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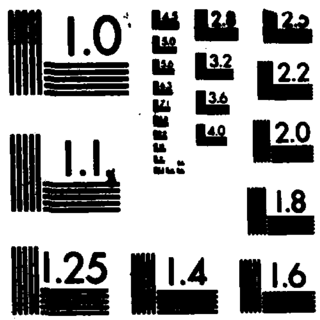

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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THE ELECTRONIC CHART

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ABSTRACT

All indications are that technology will lead mariners to seek newer and better ways to control their ships. By looking at some of the integrated navigation systems presently available, this paper attempts to look at the problems, some of the questions raised, and some rudimentary answers associated with the electronic chart. The subject is complex and there has not been enough public discussion to make many firm determinations. This paper is aimed at stimulating thought in an effort to get members of the hydrographic community to consider the electronic chart in their future planning.

INTRODUCTION

The future of the hydrographic chart will soon be greatly altered by the advent of the "Information Age." The paper hydrographic chart, as we know it today, may very well become supplanted by digital data displayed in a graphic manner on an electronic screen.

The electronic navigation chart is one of the multitude of new products which are being born as the result of the much heralded transformation from the Industrial to the Information Age. This paper will briefly investigate what this means to the use of navigational charts aboard seagoing ships. The idea for the paper came partly as the result of a paper given by Mr. Mike Eaton at the Canadian Hydrographic Conference in Ottawa, April 1983. In his paper he stated that we, as hydrographers, must begin to prepare for the advent of the electronic chart. At the time, I was involved in the definition of requirements for several automated chart systems and felt then, as I do now, that we were really too late in our preparation for this new age. While I don't pretend to be clairvoyant in this matter, I feel that there is an extremely good chance that all which I shall write about here will come true in the next ten to fifteen years. If this occurs, the hydrographic community must begin this very moment to prepare for it.

Automation is becoming more and more pervasive in our lives and it is beginning to revolutionize the management of vast amounts of information associated with various operations. We see computers monitoring various functions aboard ship from food messing and spare parts to cargo stowage and paymaster activities. With an integrated ship control system, the master of the ship of the future will do his navigation and plan his courses taking into consideration weather and seasonal routing, as well as monitor his fuel usage on such a system. Remote stations throughout the ship will enable the officers and crew to access the computer in either interactive or passive modes. One such advantage will be the availability to the Commanding Officer/Master of all important navigational information in his cabin at any time.

DEFINITION OF THE ELECTRONIC CHART

The definition of the electronic chart, for the purpose of this paper, is navigation information which is transmitted or presented in an electronic manner. At a workshop held in October 1983, in Baltimore, there was a wide-ranging discussion on the exact meaning of an electronic chart. The most important idea to come from these discussions was that the electronic chart is nothing more than a sub-subsystem to the navigation subsystem within some greater, integrated, ship control and administrative system. A line diagram of such a system is shown in Figure 1. In the overall scheme of things, the electronic chart will be only a small but very important part.

The navigation subsystem will be capable of integrating many navigational functions to provide the synergy so necessary in these days of information growth. It will be able to sort through the masses of information and cull out the most meaningful data for the solution of the navigation problem. This does not mean that data will be denied the user, it will only be sorted out. The user would be able to call up any information contained in the system and display it at will. The arrival of the Global Positioning System (GPS) on the scene will ease the positioning problem but there will always be a need for [redacted] methods such as [redacted], lines of bearing direct from alidades, or celestial sighting data direct from an electronic sextant.

One of the beauties of an automated system will be the capability for receiving, sorting, and incorporating data from the Automated Notice to Mariners System (ANMS), presently available from the Defense Mapping Agency (DMA).

There are, in fact, many examples of integrated navigation systems now under development or on the market. While they might appear rather innovative, they have only made a start. Some examples of these systems are, in alphabetical order:

> Bowditch Navigation Systems Corporation's <u>Bowditch Navigator</u> displays a microform image of a paper chart on a screen which is driven by radiolocation system inputs. It is used for navigating vessels in harbor. The Bowditch Navigator allows for an integrated approach by the incorporation of additional functions such as way point identification and location of vessel with respect to intended track.

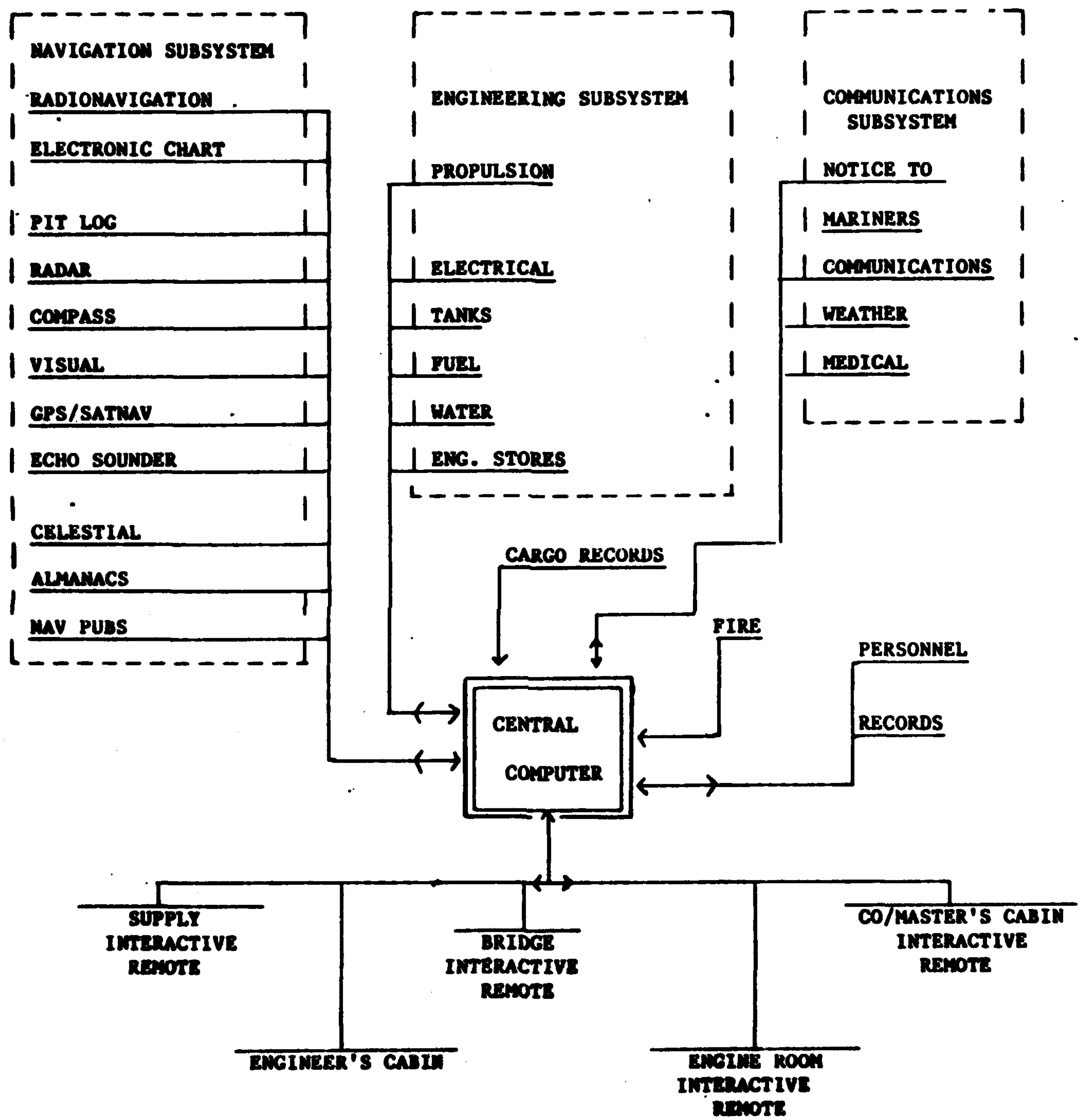

FIGURE 1. LINE DIAGRAM OF INTEGRATED SHIP CONTROL SYSTEM

The Command Display and Control System (COMDAC), being developed for the U.S. Coast Guard by Sperry, is an integrated navigation, collision avoidance and tracking system which displays an electronic chart on a cathode ray tube (CRT). This chart provides generalized features such as shorelines, danger bearings, channels and buoys. The system will combine navigation with tracking and recording capabilities to be used in multiple roles including the tracking and interception of lawbreakers, and the documentation and recording of the circumstances for use in any litigation arising.

The Hydrofoil Collision Avoidance and Tracking System (HYCATS), has been developed by Sperry for the U.S. Navy and is presently deployed aboard U.S.S. PEGASUS, a hydrofoil gunboat. It is similar to COMDAC, but is designed more for high speed navigation and collision avoidance. It uses either a generalized electronic chart or a televised paper chart as its base and combines it with radar into an integrated display.

Navigation Sciences Corporation's VIEWNAV provides the user with an electronic chart over which a ship symbol in accordance with a differential LORAN C signal. The chart presentation overlays the raster radar return at scale. The display is designed such that the radar return from the land and charted features is masked out by these charted features. There is no land return unless the feature has been digitized and a new pier, installed since digitization, would appear in a characteristic red alongside the digitized land color of yellow. An added capability is realized by the independence of the radionavigational data from the radar, thus allowing the user to check the two systems against each other. There are a number of integrated features such as way point location and location with respect to intended track. The VIEWNAV electronic chart has a presentation which is more like the standard chart than the last two examples.

In addition to the above systems, there are numerous other activities going on throughout the world in this field. The Japanese are presently developing two systems, while there are noises from Europe that similar activities are underway there.

FUNCTIONS OF THE ELECTRONIC CHART

There was general consensus at the October workshop that electronic charts must be compatible with radar scene displays. The capability to superimpose radar images on a chart allows great benefits in piloting situations and gives the integrated navigation system its greatest synergism. Because we are combining two presentations into one, there must be constraints on data density, format, colors, and allowable amount of textual information.

Electronic displays are presently limited by the relatively small size of the cathode ray tubes available. Future advances in large screen technology will allow significant improvements in presentation. Hughes Aircraft is presently working on a Plotter and Combat System (PACS) display for the Navy. The PACS will utilize a liquid crystal light valve to project an image on a 23"x31" plotting table from below. Such technology has developed a display one meter on the diagonal with an anticipated two meter (on diagonal) screen in late 1984. It should not be long before we shall see thin (about 2 inches thick) screens using electroluminescent technology. One such advance may come through the use of the currently-available liquid crystal plasma screens.

One thing that we as hydrographers will see from this surge in technology is a marked change in the representation of the information. Chart symbols will have to be modified to be more suitable for electronic display. The use of generalized depth contours, rather than spot soundings, will allow for a relatively clutter-free chart and the contour interval decisions will be made by the mariner. Certain ones may accordingly be emphasized to draw attention to specific ship draft or keel depth limits. With the ability to select the types of information displayed on the screen, the mariner may avail himself of the great potential for presentation of numerous categories of data.

The minimum data which should be available to the electronic chart user are:

-Shoreline, including piers, bridges and other cultural details necessary to safe navigation.
-Bathymetry.
-Shoals, dangers or selected isobaths.
-Channels or traffic separation schemes.
-Navigational aids including buoys, lights and marks.
-Radar and visually-significant features and topography.

Some of the additional functions which would have to be generated and overlaid on the electronic chart are the plotting of own ship's and other vessels' tracks (course, speed and closest point of approach), way points, danger bearing lines, set and drift calculations and similar navigational information.

One such function which is being considered by a manufacturer is the ability to cause lights and lighted buoys to flash on the screen with the same periods and colors as the actual lights themselves. With the selectivity functions, the user might "turn off" these lights to prevent distraction during daytime navigation.

The navigational chart must be current to be of use to the professional mariner. The electronic chart concept offers an outstanding solution to problem of keeping products up to date. With paper charts, the user is tied to the reprinting cycle or to hand corrections based on weekly Notices to Mariners. With the electronic chart, corrections will be made automatically through use of direct input from the Automated Notice to Mariners System. DMA is making Notice to Mariners information from its computer available directly to ships by way of Inmarsat and modems.

Above all, an integrated navigation system and the included electronic chart must be reliable. The systems themselves must be redundant to allow for breakdown. A viable alternative is to develop the systems in triplicate and monitor the solutions of each parallel system simultaneously. If one of the three disagrees with the other two, its data will be disregarded and an alarm given. Such redundancy is not beyond reason when one considers the plunge in computer prices and size over the past few years.

The integrated approach of these automated systems makes them desirable in situations where the full utilization of outside navigational aids is denied by the environment. In fact, one such system is already being considered by the oil industry in the Canadian Arctic where a need exists to combine navigational information with the latest weather and ice information in order to operate more effectively in that hostile environment. There, it is of critical importance for the navigator to be able to match radar with a charted representation of the land. Such techniques are of great value to navigators in areas were ice makes buoyage seasonably limited.

Any aspect of the maritime industry which requires some knowledge of the bottom topography and the water column will benefit from electronic charting. As implied above, the electronic chart may not look the same as the paper one which we know today. Certainly there will be plan views, but with the growth of three-dimensional displays for Computer Assisted Design-Computer Assisted Manufacturing (CAD-CAM), it will not be long before they will be available for fishermen, dredgers or submariners to fly across the bottom, avoiding danger areas such as wrecks and pipelines which would be specially portrayed. Such displays might also provide vital information to mine warfare forces. These displays might look like that shown in Figure 2. on the next page.

Two dimensional displays are already being used by fishermen on Long Island Sound and in Japan. Another use could be in hydrographic survey work where presently-held data could be displayed and real time surveyed information, corrected for sound velocity, tide and transducer depth could be compared. The advent of the Global Positioning System will greatly expand the possibilities for electronic navigation.

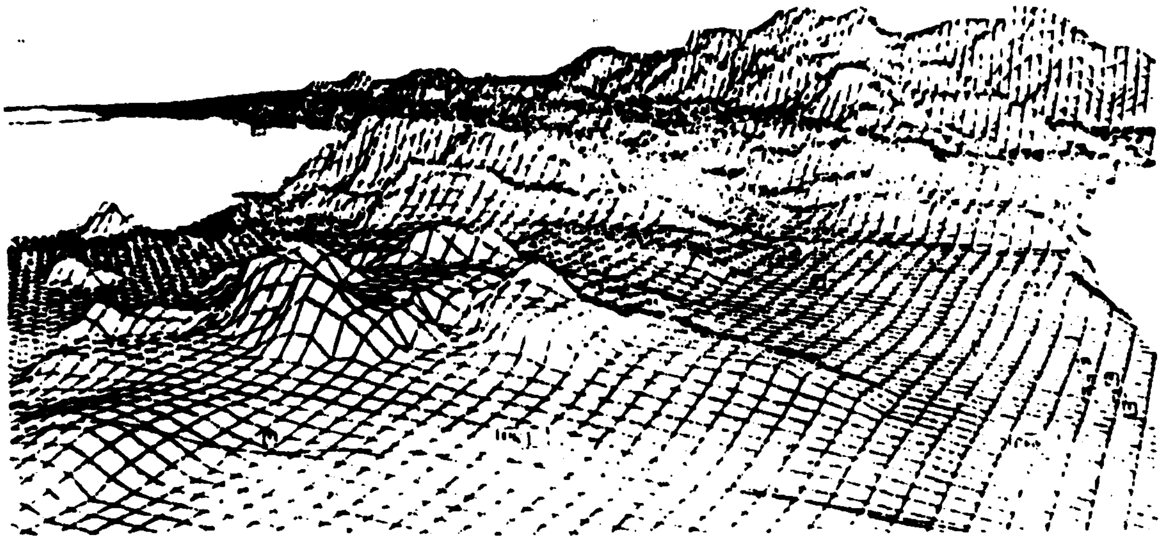

Figure 2.
Perspective View of the Ocean Floor

WHO DOES WHAT TO WHOM?

Generally speaking, we can say that there are three communities of interest associated with the production and use of electronic charts. These are the government, the value-added producers (or middlemen) and the end-users. Each of these communities are inextricably linked to each other and the responsibilities of one to each other are as yet undefined.

The first is the government, which because of the magnitude of the task and the expense of hydrographic surveying, is the major producer, collector, and producer of "raw" data. These data are incorporated in hydrographic charts which are generally produced by governmental agencies.

At present the government can be considered as a source producer for electronic chart data because all current systems are straightforward digitizations of paper charts. Such a condition cannot last long as integrated systems continue to proliferate. The effort to digitize data for the myriad possible systems will overload any capability to digitize in such an uneconomical manner. The only alternative for the governmental producer will be to generate omnibus data bases from which a standard number of digital data products will be produced. To do otherwise would result in the government expending vast amounts of money on numerous, system-specific digital products.

The format for these digital products must be very well thought out in order to provide the maximum of flexibility of use for the next user in line. Some consideration will have to be given to how updated information will be passed through the different stages to the end user.

Determination of the data and upgrading formats must be made by conducting careful liaison between all potential levels. Chief among the players in the game of developing the format will be the value-added producers, the next community to be discussed.

Another aspect of the governmental role is that of regulator, not only of the standards, but also of how the data are handled by members of the other communities. This question is difficult because we are dealing with many unknowns. The government, being the present, largest producer of charts, will have to set the standards, but it presently doesn't have the experience in this area. The role of the government as a regulator is well-known and it is reasonable to believe that it will be responsible for the content and currency of electronic charts, just as it is now for the currency and adequacy of nautical charts carried by vessels in its waters. Some method will have to be developed to allow the government to judge the adequacy of an electronic chart. This will be very difficult without some indication or record of what notice to mariners information has been received and entered into the system?

The responsibilities of the second community, the value-added producers, becomes even more complex because they will be taking government data and modifying it to fit their systems. The value-added producers, as described here, are those entities which will be taking digital hydrographic data and converting them for use by the end user by either applying software, equipment or both. The liability which these companies must undertake is a function of the accuracy and currency with which they deliver their products. The matter of standards applies here because if their process can take standardized "raw" data and convert it to a more usable form through an approved process, much of the liability will be diluted, or even passed through to the original source. This is a matter which must be given careful study. The questions of process approval and standards must, therefore, be considered early in the development of the electronic chart.

The most important result to come out of the October meeting was the unanimous call for producers of digital data to quickly settle on a standardized data exchange format. The more time that passes, the more entrenched will become the various data formats. A plethora of formats, with the resultant difficulty to intercommunicate, will result in harmful duplication of effort and requirements for costly equipment suites.

The legal ramifications and liability which each company must assume is a matter which bears study. The manufacturers must also address problems associated with payment and control. It will be extremely important for them to devise ways to control their data to prevent unauthorized copying, with the attendant problems of accuracy, etc. The matter of fair payment also creates the potential for a major challenge. Perhaps a system of leasing the equipment would be the answer, but what if the equipment breaks down in mid-ocean? None of these are easy questions to answer.

The third community, the end-users have the problem of using the integrated systems and the masses of data in a wise and responsible way. The mariner is currently required to carry certain charts in order to navigate in North American waters. Such a responsibility will also pertain to electronic charts, but with the ability for the navigator to pick and choose the scale of the chart and the information displayed, the potential for error is increased. For instance, the mariner entering a narrow harbor should display a large scale chart with minimum information such as channels, buoys, coastline and dangers. This will be difficult to regulate and one might expect to see some form of "black box" recorder such as are carried aboard commercial airliners.

SUMMARY

The potential for change is growing and we have to be ready to respond. The opportunities for interesting and challenging decisions are ahead. I think that we are on the threshold of one of the most exciting periods that the field of mapping and charting have ever experienced. Good luck!