Technology Push, Technology Pull and the History of Hydrography in the Twentieth Century

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Abstract

The phrase, "the history of hydrography " evokes wonderful images of survey vessels entering uncharted waters, of exploration and discovery in remote and unknown regions, of transforming the white spaces on charts into safely sounded areas. Stories of human courage, determination and perseverance are inspirational and indeed, influenced many of us to enter this profession. Besides exploring unknown geography, hydrography also pushes the frontiers of technology. Newly developed technology permits, even forces, increased endeavors in geographic exploration. This paper presents an overview of the technological history of hydrography during the twentieth century, and at times is forced into the nineteenth century to do so, and relates advances in technology to the field of hydrography and the society it serves.

Introduction

There is a real danger that this type of paper could be simply a recital of events of the last century, a timely and hopefully worthwhile resume of the last hundred years of progress. We found, however, in the course of preparing this paper, that there is so much more; we want to learn from the past century and, in a companion paper, apply what we have learned to predicting the future. In this paper we consolidate our observations of development and innovation in hydrography and apply them to the history of hydrography in the last century. This application serves to refine and confirm our models, with which we proceed in the companion paper to predict the future. (Monahan, Wells and Hughes-Clarke, this volume)

We are keenly aware that everyone attending the conference has played a role in the events we outline here, as we have ourselves, and we have no desire to offend anyone by omitting parts of the story. We have attempted to distance ourselves from events in order to provide a balanced viewpoint. Certain events are not mentioned: since this may be through oversight, we would appreciate hearing of any that should be included should this paper be rewritten at some future point.

Table One is the beginnings of a compilation of events that have effected the history of hydrography. We do not refer to or explain every event listed in it; we provide it to establish context and give some idea of the range of events that have had an impact on hydrography. Recognizing that this table is not comprehensive, we would welcome any additions. There are a number of sources for the history of the elements in this table, and we do not intend to recite them here. Rather we are motivated by attempting to understand globally what has happened and using that understanding to help in predicting the future.

The elements that contribute to the history of hydrography- a brief synopsis

Exploration and discovery

Even today, hydrographers are explorers, and the early explorers had to practice the hydrographers' arts. The beginnings of the 20^{th} century were dominated by geographical exploration; neither pole had been reached, for example, and there was still conjecture about whether there was undiscovered land near the North Pole. A great deal of exploration, perhaps crowned by Amundsen's 1903 voyage through the Northwest Passage, was undertaken. This was driven partly by the restless expansionism of the era, but more by the desire of the European nations to establish sovereignty and to open new sea routes to and harbors in, the new territory. It gave to hydrography more shoreline and some soundings. Perhaps more important, it left a legacy of believing that users of hydrographic products would have to be independent from all other support and that the charts and Sailing Directions and Tide Tables they carried with them would have to include every scrap of information that could possibly be of use. This type of thinking still dominates the design of hydrographic products, even though modern day mariners have instantaneous electronic access to more information than existed in the entire world in 1900.

There were signs of the communication revolution that was to come. Marconi had developed "radio telegraphy" and dots and dashes were beginning to occupy the airwaves. Human beings were beginning to occupy the air itself, and the new aviators pushed their machines greater and greater distances, exploring the seas from above, presaging the advent of remote sensing satellites in the 1970s. It is amazing to think, while leaving the flight deck of a survey ship in a helicopter, that less than 100 years ago, powered flight had not yet taken place.

As surface exploration became more and more complete, exploration of another dimension began to grow, with the sea floor itself receiving more attention as the shorelines that surround it were more completely mapped. Echo sounding was developed, submarines and bathyscaphs were perfected, scuba was invented, and underwater photography permitted exploration of the undersea. Nuclear powered submarines navigated to the North Pole in 1957 and circumnavigated the earth while remaining underwater in 1960.

Just three years before, a very different vehicle also circumnavigated the earth: mankind ascended to new heights, heralded by the faint beeps from Sputnik. Three years later, the first weather satellite was launched, and ships at sea became a little less isolated.

By 1984 there were 1462 satellites in orbit, and some of them shared with ships and aircraft instruments that explored the ocean floor's composition through indirect measurements. To supplement these, the Deep Sea Drilling Project (DSDP) project was launched in 1968, recovering samples from within the floors of most areas of the oceans. Indeed, exploration was so complete that it became difficult to find a "first": some of us participated in Hudson '70, the first circumnavigation of the Americas.

And what of the early motivator, the desire to establish sovereignty through exploration? It manifested itself in the United Nations Convention on Law of the Sea (UNCLOS) which gives approximately one third of the sea floor to Coastal States as Exclusive Economic Zones, and opens the door for 50 or 60 of them to claim vast continental shelves.

The changing nature of shipping and transportation

At the beginnings of the twentieth century, shipping was guided by the fact that once ships dropped out of sight of land, they were small universes of their own, and the Captain was Captain "under God". And once the shore did drop below the horizon, they were navigated to positions that were often in error by many miles. Yet over that horizon, very early in the century, appeared flying machines. And something else: radio waves. It was not long before ships were communicating with land, and as early as 1904 an International Distress Signal was adopted.

Shipping grew in volume and ships grew in size. Great canals were dug to shorten shipping lanes. Gradually, safety was improved, ranging from the International Ice Patrol to lighted buoys. Radar was introduced in WW2 and shortly after hostilities ended, in a major philosophical departure from the Captain "under God" concept, was installed in ports to control the shipping in the approaches. Ships became larger and larger, crews smaller and smaller and some cargoes more and more toxic.

Technological Changes and Hydrography

As the century began, mechanical sounding was in the incremental refinement stage, with improvements coming from using different types of wire, for instance, and positioning was entirely visual. The exigencies of WW1 intensified the development of underwater acoustics and by the early 1920s, "continuous" echosounder profiles across the oceans were making news. As well as revealing new features on the sea floor, these early echosounders discovered a new phenomenon in the water itself, the Deep Scattering Layer. This was the bane of deep-sea hydrographers for years, but a boon for marine biologists. Positioning remained visual until WW2, when a number of electronic systems were developed, initially to assist in positioning aircraft on bombing raids. After hostilities ceased, a number of these were declassified for civilian roles, and non-visual positioning permitted the extension of hydrographic surveys to the edges of the continental shelves. Echosounders were refined, and eventually pointed off-nadir, leading to sidescan and multibeam. Satellite positioning evolved to the present state of providing sub-meter positions everywhere in all weathers. Data in ever increasing quantities were processed and stored, and new products in the electronic chart family produced from them.

What we have observed about the Generalized Development Process

In this paper we attempt to assemble an understanding of a vastly complex topic and how it interacts with the society it serves, even though we know that all models, including this one, are oversimplifications. We do so in the belief that the model we develop will be useful, ‘warts and all’. What we present here is preliminary, based primarily on our experiences.

Development

The process of development has been studied extensively and literature has grown up around it. Naturally, there are proponents of different theories, some of which support one another some of which are opposed. We synthesize these together with our own experiences below.

General Model

1. An established or known field progresses incrementally in successive steps. (*e.g. just about everything)*
2. Suddenly, out of the blue, something so drastically different appears that it produces an entirely new field, which will henceforth proceed incrementally itself. This has been called a number of terms, with paradigm shift being the most resonant. (*e.g. the use of sound to measure water depth)*
3. Push and pull on the established field by the new paradigm can
    a) be fatal *(e.g. copper engraving for printing charts stopped)*
    b) cause established field to slow its development and plateau or stagnate
    c) cause the established field to speed up its development for a while
    d) drive the established methods into a niche *(e.g. sextants and celestial navigation still practiced as a recreation).*
4. There will be a time lag between introduction of “new” and leveling off of “old”, since
    a) adherents of “old” will push back by stepping up pace of its development
    b) it takes society some time to realize power and value of the “new”
    c) costs associated with moving to the “new” will pull back adopters

d) "old" may in fact improve itself and appear to keep its place for some time. (*e.g. Loran C in the face of GPS)*

5. Push and pull on the new paradigm by the established field can
   a) slow its introduction
   e) legislate it and confine
   f) kill it altogether.
6. Some people will never accept the new approach.
7. Some people will attempt to adopt the new approach to the old technology. *(e.g. in 1976, after automatic data loggers and plotters had been introduced, people were putting pocket calculators onto station pointers)*
8. Paradigm shifts can produce associated blind alleys that look promising but do not pan out. *(e.g. the success of deep-diving bathyscapes led to the development of navigation systems for them that no one wanted)*.
9. Any new development can be used inappropriately. *(eg multibeam in very shallow water)*

10. 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. *(e.g. Doppler effect described in 1842, used in 1957 to calculate Sputnik's orbit)*

11. An attempt at introducing a new paradigm before the necessary supporting technology or organizational structures are in place usually fails and has to wait until its time comes.

12. Developments don't always solve the problem the developer was working on, but do solve something useful. (*e.g. Bell was trying to invent a hearing aid, not a telephone e.g. after using ECDIS for a couple of hours to navigate with (its intended purpose), the officers of CCGS Griffon started using it to refine the models of the ship's handling characteristics issued by the ship's builder*)

13. Once it is apparent that the new paradigm will work, other producers are attracted to it and produce their version. There is often competition between different versions. *(e.g. in hyperbolic radio positioning, Decca and Consul slugged it out, with Decca winning the marine field*).

14. Solutions cause problems.

15. Paradigm shifts occur because:
   a) Market theory - the customers demand the new product
   b) Techno theory "because other technologies enable it (pull it)".
   c) Techno theory two "because other technologies create a situation that push to be addressed'.
   d) Mountain-climbers theory " because it can".
   e) Serendipity theory, "because, like, whatever".

We now illustrate this general model with examples drawn from hydrography's rich history. Note - Numbers refer to those used in the general model.

Example 1 Measuring water depth

1. Depth was measured by hand lead in shallow water or by mechanical sounding machines, which were gradually improved through use of stronger wire or faster motors. 2. About 1913, Behm and/or Langevin arrived at the idea of using sound to measure water depth. (Paradigm shift). This was fatal to mechanical depth measurement (3a). Step 4 was accelerated by WW I, which demanded the use of sound to detect submarines, followed by seafloor mapping a few years later. We have no evidence of Steps 5, 6 or 7 operating in this case. Step 8 might be exemplified by the attempts to position ships by using two submerged sound sources at known positions projecting energy at known times. Theoretical work (Step 9) included the measurement of sound velocity in water in 1826 and the Curie's 1880 work on piezo-electricity in quartz. In 1838, Bonnycastle failed in his attempt to measure depth "by the echo" (Step 10). The problems caused by this solution (Step 13) have dominated hydrography development and include logging and recording data, the development of data bases, ...why did this shift occur? Probably because of 14 a and 14 b. Since then, echo sounding has established its own Step 1, progressing incrementally to higher ping rates, greater depth ranges, more focussed signals, and multibeam and side scan.

Example 2 Gyro Compass

Magnetic compasses progressed slowly during the 19th century. (Step 1). It could be argued, in battle ships at least, they in fact retrogressed. Construction of metal ships started in the early part of the century and by 1860 most of the navies of the world were equipped with ironclads. Compass designs which had worked in wooden ships became very unstable in these vessels, and corrective action seems to have been taken in a very desultory manner. Another technology impacted these compasses very forcibly, the introduction of the torpedo. Torpedoes could be launched at night from small boats or submarines. To defend against these, navies began equipping their battle ships with search-lights, but search lights needed electricity. The equipment used to generate electricity in those days radiated enough emf to throw the magnetic compasses off by as much as 45 degrees! Navies were aware of this problem and reacted by putting some efforts into incrementally improving the existing magnetic compasses. Now the story gets more interesting. At the turn of the century, becoming the first person to reach either of the poles was a major motivator among adventures, a young German, Anschutz-Kaempfe, decided that the best way to get to the north pole would be by submarine operating under the ice. Aware that a magnetic compass would be useless near the geographic pole, he began trying to develop a gyro-compass. He found that the theoretical work had been done fifty years before by Foucault who in 1852 foresaw their development (Step 9), but did not build one, although there were lab experiments intermittently in the intervening years. By 1908 Anschutz-Kaempfe had a production model in use by the German navy who he was able convince to buy because the problems with magnetic compasses on battle ships discussed above had not been solved by incremental improvements. (To the navy, this was a Step 2 paradigm shift.)

The impact on the established technology was Step 3b and 3d, there being some improvements to magnetic compasses, which were driven into the niche of providing backup on larger vessels as well as use on smaller vessels that could not afford a gyro. The time lags of Step 4 effected other navies, some since they could not appreciate the advantages of using a gyro, others who would not buy equipment from a nation whom they viewed as a possible hostile. In a way, Step 11 was true for Anschutz-Kaempfe, who never made his voyage under the Arctic ice, yet did provide priceless benefit to mariners everywhere. As to the causes, the market was eager for the product once developed (Step 14a?), and in the market other technology had created a situation that had to be addressed (Step 14c).

<u>Example 3 Survey vehicle speed</u>

Now an example of a field that has not yet achieved the levels of success desired by its protagonists. It has been long recognized that one of the serious limitations to mapping the seafloor is the speed of ships, or more accurately, the speed of instruments that are measuring the bottom. In the age of mechanical sounding, the vessel had to stop for deep soundings, and could move only slowly while obtaining soundings in shallow water. (Step 1). Echosounders meant that the vessel could move continuously and cover much more of the seafloor per unit time. (This was a step 2 advance). Increasing the speed of the survey vessel (Step 1) has brought benefits, but echosounders do have a limitation on how fast they can move while still receiving good signals. Attempts at overcoming this limitation lead to investigations of the contributing factors which led to improvements like mounting the transducer on a ram to get it below the surface cavitation threshold, which did permit the instruments the capability of operating at higher speeds than normal survey vessels are capable of. Additionally, attempts to use the echosounder in faster vehicles were made (ie attempts at step 2). For instance, CHS has towed transducers from helicopters, mounted them on hovercraft, and installed them in the floats of seaplanes, with limited success.

Another way round the limited speed of vessels comes from turning the sound beam away from the vertical. Both side-scan sonar and MBES cover vastly greater areas of the seafloor at the same vessel speed than can a single beam sounder, although solving this problem was not the intent of their original designers. (Step 11)

How about a different instrument in a different vehicle? The obvious choice is aerial photography and as early as 1924, the International Hydrographic Review makes the enigmatic statement that “photographic exploration of the sea-bottom from aircraft is still in the experimental stage”. Air photo mapping of shallow waters has been tried repeatedly, and with each advance in airphoto technology, retried, but with very limited success. Visual detection of shoals and “bombing” them from helicopters does work, however. The poor results with passive photography led some researchers into applying the active technique of LIDAR, which has been made to work to depths of 50 m or more (Step 2). It is interesting to ask why it has not been more widely accepted than it has. (Step 5)

This section would not be complete without mention of the fastest vehicle of all, the earth orbiting satellite. From these, the entire world ocean can be scanned to some resolution in a matter of days. The most successful application of them to mapping the seafloor comes from the Seasat altimeter, which measures the height of the sea surface. Off the continental shelves, this is found to conform to the topography of the seafloor at longer wavelengths. (Step 2) These findings were bitterly opposed by some traditional blue-water marine geophysicists. (Steps 4, 5 and 6).

Overall, despite these advances, most mapping is still done from ships and launches.

<u>Example 4 chart standardization</u>

An example from charting. Until the 1920s, nations produced their own charts according to their own rules, or in some cases according to the rules of one of the charting offices that had assigned themselves a worldwide role. (These were often the colonial powers – Canada modeled its charts after those of the UK, for example). Consequently charts had a different appearance in different parts of the world, with colors, symbols and means of portrayal all varying from country to country. They were often not drawn to the same reference system, since the Greenwich Meridian was not adopted as the world standard until 1912. The buoys and daymarks installed by the Coastal States were not of uniform color or construction. Looking back, this appears chaotic. How did it change? In the 1920s, aircraft developed to the point where they frequently traveled over the sea. They needed maps or charts of shorelines and observable features, and some HOs responded by making aeronautical maps of coastal areas. Because the speed of the aircraft was so much higher than that of shipping, it was recognized that there may not have been time to switch between the many different symbols produced by different countries, nor the room in aircraft to carry all the dictionaries and reference material necessary, and the drive for standard symbols was launched. (Step 2) The obvious advantages in safety allowed this to overflow into nautical charting, where it continued to advance incrementally for many years. It is still going on. The adoption by the IHO of WGS 84 is one example (although not yet concluded, apparently, since the International Union of Geodesy and Geophysics recommends the use of the International Terrestrial Reference System).

The advent of Electronic Charting brought the need to develop new standards. Initially, these were adaptations of the old and aimed at solely their appearance. There is a growing awareness that the power behind them is great enough to allow a paradigm shift into TVOs, and we await this development eagerly.

Conclusions

What is the most amazing thing about this past century? Is it the progress in mapping this world we inhabit? Is it going into a Toyota dealer in small-town Canada and asking for a part, and getting a part whose fundamental ore came from the Labrador, was transported by sea to Japan where it was turned into metal using coal from BC, also transported by sea, then the finished part was shipped back to Canada, arriving on time and within budget, in part because the sea lanes have been properly charted? Is it the fact that one of our grandfathers rounded Cape Horn in a windjammer and we did so in a diesel ship? Or is it the fact that we have imaged the far side of the moon to a resolution of one and a half metres, and the seafloor covering two thirds of our own planet to only 10 or 15 km?

What things do we leave behind with the passing century? Positioning problems - Positioning once produced poor results after great labors now produces incredibly accurate results at the flick of a finger, and soon won't even need the finger.

How fortunate we are to have participated in so much progress.

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TABLE ONE

YR	EXPLORATION	TRANSPORTATION	TECHNOLOGY	SCIENCE/ HYDROGRAPHY	SOCIETAL/ ORGANIZATIONAL
1800			Volta produces electricity from cell		Spanish HO founded
1801	Flinders-exp south Australia	Fulton builds first submarine			
1802					
1803		Fulton propells a boat by steam			
1804					
1805					
1806				Beaufort wind scale developed	
1807				von Humboldt's first book	US HO Founded
1808		iron anchor chains patented			
1809					
1810					
1811					
1812					
1813					
1814					
1815					
1816					
1817					
1818				Deep sounding in Baffin Bay	
1819					
1820				Marcet-water from all oceans same chemistry	
1821					
1822		Fresnel lens for lighthouses			
1823			Babbage calculating engine		
1824					
1825					
1826				sound speed measured in Lake Geneva	
1827					Russian HO founded
1829		screw propellor			
1830					
1831	Clark Ross -position of magnetic north pole			Darwin/Beagle voyage starts	
1832				Coriolis - force in ocean circ	US Coast Survey begins surveys
1833			Gauss Weber electric telegraph	tide table production starts	
1834					
1835					
1836					
1837			Morse electric telegraph displayed		
1838	US Exploring Expedition starts			Bonnycastle fails in attempt to measure depth "by the echo"	
1839	Erebus/Terror to Antarctic		Steinheil electric clock		

1840	Wilkes claims dicovery of Antarctica				Belgian HO estab
1841				Bessel elepticity of earth 1/299	
1842				Doppler Effect	
1843		first propeller-driven Atlantic crossing		Aime -detachable weight sounder	
1844					
1845	Erebus/Terror-Arctic Franklin	cable across English Channel			
1846					
1847				Maury-wind and current charts	
1848					
1849				Fizeau measures speed of light	
1850					
1851					Finish HO established
1852				Foucault forsees gyrocompass	
1853					
1854				Brooke sounding machine	
1855			Goebel electric light bulb	Maury Atlantic Bathymetry map	
1856				Maury "Physical Geog of Sea"	
1857					
1858		electricity in lighthouses			
1859		Suez Canal begun			
1860					Belgian HO estab
1861					German HO founded
1862					
1863					
1864					
1865		Atlantic cable completed		Clerk Maxwell "Treatise on electricity and magnetism"	
		first oil pipeline (Pennsylvania)			
1866		underwater torpedo			US Navy HOffice formally estab
1867					
1868					Hamburg Naval Observatory
1869		Cutty Sark launched		Saxby Tide, Bay of Fundy	
1870					
1871					Japanese HO established
1872				Portales map sediment US Atlantic shelf	
			Kelvin snding machine (mech-wire)	Challenger cruise begin	Italian HO established
1873			colour photographs		
1874				Dutch HO officialy established	Chilean HO Founded
1875					
1876			Bell telephone	Challenger cruise ends	Brasilian HO established
1877					
1878	NE Passage ?				
1879					Argentine HO established
1880			practical electric light		
			electrostatic generator		

			Curies -piezo-electricity in quartz		
1881	Jeanette drift in Arctic				
1882				failed attempts at uniform bouyage	
1883				term "oceanography" coined	beginning of CHS
1884					
1885					
1886					
1887					
1888	Nansen crosses Greenland		Tesla electric motor		
1889			Hollerith punch cards		
1890					
1891				Langley "Experiments in aerodynamics"	
1892		Deisel engine			
1893	Nansen Arctic ocean voyage	Corinth Canal			
1894	First landing on Antactica				
1895		Kiel Canal	Marconi, radio telegraphy		
1896				Rutherford magnetic detection of electical waves	
1897					
1898		Zeppelin airship	photos taken with artificial light		
1899		icebreaker St Petersburg	magnetic recording of sound	hydrophones to detect other vessels	
1900			Fessenden xmit human voice by radio		
1901		underwater bell bouys	Marconi message across Atlantic		Philippines HO established
1902		Pacific cable completed			ICES established
1903	Amunsen North-West Psg	Wrights- airplane		first chart published in Canada	Peruvian HO established
1904		panama canal started	telegraphic xmission of photo	GEBCO First Edition pub	
				International radio distress call CQD	
				RDF demonstrated	
				radar demonstrated but no buyers	
1905					
1906					
1907					
1908			Anschutz gyrocompass in use		
1909	Peary to North Pole		Bakelite (first plastic)	Carnegie' nonmagnetic ship built	Turkish HO founded
1910				Challenger reports pub'd	Prince Albert Oceanog Museum
1911	Amundsen South Pole				
1912	Stefansson Anderson, northern Canada			Greenwich adopted as reference	
		Titanic sinks -ice patrol founded			
1913			mass production Henry Ford	Behm Langevin echosounder	
1914		panama canal opened	Fessenden echos off iceberg and seafloor	Goddard rocketry experiments	
1915			radio beacons	Wegener -continental drift	US Coast Guard

					Established
1916			Langevin underwater ultrasonic source for sub detection		Uruguayan HO founded
1917					
1918					Estonian HO established
1919	Alcock Brown Transatlantic flight				
1920				radio-ranging	Australian HO established
				Polish HO established	Greek HO established
1921		Bluenose launched		Oberth "Rocket into interplanetary space"	IHB Founded
1922			first 'continuous' profile across Atlantic	echo-sounders in use	Croatian HO established
				corrn of copper plates by elctrolysis	Cuban HO established
				Yugoslavian HO established	Thai HO established
1923	first USSR polar station	autogyro principles	Venning Meinez gravity from subs	Bauer earths mag field	
1924	airship across Atlantic			Sweden latticed chart for D/F	Scripps adds oceanography
1925	offshore oil tapped-not sure of date or location		Baird -television		
1926	airship over north pole		Goddard liquid fuel rocket		
1927					
1928			geiger counter		
1929	flight over south pole		quartz-crystal clock		
		airplane flies on instruments			
1930					Woods Hole OI incorporated
1931	Wilkins sub under arctic ice to 82deg 15 North				
1932				gravity from submarines	Ecuadorean HO established
				Norwegian HO established	Icelandic HO established
1933		Flashing lights on bouys			
1934					
1935			Watson Watt radar		
1936		deisel electric ship		notices by wireless	
1937			nylon	airphotos for shoreline	
1938	round world flight			Spilhaus -bathythermograph	
1939			Sikorsky helicopter	Matthews Tables 2nd ed	
1940					
1941			Haas underwater photo	Iselin -Ewing Sound xmission in sea	
				LORAN begun (in secret)	
1942			electronic computer		
		turboprop engine	mag tape recording		
1943	St Roche northwest passage				
1944				Inertial Navigation Systems (in V1 or V2)	
1945					Indonesian HO established
1946			xerox	LORAN declassified	Syrian HO established
1947	KonTiki -raft Peru to Polynesia			Omega proposed	Suriname HO established
					Venezuelan HO established
1948		port radar (Liverpool)			Dominican HO established

1949				uniform bouyage adopted	Chinese HO established
					Pakistani HO established
1950					Korean HO established
1951					Egyptian HO established
1952					
1953					
1954		atomic powered subs			
1955				Two range Decca surveys	South African HO established
1956			work begins on visual telephone	Tellurometer	
1957	Sputnik			LORAN C	International Geophysical Year
1958	USS Nautilus under ice north pole				NASA established
					Nigerian HO established
1959		St Lawrence seaway opened		logging to paper tape	First Oceanog Gongress
1960	sub circumanvigates earth underwater		laser developed	hi-fix?	Surv Eng at UNB
	bathyscape to 35,800 feet	first weather satelite		container ships -when?	Iranian HO established
	US starts building Polaris submarines			over-ice surveys PCSP	
1961					
1962			Carson "Silent Spring"	folded small-craft charts	
1963					
1964	North Sea Oil Licenses			narrow-beam transducer	
				helicopter tows transducer experiments	
1965				Heezen and Tharpe map	Singapore HO established
				Minifix for inshore surveys	
1966	instruments land on Moon			Omega making regular xmissions	
1967				TRANSIT made public	
1968	DSDP Glomar Challenger starts			digitizing UKHO	
1969				Hovercraft survey trials	Malaysian HO established
1970	CSS Hudson circumnavigates the Americas				Fijian HO established
	moon samples brought back				
1971		372, 400 ton ship built			Colombian HO established
1972				HAAPS surveys	
1973					Danish HO established
1974				INDAPS designed and deployed	
1975				end of sextant surveys	
1976				GEBCO Fifth Edn	
1977					Algerian HO established
1978	solo walk to North Pole		oil drilling in Baltimore Canyon		Bahrainian HO established
1979				lidar in Canada	Papua-New Guinea HO
1980		Titanic found		Echo-sounding corrn tables. 3rd Edn	

1981					
1982				Congolese HO established	UNCLOS Signed
1983	Alpha Ridge Expedition		electronic charting begins?	IALA Bouyage system	Guatemalan HO established Trinidan and Tobago HO
1984			Macintosh computer	GEBCO Fifth Edition	Cyprian HO established
				WGS 84	Sri Lankan HO established
1985	vents in mid-ocean ridge			TIBS	
1986					
1987		SP 44, Edn 3	Sinclair portable computer		Tunisian HO established
1988		fiberoptic cable across Atlantic			Ocean Mapping Group Estab
1989				World Vector Shoreline	Mozambique HO established
1990					Tongan HO established
1991					
1992					Omani HO established
1993	SCICEX begins				
1994					UNCLOS Ratified
1995					
1996					
1997					Ukranian HO established
1998				SP 44, Edn 4	UAR HO established
1999					
2000				Long-range Real-Time Kinematic (LRTK) service	

THE ITEMS BELOW SHOULD BE ADDED BUT DATES UNCLEAR

INMARSAT

use of differential GPS for hydrographic surveying

The shape of the earth given by artificial satellites

Side scan sonar for hydrography

Data loggers

100% bottom coverage shallow water sweep surveys

Contours and contouring in hydrography

photobathymetry.

interactive compilation

Hydrographic survey bar sweeper

Determination of danger lines with a helicopter

DGPS

Detailed sea bed mapping for a pipeline

GIS-software for nautical charting

Inertial survey system (ISS)

Time varying objects

Range errors in microwave positioning systems

Dolphin

Discovery of black smokers

Pharmaceuticals from ocean			
Fisheries sonar.			
Satellite bathymetry			
Satelite positioning—			
Electronic calculators			
Representation of relief on charts			
Helicopters used in surveys			
Scuba gear			
civilian use of GPS			