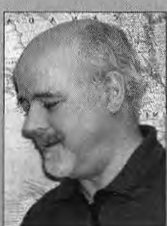

Challenges and Opportunities for Hydrography in The New Century

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Now that we are past the media-generated hype of the arrival of a 'new millennium,' it is important to take stock of where the field of hydrography stands in relation to the real changes that are occurring in our world. Within the marine sphere we see: an ever-growing range of ocean activities carried out over wider areas, in greater depths and through extended weather windows; technologies, both mature and new, that enable and push existing as well as newly created enterprises in the marine field; the ratification of the United Nations Convention on Law of the Sea (UNCLOS), leading to most Coastal States introducing coastal or oceanic management schemes and preparing to claim a juridical Continental Shelf; and increased environmental protection activities and the establishment of Marine Protected Areas. Global trends that encompass hydrography include: the digital revolution, which not only changes the products and information that can be extracted from raw data, but also raises questions of ownership and liability; and the changing views of the interplay of roles between Government, private industry and the universities as to how the public are provided the informational products they need.

Against this backdrop, how hydrography is carried out will be re-defined. Already it can be seen that what was once the exclusive domain of Hydrographic Offices (HO) is becoming increasingly populated by other government agencies with marine responsibilities, port authorities, resource companies like oil and gas companies, resource entrepreneurs like fishers, marine communications companies like cable owners, marine surveying service companies like dredgers, surveyors, coastal land management companies, and scientists in government and academia who are involved in better understanding the oceans. What hydrography encompasses will expand, driven primarily by the new capabilities that technology offers to users of the oceans. In addition to meeting the needs of navigation in a digital manner, the marine information requirements of the expanding marine world of the new century will have to be met.

This paper elaborates the trends currently visible and develops a new definition of 'hydrography'. Based on this definition, it discusses ways in which the different components within hydrography can situate themselves. It points out the enormous social benefit to all users of hydrographic information of having one central national clearinghouse for all such data. This concept of course, also imposes a new requirement on HOs (as that clearing house) to be more receptive of data collected by others, and provide more open access to data holdings for all potential users.

Introduction

The history of exploration and mapping of the land's surface of the Americas during the last few centuries contains some valuable lessons for hydrographic agencies at the beginning of the new millennium. Both indigenous peoples and foreign explorers mapped transportation routes, and these maps were used to guide the transport of those who travelled over the land. As settlement of new areas followed, other types of maps were required, beginning with simple descriptive maps to assign land to individuals, to lay out farms and ranches, to plan the routes for railways... To support economic development, other physical themes were added, beginning with geology, soils, woodlands...over time the number of themes, type of map, and scale of investigation grew, until today there are maps covering a plethora of subjects from dam sites to drainage basins, from acid rain areas to zoographic zones. Types of maps increased in number to meet the broadened demand, some from existing map suppliers who broadened their product line, others from new suppliers.

Development at sea has been slower than on land, but recent developments show that the gap is being narrowed. Centuries of hydrography were dedicated to mapping transportation routes, and a great deal of hydrographic energy still goes into that activity. However, just as on land, as human activities in the oceans grow in number and variety, there are new requirements for maps of themes other than traditional transportation and, at present, not all these requirements are being met. Those who need the new maps are sometimes able to obtain them, sometimes must accept something less than they need, and are sometimes so ignored by established mapping agencies that they are forced to produce their own. While there are many reasons why this situation exists, and while there are sporadic efforts to meet the needs which may lead to more producers being drawn into the map-making fold, there is an opportunity which we believe Hydrographic Offices (HOs) should assertively grasp. Nature abhors a vacuum, and the demands for marine maps of many types will be met, regardless of who the provider is. Some HOs are already grasping this opportunity to lead this new thrust, while others still remain within the specialised field of transportation mapping.

Of course, the entire world of mapping is vastly different than it was during the period when land mapping expanded from transportation to other themes. Technological developments like the introduction of GPS mean that positioning is available to all. The Geographic Information System (GIS) arena is rapidly evolving from a field requiring specific training into a general type of software that professionals in fields ranging from aquaculture to coastal zone management are able to use easily. The Internet as a major driving force is just coming into its own. Organisationally, too, there is evolution as the mix between private and public sectors strives towards a new balance.

Expanded Range of Ocean Activities

All hydrographers know that water covers over two-thirds of the Earth's entire surface. What is occasionally overlooked is that within the one-third remaining, the bulk of the human population is concentrated in the coastal zones (the UN predicts that by 2020, 60 per cent of the world's population will live within 60 km of a shoreline). This factor has long forced a strong interaction between coastal populations and the sea. Maritime transportation and fishing were the earliest and most relevant manifestations of this interaction, demanding supporting tools to sustain them. Out of that demand, hydrography was born.

But the field of hydrography must adjust to the changing world. Although hydrography has played and will continue to play a vital role in maritime shipping safety and efficiency, there are many more activities to which it already makes significant contributions. Today's sea usage has expanded from what it used to be in the past, and the many new sea activities demand different supporting tools. Among the new activities, we can mention: Ports and harbour management, cables and pipelines, tourism and recreation, oil and gas exploration, marine minerals, commercial fishery, aquaculture and fish ranching, maritime services, oceans equipment and technology, sovereignty and security, UNCLOS and the geography of the oceans, bilateral boundaries, oceans governance, defence, enforcement, environmental impacts and protection, coastal zone management, and managing the inter-tidal zone and marine protected areas.

Just as the needs of navigators for spatial information were met by charts, the new ocean users need a spatial infrastructure for their activities, and hydrography can provide it. HOs can now aspire to provide national leadership in designing a clearinghouse for hydrographic information, while other groups involved in hydrography can participate as partners with the HOs, while retaining ownership of their own data.

Enabling Technologies

Hydrographic technology has changed dramatically over the past several decades, and will continue to change and evolve in the future. Before specifically looking at the evolution of hydrographic technologies in the next section, it is worthwhile considering the evolution of two underlying enabling technologies that have fuelled all these changes, as well as the broader emergence of 'information technology' in many other fields. These two enabling technologies are microelectronics and communications bandwidth.

Since their invention in the 1960's, the characteristics of microelectronic devices have evolved exponentially, best described by 'doubling times.' Trends over the past 35 years are: processing speed has doubled every 48 months, device costs have halved every 36 months, and data storage device costs have halved every 18 months. Equivalently, each decade devices become five times faster, and cost 7 per cent of their original cost, while the cost of data storage drops to 1 per cent of its original cost.

These trends have fuelled the development of products, applications, and derivative technologies (see examples in the next section). Breakthroughs in microelectronic physics continue, so there is, as of yet, no indication that fundamental limitations will end these trends any time soon. Microelectronics technology is mature, but developments have not slowed.

A second enabling technology which is not yet as mature as microelectronics is communications technology, which has over the past decade or so been evolving in three mainly independent directions: faster speed, global interconnections, and mobile terminals, each with rapidly decreasing costs.

Faster speed: The time required for transferring a 1-Gigbyte file using various protocols and methods has evolved as follows:

Using	
28.8 kbaud modem	75 hours
Digital Subscriber Line	30 Minutes
T3 Line	3 Minutes
10 Base T Ethernet	13 Minutes
100 Base T Ethernet	80 Seconds
1000 Base T Ethernet	8 Seconds

Global interconnections: The demand created by the explosive growth in Internet use resulted in the laying of over 600,000 km of fibre-optic cables crossing the world's oceans between 1985 and 1990. Until the recent (2001) crash in communications technology stocks, based on the realisation that this capacity had temporarily outstripped demand, there were plans to lay another 600,000 km of transoceanic fibre over the next five years.

Mobile: Mobile communications requires a wireless (radio) infrastructure. So far the main emphasis in the development of wireless infrastructure has been on local line-of-sight cell technology. Much of the world now uses local mobile communications, which is mainly useful on land or near coastlines. The future trend is to broaden the range to global (ocean-wide) communications using satellite-based infrastructure. Inmarsat has been available for some time, but so far with costs and data rates that are not compatible with explosive growth. The challenge here is not purely technological, but to devise a business model with low enough costs to encourage widespread initial customer acceptance, which then funds expansion, further lowering of costs, and broader acceptance.

The fusion of all three of these trends into fast, global, mobile communications is an eventual (perhaps inevitable) goal, which when reached, will have at least as significant an impact on information technologies as microelectronics. Fast, global, mobile communications will realise real-time access to information from anywhere, anytime, by anyone. Some of the geomatics (spatial information) possibilities of this infrastructure are being developed by NASA and its partners in the Digital Earth initiative (see www.digitalearth.gov).

While this goal will take some time to realize (perhaps less than a decade, perhaps longer), it is wise for HOs to consider technological investments today, which will be enhanced, rather than outmoded, by faster, global, mobile communications, in whatever combination.

Hydrography at a Crossroads: Preparing for the New Millennium

The scope of ocean mapping has evolved dramatically in the last 20 years. Four revolutions in ocean mapping technologies have permitted new ocean mapping applications.

Positioning

Since 1994, most positioning at sea has been done using the Global Positioning System (GPS), which routinely supplies inexpensive, globally referenced, consistent, accurate positions, easily accessible to the smallest pleasure boat and largest tanker. In many cases, GPS positional uncertainty is much smaller than uncertainties in existing ocean maps and nautical charts. Replacing paper nautical charts with ones having smaller uncertainties, compatible with GPS uncertainties, is a big challenge; one that some advocates of Electronic Charts argue is not worth undertaking.

Seabed Information

Several new approaches to mapping the seabed (multi-transducer boom-sweep systems; multibeam sonar systems; and airborne laser bathymetry) permit close to 100 per cent coverage in mapping the seabed. For the first time ocean mapping can produce complete pictures of seabed topography, providing products similar to the land maps based on aerial photography. Small features such as anchor and iceberg scours, and small and large sand and gravel wave fields can be mapped and analyzed. In addition, some of these new systems also map acoustic backscatter information, which is related to seabed material type (sand, silt, clay, pebbles, boulders, bedrock, carbonate, silica, etc.), and textural classification (characteristic roughness based on grain size and geologic and hydrodynamic processes at work on the seabed, e.g., bed forms, furrows). Ocean mapping now deals with what the seabed is made of, as well as where it is located.

Remote Sensing Information

Satellite and airborne imaging technologies have revolutionised ocean mapping in several ways. Altimetry from satellites maps changes in and features of the ocean surface (averaged over a 1 km^2 footprint) as small as a few centimetres in height. Such information can be used to track changes in El Nino / La Nina as well as to reveal the existence of undersea topography, whose gravitational pull causes the sea surface to deflect. Information about the dynamic behaviour of the ocean (such as tides and the slope across ocean currents) and about weather and climate (for example, atmospheric highs which depress the sea surface and prevailing winds which pile water up along a coastline) can also be extracted. Another remote sensing technology maps small variations in the temperature of the ocean surface. Since certain fish and their food chains thrive within narrow temperature ranges, these maps are excellent indicators of where these species are likely to be found. Gradual declassification of high-resolution remote sensing technologies once reserved for spy satellites permits mapping of coastlines and other features with ever-smaller footprints and finer detail. Currently features as small as 1 m can be mapped in some areas, allowing erosion to be monitored, and changes to be detected due to marine construction. As higher resolutions become more widespread, mapping and monitoring many other ocean environmental changes will become possible.

Digital Products

Over the past two decades, all of surveying, mapping, charting, and cartography have undergone a revolution and become an Information Technology whose basic products can be used in GIS. The collective name for these computer-assisted surveying and mapping activities has come to be known as 'Geomatics.' One consequence is that ocean maps and hydrographic charts are evolving from 'analogue' (paper chart) products to 'digital' products, although the complete transition will take some time. Many of these digital ocean-mapping products have proven useful to customers who have no intention of using them for navigational purposes. They meet the changing needs of scientists, managers, policy makers, and commercial enterprise. A marine GIS allows the addition or updating of new information as overlays on existing base layers, and the analysis of the content and impact of the information shown. This capability permits decision-making in ways never before possible, related to many aspects of coastal zone and marine resource management, such as aquaculture, port and harbour dredging and construction, waste dumping, erosion control, pollution track prediction, marine geology, ecology, best area use, transportation, and other domains. Technological advances now allow us to handle the massive data sets acquired using multibeam sonar systems, and to visualise and grid it.

After a decade of developing standards, in November 1995 the International Maritime Organization issued a performance standard for Electronic Chart Display and Information Systems (ECDIS), a special form of GIS which, if this performance standard is met, qualifies an ECDIS as a 'paper-chart replacement' system as of 1999. In parallel, many other GIS products, 'unofficial' Electronic Chart Systems (ECS), have emerged which, while not qualifying as paper chart replacements; still provide broader and more convenient navigational assistance to users than do paper charts. These two developments have led hydrographers and other chart providers to divert much of their effort away from paper chart production to the development of 'digital charts' in both ECS and ECDIS forms. It is forcing debate over a redefinition of the basic hydrographic charting product, which some now consider to be the digital database from which can be derived a paper chart, a digital chart, or a data layer for non-navigational purposes within a GIS.

The development of ship-based 'electronic charts' may be thought of as the apex of hydrographic mapping. The incorporation of tidal information in such systems allows large ships to navigate more safely in shallow waters than if they just had a chart showing depth below datum. Extending capability to include real-time sea-level information makes it possible to include less predictable effects associated with winds and freshwater runoff. In a simple geographic area such as a narrow river where this kind of system may be made to work reliably, the enhanced safety and broader navigation windows offered by an ECDIS enhanced by real-time information are already perceived as of significant commercial benefit.

There is no doubt that further development of data-enhanced ECDIS systems will be beneficial to shipping and to the high-tech companies that develop and market these systems. ECDIS is an example for potential future developments.

New Hydrography Paridigm; New Hydrography Definition

A modern way of looking at hydrography and hydrographic information (indeed at all of spatial information, perhaps all information of any kind) is that information exists only to facilitate 'informed decision making.'

This view is based on an appreciation that 'informed decision making' is among the highest-order human activities. Many human activities can be decomposed into a sequence of decisions. These decisions will result in greater success (achievement of the goals sought) to the degree that they are 'informed' – that is based on appropriate information.

Let us consider some examples:

- Safe and efficient navigation is a sequence of decisions, most simply whether or not to change speed or direction at any point along the route. These decisions will be successful (will result in a safe and efficient passage) to the degree that they are 'informed' (when all information which might affect safety and efficiency of the passage is available and understood by the navigator)

- Geomorphological interpretation is a set of decisions about which particular processes or events are appropriately associated with particular observed features. This interpretation will be successful (will be scientifically defensible) to the degree that it is 'informed' (when all information containing geomorphologic evidence is available, and understood by the geomorphologist)

- Fishing is a sequence of decisions, such as where and when to set and recover fishing gear, trawl speed and direction, etc. These decisions will be successful (will result in a hold full of fish in the shortest possible time) to the degree that they are 'informed' (when all information about the habitat, school behaviour, and location of fish is available and understood by the fisher)

Most decisions, including all the examples above, involve some element of uncertainty and risk. The goal of 'informed' decision-making is to reduce, to whatever degree is possible, this uncertainty and risk. The 'quality' of a decision can be viewed as being inversely proportional to the uncertainty associated with that decision. Similarly the 'quality' of information can be viewed as being inversely proportional to the uncertainty associated with that information.

These considerations lead to the following conclusions about hydrographic information:

- The quality of decisions based on hydrographic information is directly proportional to the quality of the information used, the completeness and the appropriateness of the information available, and the understanding of the information (and of its quality) by the decision-maker

- Managing the uncertainties associated with hydrographic measurements consists of the following steps:
  a) Establish the confidence region required for hydrographic measurements, so that decisions of a particular type (e.g. following a safe navigation route), when based on these measurements, are made with acceptable confidence
  b) Design or select a measurement system (e.g. multibeam equipment, operating procedures, quality control methods) which will achieve this required confidence region
  c) Assess the confidence region actually achieved, and compare this with the required confidence region
  d) Present these uncertainties (or confidence regions) in an easily understood way to those who will be making decisions based on hydrographic information

  Methods are available and in use by HOs to accomplish tasks a), b) and c). Work remains to develop all-important and appropriate representation methods, as specified in d)

- Uncertainties associated with thematic interpretation using hydrographic data, such as interpreting bottom type, habitat, and coastal zone regimes (an informed decision-making process in itself), are more difficult to manage and represent, due to their often-inherent 'fuzzy' nature

This view of the role of hydrography, as the supplier of information for informed decision making, leads naturally to a new definition of hydrography itself (Hecht, 2001):

"Hydrography is the total set of spatial data and information, and the applied science of its acquisition, maintaining and processing, necessary to describe the topographical, physical and dynamical nature of the hydrosphere and its borders to the solid earth, and the associated facilities and structures."

This definition consists of two parts: the task and the purpose of hydrography. While the task remains largely the traditional one - data acquisition – the purpose shifts emphasis from constructing hydrographic products to distributing hydrographic information, based on the enabling technologies governing the forthcoming developments described above: microelectronics and communication bandwidth. Digital information is not 'inert' like physical products – once fed into a network, it will spread almost automatically. Of even greater importance, digital information can be processed in many diverse ways, and tailored to specific needs, using the power of today's software. It is particularly this characteristic that opens an entirely new universe of services and applications – as the experience with the Internet already shows.

How Hydrographic Offices Can Re-structure and Adapt

To respond to the many challenges and changes that loom on the oceanic horizon, some modification is necessary to the way that 'hydrographic business' is conducted. Traditionally, hydrographic data was collected for use in the creation of specific documents designed to fulfil the needs of surface navigation. The many other uses of the same data were generally disregarded. The primary change in mind-set that will allow hydrographic offices to progress into a rich future will be to realise, accept, and embrace the fact that for the same effort, there are a host of other uses that can be met using the same basic data.

We now examine some ways in which this change can manifest itself within the traditional hydrographic business model. For organisational simplicity, we have broken this into three main blocks, namely:
- Collecting data (raw material)
- Managing data (manufacturing process)
- Distributing and updating the manufactured product

Collecting Data

Internal Data Collection - The greatest expense when collecting data is the platform and the personnel aboard it. Increasing the volume and the diversity of gathered data beyond that required to build nautical charts will reduce the relative cost of all final products, even though there may be a small increase in the immediate survey cost. In this way, information to generate other types of products will be available to HOs. This type of synergetic gain can come from using instruments that either collect more than one type of data, or collect data that can be interpreted in more that one way [e.g., some multibeam systems collect depth data and backscatter intensity, depths can be portrayed for the safety of navigation (shoal-biased) or for the description of geomorphology]. Deciding which data are optimal to collect will require some investigation and experience. Another gain can come from platform time-sharing among several HOs, science institutions, educational organisations, and commercial companies, maximising use of the platform, equipped with all sort of sensors by a multivariate spectrum of users.

Outside Data Sources - In the past, some HOs have been reluctant to use data they did not collect themselves. It is time to re-think this policy, for two reasons. One is that with modern technology, and with the increased availability of trained personnel outside HOs, surveying is now being performed by various organisations at a level of quality that meets or exceeds hydrographic specifications. The second is that relevant data are being collected and made available from satellites. It is possible to down load sea-surface height from which to derive estimates of ocean depths, ocean temperature, and sound speed profiles. ...more. Although these may not be at the scale that the HO is aiming for, they are at a level of detail sufficient for many purposes, including planning hydrographic operations, and may be incorporated into HOs ocean data holdings.

Managing Data

Hydrographic offices obtain their raw material from their own expensive and sometimes arduous hydrographic surveys, from their tide gauge networks, and we hope from other agencies. In the past, hydrographic data was primarily used to manufacture one product, the navigational chart. In the future, this has to change, or others will be able and ready to supply new products to meet the rising and varied demands, and there will be only a narrow and circumscribed future for HOs.

The new mindset must embrace the idea that the data themselves are a valuable product, one which many users in the new range of marine and coastal monitoring activities described in early sections of this paper are anxious to obtain. HOs who embrace this idea can become THE source for marine information in their area of responsibility. Those who do not will find lost opportunities as potential clients will seek other sources to meet their needs, and HOs' role will be diminished. Of course, to meet the new needs the data must be organised and accessible. With the proper design and appropriate access policies, the hydrographic database can become the major marine data source in each country. And the database will not only serve outside clients, it will serve the HO as it makes navigational charts and a new line of products.

HOs already possess some fundamental elements of this database. Many HOs have large volumes of accumulated data, most of it uniquc and some of it going back over a century. It is possible to extract new information based on the analysis of these large amounts of legacy data by applying Data Warehousing (DW), Data Mining (DM) and Knowledge Database Discovery (KDD) concepts. Applying these can lead to the creation of a strong and viable hydrographic / ocean mapping / marine science database, which makes a valuable contribution to the future of marine science in its own right.

Outputs from the database will include traditional hydrographic products, data products customized for use at the request of new and different users, and new hydrographic products. Our paper navigational charts most likely will continue to be a part of the normal suite of products, even with the introduction of raster and electronic navigational charts. It may be that 20 years in the future recreational boaters may be the only ones using the paper chart. However, the distribution of the paper chart is already undergoing change; the 'Print On Demand' (POD) concept has been introduced in some HOs. Mariners can order, in cooperation with the HO, charts through a chart agent, by telephone, or by electronic-mail and receive charts printed using POD technology that are corrected to the order date for all weekly updates from notice to mariner publications and new source applications. They are available by next-day delivery service or immediately from the chart agents' small up-to-date inventory. Up-to-date charts also could be offered that are tailored to the mariners' needs. They could be printed with trackline data supplied by the vessel and information could also be included in the margins on tides and currents, Coast Pilot text, port authority updates, and other information as available.

Hydrographic data and other nautical charting data can be served to meet the needs of the non-navigational community. Various data sets and products can be developed that could be of value in the coastal zone management arena for use in evaluating the impacts of growing coastal communities, storm surge mapping, pollution impact analysis, and appraising beach replenishment. Nautical charts contain information critical to navigational users (such as compass roses, aids to navigation, separation schemes) that can detract, hinder, or block applied information that the coastal community wishes to lay over the images using GIS. A digital, geo-referenced coastal map could be derived directly from the existing chart that contains only hydrographic depths and contours, topography, and shoreline base information.

Associated vector shoreline could also be offered for GIS use along with the feature attributes in the electronic navigational charts, such as depth information over wrecks and obstructions, or bathymetry that can be spatially processed with environmental information for data analysis.

Acoustic seafloor backscatter intensity data are now being routinely acquired for many models of multibeam systems during surveying operations. Characterization of the seafloor is of great interest to many varied users in support of activities such as environmental monitoring, fisheries management, dredging operations, beach replenishment, and research. Mosaics or the backscatter data can be offered to users in conjunction with bottom sample data to ground truth the backscatter data.

As an example of how to create another new hydrographic product, consider a single 'sounding ping'. It is possible to extract a number of types and amounts of information from a single ping. First, the leading edge of the ping produces a shoal-biased safe navigation depth while the mean of the returned signal produces a true surface or geomorphologic depth. Then, backscatter and derived information about the composition of the seabed can be extracted. Sometimes there is information about free-swimming fish. And finally, often there is information about the physical properties and movement of the seawater that the sound wave traversed. For surveys using today's technology, these types of information can be had at very little additional cost, since the major cost is incurred in the vessel. And they can be had for a fraction of the cost of mounting a separate survey to collect them. Unfortunately, they will not always be extractable from legacy data, since they require that the full acoustic waveform be recorded, and this was not often done in the past. Indeed, many older echo sounders were designed to blank out the water column, preventing the full suite of data from being collected. This is just one example at the raw level where data are analysed at a small scale, and this multiplying effect will grow as more users exercise the database.

Distributing and Updating

Another area where major improvements can be achieved, pushed by the key technological trend of using the Internet as a means of communication, is distribution and updating. The old idea of 'if someone is going to the sea, he better get ready on land' will be no longer true (at least regarding marine information requirements). Technology will extend HOs' delivery capabilities to all potential users anywhere around the world. This will enable, for example, mariners to have a real-time route and re-route planning capability without having brought the necessary data in physical form with them as they boarded their vessels. With the appropriate digital data infrastructure, it will be possible to provide any kind of marine data to fulfil a particular need, customised to suite the user's requirements, while still providing traditional navigational users with products that meet agreed standards.

Appropriate Organisational Structure

The organizational structure of the hydrographic 'business' must include defining or redefining appropriate and productive roles of Government, industry, and academia. It also must address the internal organisation of the HO, co-operation between HOs, and with the IHO. Organisational forces engendered by the digital revolution must be included as major contributing factors. Links to land mapping agencies will no doubt be expanded as the century progresses.

What will HOs have to organise themselves to do?

a) Data collection – Both 'pure' hydrographic data, i.e. water depths, tides and currents and some new types of data as well
b) Expertise – HOs must maintain expertise in hydrographic surveying techniques and procedures to ensure that acquired data meet requirements and standards, whether collected by the HO, other agencies, or contractors to the HO
c) Data assembly – In the analogue world, this consisted of bringing together all the other data used in making a chart. In the first wave of the digital world, this meant building databases to hold these data. In the next wave, it may mean building digital links (Spatial Fusion) to specialized databases wherever they are located. Data in this category varies from HO to HO, but includes items like shoreline,

place names, aids, traffic separation schemes, legal boundaries, magnetic declination, topography, dredged areas and the many other items listed in Chart 1

d) Data Archiving – The data collected and the data assembled must be stored in some archive as spatial objects
e) Quality Assurance – This must occur at all stages. Recent developments in producing spatial objects (S57) must change the nature of QA and the organisation needed to support it
f) Production of products – A variety of products can be made from the spatial objects in the archive, ranging from navigational charts to administrative boundary maps to bottom type maps to ocean governance maps to
g) Production of data sets – Some users will need a data set on which they can perform their own analysis and produce their own products
h) Dissemination of products and data sets – Dissemination may be different for those products, which are mandatory, e.g. navigation charts, and those that are not
i) Updating and dissemination of updates – Mandatory products will have some specified time to produce an update and convey it to users
j) Perform research and development to make the activities listed above more efficient
k) Educate and train personnel to perform the activities listed above

HOs should encourage (perhaps lead) in the development of systems / approaches / collaborations which will exploit the continued advancement of microelectronics technology, and the coming arrival of fast, global, mobile communications technologies, so that the end user will be provided with better (e.g. real-time, diverse) information upon which to base 'informed decision making.'

HOs have to organize themselves into hydrographic information service providers. This cannot happen unless HOs network themselves to exchange information across borders, and to facilitate user access. A first step towards such a networked operation, though limited yet to facilitate data exchange between a RENC(Regional ENC Coordinating Centre)1. and cooperating HOs particularly for ECDIS, has been successfully implemented at PRIMAR in Europe. Termed 'Virtual Private Network (VPN), it is actually a secure extranet using internet technology for the information exchange. A more comprehensive concept, again limited to ECDIS application, has already been devised as 'virtual RENC' which still remains to be developed, however. The U.S. has also recently addressed this issue by offering provisional ENCs freely over the Internet to any user.

Any hydrographic network will sooner or later become part of the Internet. Thus, as soon as hydrographic information becomes part of public information for decision making (or derived commercial products), it will complement other publicly available spatial data and information. This will inevitably trigger forces to integrate hydrographic information into a comprehensive geospatial data exchange. This can clearly be seen from those already existing global initiatives like 'Digital Earth' referred to earlier in this paper; these initiatives provide the necessary framework for making the integration happen. This 'infrastructure' will have to provide more than just data access. Particularly, it will have to provide interfaces for a variety of processing software types, and thereby provide support for a variety of data formats.

At the end of the day, users will not care about the nature or source of the data, whether it is hydrographic, topographic, atmospheric or whatever. Like newspaper reports about all relevant issues of the world, the 'portals' linking different data sets will ultimately have to feature all spatial data considered of some public benefit. The future will have to decide how far commercial interests will govern this. But given the fact that most of the spatial data collected is produced by government offices financed by taxes, one can guess that the public interest ultimately will dominate, as it is today in the U.S.

Thus, HOs will have a chance to contribute to a development that can be phrased as a vision: 'accurate and up-to-date, high-resolution geographic information will be readily available for any place on the globe (sea, land) and for any purpose.'

Conclusion

A Vision of what HOs Could Become: Digital and Virtual HOs

It is of course impossible to predict the future, but we suggest that the following will be some of the major elements of the hydrographic scene in the near future.

- Fewer traditional hydrographic 'products,' but a much greater diversity of products based on hydrographic data, knowledge, and skills
- National boundaries will have less importance, as far as data sources and services are concerned
- HOs will survive or die based on the quality of data, and quality of data access that they provide, and partnerships fostered with other data providers
- End users (the 'informed decision makers') will assemble / integrate the various layers of information, from a variety of sources and independent data holdings, by themselves in real time, using Internet tools that are as simple and friendly as are browsers and email clients today
- Hydrographic information will be managed / made available on hundreds of servers supported by those who 'own' the data or value-added information / services based on data
- Important roles for HOs remain: establish national and international standards for data quality, data quality assurance, and data access; maintain expertise in hydrographic surveying techniques and procedures; encourage / establish broad participation with other data suppliers in a common data warehouse framework; and establish new access channels between data holdings and end users

In the past the paper chart, a product represented the most efficient and effective access channel between hydrographic data and the end user. The new technologies described and predicted in this paper change this perception. It will soon be possible for individual end users (informed decision makers) to assemble and integrate the hydrographic (and other) information they need, at the time they need it, from data holdings warehoused on computer servers scattered throughout the world. Hydrographic Offices can continue to play a central role in this new access channel – defining it, shaping it, setting appropriate standards for it, and supplying critical data through it.

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Biographies

Dave Monahan is Director, Ocean Mapping, Canadian Hydrographic Service in Ottawa and Hydrographer in Residence with the Department of Geodesy and Geomatics Engineering at the University of New Brunswick. He is Vice-Chairman of the international Hydrographic Organisation's General Bathymetric Chart of the Oceans project, and has over the past thirty years has worked in most elements of hydrography.

Horst Hecht has a master degree in Meteorology. He was head of the IT division until 1988 at the German Hydrographic Institute, became then appointed Director of the Hydrographic Department of what is now the Federal Maritime and Hydrographic Agency. He has been involved with ECDIS standardisation. Horst Hecht is the author of numerous articles related to hydrography and is co-author of a Textbook on Electronic Charts.

Dave Wells retired from the University of New Brunswick in 1998, after two decades of teaching hydrographic surveying there. He now follows the seasons, and this year taught at four universities: University of Southern Mississippi from January to May; University of New Hampshire in May and June; Universiti Teknologi Malaysia during the summer; and from September to December back to the University of New Brunswick, where is now Professor Emeritus, and where this fall he introduced three new hydrography courses (on tides, kinematic positioning, and hydrographic data management). Dave and three colleagues teach a short course on multibeam sonar surveying four times each year at various locations around the world. Since 1990 Dave has been a member of the FIG/IHO International Advisory Board on Standards of Competence in Hydrographic Surveying, which meets for 10 days each year in exotic locations. Dave is exploring the possibility of doing some of his teaching via online (or CD) course delivery, perhaps reducing some of his hectic travel.

Maureen Kenny is a Captain in the U.S. National Oceanic and Atmospheric Administration with over 26 years of experience in the hydrographic arena, including assignments ranging from survey data acquisition to the delivery of products and the advancement of new technologies. Her career includes sea tours on three of NOAA's hydrographic survey vessels, most recently as Commanding Officer. She is presently Deputy Director of NOAA's Centre for Operational Oceanographic Products and Services of the National Ocean Service which acquires, analyses, and distributes historical and real-time observations and predictions of water levels, currents, and other data.

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