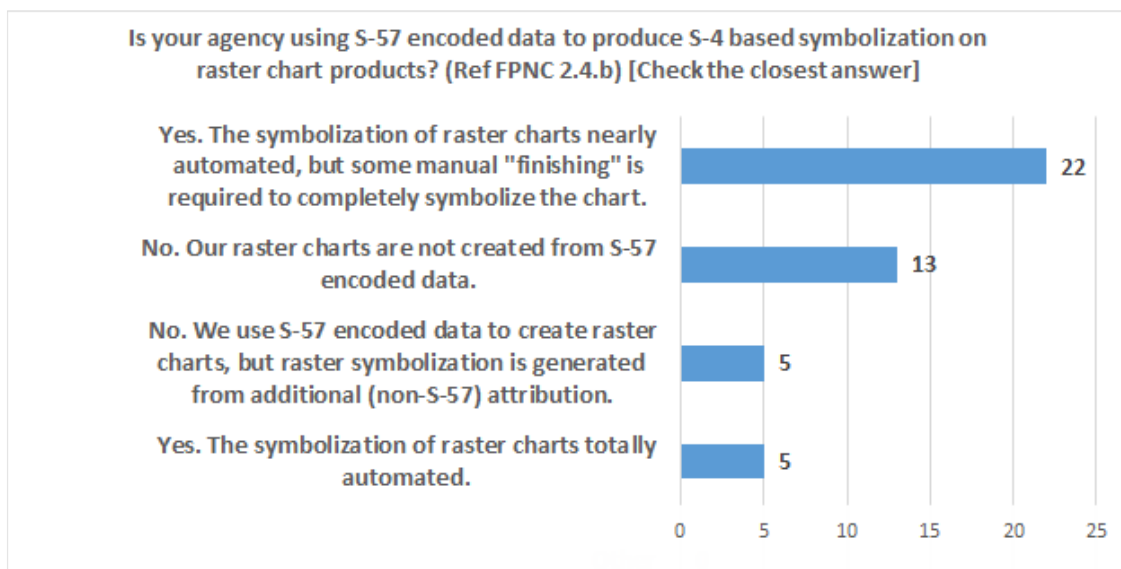

Figure 11.

c. Print on Demand (POD)

The current paper chart 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.

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, section B-201.3 requires);

• 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 (see Figure 12).
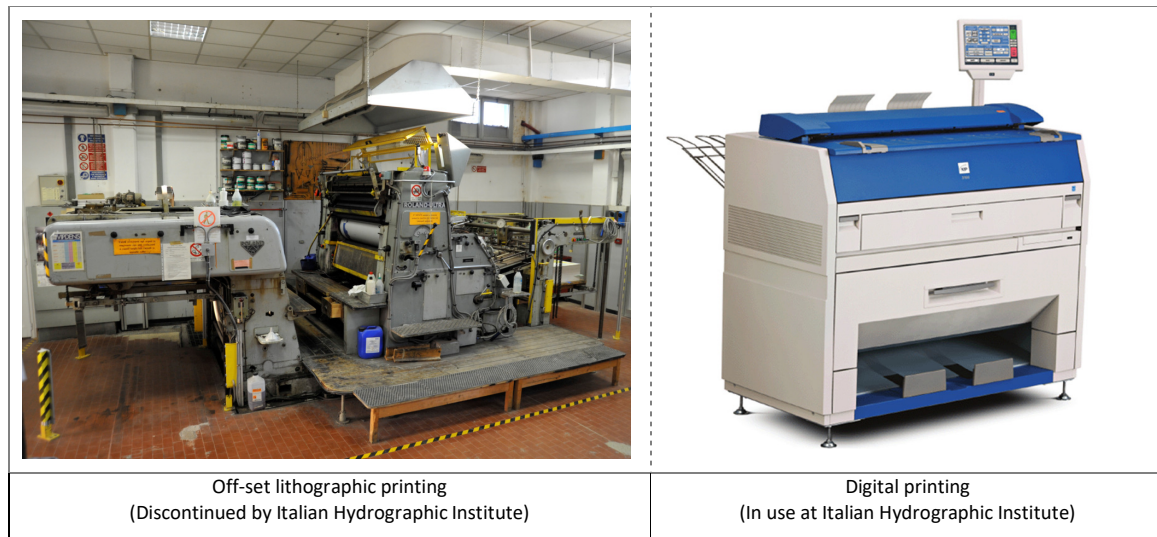

| Off-set lithographic printing (Discontinued by Italian Hydrographic Institute) | Digital printing (In use at Italian Hydrographic Institute) |

Fig. 12.

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 13 through 16. 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 13.
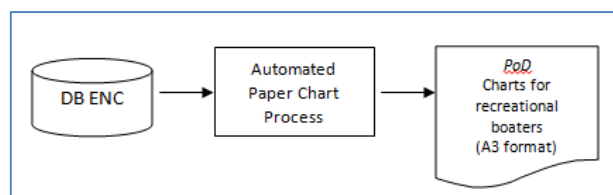

Fig. 13. ENC to recreational boating charts workflow

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 14, 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.
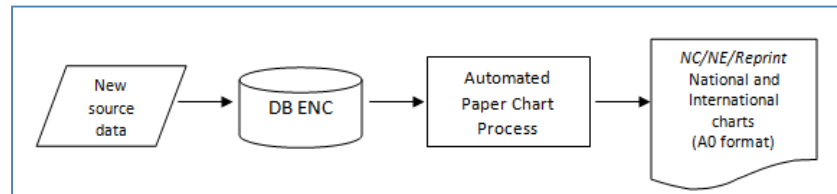

Fig. 14. ENC to paper nautical chart workflow

The Italian Hydrographic Institute now uses the workflow in Figure 14 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, as shown in Figure 15.
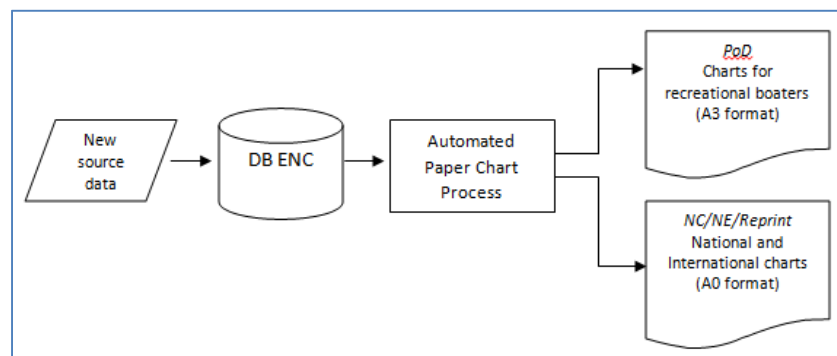
Fig.15. Combined ENC to paper nautical chart workflow

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 16). These will eventually be replaced by the modern, efficient production processes and software to take advantage of the POD workflow (Figure 15 above).

Fig.16 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

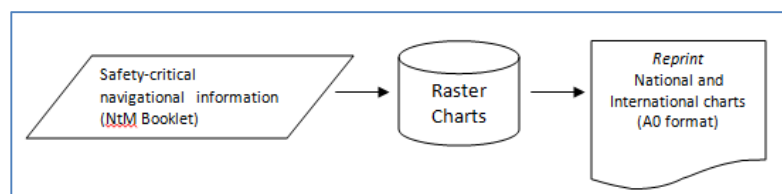remains a challenge, because of the limited availability of human resources and time needed to output both products (including the extra portrayal finishing required for paper charts).

The advantages of POD are not to be underestimated. POD printing has become a common technology (72% of IHO member states responding to the NCWG survey use POD for at least part of their chart replication effort, as shown in Figure 17). This 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.

- SURVEY RESULTS
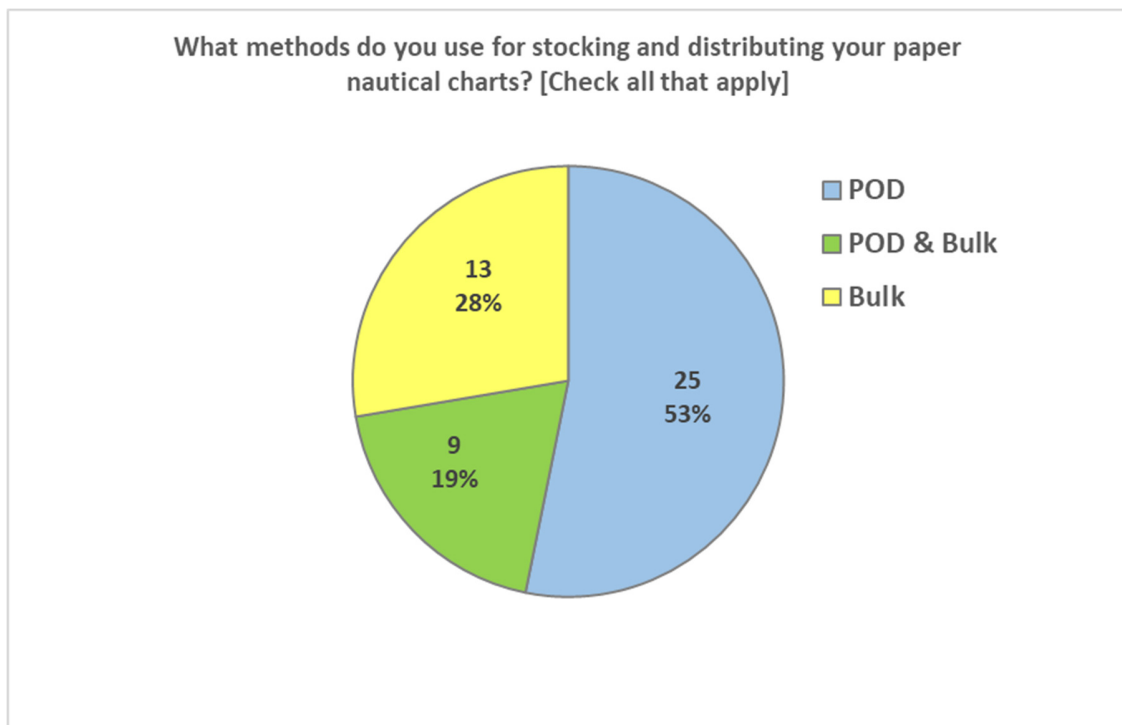
Figure 17.

This question was meant to determine the *current* method(s) of paper chart reproduction in use by each member state. Member states were provided with two options (plus "Other") to select an answer from, and were prompted to "Check all that apply." The options were:

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

Many hydrographic offices use both methods, or are in a transition from one to the other. Thus, the results are portrayed in a pie chart in Figure 17 that shows HOs using "Large Stock" or "Bulk" printing in yellow, HOs using "Small Quantity" or POD printing in blue, and HOs that use both in green.

Several of the "Other" responses clearly inferred use of either one method or the other, or both. Thus, eleven of the "Other" responses where categorized as POD, Bulk, or POD & Bulk, as shown in Table 6, for

the purpose of their inclusion in Figure 17. Three remaining "Other" responses were left as "Other" and are not included in the pie chart.

Pie Chart Category	"Other" entry
POD	Generally a print-to-order service is provided, when high selling charts are printed additional small quantities are produced to satisfy anticipated customer demand.
POD	Print on Demand
POD	Single charts, or small quantities, of charts are printed or plotted as orders are received. Print on demand
POD	Distributed directly to end-users via distributors.
POD & Bulk	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. As info only: For 2018 91.8 % pre-printed, 8.2 % Printed on Demand
POD & Bulk	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. Large stock for new editions to meet initial market demand.
POD & Bulk	Large stocks of charts are printed in advance and stored for distribution. When out of stock, the charts are plotted [as orders] are received.
POD & Bulk	We still keep large stocks of charts printed in advance for quick demand. At same time, print small quantities for online order which need latest correction.
Bulk	Number of copies printed based on annual consumption and distributed through chart agents.
Bulk	Since, India is the Primary Charting Authority for Mauritius, charts are demanded from India and stocked up at the Cartography Section of the Ministry of Housing and Lands, Mauritius.
Bulk	Reasonable amount of charts is printed according to need and stocked for distribution. Reprints are ordered when necessary.
-	At present, we are not distributing our paper nautical charts
-	The HO has Bilateral Agreement with UKHO for paper chart production.
-	We do not print paper charts

Table 6.

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, this decline started even earlier. As shown in Figure 18, sales of paper nautical charts have been dropping for over a decade. The number of charts sold in 2018 are about half of those sole in 2008.

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 charts hung in beach houses and seaside 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 United States recently announced that it will end production of traditional NOAA paper nautical charts and related raster chart products by January 2025.

- SURVEY RESULTS

Information about sales of ENCs and paper nautical charts between 2008 and 2018 was requested in the NCWG survey. IHO member states were asked to report the number of sales of pre-printed paper nautical charts – often printed in large press runs by offset lithography and distributed from a warehouse – called "bulk" in the survey, and Print-on-Demand (POD) distribution methods, in which charts are printed one or a few at a time and distributed immediately.

Eleven years of paper chart and ENC sales numbers were aggregated to produce the graphs shown in Figures 18 - 21. The intent of this portion of the survey was to assess the current state and trends of the production and use of paper charts and ENCs. The trends portrayed in the graphs are unmistakable:

- Reported sales of ENCs surpassed those for paper nautical charts in 2009.
- Reported sales from 2008 to 2018 also show the following:
  - ENC sales increased sevenfold
  - Paper chart sales decreased by half
  - Paper charts reproduced in large press runs decreased by a third
  - Paper charts reproduced by print-on-demand methods doubled

Caveats to understanding the aggregated paper chart and ENC sales shown in Figures 18 – 21.

- Not every chart and ENC producing nation responded to the survey (see Section 1.5, Survey of IHO Member States).
- Not every survey respondent provided paper chart sales numbers. These were:

| Germany[1] | Tunisia | United Kingdom[2] |
| Russian Federation | Ukraine | Venezuela |

- Not every survey respondent provided ENC sales numbers. These were:

Bangladesh	Russian Federation	United Kingdom[4]
Germany[3]	Tunisia	Venezuela
Oman	Ukraine	

- Some counties explicitly noted distributions to military and other government users as part of their "sales." It is likely that other countries did so as well without noting so. These distributions were included in the aggregated sales shown in the graphs.
- The United States reported paper charts distributions to military and other government users in each of five years, 130 623 (2014), 136 330 (2015), 129 104 (2016), 165 977 (2017), and 160 012 (2018). However, many of these charts are categorized as "Limited Distribution" and are not available for public sale. These chart distributions were not included in the aggregated sales shown in the graphs.
- As do most other ENC producing nations, the United States distributes its ENCs through a Regional ENC Coordination Centre (RENC), but it also enables free downloads of all US ENCs from the NOAA website. Only the ENCs distributed through the RENC were tallied in the aggregated sales shown in the graphs.

[1] Germany did not provide bulk or POD chart sales, but stated that all paper chart sales decreased by 81.5% from 2008 to 2018.
[2] The UK did not provide bulk or POD chart sales, but stated that while POD sales increased by 41% from 2008 to 2018, overall paper chart sales decreased by 52% during the same period.

- SURVEY RESULTS

Figures 18 and 19 show sales numbers for member states that reported sales of bulk and POD charts. In Figure 18 the bulk and POD sales bars are stacked over each other to show the overall decline of all paper chart sales. Figure 19 more clearly shows the change in paper chart replication methods.
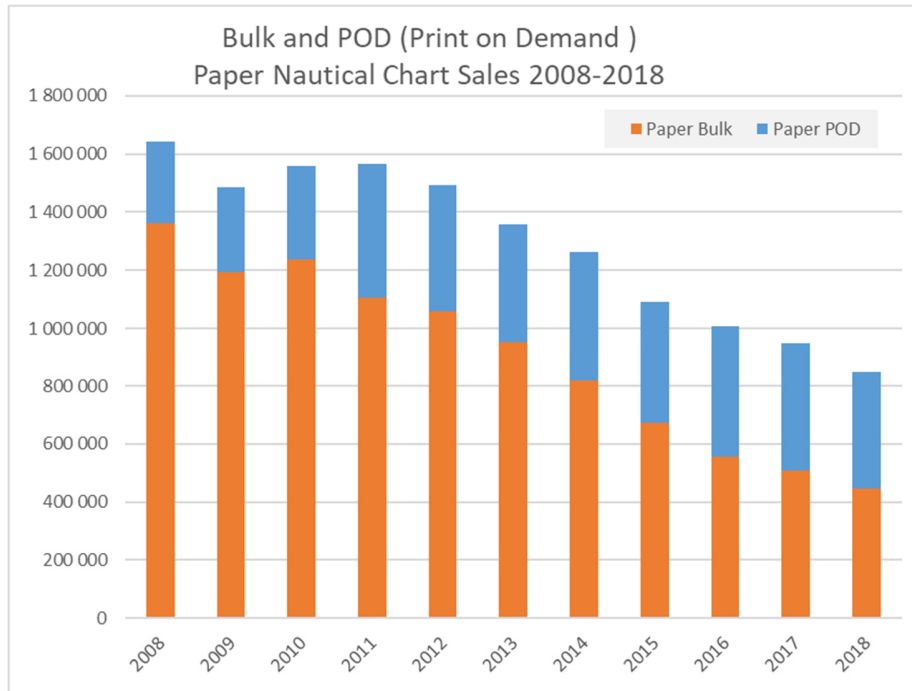

Fig. 18. Lithographic and print-on-demand annual nautical chart sales
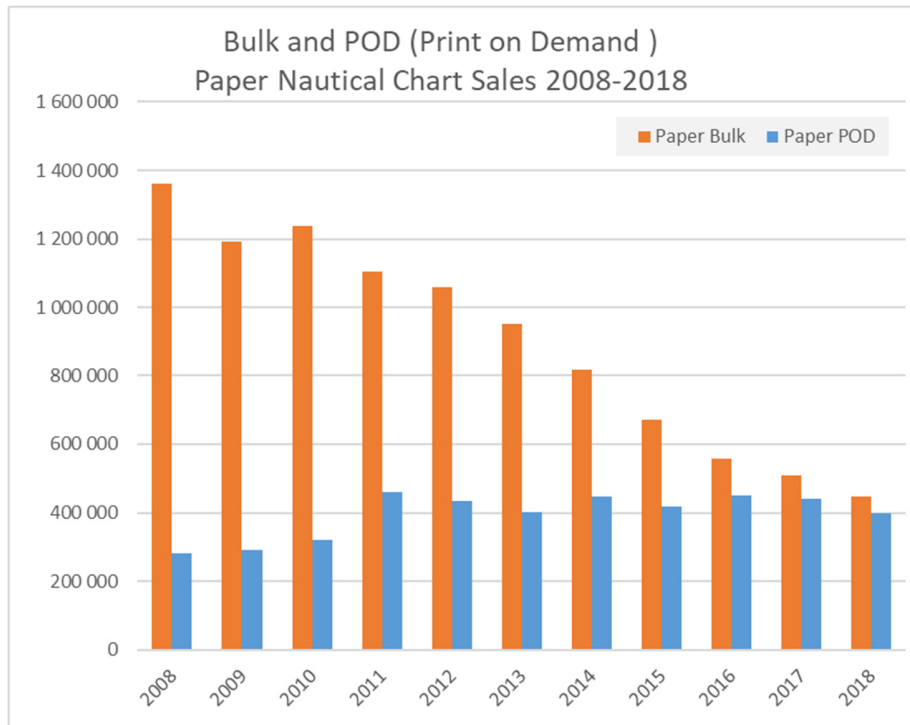
29

Fig. 19. Lithographic and print-on-demand annual nautical chart sales

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 in 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 the full potential of ENCs 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 is 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.

– SURVEY RESULTS

Figure 20 shows the sevenfold increase in ENC sales between 2008 and 2018. 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, as shown in Figure 21.
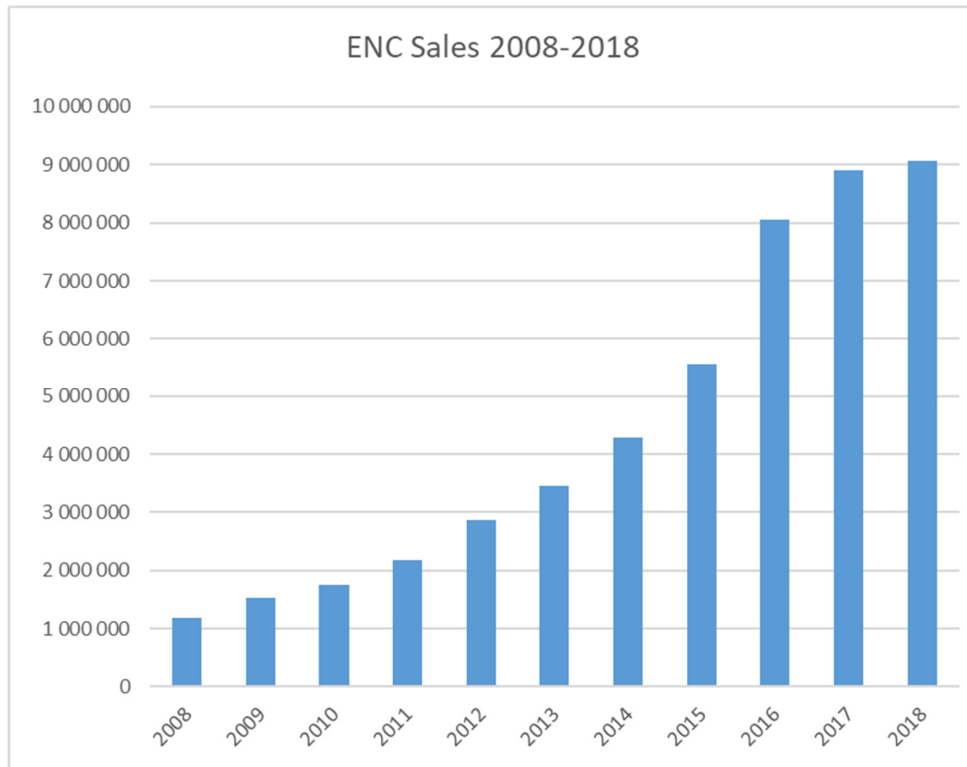
Fig 20. Reported ENC sales

In addition to implementation of the IMO mandate for the use of ECDIS and other factors discussed above, there are some characteristics of the ENC format and its distribution model that account for some of the higher ENC sales. These include the 5MB size limit for each ENC cell. If any ENC gets close to this limit, it is usually split into two or more pieces, resulting in more ENCs for sale for the same area extent. Recent efforts by some HOs to rescheme ENCs into a gridded layout also typically increases the number of ENCs. In the case of the US, the suite of NOAA ENCs is expected to increase from about 1200 to 9000 cells when its rescheming is complete. Rescheming aside, many HOs are also regularly adding new ENC cells (usually in a larger scale) to enhance their ENC coverage, sometimes without creating a corresponding paper chart.

Finally, whereas new editions of paper charts are rarely issued or purchased more often than every two or three years (and often at much longer intervening intervals, especially for smaller scale charts) ENCs must be purchased (or licensed) every year. Nevertheless, the trend of lowering paper charts sales and raising ENC sales is inescapable and cannot entirely be attributed to these ENC format and distribution characteristics.

Fig 21. Reported ENC and paper chart sales

c. Diminishing need for Raster Navigational Charts (RNCs) for ECDIS

The RNC served as a stopgap product for areas in which ENC coverage was not available to be used in ECDIS. Most areas of the world 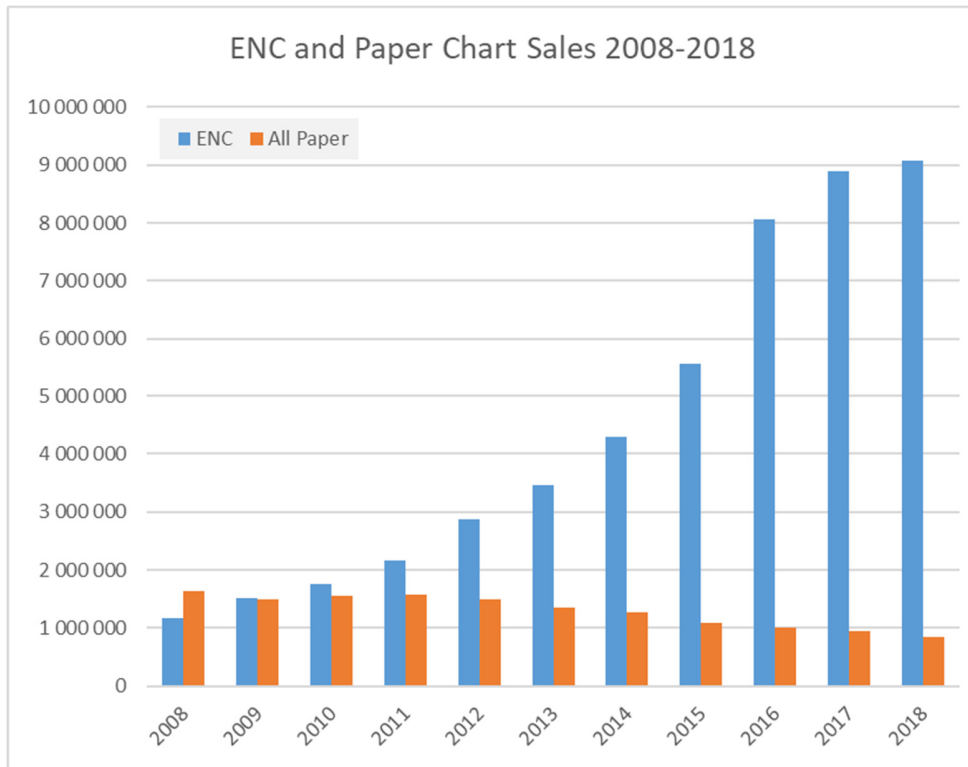now have adequate ENC coverage and thus the need for RNCs has declined. Some third-party data providers sell products based on RNCs, but only six IHO member states reported that they still produce RNCs, while almost all member states report production of paper charts and ENCs, as shown in figure 22.

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 is small, 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. Although nearly all member states responding to the survey reported producing paper charts, only six make RNCs. The US recently announced that it will cease all raster chart production, including RNCs by 2025.

d. Recreational boaters' use of paper and digital charts

The means of meeting the needs of recreational (leisure) boaters varies from place to place, as is shown in the variety of responses shown in Table 7. 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 reported a variety of ways in which the needs of recreational boaters were being met, as shown in Table 7.

What products or services does your agency provide specifically for recreational boaters?	
Argentina	Special Paper Chart
Australia	Nil. Products such as 'Boating charts' or 'Beacon to Beacon guides' are compiled by some State government agencies.
Bangladesh	No demands from recreational boaters.
Belgium	Production of small craft paper charts
Brazil	Raster Navigational Charts (RNC).
Canada	Small craft charts and (pleasure) cruising atlases.
Chile	None
Colombia	Nautical and tourist Guides of Colombia review
Croatia	Paper charts: One folio consisting of 29 A2-sized charts
Cuba	Yachting charts (8 Albums)
Cyprus	None
Denmark	None. Created by external licensees.
Estonia	We provide gpx format coordinates for shipping routes and produce 4 chart albums
Finland	Chart folios and special yachting charts. Atlases cover nearly all sea areas and major lakes. Yachting charts are available from some lakes. Both have content and portrayal nearly identical with standard nautical charts. Only format differs.
France	Folded charts printed on special paper (cartes L). Customized compilation of nautical products in an area (Sailing directions, List of Lights, Tides predictions, but no charts: NautiShom). refer to https://diffusion.shom.fr/loisirs/
Greece	Nautilus Charts Android application.
Iceland	None
India	NIL
Italy	Print on demand service: Charts for recreational boaters are updated and printed every 2 weeks
Japan	We do not have any products and services primarily geared toward recreational boaters for now. However, some of the Japanese private sectors definitely offer the yachting chart and the electronic reference chart to that user segment.
Korea, Republic of	Small craft charts and yacht charts
Malaysia	Malaysia did not have any demand for recreational boaters yet. We only produce standard paper nautical charts.
Malta	Malta does not have any products for recreational services at the moment.
Mauritius	NIL
Mexico	Paper chart and raster chart, we also have agreements with Jeppesen Maritime and EVG OceanGrafix and Indumar UKHO.
Netherlands	Small commercial vessels and leisure craft usually use the 1800-Series (8 atlases). These official charts cover all of the Dutch coast and major inland waters.
Norway	Nothing

Oman	Oman Maritime Book
Peru	None
Poland	Small Craft Charts
Portugal	Recreational and inland charts; wave forecast; publications.
Romania	No products or services
Russian Federation	Not produce
Singapore	Electronic Chart Systems (ECS)
South Africa	Small craft charts which includes large scale inset panels of small harbours, sailing directions and facilities diagram; Charts for Inland Waters (Dams)
Suriname	IC-ENC VAR services
Sweden	Small craft charts and S-57 licenses
Thailand	None
Tunisia	Standard paper nautical charts; Electronic navigational charts (ENC)
Ukraine	Albums of Nautical Charts - Navigational and Hydrographic Overviews
United Kingdom	Admiralty Leisure Folios
United States	Some "small craft" charts are produced, but these are being phased out in favour of standard nautical charts.

Table 7

e. Types of nautical chart types

IHO member states reported making the types of nautical charts shown in Figure 22.
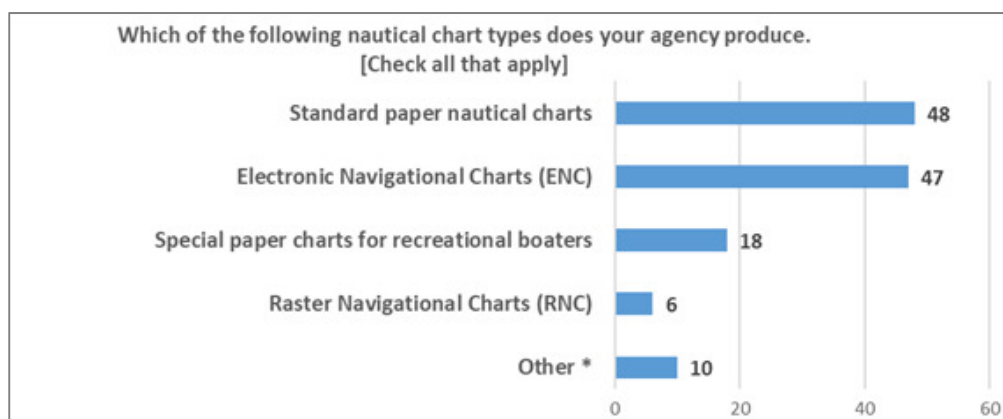
Figure 22.
* Ten member states provided the additional "Other" responses shown in Table 8.

Argentina	Croquis
Belgium	ECS for pilots, Inland ENC
Brazil	IENC in non-SOLAS rivers
Croatia	Thematic Charts
France	Up-to-date GeoTiffs, which can be used for navigation of leisure boats
Netherlands	Mariners Routeing Guide, Deep Draught Planning Guide
Portugal	Fishery Support Charts
Spain	Military Nautical Charts and AML

United Kingdom	Port Approach Guides, Mariners Routeing Guides, Routeing Charts, MagVar charts, Security Charts, Bespoke ENCs for cruise companies
United States	Digital Nautical Charts are produced by the US NGA

Table 8, Additional nautical chart types produced by some member states.

Brazil and Belgium noted that they produce Inland ENCs. The Inland ENC Harmonization Group reports in their IENC Production Overview that 55 629 km of IENC coverage has been produced by the countries listed in Table 9.

Belgium	France	Russian Federation
Brazil	Germany	Serbia
Bulgaria	Hungary	Slovakia
China	Luxembourg	Switzerland
Croatia	Netherlands	Ukraine
Czech Republic	Poland	United States
	Romania	

Table 9, Countries producing IENC.

Although much of this survey is focused on "blue water" ocean navigation. It should be noted that a significant amount of some member states' efforts are devoted to supporting "brown water" navigation. Brazil, for example, reports that 59% of its paper chart production effort is focused on non-SOLAS riverine areas.

3   Future Environment

3.1   Product Coverage

- SURVEY RESULTS

Figure 23 identifies a small, but potentially significant trend when it is compared to the survey responses summarized in Figure 22, which asked, "Which of the following chart types does your agency produce?" Figure 23 summarizes responses to a similar question, the first part of which is, "***When you create new or larger scale coverage …?***" Three fewer member states create new standard paper charts and one fewer member state creates new RNCs when new or larger scale coverage is created, while the same number of member states say they produce ENCs in responses to both questions. That is, 48 agencies maintain standard paper charts, but only 45 of them are continuing to create a corresponding paper chart when a larger scale or new ENC coverage is created. This approach is also discussed in section 3.1.c, "ENC-only coverage."

Fig. 23 Products created when new coverage is made available.
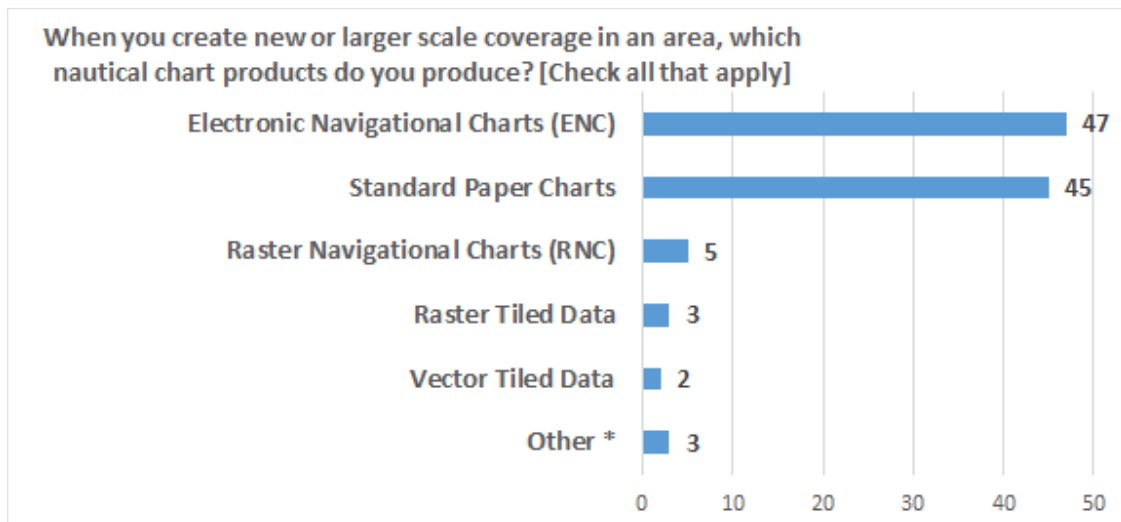* Five member states provided the additional "Other" responses shown in Table 10.

Brazil	IENC in non-SOLAS rivers
Estonia	Berthing and harbour coverage for chart albums for recreational boaters
Suriname	Small Craft Charts
United Kingdom	New ENC coverage does not automatically generate equivalent paper charts (but all safety critical data is provided to the mariner).

a. International (INT) charts

In January 2016[1], 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[2] 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 11) the future of the INT chart concept itself is now in question.

---

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

Region	Commission	Scheduled	New publications reported in 2017	Published Total	Regional Database Version
A	USCHC	15	0	15	3.0.0
B	MACHC	82	2	49	3.0.1
C1	SWAtHC	51	1	36	3.0.2
C2	SEPRHC	44	0	7	3.0.0
D	NSHC	217	2	217	3.0.5
E	BSHC	302	2	292	3.0.8
F	MBSHC	248	4	172	3.0.3
G	EAtHC	172	1	141	3.0.3
H	SAIHC	125	6	99	3.0.4
I	RSAHC	143	0	100	3.0.1
J	NIOHC	172	2	144	3.0.2
K	EAHC	294	0	240	3.0.0
L	SWPHC	67	6	62	3.0.2
M	HCA	117	4	84	3.0.4
N	ARHC	12	1	9	3.0.1
1:10 Million		25	0	24	3.0.0

Table 11. 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's 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 for producing both national and INT charts sometimes 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[1] set of INT paper charts for international shipping (large, medium and small scales), even for ECDIS back-up arrangements[2].

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

---

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

[2] 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.

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 printer's chart portfolio.

Over the years, the concept has become less attractive because there were only a few HOs, having international maritime requirements, 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 for route planning and back-of-bridge functions, it seems that the demand for INT charts (or the demand for paper charts meeting INT chart S-4 standards) has decreased significantly. One could ask, 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 US 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?

Furthermore, if 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[1], this is not the case anymore. The IHO, the Regional Hydrographic Commissions, and ENC producers now have better tools to adapt their ENC scheming and production plans than to refer to and replicate INT chart coverage.

What's next?

Global INT chart coverage at all scales has reached a high level of maturity, as shown in Figure 24.

---

[1] 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).
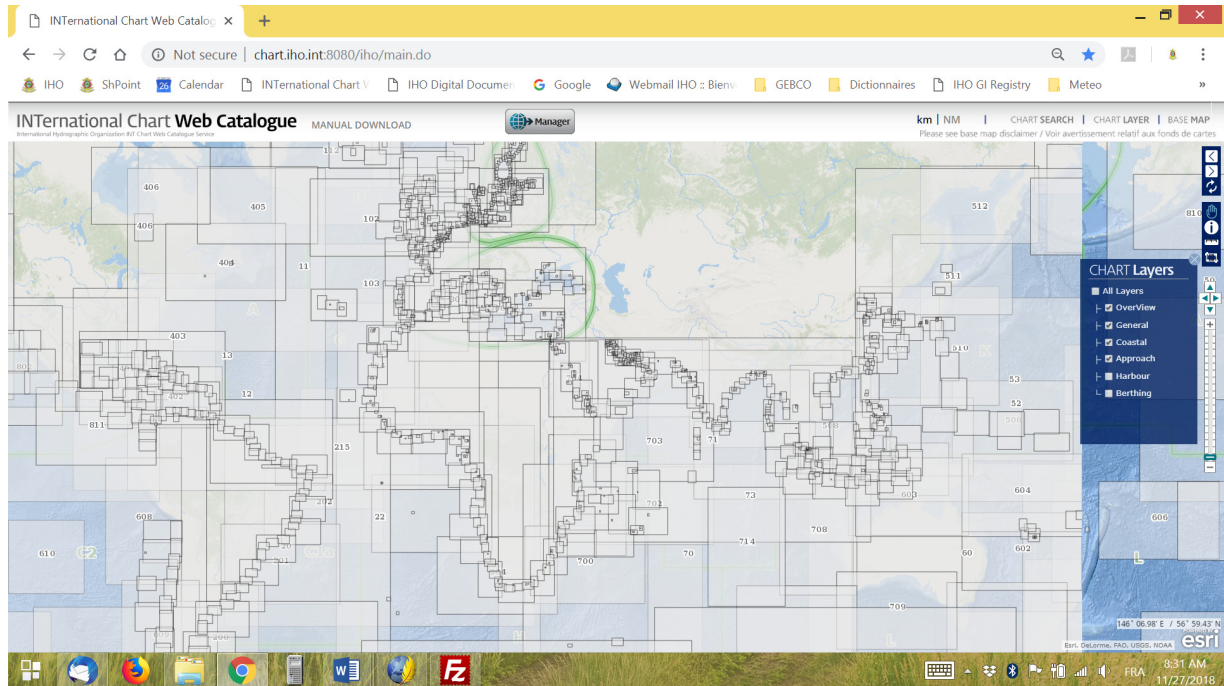
Fig. 24. Global INT chart coverage (overview, general coastal, and approach)

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 has declined (See Figure 25)[1].
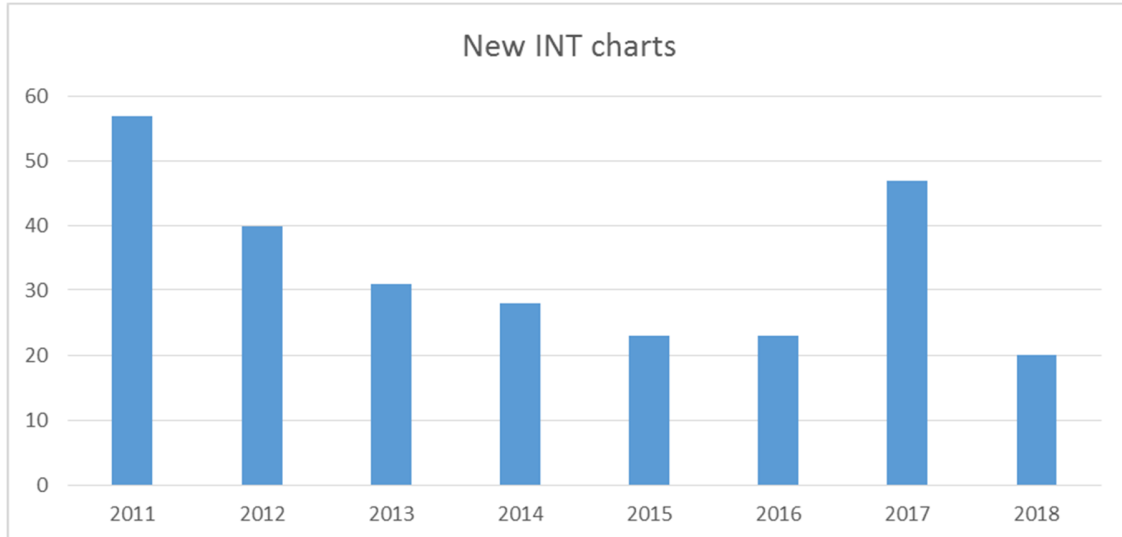
Fig. 25. INT chart production figures, 2011-2018

---

[1] 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.

Figure 26.

Twenty-seven member states either provided no answer or stated that they planned on making no new INT charts in the next three years. All responses are summarized in Figure 26. If a range was provided, such as "2-3 charts," then the higher value was used in the histogram.

The large number of member states reporting that they will produce no INT charts in the next three years can be attributed to a number of factors. A complete set on INT c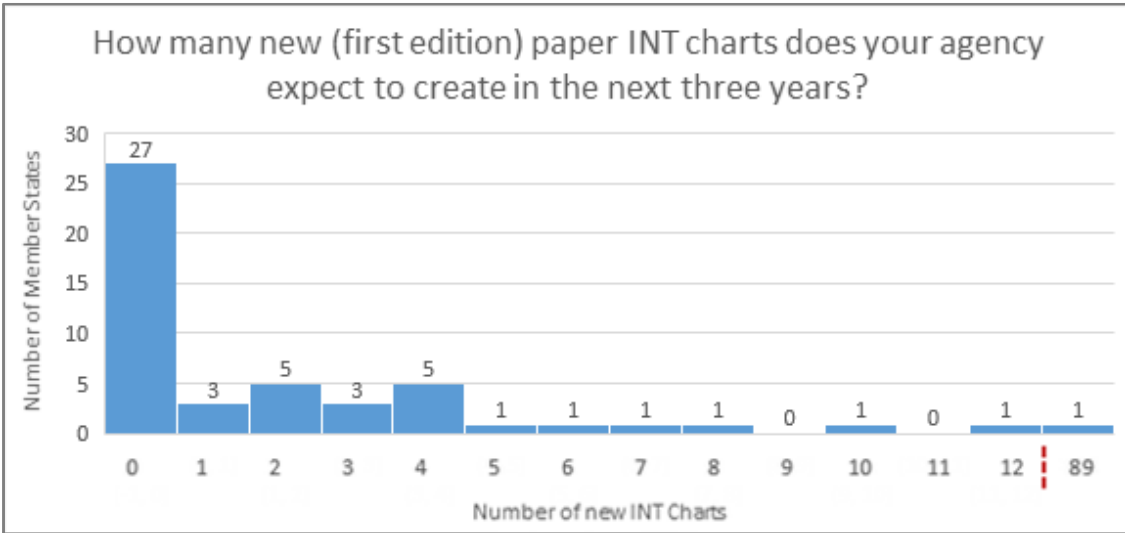harts may already exist in an area and therefore no additional INT charts need to be created. Some HOs may not have the capacity to produce INT charts or another HO may be producing INT charts over an area where several member states exist, so that the other HOs have no need to produce INT charts. HOs in other areas believe that creating new INT charts is unnecessary, because national charts fully meet the needs of the international community. Individual responses to the survey are listed in Table 12.

This trend of low INT chart production 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 [1], 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 with 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 State	How many new (first edition) paper INT charts does your agency expect to create in the next three years?
Argentina	12
Australia	Nil
Bahrain	1
Bangladesh	Nil. All INT Charts have already been published.
Belgium	None
Brazil	Two
Canada	0
Chile	0
Colombia	
Croatia	Four (4)
Cuba	None

---

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

Cyprus	None
Denmark	
Ecuador	
Estonia	7 INT first editions
Finland	None, all schemed charts have already been produced
France	10
Germany	
Greece	3
Iceland	3 - 4
India	NIL
Indonesia	
Iran	89 INT Charts
Italy	2 new INT charts
Japan	0
Korea, Republic of	5
Malaysia	We do not plan any
Malta	Malta does not have any INT paper Charts
Mauritius	3
Mexico	Two nautical charts
Netherlands	No new INT-coverage, however due to rescheming first editions may be created
Norway	Approximately 2
Oman	
Peru	None
Poland	1 - 2
Portugal	8
Romania	4 INT charts
Russian Federation	No new paper INT charts
Singapore	One
South Africa	4 - 6 new charts
Spain	0
Suriname	None. The whole coastal area is already covered within 2 INT charts.
Sweden	0
Thailand	No
Tunisia	INT 3212
Turkey	
Ukraine	Four
United Kingdom	
United States	NOAA has no plans to make any INT charts. NGA expects to make 3 INT charts in the next three years outside of US waters in areas where they serve as a PCA.
Venezuela	4

Table 12.

b. Rescheming paper chart coverage.

Member states were asked about their intentions to rescheme paper chart products. Although the majority of survey respondents indicated no interest in rescheming paper charts (see Figure 27) over a quarter of the IHO member states said they intended to rescheme the layouts of their paper charts for a variety of reasons, as listed in Table 12. These rescheming efforts may indicate a continued need for coordination within and across charting regions Regional Hydrographic Commissions by the RHCs' chart coordinating committees, even if the rescheming efforts are related to national chart coverage and not INT charts.

- SURVEY RESULTS
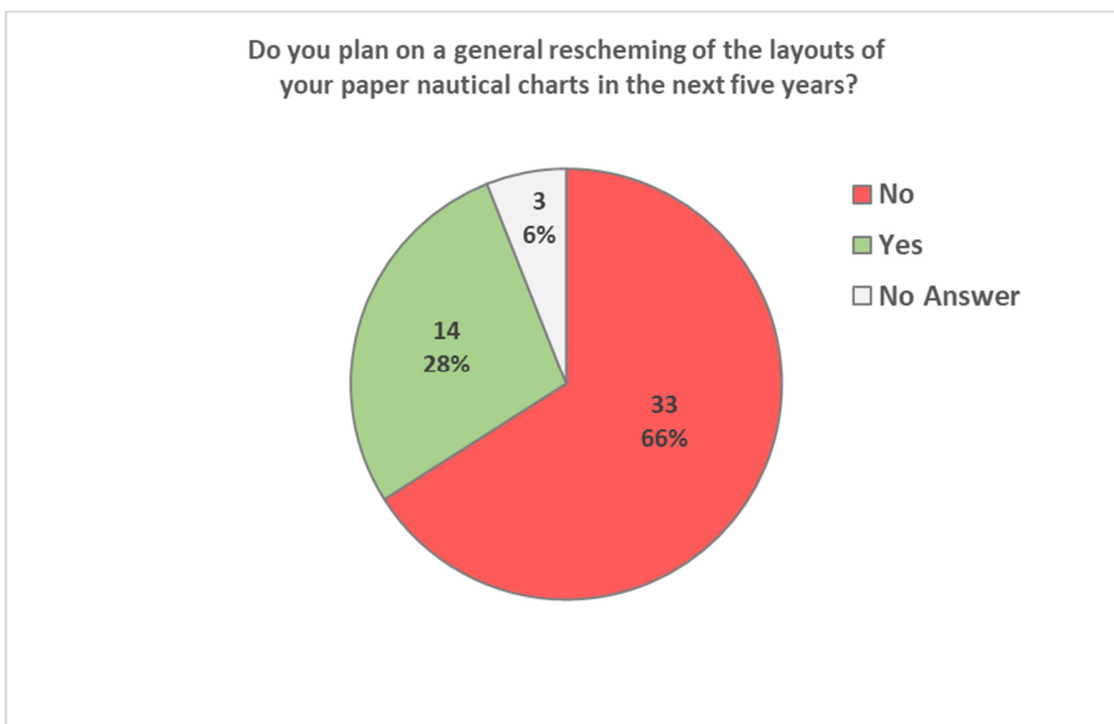
Figure 27

If rescheming paper nautical charts is planned, please explain the rational for rescheming (to better align with ENC coverage and scales, reduction in raster chart coverage, etc.)	
Planning paper chart rescheming:	
Argentina	To better align with ENC coverage and scales
Canada	CHS is moving to a gridded scheme for ENCs and will be re-aligning paper charts to be auto-generated from ENCs.
Cyprus	Maintain the basic schema of ENCs, and all other products shall be produced based on the ENC database
Denmark	Better align with ENC coverage and scales and to ensure we have adequate coverage in.
Iran	Our Paper Charts will be aligned with already produced ENCs

Japan	We are looking at making paper chart line-ups even more selective from its coverage perspective for every chart from wider area to detailed version. We really look to do this because there still seems many overlapped parts of the coverage caused by more than two distinct charts so we definitely work on it for making overall chart coverage less messy and more optimized for every its end user.
Korea, Republic of	To make better data with ENC scales
Mauritius	In order to have a better coverage of Nautical products within the EEZ of Mauritius.
Mexico	For larger scale charts, cover with approximation use and only obtain a portulan or mooring chart, that is, two charts in some cases depending on the importance of the port covering it with only a chart of portulano use, aligned to the paper scale.
Netherlands	Further optimization, reduce overlaps
Portugal	Reduction of redundant coverage; Cancel national charts where INT chart exists; create special maps/charts for low usage areas/harbours without relevant navigation and cancel existing nautical charts, namely, in areas where maintaining update information is unpractical
Spain	To better align with ENC coverage and scales
Thailand	1. Base of updating paper chart and ENC in Thai waters. 2. To be both of paper chart and ENC have the same limit and scale.
United Kingdom	To better align with ENC coverage and scales, reduction in raster chart coverage Rationalising coverage, reducing maintenance of the paper products.
Venezuela	There are information gaps identified by the CHR
Not planning paper chart rescheming:	
Colombia	Not [rescheming], the scales of papers charts and ENC are different
Croatia	There is a need for partial re-scheming to better align with ENC coverage and scale and reduction in the number of paper charts.
Malaysia	Rescheming is required when there is extension or new construction of berth, jetty and other conspicuous structure that need new scheme to help the user to navigate safely.
Russian Federation	We don't have plan [to rescheme]

Table 13

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 apparent adoption of this approach by a few other member states is reflected in Figure 23 and the discussion of product coverage in section 3.1 above.

The US is also 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.

Thus, as new, larger scale US 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 capabilities. In fact, as noted in Section 2.5.a., 'Declining demand for paper charts', NOAA recently announced that it will end production of all traditional paper nautical charts by January 2025, so all coverage in US waters will ultimately be 'ENC-only.'

- SURVEY RESULTS

Do you have corresponding paper nautical chart coverage for your ENCs? [Check the closest answer]

- 1 / 2%
- 0 / 0%
- 2 / 4%
- 5 / 10%
- 41 / 84%

■ Nearly every one of our ENCs ...
■ About 75% of our ENCs ...
□ About 50% of our ENCs ...
□ About 25% of our ENCs ...
■ None of our ENCs ...

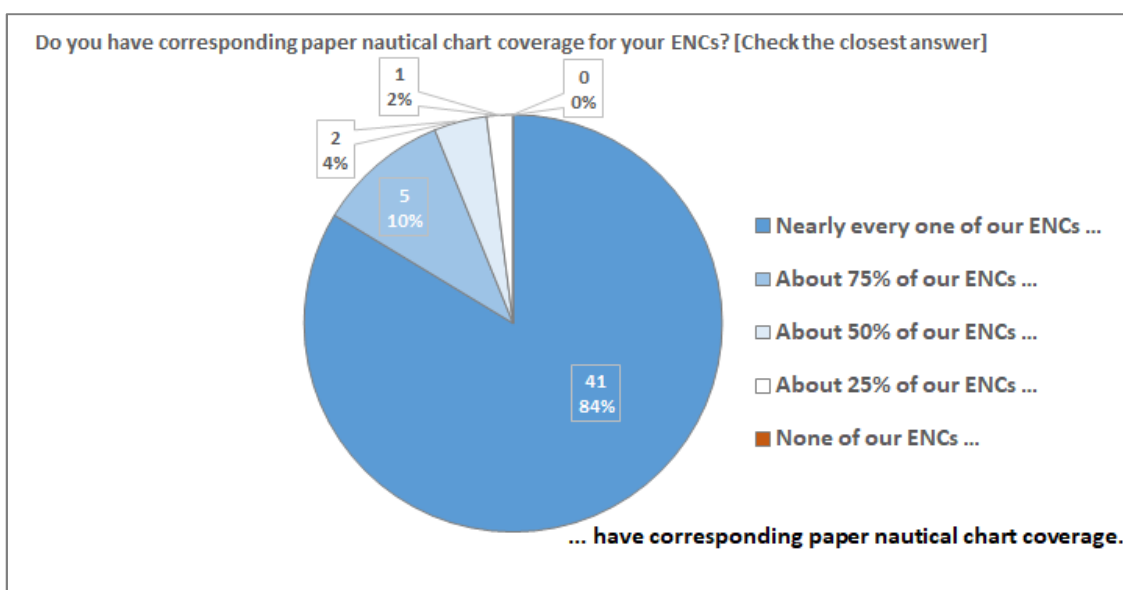... have corresponding paper nautical chart coverage.

Figure 28

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.

3.2   Alternative Methods of Paper Chart Provision

a. Printing paper charts from ENCs

One alternative to traditional paper charts that could improve efficiency is to directly render ENC datasets to paper using the S-52 Presentation Library.

Since S-52 symbolization rules already exist, S-52 symbology can automatically be applied to an ENC. Some of the key advantages to this approach include:

- The automatic application of symbology. Because the charted content is now rendered using ENC data directly, there is no need to perform a translation from ENC to a different vector or raster format, no need to translate data to S-4 symbols, and no need to have them heavily reviewed for cartographic accuracy.
- The simplification or elimination of hand corrections (notices 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 of text and line displacement. 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.

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

This approach would allow hydrographic offices to:

- Continue making traditional paper charts, without the pushback that could accompany the utilization of S-52 symbology as a replacement for S-4.
- Improve accuracy and consistency across paper products by clearly defining the relationship between S-57 encoding and S-4, rather than being accomplished manually by a human or automatically by a program that was built on inferring this relationship.

- Improve efficiency in production as the application of the symbology to the data would be automatic, and without need for comprehensive review.

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

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

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

- SURVEY RESULTS

Over 70% of the member states responding to the NCWG survey indicated that they either are, or are exploring ways of creating paper charts directly from ENC data, as shown in Figure 29.
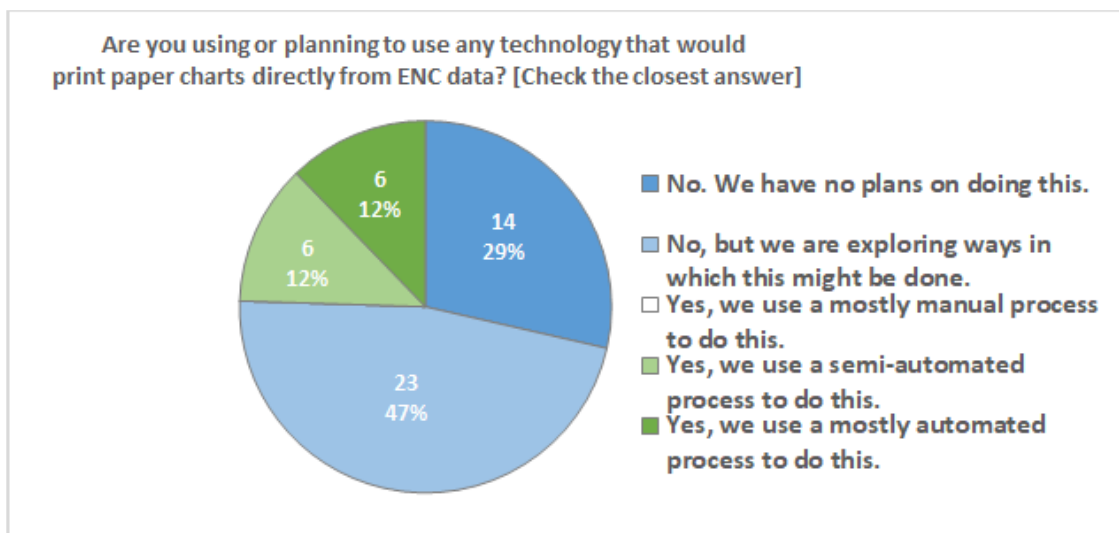

Figure 29

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 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 revision (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 S-4 are applied via a machine-readable technique, it is unlikely the automated output will provide the precise quality (or aesthetics) 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.
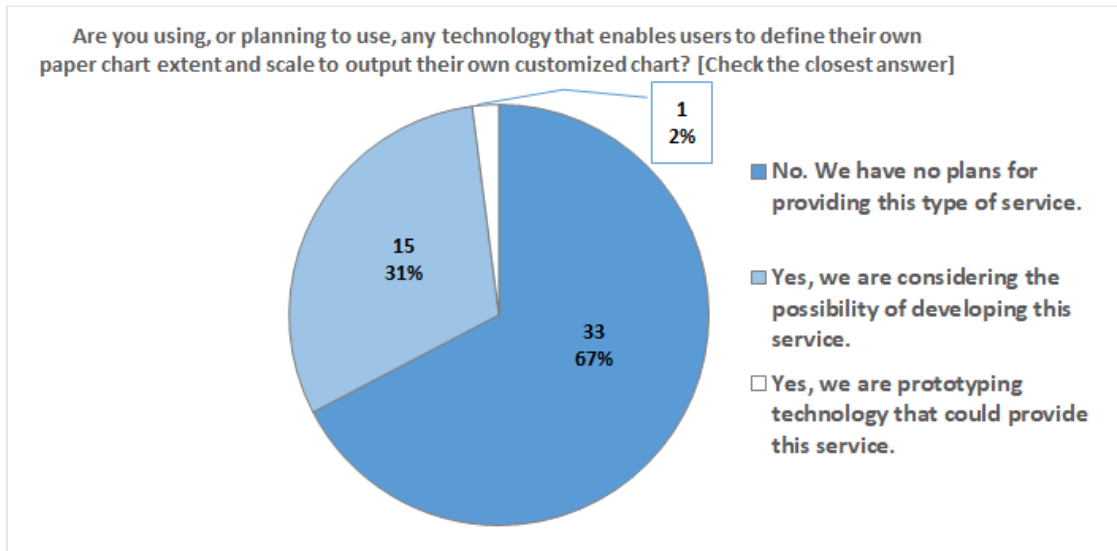
Are you using, or planning to use, any technology that enables users to define their own paper chart extent and scale to output their own customized chart? [Check the closest answer]

1
2%

15
31%

33
67%

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

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

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

Figure 30.

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 S-4 (also called INT1 symbology) maximizes readability.

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

A weakness of an S-52 driven display is that it lacks many basic cartographic conventions that minimize clutter and otherwise make a chart easier to read. Some of these issues are outlined in NCWG3-08.8A. Nautical cartographers using S-4 symbology have perfected the craft of generating navigational products that maximize readability. Some aspects of 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 attributes" 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 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.

The NCWG will continue to work in close co-operation with the other working groups, delivering cartographic advice, to support and enhance the portrayal of ENCs.

3.3 e-Navigation

The IMO states that 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."

In June 2019, the IMO Maritime Safety Committee (MSC), 101 session approved a number of circulars related to the development of e-navigation. This included a resolution on guidance on the definition and harmonization of the format and structure of Maritime Services in the context of e-navigation. The purpose of the guidance is to ensure that maritime-related information and data exchanged as part of different Maritime Services are implemented internationally in a harmonized, standardized and unified format. *All Maritime Services should be conformant with the International Hydrographic Organization (IHO) S-100 framework standard, which specifies the method for data modelling and developing product specifications.*

It is important to note that this guidance further strengthens the future importance of the IHO S-100 family of products and the S-101 ENC in particular, as the ENC will likely serve as the "base map" for many other product layers that will be integrated into an ECDIS or other display engine. The paper chart, unlike S-100 products, cannot be integrated with additional layers of information in a practical way. As the development of e-navigation matures and its benefits become clear, the limitations of the continued use of paper nautical charts will become ever more apparent.

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.

- SURVEY RESULTS

IHO member states were asked to provide their perception of the relative level of impact of a "world without paper nautical charts" in five categories. It is interesting that the impact to "User Requirements" was accessed at the highest medium-to-high level, while the potential impact to "Sales Revenue" was assessed at the lowest medium-to-low level. For the remaining community of paper chart users, their need to adopt ENC-based products or other alternative navigational products would certainly have a large impact. One the other hand, perhaps many HOs are already seeing most of their sales revenue being derived from ENCs, and not from the diminishing paper chart sales.
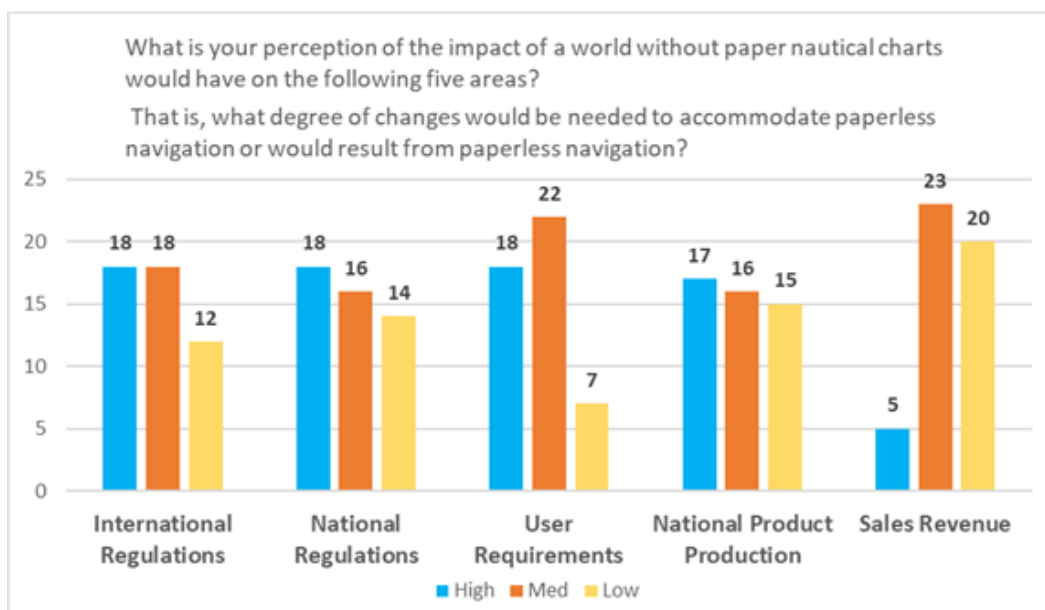
Figure 31.

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 is written at a sufficiently high level to avoid mentioning specific products. This is often the case for national regulations, as well.

However, changes would be required to IMO recommendations and national guidelines for all sizes of vessels where specific product types are 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.

- S U R V E Y   R E S U L T S

What types of changes in your maritime national regulations would be required to enable the disuse of paper nautical charts?	
Argentina	High changes will be necessary
Australia	Minor changes to the Navigation Act 2012 in subsection 224 to clear up reference to type of nautical charts needed for carriage. The Navigation Act requires use of official charts, whether ENC or paper. Of the two types, it is SOLAS that drives a legacy view of paper charts and infers a level of detail within them that already differs from practical experience. This inference arises from the combination of several separate clauses.
Bahrain	New laws to allow for paperless navigation
Bangladesh	Maritime national regulations are required to be amended accordingly to ensure the strict compliance of using ENC for International voyage. But the back-up arrangement of simplified paper charts are to be ensured by all ships.

Belgium	There will be a need to adjust the current Belgian legislation.
Brazil	Update chart carriage regulations for Brazilian jurisdictional waters and ports; Update the ECS carriage national regulations for some ship classes; Update national training regulations in navigation on some ship classes for mariners.
Canada	National regulations will need to recognize digital representations of the official navigational product i.e. the ENC, as back-ups in different media such as tablets or stand-alone laptops. Currently, in Canada, ECSs are not officially accepted as primary or back-up systems for navigation.
Chile	
Colombia	anyone
Croatia	Reviewing and amending the existing Maritime Law and other related regulations and guidelines,
Cuba	
Cyprus	Minor changes on regulations
Denmark	Multiple law changes likely inspired by the required changes in SOLAS.
Ecuador	
Estonia	Changes in different national regulations related to use of paper chart
Finland	Ship voyage planning regulations should be renewed and extended to small vessels. Chart plotters should be authorized as proper navigational charts. This would require significant changes in chart plotter update mechanism and production chain.
France	None, as it is already possible to navigate without any paper chart.
Germany	
Greece	The regulations are set by the Ministry of Mercantile Marine and Island Policy.
Iceland	
India	The regulations for Indian flag shipping would be promulgated by DG Shipping, Ministry of Shipping, Govt. of India based on IMO regulations.
Indonesia	None
Iran	Considering the software and hardware needs, this subject should be carry out by Iranian Maritime Administration, of course with the cooperation of Iranian ship owners and shipping companies.
Italy	National maritime regulations will need to be amended.
Japan	Some of the official notifications have had specific paper chart names and numbers explicitly. Therefore we think there would have to be a definition which can bring clarity on how this sort of notifications should be essentially well suited.
Korea, Republic of	No specific comment
Malaysia	No change is required since we follow international regulation (SOLAS Chapter V) for national laws.
Malta	Such changes would be in the form of an amendment to our subsidiary legislation and/or code of practice.
Mauritius	The maritime national regulations are promulgated by the shipping Division under the Ministry of Ocean Economy Marine Resources Fisheries and Shipping based on the regulations promulgated by IMO.

Mexico	A) Laws and regulations b) Ships of certain size it could be mandatory c) Fishermen could be the exception (little boats) d) Production of digital charts in all the formats by national maritime authority
Netherlands	Required changes to national regulations would be few, as NL regulations already allow paperless navigation. Paper is allowed as a back-up. If paper would cease to exist, this would only mean that description of back up facilities would have to change.
Norway	Minor changes.
Oman	
Peru	It would be necessary a change on a National Decree which approves the regulation that or flag ships must have paper charts
Poland	If the IMO regulations are put into practice, the national maritime regulations will have to be amended. In Poland, the Ministry of Marine Industries and Inland Navigation is responsible for introducing these amendments.
Portugal	IAW SOLAS CHANGES
Romania	Laws for the implementation of law 395 of October 11, 2004 on maritime hydrographic activity should be promoted and approved.
Russian Federation	Changing of the national laws
Singapore	Nil.
South Africa	It will have no impact on the regulations of the Maritime Authority. Engagements with various sectors of the marine industry would need to take place over a period of time before the enabling of the disuse of paper charts, only once mandated by the IHO/ IMO and related entities.
Spain	none
Suriname	Our national regulations refers to the requirements of SOLAS as reference for official charts.
Sweden	The use of paper charts must then be prohibited for navigation.
Thailand	Regulation of SOLAS Convention should be enabled the disuse of paper nautical charts.
Tunisia	The Tunisian maritime regulation deals usually with IMO regulations and recommendations
Turkey	
Ukraine	The issue is out of the SHSU competence.
United Kingdom	
United States	USCG already allows for commercial vessels to use ENCs. However, adjustments would have to be made to the way Notices to Mariners were written, as many of the notifications (not just chart corrections) make references to particular chart numbers.
Venezuela	Modification To National Laws

Table 14.

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 activities would also need appropriate products, which are not necessarily paper charts.

ENC quality and coverage in some areas still needs to improve by removing 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." (Although some HOs are already doing the opposite; that is, noting on their paper charts that mariners should "Use ENCs.") Nevertheless, achieving consistent, complete ENC coverage on a global scale is not a simple process due to the number of individual producing authorities contributing to world ENC coverage and differences in individual capacity and capabilities.

Many ENCs have hydrographic survey data attributed with a CATZOC (category of zone of confidence) of "Unassessed." Paper chart equivalents 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.

5 NCWG Recommendations for:

5.1 IHO

a. Regarding the creation of paper nautical charts from ENC data

There was much discussion of this topic at NCWG-5 (also see section 2.4.b of this report) and the working group recognized that there are several related efforts that could support the creation of paper

charts from S-101 data or that could be outcomes of such and effort. There was general support for this effort by working group members at NCWG-5 and 71% of respondents to the NCWG survey (see Figure 29) also stated that their HO was either actively pursuing or considering such an effort.

Recommendations to HSSC:

- Add task to NCWG workplan to develop ways to enable or enhance HOs' ability to produce paper charts or raster chart images directly from S-101 data.
- Focus should be on S-101 data, but one should be aware that some HOs' will also want to create paper charts from S-57 encoded ENCs. The recent development of an S-57 to S-101 data converter may serve to facilitate this.
- It is also recognized that this effort may ultimately provide the foundation needed to create database driven INT1 documents and a modernized version of S-4 (or other specification) that describes compilation guidance needed for the production of both paper/raster nautical charts and ENCs.
- Additional aspects of the effort could include:
    - Creation of a Scalable Vector Graphics (SVG) Symbol Library of S-4 symbols, starting with the most commonly used ones first. SVG is the same graphics format used for the S-101 Portrayal Catalogue.
    - Creation of engineering drawings, as necessary, to specify the exact characteristics of the S-4 symbols.
    - Creation of a standard set of portrayal rules to facilitate paper chart symbolization of S-101 data. These could be modified from existing IHO S-52 and/or S-101 portrayal catalogue rules, or other portrayal rules developed by a hydrographic office.
    - Understanding that the paper chart output from S-101-based data will look different from existing, traditional "standard" paper nautical charts and some simplification of the portrayal may be necessary and desired.
    - This effort could also facilitate a greater harmonization of S-4 and ECDIS symbolization. As noted in section 3.2.c of this report, the benefits of harmonizing these symbolization specifications could:
        - 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 and use, regardless of navigational product.
        - Enable the maintenance of a single visualization standard for all maritime products.
        - Provide a stronger role for the NCWG in managing digital symbology specifications for both raster and vector products.

b. Regarding the creation of a new standard for "Simplified Charts" or "Back-up Charts"

Although some hydrographic offices are exploring the creation of simplified charts or charts for back-up, the responses to the FOPNC survey (see Figure 7) and discussion at the NCWG-5 meeting did not show strong support for developing a separate specification or guidance at this time. Discussions at NCWG-5 also considered the strategies for back-up described in section 2.3.a in early drafts of this report and noted that the existence of two chart specifications (standard and back-up) would likely cause confusion amongst mariners.

It was recognized that some simplification of charts is likely to take place as part of the workplan item to create paper charts from ENCs (see 5.1.a above) and that these charts may be especially suitable as a back-up, but no separate effort focused on simplification is needed at this time. It may be too early in

the development of paper charts from ENC data to develop a simplified specification, because it is not yet completely understood what is possible. The "creation of a standard set of portrayal rules to facilitate paper chart symbolization of ENC data," as discussed in 5.1.a may ultimately serve as a de facto simplified chart specification.

Recommendations to HSSC:

NCWG does not recommend adding a NCWG Workplan item to develop a separate specification for simplified or back-up nautical charts at this time.

c. Regarding the "freezing" of future modifications to S-4 and INT1

There was no significant support at NCWG-5 for officially freezing S-4 and INT1, as this would restrict any flexibility to make improvements that may be needed in the future. Recently there has not been many S-4 changes proposed by member states and these have generally been clarifications to existing content or changes that improve automated symbolisation.

Recommendations to HSSC:

NCWG does not recommend freezing maintenance of S-4 or INT1.

d. Regarding the future of the INT chart concept, INT chart production, and INT chart coordinating working groups (ICCWG)

There was much discussion of this topic at NCWG-5. It was finally agreed that the production of INT charts continues to be important in some regions, but not in others. In fact some regions have no need or interest in producing any new INT charts.

Recommendations to IRCC:

Understanding that some INT chart production will continue, there was a general consensus within NCWG that the efforts of the ICCWGs should focus on coordinating and registering ENC schemes amongst ENC producing agencies.

Nevertheless, the following guidance is recommended for any continuing INT chart production:

- 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.
- 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.).
- 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.

e. Regarding the End of Paper Nautical Chart Production by Some Hydrographic Offices

The IHO should recognize that some of the paper nautical chart producers are at this moment seriously considering or are already undertaking steps to cease all traditional, standard paper and raster nautical chart production. While production of paper charts may be produced by some hydrographic offices and commercial vendors for years to come, it is apparent that the efforts of the IHO, IMO, and other navigation related agencies should be focused primarily on the creation and use of digital products, and especially IHO S-100 based products.

Shore-based and non-navigational uses of paper nautical charts and the transition of these users to digital products should be considered by the IHO and its members as the development of e-navigation and other digital efforts move forward.

f. Regarding the realignment of HSSC working groups

NCWG-5 discussed and agreed to make recommendations to its terms of reference to emphasize that need to focus on supporting digital navigational products. In addition to other proposed changes in the ToR, the Objections Section was changed as shown below.

> a) To provide expert and authoritative advice and guidance to IHO Member States, relevant IHO bodies and non-IHO entities on the concepts of nautical cartography, including
>
> (i) Its application to nautical charts existing in any physical or digital form;
>
> (i) The definition and the construction of digital chart content for the optimal and efficient production and maintenance of nautical chart products (S-57 ENCs, S-101 ENCs, paper charts meeting IHO standards if needed)
>
> (ii) The development of specifications for symbolization of any data required to be displayed on nautical charts from ENC on ECDIS (S-57 based, S-100 based, dual-fuel) and on paper charts meeting IHO standards if needed
>
> (iii) The interoperable integration of the nautical chart and other cartographic nautical products for e-Navigation in support of the S-100 implementation roadmap. This includes resolving portrayal issues related to the simultaneous display of a nautical chart in combination with navigational information and non-navigational information within an integrated navigation system.

Recommendations to HSSC:

NCWG recommends that HSSC approve the changes to the NCWG Terms of Reference as included in the NCWG report to HSSC-12.

No other recommendations related to realigning any other HSSC working groups are proposed.

6   Other remarks and recommendations from IHO member states

- SURVEY RESULTS

	Are there any other comments that you would like to add regarding the future of the paper nautical chart?
Argentina	As regards the printing of paper nautical charts, we consider it is most necessary to continue to create new editions, without the possibility of derogation. People sailing for recreational purposes or practicing artisan fishing are a mere example of users who, for the performance of their activities, either occupational of recreational, rely in the paper chart production being printed by our service. Another qualified user is warships that must carry paper nautical charts as a last resort to a collapse of electronic systems on board.

Australia	The AHO presented a paper at HSSC11 (HSSC11-05.4F) proposing the development of a new S-100 Product Specification to support a new looking 'official' paper chart automatically derived from S-101 data. The purpose of this new product would be to serve as back-up (under a new definition proposed in the same paper) of ECDIS and not to be used as the principal means of navigation. Differences in symbology must be addressed - future navigators and mariners familiar with only ENC symbology will struggle with unfamiliar paper chart symbology. If the switch back to paper charts is because they have been forced to use back-up arrangements, they are likely to be under time pressure, and therefore unlikely to have time to refer to symbology guides. PLEASE NOTE: The following comments are applicable to our response to questions 13 - 23: These figures include sales of Australian charts plus Papua New Guinea charts (which AHO published as Primary Charting Authority) and sold as AUS charts. PLEASE NOTE: The following comments are applicable to our response to questions 24 - 34: These figures include sales of Australian charts plus charts which AHO publishes as Primary Charting Authority: Papua New Guinea charts (from 2008) sold as AUS charts and Solomon Islands charts (from 2017) sold as SLB charts. The total does not include printing of charts adopted by the UKHO.
Bangladesh	Before ensuring a world without paper nautical charts, ENCs of all national and INT series charts are to be ensured by all the member countries of IHO. Back-up arrangement of simplified paper charts are to be ensured as carriage requirement at sea and for domestic voyage.
Brazil	59% of the Brazilian paper chart production effort is focused on non-SOLAS riverine areas. Therefore, at the moment, Brazil will continue to produce nautical charts in order to meet the mariners' demand for this type of product in inland waters.
Canada	As an HO, we do need to simplify and expedite the creation of the paper chart. Still making it safe and accurate but with less manual cartographic work.
Colombia	Currently, not all users have ECDIS in their ships. So, they must use the paper charts

Croatia	1. It is important to understand that the pace of technology development is much quicker than the charting authority and user community can keep up with. Some negative consequences of that disharmony are visible in the case of ECDIS and ENC. Even though the period of ENC/ECDIS implementation has ended, there are still some problems regarding ENC/ECDIS which should have been fully eliminated before mandating them as primary navigational aids. 2. Making distinction and the existence of differences between professional and recreational mariners / users of navigational charts, that in fact come from the SOLAS Convention, brought a huge problem in regulating chart requirements for non-SOLAS ships, particularly for yachts and recreational boats. If safety of life at sea depends among others on the quality of navigational charts and publications, the question arises why regulations (INT and National) make a difference between safety of life on big and small ships, even though all can be equally endangered if using lower-quality and less reliable unofficial navigational charts and publications, whether paper or electronic. In that sense, one could argue that it would be worthwhile to consider introducing in INT regulations or guidelines the relevant provision on mandatory carriage of official navigational publications for non-SOLAS vessels, especially yachts and boats. This is supported by the fact that good ENC coverage has been achieved for all navigation areas, including those for non-SOLAS vessels, yachts and boats. Mandatory use of ENCs in ECS or simplified ECDIS could be a good and quality solution. In that case, other alternative mentioned options regarding the requirement for availability of customized paper charts would be more likely and acceptable to both national HOs and users.
Cuba	
Cyprus	Cyprus, with the exception of international shipping, has a minor domestic maritime sector covering mostly tourism. Apart from that, there is an increasing need of recreational use for charts. Cyprus, for the time being, covers its charting obligations through bilateral agreements with UKHO. In the next few years we intend on taking over the responsibility of producing our own ENCs. We shall maintain a whole ENC coverage that covers all the demands of the mariners. All interested parties, with the exception of international shipping, shall buy services online
Denmark	Question 10, "Is your agency using S-57 encoded data to produce S-4 based symbolization on raster chart products?" Yes. The symbolization of raster charts nearly automated, but some manual "finishing" is required to completely symbolize the chart (for Greenland charts), However, Danish/Faroese raster charts are not created from S-57 encoded data. Question 51, "Do you plan on a general rescheming of the layouts of your paper nautical charts in the next five years?" Yes for Greenland charts, but no for Danish/Faroese charts.
Ecuador	Nautical Paper Charts should be maintained as a security measure in the event that the ship's energy is damaged in order to safeguard human life at sea

France	Comment on question 56: As for "chart-on-demand", SHOM provides a service in which a user can create and print his own customized chart (with added information), based on our raster-tiled data for instance (cf. https://data.shom.fr/dessin), but not for navigation purposes. General comment: The user requirements and needs should be at the centre of the reflexion, and non-SOLAS users (Navy ships, leisure boats, fishing boats, ...) and their needs are to be considered as well.
Germany	Paper chart do not allow detailed bathymetry. Update cycles of paper charts are a barrier in the age of big data. Paper charts cannot be overlaid with other information such as AIS, radar or currents. Young nautical officers are more oriented to digital information. The hardware is getting more and more powerful and can generate a navigation image even on battery power for weeks. Paper charts do not offer optimal safety. It is questionable whether a redundant nautical chart will improve safety in the future. The use of paper charts is diminishing significantly and the production resources are disproportionally high compared to ENC
Greece	Greece is a country with so many islands and waterways. For this reason, it is very difficult to stop producing paper charts. Therefore, our Paper Chart folio will not be reduced.
Indonesia	if its possible, to innovate the portrayal of paper chart (INT 1) on ECDIS instead of S-52 display or it can be called ECDIS smart display
Iran	Considering the huge number of wooden dhows which are active in fishing and trading goods in the world , especially in the Middle East and East Asia, and since they are not easily accessed to ENC Charts , also you could add to this, supply vessels, pilot boats, etc., which are using paper nautical charts. Therefore paper charts should be produced printed and distribute among potential users for some years to come.
Japan	1. Question No.13-23, we know obviously offset litho pressed chart is being represented for what we should report to you here are based on, but then that also makes us wonder how digital print chart should be treated for answering your Questions correctly. What we ended up bringing clarity on this concern is that just Counting digital print chat IN our answers here. If it wouldn't meet with what you expect from us, Please let us know. 2. Question No.24-34, continuously looking at introducing POD model into our print production line but not still in place down here. This is absolutely the right reason why our answers to the Questions are simply more of drawing 0(zero)-series at this point.
Malaysia	In order to fully replace the usage of paper nautical charts, a new type of ENC hardware must be develop which does not rely on ship power supply instead of battery and alternative power supply such as solar and other kind of renewable energy.
Malta	There is still considerable interest and demand from the maritime industry for paper charts but the demand will decline significantly in the coming years.

Mauritius	The usage of paper charts is likely to continue until the requisite infrastructure to use ENC/ Digital products is available with all the sea going vessels which are in compliance with the regulations of SOLAS and IMO.
Mexico	Maybe is not appropriate to stop producing paper charts, it can be in some years later
Netherlands	Sales figures provided in this survey (question 13-34 and 37-47) are to be treated as commercially confidential. Not to be published separately on the internet
Norway	Norway currently produce paper maps from ENCs, but that it is not fully automatic. In the short term we are not focusing on fully automating this process. There are also no plans to stop publishing paper charts as we still have a significant number of users and sales.
Peru	It will be necessary to have a secondary option as a contingency plan that will supply ENC, nowadays paper charts are used for that.
Poland	Despite the fact that more and more new technologies and ENC display systems are being deployed on board, paper charts should be kept available and used. These charts are the only means to navigate when e.g. ship power circuits fail.
Romania	In connection with question 58 and all Romanian ships should in future be fully equipped with ECDIS and Electronic back-up navigation equipment, so that no more Paper Chart are required.
South Africa	No comments at present as survey is very comprehensive in covering this topic. South Africa at present still considers the paper chart as a primary source for navigation. Many small craft users may not have the capability of using ENC data or may not be able to afford the technology and thus comprise safety to navigation. Our new system will allow for creation and printing of paper charts directly from ENCs.
Spain	Some nautical paper charts will continue to be used for quite some time due to the type of boats
Thailand	We are agree to use any technology that would print paper charts directly from ENC Data.
Tunisia	We consider that the paper nautical chart would still be used for the next years and could be provided on demand for all users
Venezuela	I think we should focus on the production of electronic cartography, the technological era demands it that way.

Annex A – Minimum Mandatory Content for Back-up 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
Foul areas
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
ADMARE, such as territorial waters
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
Vegetation
Built up areas and buildings

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

Retain 75 000 chart as Back-up 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.