Navigation Charts Of the Future

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Ray Kurzweil in his book "The Singularity is Near" mentions that the pace of change of our human created technology is accelerating and its powers are expanding at an exponential pace. Exponential pace is deceptive. It starts out almost imperceptibly and then explodes with unexpected fury.
The rate at which technology is developing makes future predictions a tricky task. But we know the future depends to a great extent on the seeds sown in the past. In this paper we will study the past and the present to guess what the future of charting is likely to be. The only thing is that the future tends to arrive much faster than we think.

KEY WORDS
Electronic charts; ECDIS; C-Map; ENC; Navigation;

TRADITION
A navigation chart is produced from the hydrographic data collected at sea. In the ancient times charts were simultaneously produced by coastal civilizations in different parts of the world. Initially they were simple sketches drawn by seafarers who referred to it when they wanted to return back to the spot. Later mathematics and science were introduced to collect the data and convert them into navigable charts. Modern paper charts that we are familiar with were first developed by the Europeans. They used the charts as a tool to explore the world and develop trade. This form of chart with minor modifications remains with us even today.

Changing Definition
In 2002 SOLAS changed the definition of a chart. A nautical chart is now defined as a *chart specifically designed to meet the requirements of marine navigation, showing depths of water, nature of bottom, elevations, configuration and characteristics of coast, dangers and aids to navigation. The term nautical chart may be applied also to a specially compiled data base (eg. the ENC), from which such a map can be displayed.* [1]

At the rate at which technology is developing and perceptions are changing a new definition would soon become applicable. The present definition of a chart implies static data. In the future, inclusion of dynamic data which forms an equally essential part of the chart has to be formalized. External non-hydrographic information such as tides, ice data, weather parameters and wave heights which change with time. Most of these data can be accurately collected only in real-time.

DIGITAL CHARTS
During the oil crisis of nineteen eighties there was a major slump in shipping. Many shipyards were closed and a lot of people were out of jobs. Giuseppe Carnevali, a naval architect and mechanical engineer by training also found himself jobless.

In 1984 he teamed up with Fosco Bianchetti to co-found Navionics. A famous magnate of that era wanted something very innovative for his yacht. The entrepreneurs suggested electronic charts (EC). They were inspired by the movie in which James Bond used ECs to chase Goldfinger. Thus the product was formally born even though the yacht for the magnate was never built. [2]

In 1985 Bianchetti left Navionics to form C-Map. He had developed new technology to store nautical charts. In the next two decades led by these two companies the ECs thrived and spread all over the world catering mainly to the light marine class. They made electronic sea maps in the vector form affordable.

During this period the product was tested, refined and perfected. A factor which helped the ECs was the advent of satellite navigation system at around the same period. The ECs combined with GPS became a meaningful navigational aid to mariners.

Advent of Electronic Charts in Commercial Shipping

In 1990 the Norwegian Shipowners Association embarked on a project to create an Electronic Chart Display and Information System (ECDIS). The project was undertaken with the assurance that the Norwegian Hydrographic Office (HO) will produce the chart data.

Two years later with a lot of money spent the complete ECDIS system was ready. However the charts were not ready. It was like having an excellent music CD-player but without the music.

In 1992 two Norwegians in this project Tor Svanes and Aslak Dirdal landed up at C-Map Italy to shop for digital charts for their ECDIS. Looking at the charts being developed at C-Map headquarters Tor had a feeling that the future lay in electronic charts. One thing led to another and in 1993 Tor and Aslak opened C-Map Norway to produce charts for the ECDIS. They launched CM93 as a new database, compliant with International Hydrographic Organisation (IHO) S-57 format.

Some chart-makers in the world started producing raster charts because it was cheaper and simple to produce. To the credit of C-Map Norway, from the very beginning they believed that the future lay in vector charts even if the process was complicated and lengthy. They also realized that the source of chart data was the HOs and such other organizations whom individual nations had made responsible to collect hydrographic data.

In the last decade C-Map has made a huge contribution in the field of ECs. They saw the problem HO's had in producing digital data and their inability to interact with the customers. They filled the gap between the HOs (owners of data) and the ships (users of data). Though some HO's looked at them as competitors, their efforts to forge a mutually beneficial relationship paid off. As a result the commercial shipping today has a good product in their hand.

S-57 ENC

In 1992 a team appointed by IHO prepared a meticulous and detailed document termed Special Publication No 57. This voluminous document was primarily meant to be a common standard for transfer of hydrographic data between HO's and for distribution to end-users. When this document was under preparation ECDIS and Electronic Navigation Charts (ENC) were still in their infancy.

In 1995 IMO came up with the performance standards for ECDIS. In it they defined the ENC as a chart issued under the authority of the government. It was not until November 1996 that the ENC Product Specification was determined and published in IHO S-57 Edition 3.0. [3]

The original purpose of S-57 as a standard for transfer of data has not been fulfilled. Instead it has been used only for encoding ENCs.

In 2002 the SOLAS was amended to include the responsibilities of national HO's with respect to conduct of hydrographic survey and production of navigation charts. Specifically chapter V regulation 9 of SOLAS asked contracting nations to carry out hydrographic surveying, prepare and issue nautical charts and other publications, promulgate notices to mariners and provide data management arrangements.

It is understandable that IMO do not have the tools to enforce this regulation on national HO's. So after fifteen years down the line we still do not have full ENC coverage. Some areas will continue to remain blank in the foreseeable future. This situation perhaps could had being avoided if the regulations had encouraged private participation on an equal footing.

SENC Method of Distributing ENCs

When the ENCs were first produced they were made available in the S-57 ASCII format. Its conversion into the binary form took place within the ECDIS computer kernel. This used to cause problems to the user due to the lengthy conversion process and untested errors popping up. To overcome this, the conversion of ENCs was undertaken in the laboratories before passing it to the customer. This was called the System ENC (SENC) method of distribution.

Initially this method of distribution was mooted in 1998 at an IHO meeting at Singapore. However, some HOs objected to it. Later in 2002 at Valparaiso this issue was once again debated. This time Tor Svanes and Chris Anderson of National Imagery and Mapping Agency (NIMA), USA were able to convince the majority to adopt this method. In 2002, the IHO CHRIS committee passed a resolution approving the distribution of ENC in SENC format. [4]

Limitations of S-57 ENC:

The S-57 ENC has some serious limitations. In its present structure it cannot support gridded bathymetry or time-varying information like tidal data. By embedding the data model within the file format makes it incapable of using a wider range of transfer mechanisms. Further it is difficult to bring out new versions to cater to contemporary standards. The current version 3.1 is frozen since 2000. [5] Apart from the design problems the chart coverage remains incomplete till today.

Unlike the US, most countries do not want ENC distribution in open-format. IHO has therefore introduced S-63 encryption system in which chart cells are licensed individually. ENCs from different vendors have different ways to encrypt/decrypt the charts. The method of distributing ENCs with S-63 encryption system remains unsatisfactory and needs to be streamlined.

These limitations have left the user unsatisfied. Simple functions like incorporation of tidal data into the chart bathymetry or merging of satellite pictures seamlessly with the chart is not possible. On the other hand there are private vendors who have produced worldwide vector chart coverage. They are able to woo the customers by offering additional facilities such as automatic voyage planning, weather overlays and voyage optimisation. In an era where Google Water permits freely downloadable charts with satellite images the shortcomings of official ENCs are hard to overlook.

The ECDIS as a project has failed to take off because of the limitation of its key component, the chart. One cannot expect ship-owners to accept a poorly designed system whole heartedly. They are forced to accept it only because it is official. Many ship-owners and ship-managers are not convinced of the high prices of ENCs and ECDIS especially when equally good or better substitutes are available at a much lower cost.

Next Gen Charts

Work is presently going on in the IHO to develop new standards for storing navigational data both hydrographic and non-hydrographic. The project termed as S-100 is expected to overcome all the limitations of S57.

According to the IHO the S-100 components are being developed within the mainstream of the geospatial information industry. This will ensure interoperability with other GIS of ISO standards such as NATO digest.

It will maximize the use of commercial off-the-shelf (COTS) software applications and development. Unlike in S-57 new components will not be developed in isolation from the rest of the geospatial information technology community.

This approach should promote greater use, thereby lowering costs in implementing S-100 for all types of geospatial applications. It will enable the use of compatible sources of geospatial data, for example combining topography and hydrography to create a coastal zone map. [6]

MIGRATING FROM S-57 TO S-100

The S-100 standards are expected to come into force by 2010. And S-101 ENC product specification will come 'not before 2012'. IHO has stated that even when S-100 standards are adopted the S-57 will be allowed to continue for as long as it is required. [7] One can guess that this approach was taken because many HO's had invested a lot of time, effort and money which should not be allowed to go down the drain. Whether this approach is beneficial to the customers is not clear.

With this announcement by IHO it is clear that the future belongs to S-100. It could mean that those HO's who have not implemented S-57 in their offices as yet, might wait for the new standards to be implemented. Thus delay the additions of new ENC cells still further.

Global Navigation Satellite System (GNSS)

An electronic chart is incomplete without a satellite navigation system. One can possibly find a correlation between demand for ECs and advancement in Global Navigation Satellite System (GNSS). Let us see what the future holds for GNSS.

Scenario Today

Global:

Only the GPS is fully operational today. A system which started in the 1978 became a commercial reality in the early nineties. Today there are 30 satellites on top. In 2000 when the Selective Availability (SA) factor was disabled the positional accuracy was significantly improved.

The Russian GLONASS was started at about the same time as the GPS. During the collapse of the Soviet system the GLONASS was neglected. Today it has only 7 operational satellites on top. With the Russian Prime Minister Vladimir Putin taking a personal interest in this programme, it seems that by 2009 GLONASS should achieve Full Operational Capability (FOC).

Europe's Galileo system has been on the anvil for a long time. Unlike the GPS and GLONASS this will be totally under the civilian control. Thus it is expected to be more sensitive to commercial needs. The implementation is however taking a long time mainly due to the large number of participant countries involved. The programme has been further delayed due to the failure of the public-private-partnership (PPP) project. Galileo will have 30 satellites on top and should have FOC by 2012.

China was initially one of the partners in Galileo. It however dropped out to pursue its own GNSS programme called COMPASS. By 2003 China had sent three test satellites up. In 2006 China announced to the world to "independently develop application technologies and products in applying satellite navigation, positioning and timing services". If all goes well by 2012 China will have a GNSS of its own.

Augmentation of GNSS

Basically there are two types of augmentations – ground based and Satellite Based Augmentation System (SBAS). Some of the SBAS are the Wide Area Augmentation System (WAAS) operational since 2003 in US, European Geostationary Navigation Overlay Service (EGNOS) and the MSAS in Japan. India (GAGAN) and China (Beidou) also have plans to provide such systems for both aircraft and marine navigation. Nigeria is the first country from Africa planning to enter this field with NIGCOMSAT.

Let's take the already operational WAAS in US. There are 25 reference stations mostly in northern US. These are GPS receivers that are placed at accurately surveyed points. These reference stations receive the same signals as the moving GPS receivers. Because their position is known, the reference stations can calculate the errors.

The error information is sent to two master stations (on the east and west coast of USA) from where it is uplinked to the two WAAS satellites. These two satellites are in geostationary orbits. They in turn transmit the information back to the earth to be received by all WAAS enabled GPS receivers. So they get improved accuracy. Depending on their geographic location it could be as good as ± 1.5 mtrs.

In terms of accuracy SBAS is almost as good as DGPS. But to a common mariner SBAS is preferable because of its many advantages.

In SBAS there is no need to carry a separate receiver to receive the satellite corrections. The same GPS receiver is good enough to get the corrections. Further, unlike the DGPS, SBAS has a much higher range and can work far from the land-based reference station.

Regional:

There are two regional satnav systems under development: Quasi-Zenith Satellite Systems (QZSS) is a Japanese initiative to enhance the GPS in their region similar to WAAS of US. The system is designed to be fully interoperable with GPS. It consists of three satellites of which at least one will be close to the zenith over Japan at any time. The planned date of launching the system is 2009.

Indian Radionavigation Satellite System (IRNSS): This is the dream of India to have its very own 7 satellites built and operated by her in the orbit. ISRO is responsible for this programme. The objectives are to have compatibility with other GNSS systems and augmentation of the GPS in the Indian Ocean region. Three satellites forming the GAGAN will be Geo-stationary and used for augmentation of GPS. The other four will be geosynchronous. [8] The first launch is expected in 2009.

Improvement of Safety at Sea

A positive development of recent years is the entry of corporate houses in the marine charting field. It means there will be an infusion of corporate culture in this industry.

The marine industry needs to incorporate some of the well-established safety practices of airlines. The risk factor can then be greatly reduced. In the future the tolerance for accidents at sea that we have today will be greatly reduced. The sea would become a much safer place. The ECs will greatly contribute towards this.

As of today the ECs produced by the government is certified by the same organization. This practice of self-certification goes against the fundamental principle of certifying all safety equipment by independent agencies (classification societies).

At the last WEND meeting in September 2008, Jeppesen proposed the adoption of Data Supply Chain Certification (DSCC). This method is intended to prevent chart data degradation from the time it originates in S-57 database and passes through various data handlers such as RENC, WEND, VARs till it is displayed on the screen of the end-user. [9]

The task of data certification can be taken up by appropriate independent agencies. It will relieve the responsibilities of HOs so they can concentrate fully on the task of data collection and cater to the increased demand for data.

Changes for the Better

In the next decade we can expect the EC and GNSS scenario to be totally different from what it is today. Some of the possibilities:

- Space: Both the GNSS and the electronic charts will be based on software defined technology. They will reside within the computer. In other words the GNSS receiver and the chart cartridge will not take up any physical space.
- Power: Requirement of power is decreasing progressively. Similarly the solar cells are becoming more powerful. A time will come when portable solar cells will be sufficient to power up the complete electronic charting system.
- Robustness: Future receivers will be able to receive a multitude of signals from different GNSS. Coupled with this the receivers will have advanced accelerators. The receivers will become much more versatile and the shadow areas will eventually disappear.
- Accuracy: In future the role of external data to improve GNSS accuracy will increase. We can expect mobile phone network providers to equip their base stations with time and positioning sensors. This could mean millimeter positioning accuracy in the vicinity of the mobile network by ranging to the base station.
- The size, weight and power required will reduce drastically. On the other hand the computers will progressively become more powerful. Soon pilots will be able to board a ship armed with only a folded e-chart and a mobile in the pocket. Once on the bridge the pilot will proceed to unfold the e-chart, tack it onto a convenient place, the mobile will provide its position and the vessel can be guided safely and efficiently to its berth.
- When operating within the steadily increasing coverage of SBAS systems, big ships will have multiple low-cost GNSS receivers placed at strategic points of the hull. All points of the big vessel can then be accurately tracked in a tight maneuver.
- With improvement in mapping and tracking technology high-value cargo will be tracked from the source to its destination easily. Alarms at all points will mean better security.
- Integration of hydrographic data into the mainstream GIS will bring revolutionary changes into the way this information will be used. Hydrography will not be limited to ECDIS alone.
- At present the time taken to produce a new chart is lengthy. In future updated information will be readily available to end-users.

Conclusion

A big hurdle that we have today is the isolation of hydrography from the mainstream GIS. Steps are being taken today to rectify this problem. Once hydrographic data is integrated with other GIS information it will lead to the data being used in many new applications. Navigation will be only one amongst them.

Futurists believe that with advances in nanotechnology we will soon be able to produce highly efficient, lightweight, inexpensive solar panels. Solar power will then be able to meet the complete world's energy needs.

Further, the cost of producing new charts will drop. The cost of replicating and transporting them to the end-user will become negligible.

The Electronic Chart product was born in the eighties during a severe shipping recession inspired by a Bond movie. A recession is not necessarily a bad thing. It forces the industry to shed flab, discard wastefulness and innovate. Today we have entered into another recession. We cannot predict how severe it will be or how long it will last. But we can safely predict that when the shipping industry emerges out of it a lot of things would have changed for the better. Perhaps the Electronic Chart producers can seek inspiration from the latest Bond flick *'Quantum of Solace'*. The future navigator would then resemble Bond as he stands on the bridge, using touch-screen technology to expertly guide the big vessel safely to its destination.

REFERENCES

1. SOLAS Chapter V
2. *HYDRO INTERNATIONAL*, May 2008>Volume 12>Number4>www.hydrointernational.com
3. HORST HECHT/BERNHARD BERKING/GERT BUTTGENBACH/MATHIAS JONAS/LEE ALEXANDER, *The Electronic Chart,* Second edition May 2006
4. IHO Technical Resolution A 3.11 http://www.iho.shom.fr/ECDIS/SENC.htm
5. LEE ALEXANDER/BARRIE GREENSLADE/ANTHONY PHARAOH/ROBERT WARD, *S-100: The New IHO Geospatial Standard for Hydrographic Data*, March 2008
6. ibid
7. ibid
8. PROF. DR. –ING. GUNTER HEIN/Jose-Angel Avila-Rodriguez/Bernd Eissfeller/Thomas Pany/Stefan Wallner/Phil Hartl, Envisioning a Future GNSS System of Systems, Inside GNSS January-February 2007
9. MICHAEL BERGMANN, Marine Data Flow, WEND11, Sep 2008.

GLOSSARY

DSCC Data Supply Chain Certification
A system of handling data intended to ensure that the transmission of data from its source to the point at which it is displayed on the end-user screen does not degrade the data.

EC: Electronic Chart; ENC
A term used to describe the data, the software and hardware system capable of displaying electronic chart information. An electronic chart designed to be used in the ECDIS and issued on the authority of government-authorized hydrographic offices is called an Electronic Navigation Chart (ENC)

GAGAN: GPS and GEO Augmented Navigation System

GLONASS: Global Navigation Satellite System
A space-based, radio-positioning, navigation and time-transfer system operated by the Government of the Russian Federation.

GNSS: Global Navigation Satellite System
A world-wide position, time and velocity radio-determination system comprising space, ground and user-segments of which GPS, GLONASS, EGNOS, COMPASS and IRNSS are components.

IHO International Hydrographic Organisation

IRNSS Indian Radionavigation Satellite System
Indian Radionavigation Satellite System is a venture of ISRO for augmentation of the GPS system in the Indian subcontinent

ISRO Indian Space Research Organisation

S-57
IHO Special Publication 57. Contains the IHO Transfer Standard for Digital Hydrographic Data. The major components of S-57 Edition 3.1 are: Theoretical Data Model , Data Structure, Object Catalogue, ENC product Specification, Use of the Object Catalogue for ENC.

S-100
A project under IHO to develop the new geospatial standards for hydrographic data. It is purported to be a wider standard catering to other users apart from ECDIS and based on the ISO TC211 standards for contemporary GIS. The ENC product specifications based on S-100 will be drawn (termed S-101) which will in due course of time replace the S-57.

SBAS
Satellite Based Augmentation System

SENC
A database in the manufacturer's internal ECDIS format produced as a result of transforming the ENC. The conversion from ENC contained in the ASCII form to SENC in a binary form may be carried outside the ECDIS in a lab. This is a preferable way to provide efficient and error-free electronic charts to the end-user.

QZSS: Quasi-Zenith Satellite System
Is the Japanese regional satellite system that will enhance the GPS in Japan.

WAAS
Wide Area Augmentation System. An SBAS system operational in the US region.

WEND: Worldwide Electronic Navigational Chart Data Base
An IHO concept, based on the set of WEND Principles, designed specifically to ensure a world-wide consistent level of high-quality, updated official ENCs through *integrated* services that support chart carriage requirements of SOLAS and the requirements of IMO PS for ECDIS.

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