Paper 12

Hydrographic Charting: the next 400 Years

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ABSTRACT

Hydrographic surveyors and cartographers on board the Dutch ship *Duyfken* were unlikely to be contemplating the future of their profession as they surveyed a small sliver of the then unnamed Cape York coastline in 1606.

However their counterparts and the many organisations, communities and individuals impacted by our oceans and coastal zones are vitally interested in the near and long term future of our marine environment.

This paper looks briefly at the past 400 years and the current state of hydrographic charting and then attempts to forecast what the world of hydrography might be like four, forty and four hundred years into the future.

Will the short term advent of four dimensional real time navigation driven from space and other technological advances simply be overwhelmed by dramatic changes in our coastlines and societies occasioned by polar meltdown? The next 400 years of charting will certainly be challenging.

BIOGRAPHICAL NOTE

Brian O'Neil's early career was in electrical engineering however two years conscription in the Army in 1965 introduced him to topographic mapping and hydrographic charting. Whilst working in the evolving IT market in 1976 Brian was appointed the Engineering Manager involved in designing and installing the first automated cartographic system for the Australian Army known as *Automap*. He has been active in GIS technology since that time with a strong emphasis on hydrography. Brian is the Managing Director of HSA Systems, a company he helped establish in 1991. He recently received an award from the Australasian Hydrographic Society for Industry

Hydrographic Charting: the next 400 Years

Introduction.

The Year 2006 is very significant to the hydrographic community in Australasia as it celebrates the inaugural "International World Hydrography Day", plus it's the "Four hundredth anniversary of the first known hydrographic survey in Australia". The two events independently and collectively have elevated awareness of hydrography in the region through the positive promotion of the Australian Hydrographer, Australasian Hydrographic Society and many others. It could be argued that 2006 is the year Hydrography really came of age in Australasia.

The above events are certainly cause for much celebration as Australasia has a proud history of hydrographic achievement. Rather than basking in past glories, albeit very well deserved, this paper reviews the current state of Hydrographic charting in Australia and then attempts to forecast what the world of hydrographic charting might look like in the next 4, 40 and 400 years. The writer has intentionally avoided fine technical detail for the sake of readability. My apologies to hydrographic professionals and industry purists.

Hydrographic Charting, just what is it?

Hydrography and hydrographic charting have a number of definitions further complicated by end user interpretations. (A Google search responded with 550,000 references) The following general descriptions will be used in this paper:

Hydrography *is that branch of applied sciences which deals with the measurement and description of the features of the seas and coastal areas for the primary purpose of navigation and all other marine purposes and activities, including –inter alia- offshore activities, research, protection of the environment, and prediction services* (International Hydrographic Organisation)

A Nautical Chart *is a graphic representation of a maritime area and adjacent coastal regions. It shows depths of water and heights of land, natural features of the seabed, details of the coastline, navigational hazards, locations of natural and man-made aids to navigation, information on tides and currents, local details of the Earth's magnetic field, and man-made structures such as harbours and bridges. It is an indispensable tool of navigation* (The Free Dictionary)

Therefore whilst hydrographic charts are incredibly useful to a broad cross section of users and organisations the accepted normal use of hydrographic or nautical charts is for the effective "navigation" of vessels. Common terms in general use today to describe hydrographic and nautical charts as defined by the International Hydrographic Organisation are:

- Navigational Chart - describing a paper chart
- Raster Navigational Chart (RNC) - a form of raster based electronic chart
- Electronic Navigational Chart (ENC) - a form of vector based electronic chart

Navigation Charts 1606 through 2006

As one would expect navigational charts have made their greatest technological advances in the past 60 years and with the advent of electronic navigational charts they have evolved to their current high point in the past 15 years. There are a number of key factors contributing to these recent gains:

- The foundation of navigation charts is of course bathymetry, being the water depth relative to sea level at a known X and Y position at a precise moment in time. Modern hydrographic surveying probably made its most significant technological advance with the introduction of echo sounders in the early 1920's and given a modern era boost during the second world war. Since then hydrographic surveying and positioning equipment has advanced significantly and in particular during the past twenty years. Consequently the accuracy and volume of bathymetric data has increased by orders of magnitude.
- In parallel, computing systems have evolved to deliver the performance and software required to process the huge volumes of data associated with survey data collection.
- The introduction of the Global Positioning System (GPS) in the early 1990's and the relaxation of selective availability (meaning more accurate positioning), in 2000 by President Bill Clinton. This provided the world wide positioning framework necessary to support electronic navigational charts.

If one had to "loosely" classify the significant navigational chart periods during the past 400 years they might look something like:

→ 1606 through 1760
Unable to accurately measure longitude, manual depth measurement. Potential to discover a new country if you're blown off course.

→ 1760 through 1920
Longitude resolved, manual depth measurement. First fleet manages to find Botany Bay.

→ 1920 through 1960
Depth sounders introduced and enhanced positioning technology.
International Hydrographic Bureau began – world wide standards defined and adopted.

→ 1960 through 1990
Electronics comes of age, introduction of sophisticated survey and position systems.
Standards continue to mature.

→ 1990 through 2006
GPS introduced, LIDAR and multi-beam survey systems etc. and development of electronic navigation chart standards and electronic navigation systems.

The above timelines could possibly be applied to the majority of social and technological advances made during the past four hundred years. Without discounting the outstanding navigation charts compiled by our early cartographers, advances in technology during the past 50 years have assisted their modern day counterparts to produce the "best ever navigation charts".

Scorecard Australia 2006

From the above one could be forgiven for thinking that the oceans and seas of the world have been fully surveyed and charted and that we should now be turning our sights on the "Seas Of The Moon". Unfortunately that's not the situation! Whilst this paper reflects on "Australia's" results to date, the same comments generally apply to the majority of maritime countries worldwide. At this time the world enjoys a standard of nautical charting unthinkable fifty years ago. However we certainly can't rest on our laurels as we are still a long way from achieving minimum product coverage and accuracy goals.
By way of introduction to this issue it is interesting to compare the relative size of the Duyfken (the Dutch ship credited with undertaking Australia's first survey in 1606) and the behemoths that traverse the world's waterways today. The Duyfken was approximately 24 metres long whereas it's not unusual to encounter ships from 250 to 450 metres long with drafts up to 35 metres. The *Duyfken* is the small image towards the bow of the tanker profile below. At any one time there can be up to 100 of these Solas class vessels traversing the waterways around the coast of Queensland alone. These are typically up to 280 metres in length, or in more meaningful terms, equivalent to approximately three football fields long!

> *Accordingly a key factor stressing today's navigational charts is the volume, size and speed of vessels plying the world's waterways compared to 50 years ago.*

Before looking at other issues it is appropriate to quantify the number and type of charts within the Australian navigational chart portfolio. To qualify as an "official" chart which has legal standing, it must be produced and maintained within the auspices of the Australian Hydrographic Service, Royal Australian Navy (AHS). That organisation celebrated it's 87th birthday recently and has had carriage and responsibility for navigation charts during the modern era. Up to that time Australian charts had been compiled by the Royal Navy and it was those seed charts which have been updated and expanded upon.

The AHS navigational chart portfolio includes:

Paper Charts:
There are approximately 430 official paper navigational charts (and 50 odd military charts) . Roughly 70% of these are on modern datum's and the balance are imperial measurement charts i.e. fathoms based. They vary in scale from 1:10,000,000 up to 1: 5,000 These charts are mandatory for Solas class vessels, have legal standing and conform to international standards for navigation charts.

Raster Navigational Charts:
Australia is blessed with a full complement of digital Raster Navigational Charts (RNC's) which are distributed by the AHS under the name Seafarer RNC. These can be used by modern navigation systems in conjunction with GPS and other sensor systems. They have legal equivalence to the paper chart when used in a type approved navigation system when no equivalent ENC is available. RNC's are basically a digital facsimile of the paper chart but with a number of innovations to support automatic updates and modern electronic navigation systems. RNC's are an ideal transition product until full ENC cover is achieved.

Electronic Navigational Charts:
These are commonly termed ENC's and unlike their functionally poor RNC cousins, are compiled generally from paper charts using an intelligent digital vector data format. As an example, depth areas are encoded using this smart vector format and navigation systems can interrogate the data and respond accordingly. ENC's are an order of magnitude more useful to mariners than RNC's and paper charts however the cost and complexity in creating this product means Australia has less than 20% ENC coverage at this time. Programs are in place to provide full ENC coverage within the next five years. Of course ENC's can be purpose compiled and a very sophisticated series of ENC's compiled at 1 metre contour intervals is in place on Australia's north east coast.

Large Scale Port Navigational Charts:
Traditionally many of Australia's ports have undertaken production of their own large scale port, approach charts and related charts. These charts are produced for shipping management, docking and other specialised port activities and fall outside the province of the mantle of "official charts". Recently the AHS has taken responsibility for production and maintenance of many of these large scale charts and in particular to create appropriate large scale ENC's. This will ensure users have a seamless portfolio of ENC's.

That all looks very impressive, and it is, but there are compelling reasons why we must continue to expand and enhance the national navigational chart portfolio:

- Less than fifty percent of the Australian coastline has been surveyed to modern survey standards.
- Exacerbating that problem Australia has an immense area to chart covering approximately one eighth of the world's surface, from the Equator to the Antarctic, west to the Cocos Islands and east to the Solomon Islands. (Granted much of that is very deep water)
- As an island State and continent Australia relies heavily on shipping trade. The value through our ports in the 2006/2007 financial year will be in excess of 200 billion dollars and climbing due to the resources export boom.

- The volume of shipping is going to increase along with the size of those vessels. Port of Melbourne is about to undertake a massive dredging project to enable it to support these new vessels.
- From a military perspective high quality navigational chart information is essential in the Littoral area as evidenced by the recent deployment of military ships to the Solomon Islands. Finding a safe passage for disembarking troops and equipment was required by an advance expedition before the next phase could proceed. The military has unique navigation requirements given the diverse nature of the surface and submarine fleets.
- To support our territorial boundaries and UNCLOS claims and disputes.
- Our electronic chart base is largely derived from a paper chart equivalent. Electronic charts are far more effective when purpose compiled from source data to meet regional requirements.
- To ensure we mitigate environmental impacts of vessel groundings
- New electronic chart standards are emerging that will require additional and better data to support 4 D navigation. (X, Y, Z and time)
- The old cliché, "time and tide waits for no man" is a compounding factor particularly when you further add sea state, tidal flows, currents, sand waves, siltation and weather.

Australia's navigational chart portfolio is the best it has ever been in 2006 however on a scale of 1 to ten in cover, effectiveness, accuracy and product capability, we are probably sitting at a five heading for six.

The Next Four Years

This period is fairly easy as it will be a time of consolidation and steady advance. We should see full ENC cover for the Australian mainland and small scale charts. Those ENC's will however be paper chart derived and whilst a quantum leap forward many will be limited by the survey cover and accuracies of the original surveys. Highlights will include:

- Continued progress on database derived chart systems however the holy grail of multi product, press button, production maintenance and distribution. is unlikely to be attained.
- Accelerated high accuracy survey of key areas and in particular Torres Strait, which is a very challenging area to traverse. A major shipping accident in this region could force vessels to navigate around Australia and cause untold financial loss.
- Survey technology will constantly improve both in cover and accuracy. Autonomous Underwater Vehicles (AUV's) will steadily be introduced for data collection. Forward looking 3D sonar systems such as the DSTO developed Petrel system will be validated and improved.
- Introduction of mandatory ECDIS (ENC based) navigation systems on all SOLAS class vessels.
- Vessels of opportunity for survey collection will be introduced

- Some thought will be given to global warming on future shipping and charting requirements.
- Development of new navigational chart products and standards will evolve along with IT systems that can better manage those complex data structures. The incompatibilities between Defence and civil chart standards will be more actively addressed
- The technology of the Virtual Ocean will start to be utilised on the bridge and within VTS systems. E.g. Google Earth. Real time tide gauges, virtual navigation marks, enhanced location systems, ECDIS and AIS technologies will start contributing to evolve the Virtual chart.

In four years time we will have completed national ENC coverage however the huge costs and time involved in undertaking marine survey means that chart accuracy and cover is still a long term ongoing requirement. New technologies will form the basis for the next paradigm shift in navigation.

The Next Forty Years

Unless we see a quantum leap in longevity technology then yours truly will either not be here to see the next forty years conclude or I will be watching the pretty lights on whatever the then nursing home multi-media of the day is. That may well be a direct insert of a 4,000 Terabyte super high definition memory modeller, thingy. (Hopefully the insertion location will be well considered) Keep in mind that today's teenagers wander the streets with their entire CD collections in their shirt pockets. Therefore predictability towards the forty year anniversary is more guess work than science. Working on the basis that navigation chart programs will continue into the coming eons then this section looks more at the issues having major impacts on those programs.

A fifth dimension in our drive to better charts will influence this period. That is the political dimension. Governments of the day rarely look further than the current parliament and getting commitment to ongoing funding five, ten and twenty years forward is particularly challenging. Notwithstanding responsibility for charting is with the RAN and they do have forward budget mechanisms. Gaining finance for these long term programs is an ongoing challenge for the Hydrographer of the day. Whilst the RAN is probably the most appropriate guardian for charting it will always be a challenge to balance military and civil priorities. So progress will largely be tied to funds availability.

It is probably trite to suggest that technology will advance faster during the next forty years than the past forty. Why? we have an incredible baseline of technology to slingshot from compared to forty years ago when the humble transistor was just displacing valves. The first microprocessors emerged in the early 70's and the Intel 4004 microprocessor of that era contained 2,300 transistors. The latest Static Ram (SRAM) chip from Intel contains more than 1 billion transistors! Of course microprocessors are but a building block and we will see major advances in all technology sectors. Advances will include:

- Multiple GPS satellite systems providing millimetre accuracies and thereby giving precise vessel location for the full cross section of that platform given it

will be hundreds of metres long. Survey accuracy will therefore be greatly enhanced.

- Bridge technology will advance and there will be less reliance on human intervention. (Indeed it is still the case today that the majority of vessel incidents are caused by human error)
- Vessel Traffic Management systems will operate more like air traffic control systems and will be able to supplement or take over bridge control if required.
- We will likely see the Internet expand dramatically with Gigabit capability from satellites thus facilitating virtual base charts from space supplemented by real time acquisition of sensor data that will correlate to manage and ensure the integrity of the vessel location, heading and speed. Tidal predictions will be handled automatically and indeed vessel productivity modelling will ensure the world's vessels are optimally scheduled. No doubt strikes will still manage to throw that into disarray from time to time. If anyone has any doubt of the veracity of these futures they should familiarise themselves with Google Earth which already supports real time tracking of vessel movements and information, and supports digital chart overlays. The example below highlights real time information on vessels in the Port of Melbourne overlaid on an ENC chart. Note the 3D red outline is derived automatically form the AIS transponder and as well as providing dimension, signifies the vessel is carrying dangerous goods.

One unknown which will dominate future charting is "global warming". One has to be very pessimistic about global warming given globalisation, the emergence of new economic super powers such as China and India, pure economic factors, the time it takes to implement new clean technologies such as carbon sequestration (possibly 15 to 25 years lead time from now) and the world unrest in general. A world that cannot feed and educate itself is unlikely to be able to manage the long term environmental controls that are required to be implemented right now. There are many pronouncements of dire consequences but a simple example using that well know Sydney beach side suburb of Narrabeen is a case in point. Should the world oceans rise by just 20 centimetres then it will have huge impacts on that suburb (and of course the rest of the world).

More severe global warming with changes of up to 6 metres by the year 2050 is a potential scenario. Shipping, ports and of course navigational charts, will be hugely impacted. One wonders whether this would be associated with civilisation meltdown or whether mankind will somehow adjust to the new world.

Terrorism could of course bring world shipping to a sudden halt through either the ad hoc sinking of vessels or by loading a number of dirty bombs into containers. This would effectively tie up the world's ports and make the recent terrorism scare at Heathrow pale into insignificance.

The emergence of air based mass transport systems could compete with shipping and may in fact overtake that mode of transport. Let's also not forget the "beam me up Scotty" factor. Trying to maintain an optimistic outlook, the next 20 years will result in dramatic advances in source survey data collection and holdings which will translate into

outstanding navigational chart Narrabeen Beach, NSW, Australia – 20 centimeter rise in sea level coverage. There will be parallel advances in electronic navigational charts, bridge systems, positioning systems, on-vessel 3D sonar and other feedback systems. That may well be the golden age of navigational charting. Those advances will continue to evolve unless any one (or more), of a number of world stability threatening scenarios come about, from war, terrorism, global warming, nuclear meltdown or collapse of world oil supplies. Regardless, by the year 2025 navigational charts will be a solid foundation resource for the world's maritime industries and users.

The Next Four Hundred Years

It is difficult not to feel some sense of pessimism when you try to visualise the world 50, 100, and 400 years hence. To try and calibrate even the local environmental challenges, NSW coal fired power stations alone emitted in excess of 880 million tonnes of carbon dioxide during the past twenty years. Whilst likely coincidental, at the time of writing, more than 95% of NSW has been declared to be in drought. The water storage in the Gosford area of the Central Coast is at a critical low of 16%! With the world population currently in the order of 6.5 billion people and projected to hit 9 billion by the year 2050 mankind has many challenges ahead. Post 2050 all things being equal navigational charts will continue to evolve in line with the technologies of the day. Navigators of the period will enjoy the finest quality charts ever. It is likely that the man/machine interface will be a thing of the past and vessels will basically autopilot without human intervention.

Closing

I didn't deliberately set out to highlight the incredible problems facing humanity when I first sought to crystal ball the state of navigational charting four hundred years hence. Looking back four hundred years provides no basis for comparison. Awareness of these challenges is increasing and one hopes that the world leaders of the next decade will be up to the task of steering us through this critical period. The Hydrographic charting fraternity in Australasia can take pride in 2006 in having a portfolio of navigational charts that substantially meets today's user requirements. That base of charts had its foundations established four hundred years ago and has been slowly advanced by passionate and committed hydrographic surveyors, hydrographers and technologists since that time. With that same commitment Australia can look forward to having full chart cover and fit for purpose navigational charts well into the future. The surveyors aboard the Duyfken 400 years ago would have been unable to comprehend let alone dream of the technology in use today. I am sure the same comments will be made when our descendants in the year 2400 reflect on the hydrographic technologies and users of the 21st century.