On the shoulders of giants: the history of hydrography in the twenty- first century

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I confess that in 1901 I said to my brother Orville that man would not fly for fifty years. Two years later we ourselves made flights. This demonstration of my impotence as a prophet gave me such a shock that ever since I have distrusted myself and avoided all predictions.

- Wilbur Wright [In a speech to the Aero Club of France (Nov 5, 1908)]

Abstract

The last two decades of the last millennium clearly illustrated the greater uses and demands humanity is putting on its ocean space. In addition to the Economic Benefits that derive from safety of navigation the years since the signing of UNCLOS have witnessed a burgeoning exploitation of non-living resources, crises in living resources, the discovery of new ways to use the ocean like pharmaceuticals. Maintaining security at sea has changed from fighting a global war to conducting surveillance, detection, identification, classification, and interdiction of maritime threats. Protecting the marine environment from a host of threats increases in importance daily.

Against this background, a number of trends that will eventually become the history of hydrography can be discerned. Globally, they include an increase in co-operative efforts by teams from several nations to map substantial areas of the sea floor, the declassification of data collected during the cold war, the conversion of the military mapping machine to civilian uses and the declaration of special or protected areas, leading to detailed mapping of localized areas. Trends driven by technology are based on microelectronics, positioning has become easier, faster and cheaper. This leads to higher expectations of the information that can be extracted from the data at higher rates of data processing and higher density bathymetric methods. The desire by Coastal States to claim an Extended Continental Shelf under Article 76 of UNCLOS will lead to a new focus on the Continental Slope, a part of the sea floor that has not received much attention in the past. The requirement to map the 2500m contour and the Foot of the Slope may lead to refinement of the ability to discriminate small features at great depths and will lead to the development and application of statistical models of the Foot of the Slope. The need to determine the nature of isolated elevations adjacent to continental margins and to determine sediment thickness will require collection of more seismic data.

This paper reviews these trends and predicts what the history of hydrography in the first part of the twenty-first century will be, when it is written.

Introduction

As we stand at the beginning of a new hundred years and look ahead, it is useful and perhaps salutary to imagine what our predecessors in the year 1900 might have thought. They lived in an age when many ships were still propelled by sail, and those that weren't were driven by coal, an age when depths were measured by mechanical means, when it was not known if there was land in the Arctic Ocean and neither Pole had been reached, there was no radar, no one had yet taken a heavier-than-air flight, there were few weather forecasts and no ice patrol to protect seafarers, magnetic compasses were good to a few degrees...From our vantage point this appears a primitive, almost dark ages, scene, and we might be tempted to pity those ancestors of ours. We shouldn't; they certainly didn't pity themselves. Just the opposite, they believed that they lived in an age of incredible achievement and accomplishment. They speculated about whether any more progress could in fact be sustained. At sea, ships were able to position themselves to the incredibly high accuracy of 2 or 3 nautical miles, great telegraph cables spanned the mighty Atlantic allowing messages to be passed in minutes rather than weeks, fresnel lens threw light many miles from lighthouses that were miracles of building construction in inhospitable places, warships could travel at over thirty knots, Marconi’s radio sets were beginning to send streams of dots and dashes from ships at sea, routes were slashed by the construction of canals at Kiel and Suez, naval forces were being equipped with submarines, Zeppelins seemed poised to take over the air...Indeed, those forbears had much to be proud of.

It is very humbling to think that we may be viewing the world with a similar outlook. It is perhaps arrogant to even try to write the history of hydrography for the future when we have lived through so many changes, and seen the pace of change accelerate in the recent past. Could anyone imagine in the year 1900 that we would be standing here in 2000 totally accustomed to MBES logging data on something called a computer positioned to within a few centimeters, collected from vessels that could operate in all weather? Could anyone imagine that submarines could traverse the Arctic Ocean beneath the ice at speeds that few surface ships could match, while logging more soundings in an hour than existed in the entire world of 1900? Could anyone imagine mapping the seafloor using a light from the sky or from space? Could anyone imagine printing charts as they were demanded and not printing them for stockpiles? Well, yes, it turns out that, here and there, a few people a hundred years ago could imagine some of these things. Searching for their modern-day equivalents will be one of the tools we try to use in this paper.

We can also examine present-day trends and extrapolate from them, but this takes us only a short way along the road into the future, since the great steps ahead come not from following trends but from leaping into a totally new path. For example, in 1900, sounding machines were being refined with larger winch drums, less resistant bearings, finer wire and better brakes, but it was not untill a totally new approach, using sound energy, was developed that hydrography leapt forward. Those toiling on the sounding machines would be toiling still and ocean mapping would have advanced very little, had only the trend been followed. But something always precedes a new trend. In 1824, the velocity of sound in water had been measured, although not with any intent towards measuring depths thereby. There is early work done in most scientific and engineering fields before a new approach receives major attention. ((And there are other harbingers, too: the arts. e.g. Jules Verne imagined submarines like the current nuclear-powered vessels long before they were built.))

So we will try to write future history from examining trends, work on the fringes, and perhaps the arts. We are aware that we are not historians and that professional historians warn that recent history is difficult to write, because of the problem of distinguishing significant from insignificant events, some of which we experienced ourselves and are consequently may not be able to view objectively.

Uses of The Oceans

Fishing

The fishing industry will still be a major user of oceans. The collapses of certain stocks in the latter part of twentieth century will have forced painful lessons on this sector. Living resources are not limitless, but with careful husbandry, will provide constant amounts of food. The transition already underway from hunting/gathering to farming/aquaculture/fish ranching will accelerate. This will create a need for mapping the suspended material in the water column beneath floating fish pens, and the ability to predict its movements. We are already seeing the benefits to scallop draggers from having detailed and accurate bottom composition maps (reduced time to reach quota, no equipment loss, no damaging of seabed that does not contain scallops which leads to increased yield). The next demand from this group will be for a system that maps the shellfish themselves and not 'merely' the sediments they live in. Those who still hunt large schools of free-swimming fish will want real-time maps of the schools as they move in relation to the nets they have deployed. And how about a mapping system that would show the approach of predators to the school, so that they could be protected (like shepherds protect flocks of sheep).

Shipping

During the twentieth century, the world's bulk goods were transported primarily by ships. About half the tonnage currently transported is oil, but if another source of energy is found, there may be no oil tankers a hundred years from now. Other bulk cargoes include coal, both for energy production and for steel making. Both uses could be eliminated by paradigm shifts in their fields. Ores themselves make up another type of bulk cargo: the need to transport them could be eliminated by the development of refining processes that treat the ore at the mine, even underground for environmental friendliness.

During the first 60 years of the 20^{th} century, thousands of passenger liners carried human cargoes as great waves of emigration reshaped the planet. There are no liners today, and for decades there were few passenger ships, but cruise ships are growing in size and number yearly, and fast passenger ferries are plentiful. One niche of the cruise ship market comprises cruises to out of the way places, or in hydrographic terms, places that have not been surveyed. Should Hydrographic Offices (HO) concentrate resources on surveying for this type of traffic, or will it be a short-lived fashion?

Throughout the twentieth century, hull sizes kept increasing, not in a smooth curve, but one with steps, as drafts (or draughts, depending on one's history) were restricted at times by shipping lines wishing to use major canals. Simple economics indicates that at some point it is more economical to build ships too large for canals but which make more money through their capacity, even though they have to travel a greater distance. Will the trend to deeper drafts continue, or will new hull designs that need less water appear? Of course, the opposite could occur, with huge submarines, which have been forecast from time to time, making an appearance.

Another trend throughout the last century was the reduction in the size of crews, one manifestation of automation. Work has been proceeding on the "one man bridge" for some time, and it is likely that before long ships will need crews on board only for docking. Otherwise, they can be remotely operated or even self-operated; this would require a paradigm shift in charts since the information formats needed by robot ships and computers is vastly different from the perceptual information processing of human navigators.

> Men might as well project a voyage to the Moon as attempt to employ steam navigation against the stormy North Atlantic Ocean. Dr. Dionysus Lardner (1793-1859), Professor of Natural Philosophy and Astronomy at University College, London.

Water

Throughout the twentieth century, hydrography concentrated its efforts on the seafloor, as did marine geology and geophysics. The water was merely an annoying curtain that obscured the really interesting objective. Looking ahead 100 years, will the water become a more important resource than the seafloor? Some authorities predict the earth is running out of drinking water. If that should be the case, one source of potable water might come from converting ocean water. Mapping salinity could become as important as mapping the seafloor is now. Mapping for construction of de-salination plants, with their filtering beds, input pipes, and salt disposal zones could be a major hydrographic activity.

Coastal Zone

The United Nations (UN) predicts that by 2020, two thirds of the world population will live within 60 km of the coast, in what is often called the coastal zone, up from the current 50 per cent. This will probably lead to further activity in the near shore, from aquaculture to recreational use. There will be an increase in the demand for conventional hydrography services. However there is another, perhaps more ominous, possibility. Global warming is currently attracting a great deal of attention, although there currently is no agreement on whether in fact global worming is happening, or if it is, just what the effect might be. One consequence might be that the permanent ice caps might melt, and their volume might lead to flooding in the coastal zone. Consequently, there is an urgent need for more accurate and comprehensive tidal observations and better long-term sea-level trend models.

Weather Extremes

In 1990, the World Meteorological Organization (WMO) predicted that we were entering a great period of weather upheaval. Every type of weather record will be broken worldwide until at least 2010, and extreme weather events will ravage the earth. The last ten years has certainly seen these predictions borne out. Although it has long been known that the oceans play the major role in world climate, it is only in the later part of the 20^{th} century that the intimate linking between oceans and atmosphere have begun to be understood. Given WMO's predictions, we would expect to see more energy being directed towards helping understand climate and the oceanic parameters that effect it. Tides and water levels are obvious candidates for more research. Mapping of ocean temperatures and deep ocean water-mass movements will become more important.

In those unfortunate areas that are struck by weather disasters, there may be hydrography work to be done. For example, flooding and high water levels can lead to landslides or rapid erosion and associated transport and deposition of sediments in new locations. Such events can bring major alterations to the floors of harbors and shipping lanes, and they will require rapid re-surveying and charting. Hydrographic teams capable of year-round, rapid response will be required.

Trends In Geomatics And Earth Sciences Observable In The Year 2000

Positioning

Establishing position at sea, especially when land is not visible, absorbed enormous resources during the 20^{th} century. In 1900, a ship might get a position to within a few miles at noon, and perhaps during a starry night, if the clouds would let it. Because of a century's investment of so much human talent, it is routine nowadays to get a position within a few metres several times per second, and to measure a survey vessel's role, pitch, yaw, squat, heave and shifting of weight of the ship's cat to minute levels of error. Position fixing has become so good that it is starting to disappear from the conscious thought of most of us, and become part of the information infrastructure. (Analogy -100 years ago, making a telephone call was a major event – call times had to be booked, a lot of human intervention was necessary, few people were connected, and service was not reliable. Today it is easy from a jet liner, a vehicle that did not exist 100 years ago, 7 nautical miles high travelling at several hundred knots, to call someone driving a car on the other side of the earth, and have the bill appear at another location at the end of the month. And to think nothing of it.

> This `telephone' has too many shortcomings to be seriously considered as a practical form of communication. The device is inherently of no value to us. Western Union internal memo, 1878)

That's where positioning is going, and the trials and tribulations, the mental effort and the physical testing that got us this far will be largely forgotten ancient history.

This will effect hydrography as a data –gathering activity in forcing (push-pull?) more accurate data collection, permitting the development of new instruments that will be enabled by the ease and accuracy of positions, and in forcing a reassessment of all data collected by earlier means. Many areas will have to be re-surveyed, on the basis of the accuracy of the positioning systems used to survey them the first time.

It will also effect hydrography as an information-providing service. For most of the last century, hydrography was able to produce products that were more accurate than practicing navigators were able to replicate. That has all changed, since mariners have available the same level of positioning accuracy as do hydrographers. At present, the accuracy available on a vessel may be greater than that shown on the chart, most of which carry an inheritance from an earlier, less accurate age. Hydrography will spend a lot of energy during the first part of the new millennium rebuilding this chart suite to match the accuracy of positioning now available.

GIS and Spatial Data

Over the latter half of the 20th century, as part of the information revolution, the special-ness of spatial data has underpinned much of hydrography's thinking about how to manage the data we transform into information. Because it consists not only of a value, but of a location as well, it has required different treatment than has non-spatial data. To deal with it, the specialty field most recently called GIS, was developed. What is the future of this activity? There are signs that it may be losing its uniqueness, in that spatial elements are being added to common software (e.g. the popular spreadsheet, Excel, will produce maps from spreadsheets at the flick of a finger, e.g. AutoCAD, the mechanical design software has added a mapping component. E.g. Matlab has a mapping add-on...list is probably longer). This may mark the beginning of a trend that will see GIS disappear inside other software.

Sea-floor Mapping

Throughout the 20th century, progress in sea floor mapping is best expressed in terms of the wavelengths of features that could be resolved (Figure 1) Mechanical sounding to single beam to multi-transducer boom-sweep systems; multibeam sonar systems; airborne laser bathymetry; and airborne electromagnetic bathymetry have recently been developed, which for the first time permit close to 100% coverage in mapping the seabed. At the turn of the millennium, ocean mapping can produce complete pictures of seabed topography, providing products better in many ways than 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, gravel, cobbles, boulders, bedrock, carbonate, silica, etc.), and textural classification (characteristic roughness length based on grain size and geologic and hydrodynamic processes at work on the seabed, e.g. bedforms, furrows, etc.). Ocean mapping now deals with what the seabed is made of, as well as where it is located. So what's next? Getting all the world mapped to this level, as proposed in the GOMap project. Increased resolution? Resolution, backscatter and penetration in one image.

Electronic Charting

Hydrographic charts were more or less invented during the time of Cook, more than two hundred years ago. Since then there have been incremental improvements, but no real paradigm shift or breakthrough occurred until the recent development of ship-based "electronic charts". These are very much in the teething stage and their development is being hampered by people trying to apply the new technology to the old product. Once this phase is over, and there are some encouraging signs, they can move towards their true potential. For example, the incorporation of real-time tidal information will allow vessels to navigate more closely to the bottom than they could on a static paper chart showing depth below datum. Extending the system to include real-time sea-level information will make it possible to include less predictable effects associated with winds and freshwater runoff. In areas where under-keel clearance is critical, the enhanced efficiency and broader navigation windows offered by enhanced real-time information will be of significant commercial benefit.

The next generation of electronic charts might include real-time information on currents in coastal areas, a more complex environment than a tidal river. A measurement system capable of providing a map of surface currents at sufficient spatial and temporal resolutions for navigation already exists. It uses HF radar (frequencies of 3-30 MHz) backscatter from the sea surface to infer surface currents from the Doppler shift of surface waves. Surface current measuring radar systems offer a flexible, practical tool for enhanced navigation in open coastal waters, for tracking oil spills and surface debris, or, in an air-sea-rescue mode, the path of disabled vessels or drifting shipwreck victims at sea. HF radar will soon become a standard instrument in the oceanographic tool-box.

High resolution in space, ability to follow changes (resolution in time), and information – packed visual presentation are the real potential of the electronic chart. Mariners will only realize the benefits they can bring after the current phase of development ends and moves to the stage of truly capitalizing on the new power.

Communication

Publishing (of journals/ charts/ tides)—internet interactions, wireless internet, internet on ships

The changing learning environment –schools, computers, virtual classrooms

Growing awareness of value of intellectual property

Remote Sensing Information

Satellite and airborne imaging technology impacted hydrography over the last few decades of the 20th century, although not to the extent their adherents would have liked. Sea surface monitoring used to be one outcome tide-gauging but recently satellite altimetry has been applied, particularly in the open areas of the oceans. Satellite altimetry measures features of the ocean surface as small as a few centimeters in height. Mapping these features reveals the existence of long wavelength seafloor topographic features, provide details about dynamic behavior of the ocean, such as tides and currents, and about weather and climate. Sea level monitoring is also very important for land positioning (heighting) and is consequently invaluable to geodesists attempting a more accurate determination of the geoid. The determination of Sea Surface Topography at coastal tide gauges is now considered to be one of the most challenging problems of geodesy. This will continue into the first few decades of the new century.

Shoreline mapping, or ‘shorelining’, has always been problematic, aided in recent years by the declassification of high-resolution remote sensing technologies once reserved for spy satellites. As footprints become smaller, resolution increases, and occasionally new features like small islets are discovered. As this trend continues it will be possible to map coastlines and other features to a level of detail where erosion to be monitored, changes due to coastal construction mapped, and the mapping and monitoring of other ocean environmental changes will become possible.

Economic pressures will increase the use of satellite-collected data since it is relatively cheap compared to many "in situ" measurements.

Pace and rhythm

Pace and breadth of development and discovery much greater during 20th c than at any other time in history. Can it continue?
Factors that slow down acceptance of new developments
Paradigm shifts
Internally, time-varying levels of energy applied to development in surveys, in cartography, in data bases,
Diffusion of technology from military to civilian, space and aviation to marine –will this continue

Organizations and Societal Attitudes

Organizationally, moved from individual labs to big science –what will come next, virtual labs or virtual Ocean Mapping Groups
A few companies ruling the world? What does this do to the insurance of ships – forget IHO and IMO, its really Lloyds of London that controls world shipping.
Will there still be navies and what will they be doing?
Improve co-ordination of data collection and assembly into common data bases
Genuine co-operative efforts by teams from several nations to map substantial areas of the sea floor
Dying echoes of the cold war lead to the release of previously classified data.
Data collected for commercial purposes increasingly used for other purposes
Conversion of Military Mapping Machine to Civilian Uses

> e.g. Call by USNO for co-operative multibeam mapping of world ocean (GOMap)
> e.g. SCICEX, using an attack submarine to collect public domain data under the Arctic ice

Declaration of Marine Protected Areas leading to detailed mapping of localised areas.

Attitudes

Changes in attitude e.g. 1960s change from 'the earth is here for us to use and abuse' we are only stewards of the earth and must pass it on to future generations' (started with Carson's 'Silent Spring"?) Hydrography at beginning of 20th century had role of exploring new areas and opening shipping routes so the earth could be exploited. We have learned since then. Sustainable development. Marine protected areas. Hydrography's role becomes one of helping protect the environment through showing safe routes to shipping and providing part of the information necessary in a clean-up response.

Ratification of UNCLOS

Ratification of the United Nations Convention on Law of the Sea (UNCLOS) brings to some thirty to sixty Coastal States the opportunity to claim a juridical continental shelf during the early years of the century. However, this will not be trivial and will require a great deal of seafloor mapping by hydrographers and geologists. Geographically, there will be a new focus on the Continental Slope, part of the sea floor that has not received much attention in the past. Because of the sheer size of the area, there may be a requirement to blend older single beam depth data with new multibeam data. Article 76 will change the emphasis in deep water portrayal from contours displayed as morphological form lines indicating the geological nature of the sea floor to an accurately located, rather than shaped, 2500m contour. The Foot of the Slope is now legitimised as a legal feature and must be mapped which may lead to refinement of the ability to discriminate small features at great depths and will lead to the development and application of statistical models of the Foot of the Slope. Isolated elevations adjacent to continental margins will have to be examined to determine whether they are continental or oceanic in origin. There is a serious need to collect seismic lines extending from the continental shelf to the deep sea to determine the 1% sediment thickness line. With the expected acquisition of new data in a little-known zone comes the concomitant need to develop and maintain a supporting data base infrastructure that will be subject to audit by the UN. This may be a more stringent requirement than any previous database has had, since organisations could set their own standards. They still can, but the desire to produce data bases that will be approved by the Commission on the Limits of the Continental Shelf (CLCS) may lead to greater International standardisation of data formats and data bases.

UNCLOS will impact Ocean Mapping at all levels:

Organisationally, with greater co-operation between nations

Professionally, with more cross-fertilisation, more disciplines involved

Scientifically, ranging from new discoveries on the continental slope to the development of new mathematical models

Technologically, with the refinement of instruments to work at Slope depths

Standards, with International standards being refined

Infra-structure, since data bases will be made more inclusive and more robust.

For some states, this will represent a major International marketing opportunity.

End of the cold war—or the changing nature of warfare

Mine countermeasures. Route surveys.

The growth of customers who have no intention of using hydrographic products for navigational purposes

E.g. CHS sells a disproportionate number of tide tables, particularly on the Pacific coast, where many people use the shoreline and beaches for recreational purposes. This type of non-navigational client will increase, boosted by the ability to customize products for specific uses. Navigation charts, which for hundreds of years have carried the burden of trying to be one product for all purposes will be liberated and able to concentrate on the needs of navigation.

<u>Application of the development model from Monahan and Wells (this volume)</u>

In a companion paper, we examined the history of hydrography and ocean mapping in the 20th Century and derived an observational model that generally fits the events of the century as history records them. Since any development is a complex mixture of intertwined forces, the model cannot be deterministic. Nevertheless, it does contain a number of points that can be applied to predicting developments we might see in the coming century.

The two streams of progress, incremental steps and paradigm-shifting leaps, place different demands on forecasters. In the sections above, we have outlined some of the incremental steps that are likely to happen in the next few years by simply projecting the current situation and progress. Forecasting a paradigm shift cannot be done this way. Possibly it cannot be done at all. No one sat down in 1900 and said “I forecast that in a few years we will be measuring depth by sound”. However, they could have said something like “The present methods of collecting soundings are much too slow. Something should be done. I’d give my right arm to be able to collect 100 soundings an hour”. Supporters of the market theory of development would support attempting to make similar statements now.

Here are a few that might be precursors of paradigm shifts:

“The present speed of survey vessels is much too slow. Something should be done. I’d give my right arm to be able to sound at 100 km an hour”.

“The present methods of conducting surveys one year and producing charts of the area several years later are much too slow. Something should be done. I’d give my right arm to be able to issue a chart the same year as the survey is conducted”.

“The present methods of producing low water lines are much too slow. Something should be done. I’d give my right arm to be have a continuously up to date, accurate and detailed low water line for all Canada”.

“The present number of days hydrographers spend at sea are much too high. Something should be done. I’d give my right arm to be able to produce charts without hydrographers leaving the office”.

“The present methods of updating the charts held by our clients are much too slow. Something should be done. I’d give my right arm to be able to be able to update all the copies of charts every day”

“The present methods of performing quality control on hydrographic products are much too slow. Something should be done. I’d give my right arm to be able to quality control everything in a few minutes”.

We invite the reader to speculate on the paradigm shifts that could solve these problems.

The above is a list of problems looking for a solution. Are there solutions looking for a problem to be applied to? We said in the model “The theory that underpins a paradigm shift is usually worked out long before the shift occurs and then ignored or left to gestate until it fits in with the surrounding structures.” Is it possible to turn this around and ask what theoretical solutions are waiting in the wings? The following scant list is possible:

Machine vision research leading to truly autonomous survey vehicles packed with instruments or transport vessels or fishing vessels (or autonomous fishing nets?)

Miniaturization of instruments and computers, leading for instance to GPS receivers being embedded within paper charts or canoe paddles.

Ground effect vehicle principles being applied to ships resulting in zero draft vessels.

The shortness of this list shows why we are not millionaires!

Conclusions: Towards a Transparent Ocean

An echo sounder tells us little about the ocean: only the local depth. An echogram, consisting of repeated soundings drawn on chart paper, tells us a lot more: it offers a profile of the ocean bottom, distorted perhaps, and of low resolution, but with significant visual content. Attempts to extract texture information from acoustic echoes now lead, after much processing, to interpretations: sandy, rocky...etc... Once the processing becomes rapid enough to be performed in real-time, the ideal output would be an image of the bottom. The acoustic signal would contribute only to a characterization of bottom type. The visual representation would come from the processing unit which would have in store a series of images corresponding to each bottom type. Imaging is the way towards transparency. Refraction and losses limit the range of image-forming acoustic systems. Nevertheless, side-scan and multibeam systems already provide some imaging capability. Developments in acoustic instrumentation, signal processing and data compression, underwater navigation and new technologies offer the hope that we will come to an age when the ocean will be no more opaque than the night. With the right equipment, one will "see" through it.

Acoustic systems that sense and adapt to the propagation properties of their environment; high data flow techniques; wavelet-based data compression; optic-fiber networks to observe the deep ocean - these are all technologies which may contribute to making our waters more transparent.

> It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow. Robert Goddard, rocketry pioneer (1882-1945)

Examples of other brave or foolhardy souls who tried to predict where hydrography was going (a.k.a. References)

Bond, B A. (1996). Strategic considerations for international hydrography in the 21st century. *The International Hydrographic Review,* September, Vol. LXXII, No. 2, pp. 7-15. Social predictions, not technical "If HOs do not find a way to respond to the market in a timely fashion, they will be progressively marginalised by commercial forces..." retrain staff, private sector involvement, cost recovery, doubts that data will be freely shared in future

Collier, M. L. (1975). Hydrographic survey systems for the 1980s — A technological forecast. *The International Hydrographic Review,* January, Vol. LII, No. 1, pp. 129-136. Forecast use of computers, microelectronics, OK, but also use of video to collect data and as a product to distribute. Data handling by computer "but for reasons of economy and convenience, computer compatible data will be supplemented by microfilm and video tape"

Douglas, G. R., and S.B. MacPhee (1986). Hydrography for the year 2000. *The International Hydrographic Review,* January, Vol. LXIII, No. 1, pp. 21-28.fast computers using AI will process sounding data rapidly, raw data communicated direct from collecting ship to shore-based (centralized or work at home confused) processing location. – increased use of remote sensing, especialy for shallow water, problems with managers who were trained one or two technologic generations ago not realizing the benefits of the new technology, digital methods will allow easy exchange of data between HOs, by 2000 large amts of data will be xmitted to ships at sea

Douglas, G. R., 1995. 35 years of hydrography: reflections on adapting to change. Proceedings Hydrocom discusses Canadian government policies, 1960-2000, CHS organizational changes in same period (like switch from compilation and drafting as separate tasks to marine cartography), overall technical changes

Hamilton, Angus, 1976. Surveying 1976-2176. Proceedings, Amer, Congress on Surveying and Mapping, Seattle, pp269-278. Predicts that emphasis in surveying should evolve from data colln to data management. Highly integrated GIS with many applications. Exchange of information with position attributes through a 'clearing house' (Angus says today that he was far too timid in his predictions)

Huff, L. C. (1981). A study of future depth recorder requirements. The International Hydrographic Review, July, Vol. LVIII, No. 2, pp. 33-40.

IHO CHRIS Technology Assessment Working Group (TAWG) 1997. Emerging Technology & Applications". They forecast the following
Top Ten Emerging Technology Trends

1) Encryption Standards
2) Electronic Docking Aids
3) Pilot Carry-On ECDIS
4) Technology For Fast/Cheap Surveys
5) Print On Demand
6) Forecasting Real-Time Under-Keel Clearance
7) Real-Time Chart Functions
8) Authenticating Electronic Data
9) Computer Assisted Compilation
10) Real-time data (water level, ice, weather, …)

(Not surprisingly, their mandate was to study encryption standards...)

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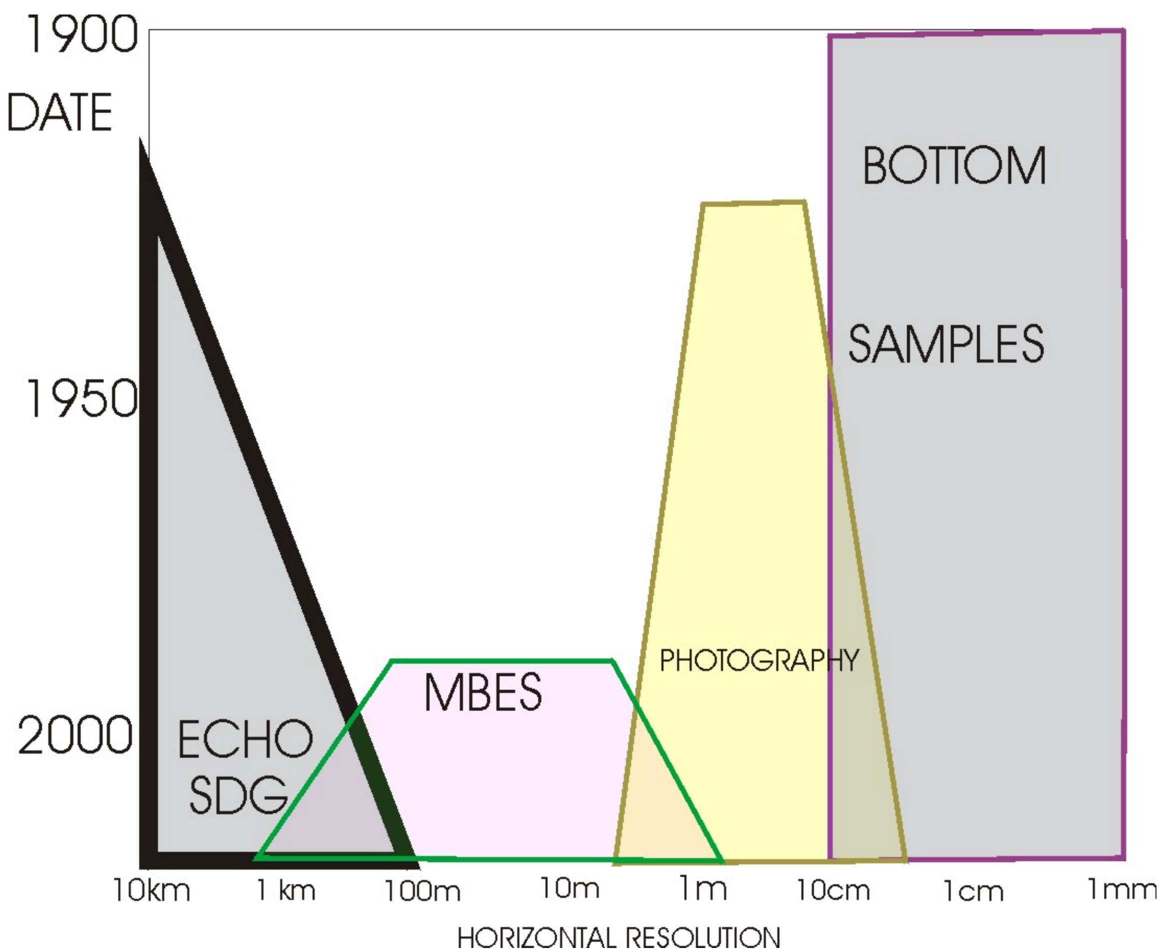
Ocean Mapping Group, University of New Brunswick, 1999. Challenges and Opportunities for Ocean Mapping in Canada. Report submitted to Oceans Policy Secretariat, Department of Fisheries and Oceans, Ottawa, Contract FP 802-8-0592

Figure 1 showing increase in resolution of seafloor features over time –side scan should be added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HORIZONTAL RESOLUTION