Rethinking the Nautical Chart: Tackling Present and Future Trends

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Introduction
We come from a nautical cartography background and have been involved over many years, in many countries, with charts and their new offspring, electronic charts. When we look back over our professional careers we conclude that there has been little actual change in the fundamental design of charts and we have all become very comfortable with their appearance, whether on paper or the screen. Reflecting on our experiences working with over twenty national mapping agencies, as well as with a number of commercial sector mapping companies, we have wondered just how sustainable this constancy will be going forward. Perhaps we have all become too comfortable with the design of our charts. Standing back, we provide a review of the legacies that form our existing nautical cartography and take a look forward to the opportunities and pressures that may force some fundamental changes in the way we think, not least whether the term “chart” has a long term future.

Background—Is anything driving change?
The development of navigational charts has been well described, as has the transformation from paper into digital within the hydrographic world. This transformation has been called by some a digital revolution, but in reality it has been more evolution than revolution. We say this because we still see the majority of electronic charts looking like facsimiles of that original paper chart. The design has remained pretty consistent across that boundary between paper and electronic charts. Perhaps the most fundamental characteristic of the chart is the spot soundings. They are a feature of nautical charts that immediately differentiates them from land maps. These soundings are carefully chosen and represent the pinnacle of the cartographer’s art, a legacy from the very first nautical charts.

But is there any demand to change from the navigators who use the charts? Within the world of the highly regulated merchant marine, it would seem that mariners value the familiarity of the paper world that they now see on the screen as electronic charts. Indeed, there are powerful arguments to be made that this familiarity is a positive attribute that makes training and the transition from paper to digital easier, and more importantly, safer. As with most markets, legislation and economics remain the over-riding factors driving change from the customer (demand) side. At present it would seem the economic arguments are either not sufficiently compelling, or are not being presented well enough, to drive change. Within the world of electronic charts, there is the additional complication that the official Electronic Navigational Charts (ENCs) must run on ‘type approved’ equipment. Major changes will get bound up in the world of regulations and of convincing equipment manufacturers that changes are worthwhile. Either way, we see little encouragement for innovation coming from the demand side. The customer focus is understandably elsewhere. We must not let this deter us from thinking of the future and the opportunities.

Is there any drive from us as cartographers for change? Within the merchant shipping sector, where the nautical chart producers are dominated by the national hydrographic services, we all know they operate under considerable constraints of funding and resourcing, continually having to juggle priorities. Combine the constraints on resourcing with increasing demands for their services with conflicting priorities, all within a highly regulated sector and this hardly makes for fertile ground for innovation. Where we have seen innovation, it has been in other sectors freer from regulation, such as the recreational boating market and environmental data. For the merchant marine products, you have to look to the private sector for imaginative “add-ons” to the electronic chart where innovation in the types of data content and the way it is presented is starting to appear.
What else is constraining change? One of the great achievements of the hydrographic community has been the development of international standards and then the achieving of adherence to those standards. This is something that is often taken for granted by those of us inside the community who can often be heard complaining about inconsistencies and lack of adherence. Talk to a land mapper and he or she will remind you of how far ahead in consistency we are within the nautical charting world. But that conversation will often then go on to say how the new cartographic standards are becoming those introduced by the likes of Google mapping. So with standards there comes a paradox. Almost by definition standards are the enemy of innovation and thus the enemy of progress. The success of standardisation has arguably only been achieved at the cost of innovation. And to be clear, we will not argue that was not a price worth paying for the resultant benefits that have accrued. Equally we cannot pretend that the process of achieving those standards was not a lengthy one; the result is that it will always lag behind technology. Perhaps there is some form of compromise whereby the standardisation is confined and minimised to where it is really needed? Would this bring greater reactivity to technological change and bring more innovation to the forefront?

The lineage of nautical cartography

The link between hydrographic surveying and navigational charts is close but not completely overlapping. Testament to the skill of both surveyors and cartographers is the role they have played in global economic development over the centuries. The world’s nautical cartographers have always sought to compile charts from many varied data sources. Their unseen, invisible skill is the judgment of what is the “best” source to choose from often conflicting material. The more visible skill is the clarity of the product, a traditional cartographic skill based as much on what is left out, as what is put in.

But the essence of the nautical chart has changed little over the years. The step changes in nautical cartography have been more about the way they are produced than about their content and appearance. This has remained the case as nautical cartographers have grappled with the advent of digital technology. The national production agencies came together some twenty or so years ago under the cooperative banner of the International Hydrographic Organization (IHO) and international standards for digital products were produced. Eventually the standards became the accepted blueprint by which official charts were designed and produced. This in turn became the benchmark for training new generations of cartographers. There was, and remains, enough work for legions of cartographers, keeping up with a constant flow of new information. In fact, for cartographers, the constancy of standards at least places one in the position of having fewer things to manage. But standards have acted as both a force for good and for stagnation. Some would say there has been a brake on marine mapping. Typically, the standards lag behind market developments, at least until each generation of change matures and becomes adopted practice.

The advent and development of Electronic Chart Display and Information Systems (ECDIS) with the Electronic Navigational Chart (ENC) potentially provided the vehicle through which to make significant changes. A major step forward for sure, but pressures of time, resource availability and the push for standardisation meant that the expedient immediate solution was a facsimile version of that original paper chart design. The benefits of the digital data come from the equipment software and its functionality operating on the same content and displaying it largely in the same way. This has very powerful benefits in that transition from paper to digital from the navigator’s perspective. Given the safety considerations of the merchant marine we cannot argue that it was anything but the right move. But those standards and the design go back thirty years. Will the next generation of mariners brought up with the internet and the “app” be able to cope with more and demand more? Will expectations be greater, starting from a more highly technological base?

Consider this, if we were starting a nautical charting program now, given what the technology produces, would we still design charts in the same way? Almost certainly not! Currently we have a product that hides, or worse, discounts, an increasing amount of information potentially valuable to the mariner.

Technological Change and Imperatives

The pace of change is increasing all around the nautical cartographer. From data collection to data presentation there is a ever present threat of being left behind. There is a danger of accepting that the old paradigm is inevitable and sufficient going forward. To take one example; the introduction of multi-beam sonar, with its greater density of data combined with advanced graphical capabilities should have been a game-changer for nautical chart design, yet we remain wedded to that familiar spot sounding.

In the beginning of what might be called the development of best nautical cartographic practice (say, from the 18th century) pretty well all soundings that were measured in the field survey were displayed on the chart; partly because they cost so much to take and partly because there was an understanding that no useless measurement would be taken; hence most or all soundings and ancillary data typically got on to the published chart. There was also the issue of primary:
many hydrographic surveys were the first accurate record of newly discovered regions. Once echo-sounders came along they generated too many soundings and bottom generalisation became a necessity. As the data density increased so the sophistication of the filtering grew until the percentage of measured soundings that were portrayed on the chart became a mere fraction of the underlying data. The mariner using the chart might well be more confident in a particular chart but much potentially more useful data was hidden from view.

By the time multi-beam, came along this filtering was reducing the compiled dataset to be far less than one percent of the total gathered data. In fact, multi-beam deals in imagery of the bottom, whereas chart design still assumes you sample point data. This makes little sense to anyone interested in the true picture of the seabed topography. So specialist users such as fishermen and scientists have deviated from the standard chart and are producing their own proper images of that seabed.

For the nautical cartographer there is still the impossible struggle to make that chart all things to all people. Despite such efforts, it has probably never been the case that a chart can satisfy the needs of all. Increasingly those compromises look impossible and the legacy chart design looks increasingly anachronistic, particular to many specialist users.

The Time Factor

Then there is the time factor to consider. Ask most cartographers to define quality and they will talk of accuracy and precision, and maybe of adhering to standards. All true. It is rare you will hear mention of the time factor but timeliness, currency or immediacy (choose a term) is a part of the overall quality of service being provided. Some would even say that charts will take as long as it takes to get it right. However, we are not talking about a static product. A chart is and should be dynamic. Talk to marine superintendents and they will say: give us what you have and tell us the limitations of the information, but we need it now. Talk to Special Forces and they say: give us the latest and give it to us now, forget the cosmetic stuff. Take the immediacy of events such as the recent boat sinking catastrophically off Christmas Island, recent earthquake and tsunamis and even the recent evacuation of refugees from Libya – all still seem to spark a frantic search for data beyond the existing chart products.

Immediacy, flexibility and interoperability are all areas to consider in future design. We are at the point where the very word “chart” starts conjuring up the wrong image of what we are capable of providing. It is too static, too much a product term. We should start talking about that “I” in ECDIS, the “information” and we should be thinking that the “S” in ECDIS standing for “service”. But we will carry on using the term in the knowledge that it is an uncomfortable straightjacket from which we may need to escape.

Training Nautical Cartographers

For most of the time that nautical charts have been produced, training of nautical cartographers has been largely an “on the job” mentoring process. Skills have been handed down perhaps in a similar way to many other skilled crafts. Over the past few decades, that training has become more structured and formalised and increasingly is provided with a degree of academic rigour through colleges and universities. Large impetus for that structure came when the Fédération Internationale des Géomètres, International Hydrographic Organization and International Cartographic Association jointly published a recommended minimum set of competencies relevant to the nautical cartographer. Its initial target audience was undoubtedly national hydrographic organisations. Its focus is the standard nautical chart and publications portfolio enshrined within the IHO regulations. It was a big step forward, but almost by definition this was a further drive towards standardisation in the way that training was built around a defined set of competences with clear products in mind.

The private sector is now looking to such standards to give some structure to its own training and to capitalise on a rich vein of best practice. But there is also a deep body of knowledge within the private sector, albeit with a different focus. The resultant students have still needed that ‘finishing’ process of on the job training. Our own experience is that the students we take from academic courses still need some training to make them “industry ready”. By industry ready we mean firstly, that the theory is blended with much more practical work. Secondly, and most importantly, is that the practical work is blended with time management and project management skills and attitudes. Our operating environment requires that our people are trained to deliver a service. It requires a more rigorous project-oriented focus to the way it views chart production – deadlines are paramount even though quality cannot be compromised. Planning and estimation are core skills. This reflects our belief that increasingly quality is about timeliness as well as precision and accuracy—it is little use to the mariner if a survey remains locked in the cartographer’s thought process for too long.

So, we are seeing the differentiation between the private – public skill sets blur. If both sectors are to continue to work together in some level of synergy then it follows their skilled personnel must have similar training and experience. Both sectors have strengths and the community would be better served by a model of education based on cooperation, not
exclusiveness. If institutional barriers can be loosened and ways found for mutuality in training, utilising the best of each sector’s strengths, this can only be to the benefit of increasing the available skill sets to industry as a whole.

The Dilemma of Nautical Cartography in National Hydrographic Services

Taking advantage of new opportunities presented by technology does need to recognise the fundamental dilemmas. In recent years the ushering in of the new electronic chart era has been all consuming for the national hydrographic services. There is a loop within which we are caught:

- new technology leads to an improved level of accuracy …
- …which in turn becomes the new norm;
- …this in turn increases the percentage of charts which now fall below the new norm;
- …this then leads to call for re-charting areas that have been previously charted because they do not meet the new norm/standard;
- …this translates into demands for a new charting program
- …which means demands for new program funding;
- …the new demands for funding programs increases the demands for better program efficiency
- …which leads to, yes indeed, new technology…
- …which creates a demand for acquisition of this new technology...

and so it goes on.

This should be a “virtuous loop” whereby technology brings improvement in surveying accuracy that drives charting programmes. Instead it is more of a “vicious loop” whereby technology leads to increasing backlogs and provides datasets that cannot be fully harnessed within the constraints of current chart design.

To illustrate, the introduction of multi-beam technology opened hydrography to a new class of end users—those far more interested in the shape of the sea floor than dangers to navigation. The development and introduction of airborne LiDAR capabilities has made the complete survey coverage of the coastal land, inshore and other shallow ocean regions possible quickly and relatively cheaply (with the emphasis on relatively). Many hydrographic operations now are directed towards more what could be called “scientific” or “environmental” missions as opposed to being strictly for safety of navigation. Consequently there has been a slow drift away from marine navigation as the only mission in some hydrographic services, partially explained, by the rationale that the safety of navigation issue is largely solved along major routes so attention can be placed elsewhere. Those nations that fortuitously are just starting to build their national capability can embrace the new IHO vision of the marine spatial data infrastructure. Here, a wider variety of needs are taken into account, collecting and organising that data and systems designed to provided multiple datasets more tailored to specific sector needs. However, the main outputs in the form of charts are still largely constrained by conventional outputs. But does this really matter? Are not the charts fit for purpose? Maybe, but when we are designing new systems for new hydrographic capabilities it does strike us as being a paradox about how much of the underlying data will not be fully used to help the efficiency of navigation.

Efficiency of Navigation

Does all this additional data now available really concern navigation and the conventional nautical chart? Can the development of the nautical chart go even further and potentially offer solutions to a number of contemporary problems? One of the IHO’s missions is to support “environmental protection”. Very often this is seen very narrowly as a facet of safety — that is navigating safely, therefore preventing accidents and hence pollution thus environmental protection. But there is another facet of environmental protection if it is looked at in the wider sense of greater efficiency in navigation. Most obviously, this is the reduction of unnecessary Greenhouse Gas (GHG) emissions through more effective routeing but there are other environmental benefits less obvious, such as the impact of weather and sea state on the life expectancy and maintenance of vessels.

The efficiency of navigation is largely under-developed playing a subordinate role to safety. There is no reason why both cannot become factors in future design. Given the need for a reduction of GHG emissions and the general consensus that carbon-based fuels will continue to become more costly to extract and refine, there is a growing demand for more efficient shipping. Hydrography has some of the tools and some of the professional expertise to help. It may be that the hydrographic services can go further and can offer solutions to a number of contemporary societal problems. The globalisation of trade has emphasised the essential role of shipping to the world’s trade. It takes little imagination to see this. By example, the minerals of Australia are shipped to the world. Manufactured goods are shipped back. Oil is shipped
all over the globe. Airlines would not be able to fly to exotic places such as the Pacific islands had not a ship previously deposited a stock of aviation fuel there. The majority of the world’s motorists would have to abandon their cars without shipping. The International Maritime Organisation (IMO) has published its report Prevention of Air Pollution from Ships which first documents the estimated current emissions level and lays out both a target level for reductions and lists the options available to meet those obligations. It is still useful to remember that CO\textsubscript{2} emissions by ship are less per transport mile than other transportation modes. Nevertheless, mariners and fleet managers are coming under increasing international maritime policy pressure to optimise environmental impacts from their voyages. The IMO has adopted amendments to MARPOL Annex VI which make mandatory incorporation of the so-called Energy Efficiency Design Index and a Ship Energy Efficiency Management Plan.

Voyage optimisation includes both economic and environmental factors. Mariners need to grapple with environmental planning; energy efficiency; fuel quality and its optimal use, the vessel’s carbon footprint, weather patterns which threaten costly delay and damage to both vessel and its cargo. The mariner needs data in order to optimise any voyage. Some of that useful data may well have been utilised in compiling the nautical chart or at least is available within hydrographic services. Such data includes, for example, better contouring and from them the derivation of safety limits. We return to the point that hydrographic data should be dynamic not static. The inclusion of dynamic data sets (currents, tides, weather), that can only be shown clumsily in paper form are now capable of being overlain and linked with ENCs. Greater use could have a significant long term role to play in that wider definition of environmental protection.

Designing for the Purpose Intended

Nautical chart design has always aimed to meet a compromise of needs among the various components of the user community. At the higher professional end there is the big ship commercial/professional navigation community with a well defined set of needs and standards governed by the IMO and the UN SOLAS (Safety of Life at Sea) Convention. Contrasting this are the many varied needs across the leisure/ pleasure craft spectrum from kayak to ocean racers. Needs therefore vary widely but are often vastly different from those of the big ship users. Scientific and engineering users in turn have vastly different needs again and their only attraction to the nautical chart is that it is often the only source of published depth data. Why are all these users, with vastly different needs, force fed the same product? There are good reasons; more accurately, there were good reasons. Economics and resource pressures in an era of paper based products all led to the compromise product. The non-navigational users have long since left the navigational chart (and digital equivalent) and looked to their own denser detail, depicted differently. The move now is to question that basic sounding from the chart, recognising that what was the cartographer’s mandate and skill ensuring depths always showed the dangerous shallow depths has led to distortions in the true seabed. Survey systems for charting purposes shoal bias in the filtering, IHO rounding rules err on the shoal side and then cartographers select based on shallowest depths. Even modern algorithms for automated sounding selection follow these principles. This is all good practice when navigation is the intention, but not for all purposes and we have seen the gradual introduction of datasets taken direct from surveys, densely populated with data or contour based. One such dataset from Seazone, a UK organisation that has gone back to survey material rather than use nautical charts, is even called TruDepth™ because true depths are what it endeavours to do in preference to the biased depths of the IHO standard products.

We will pick one other sector for illustration – that of the recreational boater. It can be argued that, for many users, when the depth is deep enough for the user’s purpose then the deep depth data adds little or no value. All those soundings are mere clutter. If your boat draws 1.5 metres who cares if the water depth is 15 or 150 metres? Perhaps at one time you might have used the echo sounder and the deeps to help locate where you are but now with GPS it is largely redundant information. So in the case of the recreational boater there is a “too deep to care” limit quite a bit different than for ship navigation. For sail boats it might be 5 metres and power boats maybe 2 metres, for kayaks 40 centimetres. It is within these limits that the existing charts and ENCs have largely compromised in favour of the bigger vessels. Within the five and two metre lines the depths and rocky areas tend to be highly generalised and sometimes just enclosed by a blanket danger line. So for this market, the product has soundings that are largely “clutter” and in the areas where they want information it is too generalised to be of anything other than general guidance.

It is tempting to say that in the compilation of a typical large scale coastal chart, the greatest proportion of the effort goes into reconciliation for depicting the inshore areas and that it is of least value. Eighty percent of the effort for twenty percent of the value? The cartographer sweats over the reconciliation and then, generalisation, seeking compromise, and, as is the way of compromises, frequently pleasing no one. Stopping the compromise means saying here is the information for this sector and so if that sector is the merchant marine could that effort be better spent ignoring the inshore areas and...
focusing on more rapid output of information (the timeliness element)? That of course leaves a vacuum in the other sectors but a vacuum maybe likely to be quickly filled by the private sector, particularly if it was done by consent and cooperation. But for the recreational user a useful “chart” is one that provides all the other information of interest to getting more out of leisure time. This is more social information than navigation information. Collecting this information, and maintaining it, is expensive and time-consuming but there are plenty of products on the market that testify to its usefulness. Perhaps the only way of getting cost effective data that is comprehensive is through the modern phenomenon that is crowd-sourcing.

Harnessing the Crowd

Right now the best medium for gathering social information is crowd-sourcing. It is pointed, it is topical, and it is gathered by people who care. So within the leisure market the intimate knowledge of fellow yachtsmen is far more important than the skill of the cartographer. So if the “chart” becomes more like the “map” then there are lots of tools for the general public to contribute map data – like OpenStreetMap (OSM). It is entirely possible to make a very useful marine product based completely on OSM which will run on a variety of very inexpensive apps. Users will add what they consider useful and other boaters can add to that or modify it in the wiki style. It is true some things get sacrificed. The standardisation, the look and feel, is often inferior to traditional charts and maps. What you get to compensate is immediacy and interoperability. There is one other fundamental issue with crowd-sourced data that has to be a concern: its reliability. The reluctance of organisations to harness crowd-sourcing is in part borne out of the need to keep a reputation intact, a reputation that is founded upon information having been checked and the source thus being authoritative. But checking provenance means control being exercised and to some this is against the spirit of crowd-sourcing which is something to be done unencumbered by rules and governance. The early experience of Wikipedia was of its notorious unreliability. But once the volume of information built up we saw more controls being brought in to check and validate entries and now caveats placed upon some data and requests for verification. Other crowd-sourced sites such as the holiday guide “Trip Advisor” have seen the value of their site diminished by rogue reviews. It appears they too are looking at ways of exercising more controls without inhibiting the contribution of the crowd, and so have started rating the contributors to give some more validity to the entries. Has Trip Advisor overtaken the more “official” sources of advice? Or is it complementary to the conventional guidebooks. Time will tell, but for the hydrographic community, the interest in these developments, is how we can learn lessons and apply them in our domain.

The use in the recreational market is perhaps the most easily recognisable. But even within the merchant shipping sector it has great potential. While the term “crowd-sourcing” may seem at first sight to be an anathema to professionalism, nautical chart producers have long relied on what might be seen as a limited form – the mariner – who has been encouraged always to report through Notices to Mariners reporting systems (Hydrographic Notes) any phenomenon that might bear on navigational safety. The system has been operating since the 19th century, perhaps a very early form of crowd-sourcing? Look at the current process for dealing with “Hydrographic Notes” and it is more about checking provenance of information than its promulgation. Only rarely in extreme cases will a navigational warning or a Notice to Mariners issued. Generally, this will be with the caveat “preliminary” and “Reported 2012”. This all has the elements of a system of crowd-sourcing and there is the possibility of harnessing the mariner community more to provide and self-check this information. Provenance checks can still go on in the background but the immediacy of presenting the information in raw form still has value.

The reliability and provenance of information will always be an issue but just as we are seeing with some of the more effective sites providing crowd-sourced information there are some controls working in the background. There are also visible controls to help the user make their own judgment on the reliability of the information and of the reliability of the source. So, fifty good reviews of a restaurant are better than one, reviewers who post regularly are in theory more reliable. To translate this across to crowd-sourcing in the marine world, the more ships that report something, the more likely its reliability. Thus there is a natural progression from our existing system into the future. It gives immediacy; it makes the most of technology. Link this through into an information overlay and maybe the “I” for information starts truly to come into ECDIS.

Conclusions

There are inherent tensions and challenges in our nautical cartography community. Amongst those tensions is the clash between standards and innovation. We do have the opportunity to make a difference if we can break out of that vicious loop to make more of technological advances, to lead rather than to follow. We should stop thinking of charts and electronic charts as products. We should move over to thinking about information. We should move to think about the service element of what we do. Make timeliness a major factor of quality, shift the
focus from product quality to service quality. “Marine information service” is a more accurate descriptor of what we do than “produce charts”. This very act of thinking only of charts with its proud history is in danger of inhibiting us as a community. For the core navigational products, there needs to be a more imaginative look at how the design can assist with “voyage or navigational efficiency”. There needs to be a degree of challenge to some of the fundamental tenets of the existing product design to achieve these improvements. Given the lengthy gestation times, this should be on our planning horizon now.

We need to concede that “one size fits all” is no longer a valid philosophy. We should be able to give different classes of user more exactly what they want and need. This may be more about finding suitable business and economic models than about technology and this may need being more flexible in the way that national agencies and the private sector interact.

We need to ensure standards are appropriately applied; they are an absolute necessity for interoperability and safety at some levels, but not for every aspect of what we do.

The community needs to embrace some of the opportunities enabled by new technology such as crowd-sourcing. The basis is already there as is the enthusiasm, but it needs organising not ignoring.

Training our people needs to evolve too. There are lessons to be learnt and shared between academia, hydrographic services, and industry. We should be encouraging imagination and innovation, exploiting technology, mixing the sectors. As with the very word chart being a term that feels sometimes like a straightjacket, so too does the term nautical cartographer.

The skills remain but the brief is wider!

References

1 We use the term “chart” throughout to refer to both paper and electronic charts; our frames of reference are the standards laid down by the International Hydrographic Organization.


3 See, for example, the following website, which demonstrates the significant contribution charts can make to the historical development of exploration and economic expansion. http://www.nauticalcharts.noaa.gov/csd/ctp/abstract.htm


5 So-called “virtuous loops (or cycles)” (as well as “vicious cycles”) are powerful social phenomena and are not easy to break out of if change is sought. See, for example, http://www.christopherspenn.com/2011/05/virtuous-and-vicious-cycles/

6 http://www.inho-ohi.net/english/home/about-the-ino/definition-of-hydrography.html


8 See http://www5imo.org/SharePoint/blastDataHelper.asp?data_id%3D27795/GHGStudyFINAL.pdf

9 See Association of Canadian Ports (http://www.acpa-ports.net/industry/industry.html)

10 The Annex is entitled Regulations for the Prevention of Air Pollution from Ships.