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INFORMATION MANAGEMENT IN THE MODERN HYDROGRAPHIC OFFICE

A CHALLENGE FOR THE 21st CENTURY

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Summary

Collectively, the various national hydrographic authorities within the auspices of the International Hydrographic Organization (IHO) are the custodians of a significant portion of the world asset of marine information. In the course of managing this information, Member States have been subject to significant changes in both technology and user requirements. The current practices that have evolved to provide a relatively uniform service of charts and other publications for the international mariner are today under increasing pressure to adapt to a wider variety of specific user needs and the methodologies for presentation. Consideration must be given as to whether the current information management practices in place today are able to meet the source data capabilities and user requirements of tomorrow.

This paper discusses a rationale for the structuring that may be required for future hydrographic information management. It examines current problems and some potential directions in the overall management and organization of the types of information held by the modern hydrographic agency. An appreciation and understanding of the issues surrounding information management in hydrographic organizations, under the auspices of the International Hydrographic Organization, must lead to a closer cooperation towards meeting the challenge of international information dissemination in the twenty-first century.

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Background

In meeting the need for a better understanding of the sea, hydrographers today are subject to significant advances in the technologies of acquiring, processing and disseminating information. Automated data acquisition systems (e.g. lidars, sonar arrays and remote sensing) are set to provide significant increases in the volume and type of information that can be obtained from the marine environment. In order to evaluate and supply such information in the form of charts and associated products and to cope with the subsequent maintenance processes, it has been necessary to adopt relatively common practices in information management with existing products. Questions must now be raised as to the suitability of the information management practices for current data to meet the future needs of the mariner. That same information is also an important scientific asset that should be available to many other users of the marine environment.

Current practices of information management are being challenged by the ability of the technology to archive, retrieve, evaluate and supply the information that is capable of being generated. There is a significant increase in the amount of source survey information becoming available in digital form as well as a growing body of previously manual data that has been transferred into digital systems format (the existing digital chart). Trends towards digital charting have progressed throughout the last decade and have now become a relatively consolidated technological application. Today the electronic chart display and its various user forms is about to make a significant impact on the way information is managed. The evaluation of very high volumes of digital information and its subsequent transition into an electronic chart format pose a challenge to the ability to match the organization of information to suit a diversity of user needs.

Computing technology makes it easier to consider dealing with only that information generated by digital systems. In the course of current technological change, there is the need to manage and disseminate information that still remains available in the traditional manuscript form. In order to meet responsibilities to the users, an effective integration of digital and traditional information media is required. Data volumes that are acceptable today require information management practices that may not be suitable in the tendency towards ultra high capacity data-logging systems. On the other hand, the traditional information sources cannot be ignored in the haste to automate.

The nature of hydrographic information

There is great diversity in the nature of the information managed for charting purposes. The decision processes that support the dissemination of selected information in the form of new charts, editions and notices to mariners are conditioned by current practices. Today there is an attempt to provide the user with the information to make decisions on survey quality through the provision of source or reliability diagrams on charts. Such decision making processes are conditional on the availability of information on the original survey data and the knowledge with which appropriate evaluation can be made.

Through education and experience, the hydrographer is equipped with the comprehension to evaluate and to make judgments on hydrographic data. But if the relevant information and understanding is not available to the user to arrive at appropriate operational judgments at sea, then there may be many disasters before moves are ultimately taken to rectify the lack of knowledge. Fear of litigation, the lack of access and knowledge about historical information and the practical processes of chart production and maintenance will probably ensure slow progress in providing evaluative information on charts. This reasoning may not apply to the future potential of the electronic chart processes. The linking of real time information sensors to static hydrographic data will require the qualification of those elements and attributes that will assist in a systems aided evaluation.

Progress towards the expert systems of tomorrow and the ubiquitous notions of artificial intelligence will require the analysis of the quantum level of hydrographic information to determine their contribution and relative weighting in the decision making processes. The development of expert systems technology will require the evaluation and quantification of the expert knowledge of the hydrographer. The essence of information management today does not specifically relate to the potentials or limitations of any commercial system within current technological limits but rather to the identification and coordination of the elements of those cognitive processes upon which judgment can be made. This is a necessary role for the Member States of the International Hydrographic Organization.

Information today and tomorrow, the nature of the problem

The collective body of hydrographic information held today has been derived, in some cases over centuries, from exploration and survey of the marine environment and has provided for safe navigation in support of trade. From the days when the soundings and content of a single large-scale survey represented almost the entire information on the published chart of ports or shelters now seldom visited, we are today confronted with technology that can repeatedly supply millions of significant survey data points over a similar sized area in a matter of hours. The ability to rapidly resurvey with significant increases in data volumes would have had little effect on the traditional user requirement of fifty years ago. Nowadays change in the significance of ports in meeting demands for commercial and national development is further affected by changes in the bulk and draft of the shipping required to meet the economies of trade. Today the electronic chart is absorbing much attention with quite significant ramifications on charting methodology, supporting information, ownership and legal implications. Tomorrow, apart from potential changes in surface and underwater navigation, the diverse potential for cultural usage of the marine environment will challenge our capacity to manage and integrate the survey information base for future users. The information base held by the modern hydrographic office has become an asset required by other potential users. It is not necessary to actually fulfil other user requirements, but the content of the information base is often shared (e.g. bathymetry). Activities surrounding ocean management practices and the exploitation of the marine environment bring a diversification into the content and use of hydrographic information.

The traditional view of a hydrographic information base is a series of charts derived from the appropriate hydrographic survey with supporting publications. The days of colonial powers and single nations compiling world-wide chart coverage are changing. The hydrographic survey in direct support of charting today does not provide the topographic information content at the same level of detail today as it did some time ago and invariably the necessary detail can be acquired in a more satisfactory and reliable form from other sources. The chart information sources are becoming more specialised as other reliable sources of charting information becomes available (e.g. port authorities and other maritime agencies). In turn the content of hydrographic survey is changing (see Table 1).

TABLE 1

Trends in hydrographic survey content

Feature	Early 1900's	2000
Soundings	Relatively few soundings.	Increasing volumes of data.
Primary reduction	Not needed.	Automated.
Secondary reduction.	Slightly more than chart scale.	Ultra high levels retained.
Depth contours.	Hand drawn.	System generated or aided.
Navigation aids.	All.	Salient.
Horizontal control.	Local.	Networked (national and global).
Topography.	Detailed.	Salient observations.
Cultural.	Comprehensive.	Very little.

The paper chart base has served the maritime community for many centuries and today still remains a relatively effective product for the navigator. It has been supplemented by many other paper information bases, such as Tide Tables, List of Lights, Radio Beacons, Sailing Directions, Port Facilities, Notices to Mariners, etc. Much of the current state of digital charting simply emulates the paper chart process, similar to word processing support of publications. Charts are the complex integration of information and, with experience over the years, both producer and user have worked with sets of charts at fixed scales commensurate with the level of detail required for navigation. The paper chart base has allowed the mariner the pertinent information required, relative to the scale of the chart and, if there is insufficient information available, then the user may have recourse to other products such as Sailing Directions. The impact of graphic representation on the paper chart has been refined over centuries, but today, with the advent of the computer, there is the potential to supply sets of dynamic information to suit different operational situations. The base of hydrographic information must be carefully managed if integration into the dynamic capabilities of electronic systems is to be successfully achieved (see Table 2).

TABLE 2

Example relationship of navigation information

Typical features on the current chart	Additional information in other products	Potential Dynamic Aspects
Lights and characteristics.	Light List details.	Coloured light sectors. Dynamic emulation. Sound generation.
Coastal features.	Description in Sailing Directions.	Radar imaging. Dynamic diagrams.
Chart depth contours.	Bathymetric contours (ex. surveys).	Colour banding for limits of operational depth. Seabed modelling.
Soundings.	Description of dangers.	Highlight of dangers with minimum depths.
Buoys and beacons.	Lists of details.	Dynamic display of characteristics.
Maritime limits.	Summary descriptions.	Highlight of operational areas.

Traditionally, large-scale charts have usually been more complete in terms of hydrographic detail, whereas in the smaller-scales the deficiency in survey has been supplemented with data from other sources. From the days of cartographic licence in completing detail in unsurveyed areas, today we are under increasing pressure to improve the spatial authenticity in the presentation of our charts. The use of satellite imagery provides a firm basis for improving the display of spatial information. This may not improve the chart for general navigational use, but it does provide a more realistic document for associated uses (e.g. search and rescue operations).

The hydrographic survey has not been the sole provider of information for charting and there is a need to integrate data from other sources. Such data is necessary for safe navigation and the hydrographic agency performs a basic intelligence role in gathering, analyzing and integrating with the basic hydrographic survey detail to form the information base. The nature of the navigation role requires constant intelligence from the environment in order to improve the quality of information provided for safety at sea. Not all the information in the data base is disseminated due to the need to exercise economy in the use of scarce resources, the limited amount of information that can be provided on the traditional paper chart, and the uncertainties that cannot be verified and do not warrant promulgation at that time.

Positioning accuracy

One of the most significant factors affecting the hydrographic community apart from the basic survey coverage is the improvement in the precision of position fixing. While all types of navigation (and surveying) systems remain important, global positioning systems have potentially the most significant impact on information management. While relative accuracy remains adequate for normal navigation on present day charting, the absolute accuracy of high precision real-time earth-centred satellite positioning systems will have a profound impact on information provided to the electronic chart navigation systems. The future navigation system will require the systematic knowledge of the relative positional accuracy of the chart base information provided from the hydrographic data bases, if integration with real-time sensors is to be achieved. In situations where greater emphasis is placed on dynamic command and control type systems, such tactical navigation will require more from our information than can probably be supplied unless greater emphasis is laid on forward thinking in information management.

The positional accuracy suitable for scaled paper charts may not be adequate for any base producing a very large scale display on a dynamic navigation control system. Information provided for the electronic chart must be able to indicate the precision that can provide automatic compensation in the user display. The non-expert user must not be able to imply an order of accuracy of the static data that does not exist. Given the wide variety of circumstances under which hydrographic survey is conducted it is necessary for greater emphasis to be placed on relative accuracies of all survey data, even within the bounds of a single survey. While practical judgments will continue to be made on information commensurate with our technologies in use at any one time, there is no doubt that the future will impose conditions that require careful consideration of the way information is assessed today for subsequent evaluation tomorrow. This may call for renewed thought on comprehensive and uniformed standards for the assessment of hydrographic data.

Survey technology

There has been considerable technological change in the methods of surveying and data gathering over the last fifty years. Even now the use of remote sensing is set to redefine the method of survey and data analysis on land, even to the extent that aerial photographic interpretation will become a thing of the past, being replaced by system aided analysis. While some changes will affect the hydrographic community, there remains the challenge of the marine environment to the gathering of information. The sea will still require expensive and challenging methodologies. Total, immediate data re-survey from satellite sensors will not be available to the hydrographic surveyor and that poses an obligation and responsibility to maintain that valuable historic asset of fragmented survey in a usable form for the future. Some level of rapid re-survey will become possible in the deployment of lidar systems and perhaps some greater use will be made of potential acoustic systems, at least in supporting historic surveys and identifying areas for more conventional detailed survey as a means of supporting re-survey and hence re-defining positional accuracy.

In considering the future management of modern digital technologies and automatic data-logging, it is considered that information content should not be limited to the notion of the present survey practice for hydrographic survey to suit the final chart. Some of the present activity with the electronic chart display tends to place emphasis on emulating the content of the paper chart. Such trends appear to be simplistic and relate data densities commensurate with a single user requirement from a selected range of scaled chart images. If a better bathymetric definition is to be more useful for, say, underwater navigation, then the survey will probably have to be re-compiled if it has not been previously interpreted from source information. It is suggested that if a base for the future electronic chart is to be established then perhaps it should be organized and designed from the beginning at the level of the survey base rather than the chart base. For it is at this level that the highest support can be made for future maritime needs. Such a fundamental level of base information ensures the need for hydrographic surveyor management and responsibility into the future.

The survey as the information base

As a starting point for the effective organization of information for future management, consideration should be given to using the fundamental building core of the hydrographic survey rather than the existing chart. This definition of the sea-bed forms the base of knowledge at the highest resolution available. In digital form it provides a seabed terrain model for other products as well as providing a basis to meet future requirements. For charting, this implies that automated sounding selection can be seriously implemented when digital soundings are available and this could be considered realistic, both in terms of potential future systems capability, and the acceptance of a level degradation to displayed detail when dynamic scaling is used in the electronic chart. The differences between automated sounding selection and human ingenuity in data selection tend to become less important when dynamic scaling is available. This would become applicable in the portrayal of constrained passages that would not be possible with the traditional paper chart at a fixed scale. Under an omni-scaling technique on future modes of the electronic chart, this will not be difficult, provided the basic survey information is effectively organized.

To be useful, a digital survey base would also require the rationalisation of all existing digital surveys into a single integrated survey model. Subsequent surveys would be progressively integrated as they were conducted in a manner similar in fashion to current GEBCO practices. From a national point of view the integration of additional survey data would not be excessively difficult or time consuming as analysis for integration into a single survey model would be required for only a relatively small overlap areas at the boundaries of previous surveys. With improved field data-logging techniques this could be achieved at sea. Complete re-survey would provide a substitution of previous survey and the integration would form part of the field process. Australia is currently developing such a unified hydrographic survey model as the General Integrated Survey Model of the Ocean (GISMO), incorporating also the GEBCO requirement. Subsequent analysis for chart production or other user requirements would be a process of system generation, having always as its base the adjusted and coordinated survey assessment of the sea.

The complexities of non-digital survey data, which currently define the majority of information, need not deter from the structure of an integrated survey base. While the element of the digital sounding is not immediately available, other aspects controlling the assessment of the manuscript survey can be readily incorporated into the digital data base for subsequent information management. This allows a total index and sub-survey area analysis of the entire national data set in a similar, but far more detailed and comprehensive manner than the notion of the reliability diagram on the chart. Such uniform treatment of the total components of, say, seabed definition, without the sounding elements in the case of non-digital surveys, permits the identification of zones of confidence for advice to the user as well as providing a tool for survey planning. For information management and control it is not necessary to have digital soundings, for while this does not allow the development of a complete integrated survey model of the ocean, the control mechanisms for information coordination are in place through a system of qualified area and sub-area polygons (see Fig. 1).

Although the information base is notionally built about the digital sounding, some useful technological developments give optimism for effective total management, provided some level of ingenuity and flexibility is adopted. Some difficulties in accessing non-digital soundings can be overcome through the processes of scanning and synchronised video or raster display with normal digital data. There has also been some promising work carried out on the character recognition of hand drawn soundings which may make inroads into providing a high level of digital sounding data. It must be emphasised that the holding of actual digital soundings is not necessary for the establishment of a system of hydrographic information management. The important issue is the recognition of

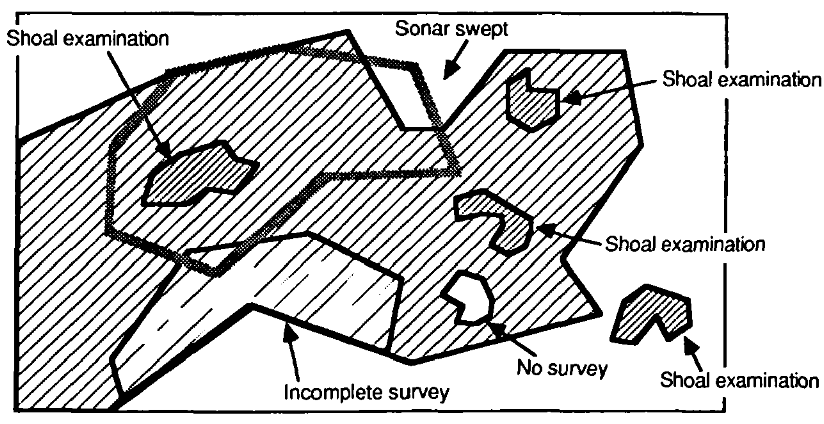

FIG. 1.— Concept of polygon boundaries on a hydrographic survey.

the need to have a coordinated assessment of all areas and sub-areas to achieve a representation of the total state of information within the respective areas of national control or interest. Such a process can be extended to other sets or groups of information (e.g. geomorphic and oceanographic information) to allow appropriate integration into the operational command systems of tomorrow.

The effect of a coordinated survey information base has far reaching effects and long term benefits in the future use of technology beside the electronic chart. Provided there can be agreement to the developing of uniform assessment criteria with the Member States of the IHO, then the standards for industry development can be established. Such standards are then coordinated throughout the Member States and confusion in interpretation is avoided. Much of the difficulty Australia has experienced in the exchange of digital data, despite the existence of national standards, can be traced to cognitive differences in interpretation, due primarily to a lack of suitably comprehensive and agreed standards at the interpretive level rather than at the systems or technical level.

As an example, the type of coordination expected from surveys can be demonstrated by the broad relationships in a data base schema being developed for an Australian hydrographic survey data management system. The schema encompasses a number of primary concepts surrounding the notion of a total digital survey sounding base covering the Australian area of interest, without the actual need to have the soundings in the case of non-digital surveys. The broad higher level structure of the present and future schema is shown in Figures 2 and 3. The association of the survey, charting, GEBCO and Notices to Mariners relationships should be noted, even though at this stage the full development of the charting and Notices to Mariners functions are not being undertaken. The development of the identifying and assessment elements of the different sections of the schema are the main purpose for the suggested coordination in this paper and will be developed below.

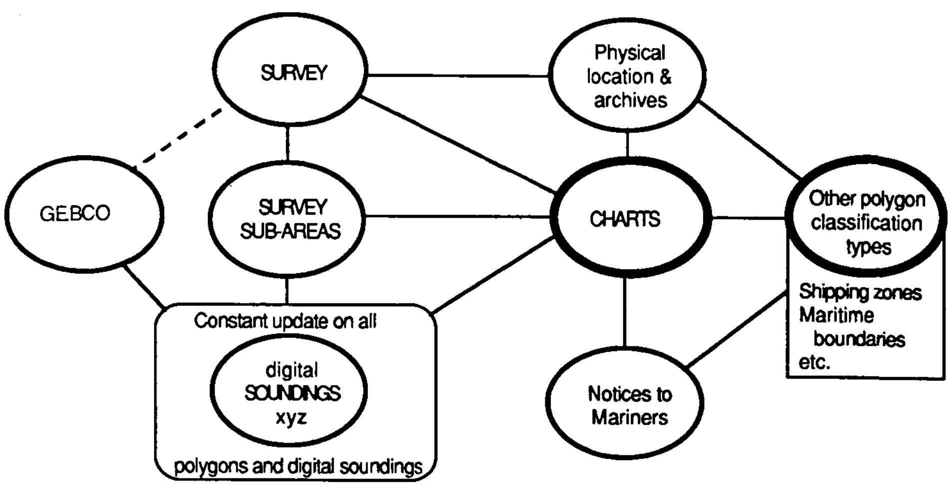

FIG. 2.— Initial phase of schema classification concept.

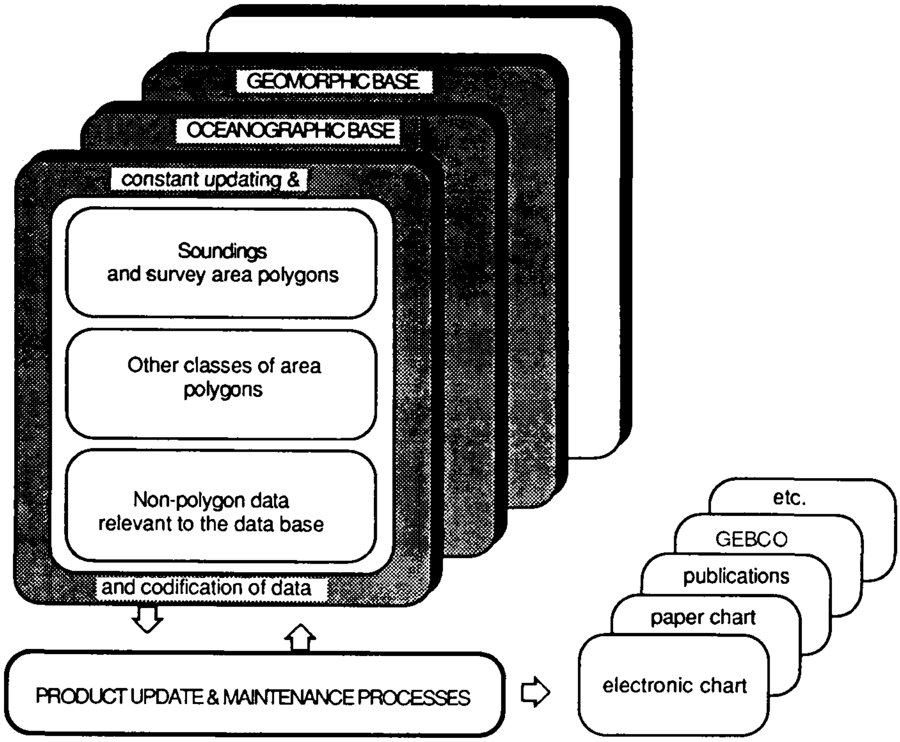

FIG. 3.— Broad structure of long term schema trend.

Polygons and elements for analysis

The polygon grouping of surveys is an important part of the information management concept. Since it can be applied to both digital and non-digital surveys of any type, it allows orderly management of all data to proceed. But the more important aspect is that of the sub-area polygon boundaries which permits the classification of all sub-sections of the survey. It is not necessary for a single polygon boundary to define the entire single classification concept. These data sets may be mutually exclusive or overlapping, depending on the purpose of classification. At certain levels, the mutually exclusive mode would be appropriate e.g. the groupings of all soundings with a selected commonality, such as line spacing. Other sets could overlap, e.g. the area of sonar or wire sweep. Perhaps one of the most important boundaries is that of the 'area-as-charted' as this would represent the residue of the survey area not superseded by further survey (or for that matter only those portions of a more recent survey considered suitable for replacing pre-existing information). The polygon boundary of the area-as-charted would represent the survey sub-polygons defining the GISMO.

The concept of polygon boundaries can be extended to any area characteristic that is necessary for hydrographic management. The obvious boundaries of traffic areas (two way routes, traffic separation schemes, etc.) and other maritime limits could be codified and referenced into the system at the appropriate level. Importantly, areas not recommended for certain classes of vessels can also be managed. Other information groups and sub-groups can be classified for portrayal on the appropriate products (paper or electronic). Geomorphic and oceanographic groupings of bottom, sub-bottom composition and water body temperature layers are some examples for treatment for supply in tomorrow's navigation and marine operations systems.

The process of grouping must be associated with clear definition and classification in order to achieve meaningful usage from the structured data. In the case of surveys and soundings, it is necessary to identify those elements for which classification can be uniquely definitive. In some cases, such as the specific

TABLE 3

Simple example of subject polygons and elements

Subject polygons (complex sets):
- Sounding area sets
  - Sounded area boundary.
  - Area accepted for GISMO (area-as-charted).
  - Detailed examination, areas 1 ... n.
  - Areas not completed 1 ... n, etc.
- Technology area sets
  - Platform type.
  - Equipment.
  - Other technology polygons:
    - Swept areas.
    - Seabed geomorphology, etc.
- Other area characteristics
  - Survey area boundary.
  - Dangerous area (sub-class).
  - Prominent feature areas.
  - Navigation assessment.

Subject elements:
- Measurement/Observation:
  - Order of horizontal accuracy.
  - Order of vertical accuracy.
  - Confidence of measurement (esp. lidar).
  - Relational elements (e.g. line spacing).
- Environmental:
  - Sea state.
  - Atmospheric data, etc.
- Technological:
  - Equipment model/type, etc.
- General:
  - Datum relationships.
  - Standards relationships, etc.

technology used to capture soundings (sonar, lidar, etc.), this presents little problem, but when the potential classification becomes more subjective in interpretation, guidance is required. There is a tendency to consider certain classifications as too difficult or too non-specific, particularly when human intuition is at stake. It is not suggested that all elements to support future artificial intelligence be established, but rather to systematically define those elements that should be recorded for future use.

The concept of the polygon and element classifications that are being codified in the Australian experiment are shown at Table 3. What is needed is the collective contribution of all hydrographers to contemplating and defining the desirable polygon and element entities for the qualification of hydrographic information and the establishment of uniform standards of interpretation for use with future data bases. The most important subsequent work in conjunction with this is the examination of the intermediate and total inter-relationships of those elements in the decision making process.

The process of evaluation of the relationships between element classifications will occupy our attention for years to come. The examination of inferential decision making from codified information will extend the areas of our knowledge and technology into the 21st century. At a more simple level, the opportunity is here today to begin the orderly process of coordination of the body of hydrographic survey information. If it can begin to be coordinated now, then it will make it easier to provide the mariner with details of survey quality, ensure we are all identifying the same elements and to ensure that industry can more effectively provide the technology of the future.

Conclusion

As custodians of respective portions of the world information base of hydrographic data, hydrographers have a responsibility to advance the techniques of information management for all potential user requirements. This proposal is not set up as a definitive statement for information management. It is to raise the early warning on the issues we may face as we approach the twenty first century.

As the era of widespread use of electronic systems for data-logging and information management approaches, there is a need to have a uniformed approach to managing and exchanging hydrographic information. It becomes more imperative as the technological methodologies of survey measurement changes and industry is about to release a variety of the electronic chart systems to the users. The diversification of user requirement and the non-homogeneous nature of the survey coverage on a large proportion of our charts makes it important to provide a uniform assessment of survey quality to the user. To service the international mariner and allow others access to our information of the sea, as well as incorporating more information into navigation and operational command and control systems of tomorrow, we must further organize our information along international lines.

There is a need to structure and classify the distinguishing elements of hydrographic information and to provide interpretation standards for data based systems in a manner that ensures international coordination for safety at sea. Such coordinated standards will assist in the future development of hydrographic equipment and support system-aided inferencing from expert systems. The benefit of sound information management would support the timely presentation to respective governments of the real shortfall in hydrographic survey on an international basis and facilitate constructive budgeting for the resources necessary to survey and chart the oceans of the world. Such coordination should be a future emphasis for the Member States of the IHO.