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NATIONAL OCEAN SURVEY AUTOMATED INFORMATION SYSTEM

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ABSTRACT

The National Ocean Survey is automating the processes required to create and maintain nautical charts. Automated techniques have been introduced in three basic areas : data management, interactive graphics, and management reporting. The National Ocean Survey Automated Information System (NOS/AIS) uses some of the latest advancements in data processing to perform these functions. An online geographically oriented data base coupled with an array of interactive graphics systems enables cartographers to maintain up-to-date charts.

INTRODUCTION

One of the primary missions of the National Ocean Survey (NOS) is the production and maintenance of nautical charts for the navigable waters of the United States and its possessions. This is a continuous effort due to the constant changes caused by natural and human processes. To measure these changes, NOAA has a fleet of ships and aircraft gathering data for charting purposes. Information is also received from other U.S. Government agencies and the private sector. The current base of charting information must be up-dated to reflect any potential dangers to navigation that are uncovered by the new data.

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In theory, new data are collected in the field, and charts are modified to reflect the changes. In practice, however, bottlenecks have developed. Sophisticated data collection techniques using computers, rapid navigation, and digital fathometers have outpaced the ability of the cartographer to use all of the new information. As the volume of data increased, NOS found itself in the position of applying only the critical adjustments to charts while the rest of the data were stored for future use.

To alleviate this problem, NOS has developed a set of computer-based systems that will speed the application of data to nautical charts. These include :

– Automated data acquisition systems aboard NOAA ships that also accomplish some preprocessing functions.

– Automated processing facilities at the Atlantic and Pacific Marine Centers for verification of data before they are sent to NOS Headquarters.

– A digitizing system to capture graphic information in digital form.

– Flatbed scribe plotters and a laser raster drum plotter to produce negatives for chart printing.

The missing link in this automated chain of processes has been recently developed under contract by the Planning Research Corporation. This system, the

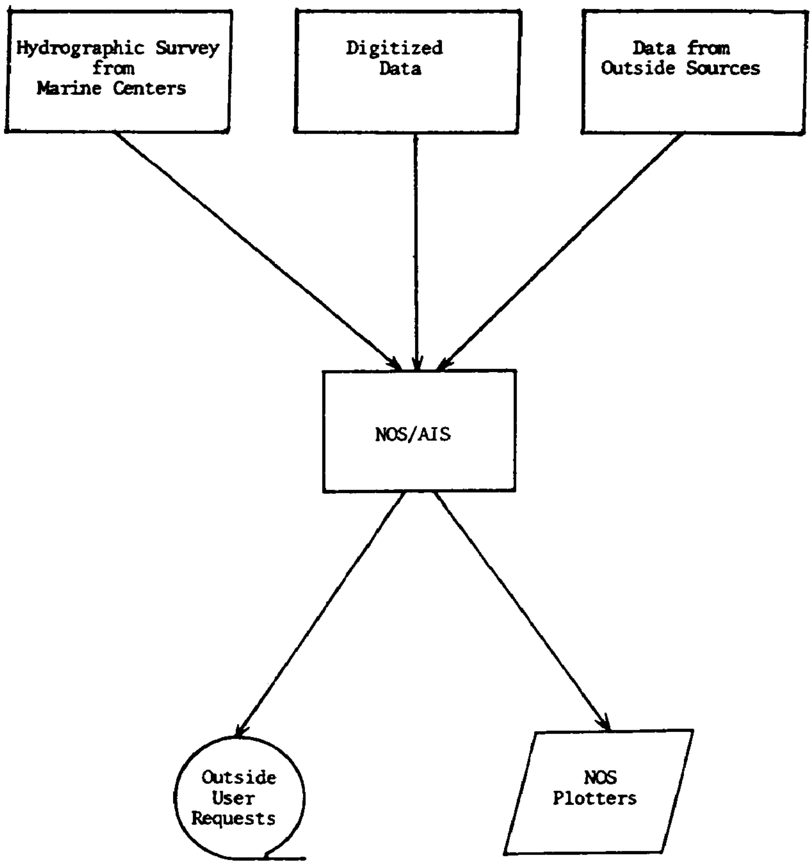

FIG. 1. – Relationship of the AIS to other computer-based systems in NOS.

National Ocean Survey Automated Information System (NOS/AIS), receives data from the Marine Centers, the digitizing subsystem, and outside sources. It stores these data in a readily accessible form and allows retrieval for interactive compilation of charts. The system also produces digital output which can be plotted for use in chart reproduction. Figure 1 shows the relationship of the AIS to other computer-based systems in NOS.

NOS/AIS

NOS/AIS is the backbone of the NOS effort to automate nautical charts. It performs three critical functions that are necessary for chart construction and maintenance. First, it provides a mechanism for managing the vast amounts of data that are required to create and maintain a complete chart product. Second, it provides the cartographer with a tool that allows the interactive manipulation of cartographic information. Third, it provides the management information necessary to control the charting process. The AIS not only handles these basic functions, it also performs them in a timely manner. An explanation will now be given on how the AIS fulfils these requirements.

DATA MANAGEMENT

NOS is responsible for charting approximately 2 million square miles of the Earth's surface. The amount of data necessary to represent this area is immense and, therefore, requires effective management. Automated data processing provides this tool in the form of an online data base.

In a data base environment all data relevant to an organization's tasks are stored in a central repository. Access to this data is controlled by a sophisticated set of computer software called a data base management system (DBMS).

The way the data are organized within a data base is very important to the successful operation of the system. An organization must analyze how its data are used and structure the data base accordingly. NOS examined two different approaches to data base organization. The first was based on a chart oriented data base. Since the ultimate output of the system is a chart, it seemed logical to organize the data base by chart product. The same cartographic feature will likely appear on multiple charts, however, due to the hierarchy of scales and overlapping coverage. Therefore, in a chart oriented data base, the same feature would be stored once for each chart on which it appeared. This redundant storage of data would greatly increase the size of the data base. It would also require each chart representation of a feature to be modified when a change occurred.

An alternative scheme for organizing the data base solved these problems. By using a geographically oriented data base each feature is stored only once. Accompanying information is used to tell how the data are depicted on the various charts. This technique eliminates redundant storage, which in turn, decreases the size of the data base and prevents conflicting depictions of features within a set of charts.

In this structure a feature is stored according to its geographic position. To make the storage scheme more manageable, the Earth's surface is subdivided into 1-degree by 1-degree squares. Certain types of data that fall within a given degree block are stored together :

- *Published traveling features and channels.* These features typically extend distances greater than 5 minutes, and they are currently published on at least one chart. Examples are pipelines, cables, and channels.
- *Unpublished traveling features and channels.* These are the same as above except that they are not currently published on any chart.
- *Small scale topographic data.* These are published and unpublished topographic data that may appear on charts of smaller scale than 1:100 000.

The data base management system used in the NOS/AIS is named TOTAL. This DBMS allows direct access to master records on disk storage devices. Direct access is important because it is the fastest way to retrieve information from a computer system. Each degree block is defined as a master record to the TOTAL data management system. This allows rapid access to the above types of information.

Near the shoreline, where data are more heavily congested, a further refinement is made to the degree block subdivisions. In these areas a master record represents an area that is 5-minutes by 5-minutes square. These types of data are stored within each of these blocks :

- *Large scale published features.* These are features that are published on charts of scale larger than 1:100 000 and are not traveling features or channels.
- *Small scale published features.* This category contains published features that appear on small scale charts, excluding traveling features and channels. If a feature appears on both small and large scale charts, it is grouped with the small scale data.
- *Unpublished features.* This group contains all unpublished features, except traveling features, channels, and small scale topographic data.

A variety of data records have been devised to represent the different types of cartographic features. Usually a group of these records is required to represent one feature. A shipwreck, for example, requires four records to be stored. The first record, called the base data record, holds information about the type of feature and its geographic position. The second record in the sequence, called the compilation fact, tells which chart entities the feature appears on. The next record describes the position, characteristics, and publication status of any nomenclature that accompanies the symbol. The last record in the sequence gives the actual text which appears on the chart, for example, "SUBMERGED WRECK".

That basically describes how the data are organized. Data are to be loaded into the data base in phases. The first area to be loaded, the Gulf of Mexico, will be completed by early 1980. Since all of the data for a given area is loaded at the same time, cartographers will be able to use the system's full capabilities just as soon as an area is loaded. Other areas will follow the Gulf as the data collection effort is completed, and the entire 3 billion character data base will be loaded by 1983.

AIS Hardware

To store and access 3 billion characters of data require a sophisticated computer system. Figure 2 is a diagram of the NOS/AIS hardware configuration.

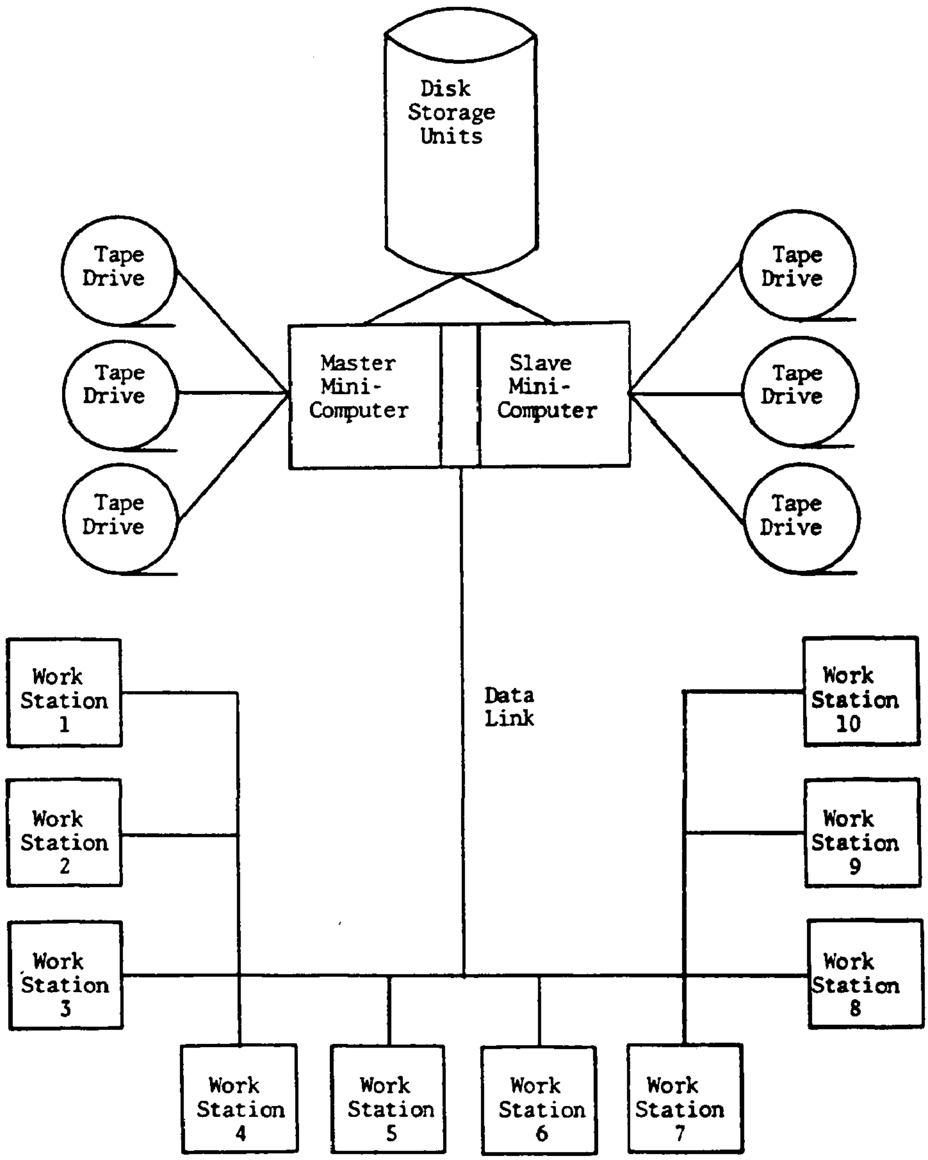

FIG. 2. – NOS/AIS hardware configuration.

The central site portion of the system consists of two Univac V76 minicomputers in a master and slave configuration. The data are stored on disk storage units with a 300 million character capacity. There are three high speed tape drives attached to each central site minicomputer. These are used to input new data to the system, to output data to the NOS plotters, and for other system functions. The central site is attached to the cartographic work stations by a high speed data link. The work stations will be described in detail later.

AIS Software

Having now seen how the data are organized, and the hardware components that are available, it would be beneficial to start a cartographic request through the system to see how everything works. This will also provide an opportunity to describe the computer software that controls the system.

A cartographer initiates the process by submitting a request for data to be sent to one of the cartographic work stations. The request may take many forms. The most frequent requests are for data that lie within a given geographic area or on a given chart. The area can be any polygon with from three to eight sides. Chart and area requests can be qualified to limit unwanted data from being sent to the work station in numerous ways. For example, one can request only published data, only unpublished data, or only a certain type of data like soundings or buoys. The request must also include control type information, for example, a user number for security purposes, a request number, and the number of the work station to which the data are to be sent.

A typical example of a cartographer's use of the system is to apply the information supplied by a new hydrographic survey to the appropriate charts. When a new survey is received at NOS Headquarters, it is loaded into the AIS "new data holding file". A cartographer then submits a request for the published data covering an area slightly larger than the survey to be retrieved from the data base.

Once the request is submitted, an executive control program schedules the various programs that are needed without operator intervention. The first program edits the request for errors. The next program checks that all of the resources needed by the request are available, that is, that the data requested from the data base are not currently being used by another cartographer. To preserve integrity in the data base, two requests cannot use the same data at the same time. If all resources are available, the retrieval program then extracts the requested data from the data base and the new data holding file and sends them over the high speed data link to the work station.

When the data arrives at the work station, the cartographer may begin the work session. The activities at the work station are a part of the second function of the AIS, interactive graphics, and will be discussed in the next section of the paper. After the cartographer has finished with the data at the work station, the new and edited data are sent back to the central site to update the data base. The update program modifies the data base records that were edited at the work station, adds records that were introduced, and archives records that are no longer applicable. Records that are archived from the online data base are written to magnetic tape for long-term storage.

The last step of the AIS data management function is to back up those portions of the data base which were modified by the work station edit. All cell blocks that underwent changes are copied to magnetic tape. These tape copies along with a backup copy of the whole data base on disk will allow recovery from a failure of the online data base.

INTERACTIVE GRAPHICS

The second major function of the NOS-AIS is to enable cartographers to use data in a graphic form. Cartographic users do not really care about data base management systems or retrieval and update programs. What they do care about is the chart's graphic image. The user wants to see cartographic symbols, shoreline, and soundings the way they are represented on the chart. He or she is not particularly interested in strings of data base records.

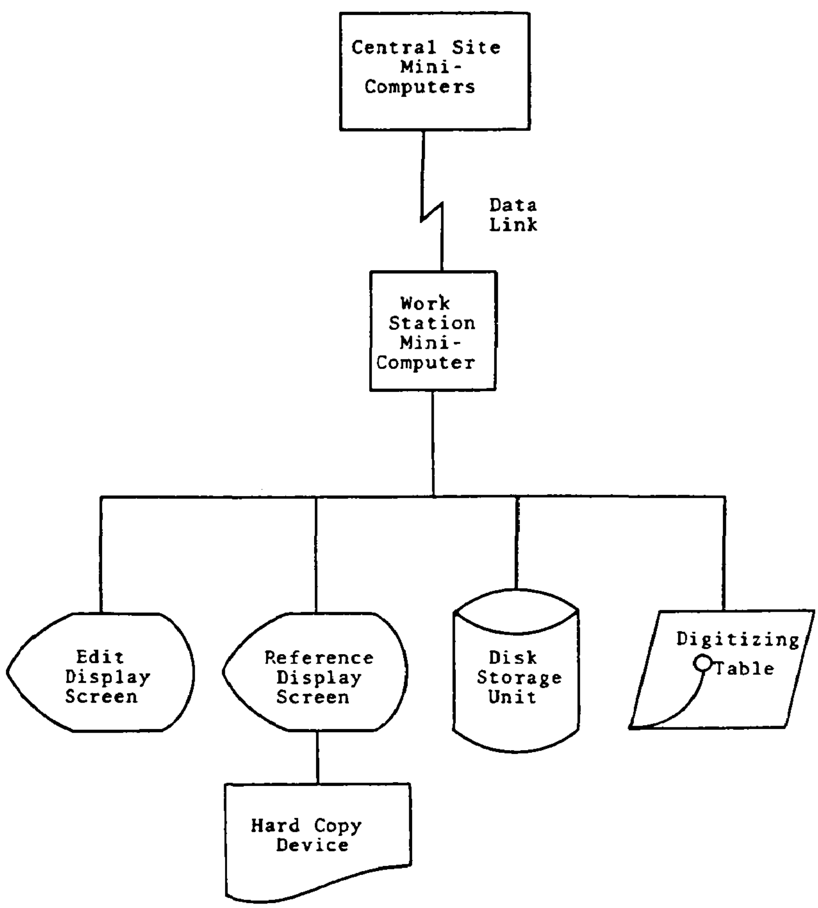

FIG. 3. – Work station hardware.

To provide the transition from strings of records to a usable graphic display, the AIS has incorporated the latest techniques in interactive graphics. Figure 3 shows the work station hardware that provides this power. At this point it should be pointed out that only 2 of the full complement of 10 work stations have been installed. Experience gained from the use of these prototype work stations will play an important part in the selection of the next eight.

The current work station configuration contains the following hardware :

- One Univac V76 minicomputer to control work station processing.
- Two disk storage units to hold work files and programs.
- One Bendix digitizing table for cartographic reference and input.
- One refresh color graphics display screen for edit.
- One graphics display screen for reference.
- One hard copy device.

These hardware components plus a large group of computer programs allow the cartographer to perform many cartographic functions.

To illustrate some of these functions, the hydrographic survey example that was introduced earlier will be continued. The example was left with the cartographic request, including the new survey, having been sent across the data link to the work station. The TOTAL data base management system is used at the work station to control access to the work file.

The cartographer has a scheduled time to use a work station. This time was chosen by the cartographer when the request was initiated. At the pre-established time, using the appropriate employee number and security identifier, the cartographer will attempt to sign on the system. Unauthorized access, based on these numbers, will cause the work station to disallow further actions, and a message will be sent to the central site operator.

Upon completion of a successful "sign on", the cartographer will place the largest scale chart to which the survey will be applied on the digitizing table. This will be used as a reference to the graphic displayed on the edit screen. The cartographer than selects the area of the chart that will be edited first. Data from the data base that are currently published on the registered chart will be displayed on the screen in the color green (The screen can display five colors). The cartographer will also ask to see preselected data from the new hydrographic survey. These are the new survey data that have been run through an automated sounding selection program. This program selects soundings that are critical to navigation and removes cluttered soundings so that an appealing graphic representation is given on a chart. These soundings are displayed on the screen in orange. If the cartographer wishes, the entire survey can also be displayed.

The cartographer then applies the soundings from the survey by publishing the appropriate ones. This is done by selecting a sounding on the screen by positioning a cursor under the displayed symbol. When a sounding is found it will blink on the screen. The "publish" button on a keyboard is depressed and the status of that sounding is changed accordingly. In the same manner, soundings from the data base may be changed to an unpublished status for the registered chart.

The survey is applied to the whole chart, and then the next smallest scale chart is registered on the digitizing table. The cartographer now asks for selected soundings. These appear in red and are those that were published on the larger scale chart. Since the level of detail at the larger scale is greater than at the smaller, only those soundings selected at the large scale will be applicable. This process will continue until the survey has been applied to all appropriate charts at the various scales.

The concept of applying data "through the scales" is a great benefit provided by the AIS. In the past, all new data were used at each scale. With the AIS a refined subset is used for each successive scale. This provides a great time saving.

When the cartographer has finished editing the data a sign-off command is issued. Before the data are sent back to the central site for update the transactions must be checked by an authorized reviewer. The reviewer signs on the work station with a special security identifier. If the chart has been incorrectly compiled, the reviewer may modify the data or have the cartographer sign back on to do so. When the chart is correct, the reviewer signs off for update. The data are then sent back to the central data base for update, as described earlier.

The application of a hydrographic survey is just one example of how the AIS aids in chart compilation. Channels, shoreline, or any cartographic feature can be added or modified in the same way. A very real benefit is gained by using the AIS to continually maintain charts. Continual maintenance means that when a change to a chart is received at NOS it is immediately applied to the existing base of chart data. In this way, a chart is ready for publication with the most current data at all times.

When a new edition of a chart is to be issued, a cartographer will make a request for a chart retrieval to the AIS. The chart will be sent to the work station and the cartographer can manipulate the data to improve the chart's appearance. This might include the rotation of cartographic symbols, repositioning nomenclature, or clearing an area for text. Rotation is accomplished by finding the desired feature and depressing the rotate button until the desired angle is reached. Repositioning of features is handled by using four function buttons which move the feature up, down, left, and right. To blank an area of shoreline the two points on the line that bound the area are found and unpublished.

With this type of interactive capability the AIS has removed the need for a cartographer to spend time drafting. With manual techniques the cartographer must draw in all of the changes. With the AIS these functions are performed by pushing a button. The cartographer's major effort is in applying cartographic skills, not drafting.

One final example of the power of the AIS must be cited before going on, and that is the creation of a new chart. In this example, assume that a smaller scale chart is being created. The cartographer will first add the geographic limits of the chart to the chart information file. Then an area retrieval will be made that encompasses the new chart. When the data arrive at the work station, the cartographer will display the data for the larger scale chart and designate it as "selected". This means that the data will be applied to another chart.. The system will ask the cartographer what chart is to be the compilation chart, that is, the one to which the selected data will be applied. The cartographer enters the number of the new chart and then proceeds to publish the appropriate data from the selected chart to the compilation, or new, chart. This technique provides considerable time saving over the manual creation of new charts.

MANAGEMENT REPORTS

The final function of the NOS/AIS is to provide management with sufficient information to aid in scheduling, controlling costs, and evaluating the system's performance. Information-gathering modules have been incorporated in the AIS software to supply input to the management reporting function. Some reports are available to cartographic management :

– **Chart job accounting.** This report gives the work station time, system time (retrieval and update), the number of transactions, and the cost incurred based on cartographer and reviewer time. The report can be generated for each chart.

– **Geographic area job accounting.** NOS cartographic staff is subdivided into seven teams, each responsible for a geographic area. This report gives time, transactions, and cost information as above, except that it is based on a whole area rather than one chart.

– **Reviewer job accounting.** This gives the same information keyed to a reviewer.

– **Outside user job accounting.** This gives the same information keyed to a request outside of NOS.

– **Cartographer job accounting.** This gives the same information on a given cartographer.

– **Work station usage.** This gives the time the work station was active, number of transactions, and various file sizes of a given work station.

– **Data base access.** This reports the frequency and types of data accessed, number of transactions, and area of data base access.

– **New document status.** This tells which new documents fall on a given chart.

– **Chart status.** This reports which charts fall on a given new document. The last two reports are used to help schedule work.

– **Chart history.** This report tells what new documents have been applied to a chart.

In addition to the above, many other reports supply information to systems programers and the Data Base Manager. All of the reports can be generated on an "as needed" basis.

CONCLUSION

NOS is one of the world's leaders in the advancing technology of automated cartography. The NOS/AIS was a pioneering effort in this field, and, as a consequence, many lessons had to be learned along the way. The most valuable information was gained once the system was in place and cartographers started using it. NOS will put this knowledge to use when the next eight work stations are procured. But this will not end the evaluation process that analyzes user needs and implements appropriate solutions. Technology is advancing at a tremendous rate. But the technical advancements are only good if they are put to use. NOS will stay abreast of technology to give its cartographers the tools they need to cope with our dynamic environment.

ADVANCED SYSTEMS – THE FUTURE

Over the centuries navigation has evolved from a very simple process to a highly complex scientific art. Although there has probably been greater advance in the science of navigation during the twentieth century than in all the previous history of mankind, the mariner is basically conservative, and fundamental changes come slowly. This situation is attributable, in part, to the fact that each new generation of navigators learns from the preceding one, and afloat the young officer generally finds that his relations with the captain are most amicable if the junior uses methods favoured by, or at least understood by, the senior.

Nevertheless, change has come, and continues to do so. One should not suppose, however, that every vessel is equipped with advanced navigation equipment, and that all seagoing personnel are proficient in the use of all modern devices. Quite the contrary. Very few ships, for instance, are equipped with inertial or Doppler sonar navigators, or with equipment for fixing position by satellite. There are still many smaller vessels without radar, Decca, or Omega equipment. The ordinary practice of navigation as described throughout this book is still the norm in the vast majority of craft afloat. It has been argued, and with merit, that greater improvement in safety and efficient ship operation could be achieved by proper training and effective utilization of equipment and methods now available than by further development of more advanced aids. Mechanical or electronic marvels are not a substitute for skilful personnel.

One of the problems of orderly improvement in navigation has been the lack of effective communication between the mariner on the one hand and the engineer and scientist on the other. The mariner has been unwilling or unable to define his requirements clearly. Perhaps his lack of knowledge of the capabilities of engineering and science has contributed to this situation. The engineer and scientist, on their part, have not always sought to understand the needs and problems of the navigator, but have too often proceeded to find a solution and then seek a problem for its application. Happy, but rare, has been the situation where one understood both positions.

Extract from "*Navigation Afloat - A Manual for the Seaman*", by Alton B. Moody, Captain, U.S. Naval Reserve, with a Foreword by M.W. Richey, M.B.E., Director, the Royal Institute of Navigation. Publishers: Hollis & Carter, London, 1980.