NEXT GENERATION PAPER CHART
By Ian HALLS (Australia)

🇬🇧 Abstract

Throughout the ages, the navigation chart has adapted to meet the requirements of the mariner to ensure safety of navigation. The portrayal of chart information and its physical presentation on manuscript materials have also changed through innovation and human factors. In more recent times, the work of the International Hydrographic Organization (IHO) has established various standards to provide consistency to charting products to meet a truly global requirement. The transition from a manuscript to a digital electronic navigation world continues at a rapid pace. A new generation of users are more familiar and comfortable with electronic technology. One of the challenges facing the IHO is the future of the paper nautical chart. The ongoing need for paper charts is not the issue discussed in this paper. What is discussed, however, is the portrayal of chart data and the way in which paper charts may be generated in the future. The issue requires careful consideration to reduce Hydrographic Office (HO) production burdens, maintain relevance and meet the customers' expectations.

> *"In matters of style, swim with the current; in matters of principle,*
> *stand like a rock." Thomas Jefferson.*

🇫🇷 Résumé

Au cours des siècles, la carte de navigation a évolué pour répondre aux besoins du navigateur afin d'assurer la sécurité de la navigation. La visualisation des renseignements cartographiques et leur présentation physique sur les supports papier ont également changé du fait des innovations et des facteurs humains. Plus récemment, les travaux de l'Organisation hydrographique internationale (OHI) ont établi différentes normes pour rendre cohérents les produits cartographiques en vue de répondre à un besoin véritablement global. La transition de la navigation avec des documents papier au monde de la navigation électronique numérique se poursuit à un rythme soutenu. La nouvelle génération d'utilisateurs est plus familiarisée et plus à l'aise avec la technologie électronique. Un des défis auxquels l'OHI doit faire face est l'avenir de la carte marine papier. Le besoin continu de cartes papier n'est pas le sujet de cet article. Ce qui y est abordé, cependant, est la visualisation des données cartographiques et la façon dont les cartes papier pourront être produites à l'avenir. Cette question requiert un examen minutieux afin de diminuer les coûts de production des Services hydrographiques (SH), de préserver la pertinence et de répondre aux attentes des clients.

> *« Sur les questions de style, nage avec le courant, sur les questions*
> *de principe, soit solide comme un roc ». Thomas Jefferson.*

Article

Resumen

A través de los tiempos, la carta de navegación se ha adaptado para satisfacer los requisitos del navegante con el fin de garantizar la seguridad de la navegación. La representación de información cartográfica y su presentación física en materiales manuscritos han cambiado también mediante la innovación y los factores humanos. En tiempos más recientes, el trabajo de la Organización Hidrográfica Internacional (OHI) ha consistido en establecer varias normas con el fin de proporcionar coherencia a los productos cartográficos para que satisfagan realmente un requisito global. La transición de un manuscrito a un mundo digital de navegación electrónica sigue avanzando a un ritmo rápido. Una nueva generación de usuarios se siente más familiarizada y cómoda con la tecnología electrónica. Uno de los desafíos a los que se enfrenta la OHI es el futuro de la carta náutica de papel. La necesidad continua de cartas de papel no es el tema que se trata en este artículo. Sin embargo, de lo que se trata, es de la representación de los datos de las cartas y del modo en el que podrán generarse las cartas de papel en el futuro. Este tema merece una cuidadosa consideración para reducir los gastos de producción del Servicio Hidrográfico (SH), mantener su pertinencia y satisfacer las expectativas de los usuarios.

> *"En cuestiones de estilo, nada con la corriente; en cuestiones de principio, mantente firme como una roca." Thomas Jefferson.*

1. A TALE OF PORTRAYALS

From the very earliest recordings of sailing directions (periploi), to the 15th and 16th century portolans of the Venetians and Genoese, through to the current paper nautical charts, the depiction of chart detail has been an art form to serve a multitude of navigation purposes. The description and portrayal of real, fictitious, cosmological and embellished detail, was subject to the current school of thought, the imagination of the cartographers, the dominant cultural influences, the artists and the adventurers. Improvements in navigation methods and technology, the ages of discovery and enlightenment and more understanding of the real world combined with innovative charting practices and tools, have influenced the portrayal of information and the physical construction of navigation charts as supposition gradually retreated in the face of knowledge.

1.1 Paper Charts

The depiction of the current paper nautical chart is the result of some decades of cooperative standardisation effort championed by the IHO and described in the Regulations for International (INT) Charts and Chart Specifications of the IHO (known as S-4) [(IHB, 2013(a)]. This publication provides the framework for modern paper chart construction, colours, symbology and supporting textual information *(Figure 1)*. S-4 is supported by a number of technical specifications such as INT1 (Symbols, Abbreviations and Terms used on Charts), INT2 (Borders, Graduations, Grids and Linear Scales) and INT3 (Use of Symbols and Abbreviations).

Whilst the IHO has adopted Karte 1 (INT1) produced by the German Federal Maritime and Hydrographic Agency (BSH, 2011), a single, global specification for paper chart symbology has been elusive with many individual HOs developing their own version of INT1 (e.g. UKHO Chart 5011, NOAA U.S. Chart No. 1, Canada Chart No. 1, etc.). Fortunately, these documents basically follow the IHO INT1 content and structure, and include additional symbols and abbreviations that have been locally adopted within a national context. The key issue is that a mariner looking at charts produced by different HOs can interpret the charted features correctly through generally adopted portrayal standards.

The S-4 specification is maintained by the IHO's Chart Standardization and Paper Chart Working Group (CSPCWG). The CSPCWG has a set of defined objectives, operating procedures and guiding principles within its Terms of Reference (IHB, 2013(b)). Due to the diligence of the working group members over many years and the implementation of modern, advanced chart production software, S-4 and INT1 are mature specifications. Changes to S-4 are relatively minor and are implemented to support new charting requirements (e.g. Archipelagic Sea Lanes and various sensitive areas).

1.2. Electronic Charts

With the development of electronic charting in the late 1980s, the IHO soon realised that S-4 and its technical components (INT1 and INT2) would not
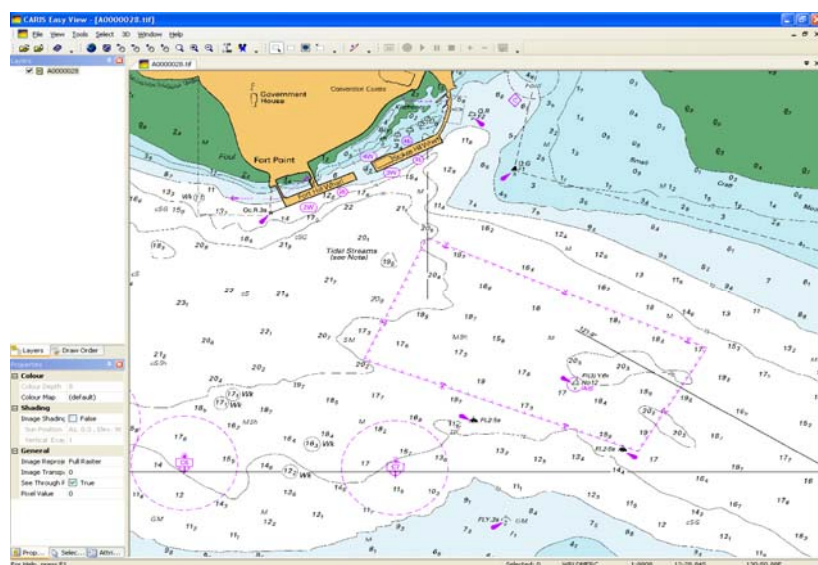
Figure 1. A typical INT1 paper chart portrayal
Extract of Chart Aus 28 Copyright Commonwealth of Australia (2008). Used with permission of the Australian Hydrographic Service.

satisfy computerised chart display for the Electronic Chart Display and Information System (ECDIS). For this reason, a new data portrayal specification needed to be developed. The Specifications for Chart Content and Display Aspects of ECDIS (S-52), describes the technical requirements for information display, symbology, environmental condition colour palettes, display screen configurations and various calibrations. S-52 includes Annex A - the Presentation Library (PL) (IHB, 2010(a)), and is maintained by the IHO's Digital Information Portrayal Working Group (DIPWG). The objective of this group is to maintain the IHO's specification for colours, symbols and display rules used to show Electronic Navigation Chart (ENC) information on ECDIS in a safe and ergonomic manner (*see Figure 2*). The membership of these working groups reflects wide international cooperation and this resulted in the general global acceptance of their resultant work.

Rather than being a paper-based portrayal specification such as INT1, the PL is provided in a machine-readable format so that electronic chart manufacturers can use it in their technology. The use of a standard set of symbology instructions should minimise the interpretation of symbology rules. This unfortunately is not always the case and a number of system manufacturers have either implemented the library with their own coding interpretations or developed their own libraries creating inconsistency issues with ENC data portrayal (Mohasseb, 2013). Through intensive stakeholder

engagement, the IHO and ECDIS manufacturers continue to address and improve these interpretations with the aim of minimising encoding and portrayal variation and ambiguity.

2. THE CHALLENGE OF TWO CHART WORLDS

In the late 1980s when ECDIS was first conceptualised and the early systems were being prototyped, there was much speculation about the future of the paper chart. It was not uncommon to hear early statements that paper charts would not exist beyond 2000. It has hard to believe that after 20 years, the paper chart is still a preferred navigation tool by many mariners.

The continued preference for the paper chart in an ever-increasing electronic age is the result of a number of factors:

- Users are familiar with long-used, paper chart products. Often user's charts are marked up with historical routes or other important information;

- HOs have taken a long time to achieve a satisfactory level of ENC coverage. This has meant that HOs need to produce and maintain multiple products, often using multiple production systems that compound complex issues in production and maintenance work-
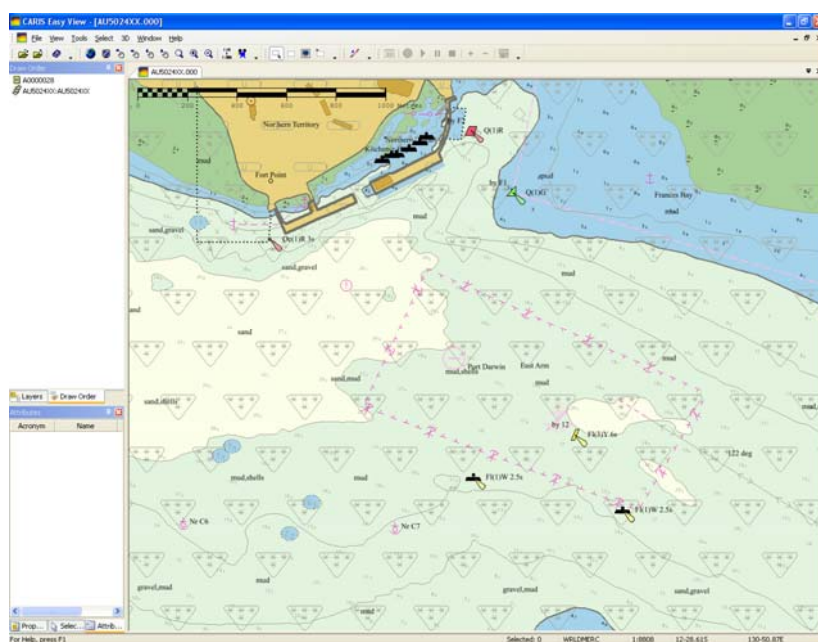
Figure 2. *S-52 portrayal of the same area depicted in Figure 1*
Extract of ENC Cell AU5XX24 Copyright Commonwealth of Australia (2008). Used with permission of the Australian Hydrographic Service.

flows, training, competency and technology and data refresh;

- The legislative process of the International Maritime Organization (IMO) has taken many years to mandate compulsory use of ECDIS resulting in a slower uptake of ECDIS technology and the necessary formal training of mariners to appreciate the technology and gain the necessary competencies;

- Official ENC data is used predominantly in type-approved ECDIS on large ships. A significant market segment doesn't require ECDIS technology (e.g. recreational users, fishing, small commercial vessels). For these users, official ENCs, non-official vector charts, raster charts and paper charts can all be used to meet their requirements;

- Many mariners are so familiar with the paper chart that a change in presentation, functionality and trust in technology can be difficult to embrace;

- The variety of cheaper electronic charting systems (ECS) product offerings, the varying levels of data quality and competitive business interests lead to a confused electronic chart market-place.

3. PAPER CHARTS AND SAFETY OF LIFE AT SEA (SOLAS) CONVENTION

The adoption at the IMO's Maritime Safety Committee 86th session (MSC86) of the amendments to SOLAS (IMO, 1974) regarding mandatory carriage for ECDIS equipment for ocean-going ships has an important impact on the future need for paper nautical charts (**see Figure 3**). Under the SOLAS revisions, the decision must be made either to fit vessels with dual or single ECDIS. Both must comply with the ECDIS performance standard and will require a back-up plan whose demands will vary between flag States. In the dual-ECDIS case, bridge staff will be able to significantly reduce (in some cases down to zero) their use of paper charts. In the single-ECDIS case, they will likely keep the paper chart as backup.

In Australia, the Australian Maritime Safety Authority (AMSA) released Marine Notice 7/2012 outlining Guidance of ECDIS for ships calling at Australian Ports. In accordance with IMO resolutions, AMSA considers the following will meet the back-up requirements for ECDIS (AMSA, 2012):

> "An independent, fully compliant second ECDIS unit, connected to ship's main and emergency power supply and connected to systems providing continuous position fixing capability; or
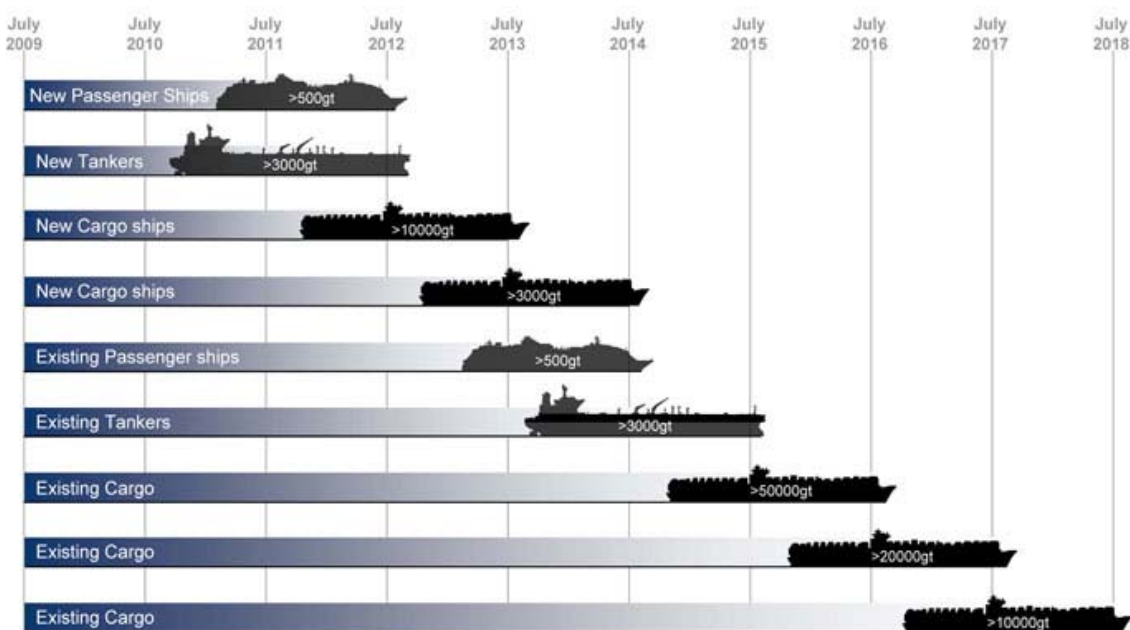

Figure 3. ECDIS Compliance Dates for SOLAS (UKHO, 2013)

Adequate and up to date paper charts (including relevant large scale charts) necessary for the intended voyage."

The IHO describes a nautical chart in S-66 (IHB, 2010(b)) as:

"Nautical charts are special purpose maps specifically designed to meet the requirements of marine navigation, showing amongst other things depths, nature of the seabed, elevations, configuration and characteristics of the coast, dangers, and aids to navigation. Nautical charts provide a graphical representation of relevant information to mariners for executing safe navigation. Nautical charts are available in analogue form as paper charts, or digitally as electronic charts."

A key component of nautical charting world-wide is standardisation of portrayal. This is emphasised in IMO SOLAS Chapter V Regulation 9, para. 3 (IMO, 1974):

"ensure the greatest possible uniformity in charts and nautical publications and to take into account, whenever possible, relevant international resolutions and recommendations."

4. THE FUTURE OF PAPER CHARTS

Given the changes to the implementation of ECDIS, what is the future of the paper chart? In a 2011 article, the then UKHO CEO, Mike Robinson, expressed a view that paper charts would still be used for many years, even if they were only used in a "get me home" scenario. Despite a prediction that the sale of UKHO digital charts will exceed the sale of paper charts around 2018, there will still be a requirement to provide paper chart products to meet the varied usages and this will continue to be a production and maintenance issue for all HOs (Robinson, 2011).

In a world that is rapidly changing in technology *(in matters of style, swim with the current)*, along with a technically-savvy younger generation of users, it is time to look critically at what the paper chart represents and how it can be provided in different ways to a changing user-base without compromising navigational safety *(in matters of principle, stand like a rock)*.

4.1. Official ENC-Derived Paper Charts

If a paper nautical chart is to exist in the future, what should it look like? Is it practical or economically feasible for HOs to continue to publish paper chart products with different portrayals? Will this be confusing to the market place?

Irrespective of the ENC/paper chart equivalency, many HOs can produce INT1 paper charts fairly easily from an ENC source. The primary hydrographic software vendors all provide an INT1 paper chart output. Hence, there is no impediment to this capability continuing. However, as uptake of ENCs continue, can users be expected to put up with two different portrayals of the fundamental navigation data? An alternative approach is for HOs to publish paper charts with a predominantly S-52 (ENC) presentation and transition away from the traditional INT1 portrayal.

To assist in the adoption of electronic charts, the author believes that there is merit in considering the need to transition INT1 paper chart portrayal to a S-52 style portrayal. From a practical production aspect and debatably a customer perspective, it makes little sense to retain two separate product portrayals. In a small and limited customer market, the major HO production software vendors all support S-52 portrayal in their symbol libraries. All of the software systems are relatively mature and whilst they can support both INT1 and S-52, a transition to one portrayal specification can utilise the best of both specifications (e.g S-52 for colours and symbols, INT1 for graticules, marginalia, title blocks and text, etc.). As part of the IHO's S-100 family of product specifications, S-4 could/should be replaced by a new S-10x Product Specification: ENC-Derived Paper Chart.

4.2. User-generated Non-official paper charts

In the world of "apps", it should be possible for users to create and print their own ENC-derived charts. These charts can be plotted from the users own ECDIS or ECS technology where the ENC data has already been purchased. In this case the plot could be generated from the System ENC (SENC) or from the purchased ENC product. HOs will need to consider a pricing model for the ENC to include some level of cost recovery for user-sourced plotting. Chart agents and other value added resellers may also provide a plotting service.

5.   S-100 PRODUCT SPECIFICATION FOR A ENC-DERIVED PAPER CHART

The traditional paper chart specifications are well described through S-4, INT1 and national variants. However, for the portrayal of ENC data on a paper format, it is recommended that a new S-10x product specification within S-100 be developed and managed either by a sub-group of one of the current IHO portrayal working groups or by a new technical working group. The purpose of the new product specification is to establish the minimum requirements for the portrayal of ENC data on a manuscript format whilst maintaining an appropriate level of maritime navigation safety. In developing such a specification, a number of issues need to be considered.

5.1 Data portrayal

S-52 specifications were designed for computer displays and not paper output. Hence, the ENC portrayal will not be aesthetic to the eye from a traditional paper chart user perspective. New symbols would need to be added to account for cartographic features such as a compass rose. With increased uptake of ENCs, users should be more familiar with ENC portrayal and so over time, portrayal interpretation issues should also reduce. To assist mariners with ENC portrayal, the UKHO has already issued the ECDIS version of INT1 - NP5012 Admiralty Guide to ENC Symbols used in ECDIS (UKHO, 2012).

5.2 Paper Plot Layout Elements

Certain "elements" need to be included in the plot layout to assist the mariner using the derived paper chart:

Graticule: Simplified latitude and longitude grid/graticule

Scale bar: Simplified scale bar

Marginalia: Plot date, ENC EN/ER update status, Geographic extents, Producer agency ENC cell names used as the source, copyright and disclaimer statements.

Scale: The scale of the plot will be determined by various user-defined options – paper size, area coverage, etc. Some warning notation may be required if the inappropriate navigation usage or ENC scale is used for plotting. This may be similar to the "overscale" warning currently shown on ECDIS displays.

Available data: Where ENC coverage is not fully available, the paper plot may contain Raster Nautical Chart (RNC) content. The ENC content should always take precedence and some rules will be required to stop users from plotting RNC versions of the large portions of paper charts.

Data Content: similar to S-52, a minimum content of ENC data (e.g. Base) is required. The user should then have the ability to add extra content to the display.

Projection: At a certain scale, the output plot should be projected to aid the intended usage. For large scale situational awareness, a UTM projection may be best. For scales smaller than 1:75,000 where the chart may be used for course plotting and navigation, the plot should be output in a Mercator projection.

Colours: S-52 provides various colour palettes. For paper chart plots, the "bright-day" palette is likely to be the preferred colour palette.

Symbology: S-52 supports a simplified and traditional symbology palette. The user should be able to select the palette they are most familiar with. Some additional cartographic symbols will need to be developed.

Explanatory/Cautionary Notes: These notes are provided to assist the mariner to interpret potential navigational issues (e.g. chart omissions, dangers, etc.) or provide advice on where to find additional information (e.g. maritime boundaries). In the ENC, these notes are provided as text and/or picture files. Rather than plot the note content on the paper copy, the user could be given the option to print any relevant files separately.

6. PLOTTING SERVICES

HOs can continue to provide plotting services for official paper charts. In many cases, chart plotting is now undertaken using Print on Demand (POD) technology rather than offset lithographic printing. POD provides options for plotting charts as either traditional INT1 portrayal or ENC-derived portrayal at large formats. Most users do not have access to large A0 plotters. Hence, large format plotting, from an economic perspective will remain with the HO, any contractors or potentially chart agents or specialist service agencies. Most users will only have access to A3/A4 printers at most. The challenge for using A0 plotters on vessels is the maintenance of consumables (i.e. inks and paper) which can be bulky, messy, expensive and susceptible to temperature and humidity.

7. LEGAL ISSUES

If a paper chart is plotted from the official HO-published ENC or RNC data, or from an approved SENC, and it has been output using the minimum required portrayal settings, it should be deemed suitable as an official and legal product. Some criteria may need to be established to ensure that the plotted output is legible in terms of scale and colours (rather than a grayscale printout).

8. CONCLUSIONS

The increasing adoption of ENCs and the changes in mandatory carriage requirements for SOLAS vessels will result in mariners using a product that has significant portrayal and capability departures from the traditional INT1 paper chart and derived raster navigation products currently in the market place. Should users have to put up with multiple navigation chart portrayals or should there be only one product portrayal based predominantly on the ENC with additional portrayal functionality to provide "cartographic representations"?

The author does not question the ongoing need for paper charts - only how paper chart content should be portrayed to users. At all times the principle of safety of navigation cannot be compromised, but this doesn't preclude looking at opportunities to streamline the production or to simplify the provision of derived paper products from an official ENC source. There is no doubt that such considerations will spark debate. However, from experience of witnessing the battle that some HOs had with the ECS entrepreneurs of the early 1990s, the IHO needs to decide if this really is an issue and be on the front foot in defining an appropriate specification. Otherwise, industry will dictate the capability.

The opinions expressed in this paper are those of the author and do not necessarily reflect those of the Hydrographer of Australia or the Royal Australian Navy.

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10. BIOGRAPHY OF THE AUTHOR

Ian HALLS commenced work at the Australian Hydrographic Office (AHO) in 1979 as a trainee nautical cartographer and has been involved in the development of nautical data management and chart production systems since the mid-1980s. This period included serving several years on IHO ECDIS/S-57 technical committees. He is a past Director of HSA Systems Pty Ltd and resumed working at the AHO in 2009 after 15 years in private industry undertaking systems engineering, hydrographic surveying and charting activities.

He is currently managing the military hydrographic data, products and services section of the AHO. Ian is also working with a small dedicated team to sustain the Digital Hydrographic Database solution developed in early 2000. This involves the

software, hardware and ICT refresh of the various source data receipt, validated data, production, distribution, and workflow sub-systems using an enterprise architecture approach.
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