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A WORLDWIDE DATABASE FOR DIGITAL NAUTICAL CHARTS

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THE CONTRIBUTION OF ELECTRONIC CHARTS TO NAVIGATION

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It is of historical interest that it was written instructions in the form of periplus [1], rather than the paper chart, that are recorded as providing the first form of document to guide marine navigators. Therefore perhaps the wheel has turned full circle when it is the digital information rather than the video display that may provide the basic guidance for the navigation of ships in the future. In 1986 when IMO and the IHO set out to develop Standards [2] and Specifications, it was decided that the product to be specified would have to be equivalent to the paper chart. In so doing they were following the guidance of the SOLAS Convention [3], which requires charts to be carried in Chapter V Regulation 20, and in Chapter I, Regulation 5, permits Administrations to substitute equivalents. Regulation V/20 does not state that the charts to be carried be paper but until recently it has been assumed that this is what is meant. What is explicit, is that the charts to be carried are to be "adequate, up-to-date and necessary for the intended voyage". Following this guidance the IMO/IHO Harmonizing Group attempted to specify an electronic system that would be equivalent to a printed paper document. This proved to be no easy task. It was extremely difficult to claim that an electronic system can be as durable and as generally reliable as a sheet of paper. What if the power breaks down? This and many other questions had to be answered before the Standards would satisfy the members of IMO [4].

It is frequently an incorrect premise to expect an automated system to precisely copy the tasks that have been carried out previously by a manual procedure. Modern systems, based on computer control, often have difficulty in precisely copying human tasks but they have capabilities far beyond those of the manually produced product. While the Standard for the new Electronic Chart Display and Information System (ECDIS) was being developed it became evident that ECDIS had a potential to do more than was possible with paper charts and conventional navigational methods. The first, and most obvious, capability was to combine instantly and continuously the navigational position with the chart data. As a result the navigator had a real time display of his ship on the chart, a great

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advantage with the increasing speed and size of ships. The second possibility is the automation of many navigational computations. Such computations are now incorporated in most modern navigation systems, such as LORAN C and GPS, and may be conveniently incorporated in an ECDIS and shown on the electronic chart. These include all the elements of way-point navigation, such as distance to go, track made good, deviation from course, time of arrival.

There are several features of ECDIS that allow it to be far more capable than the paper chart. These are the possibilities of providing alarms and warnings to the navigator when approaching a dangerous situation. The most significant of these is to provide an alarm when the vessel approaches a depth of water that equals the draft of the vessel. This line, providing the boundary between safe and unsafe, is known as the safety contour. It is the recognition of such a capability that causes ECDIS to be considered as a "grounding avoidance" system in comparison to ARPAs, which may be classed as "collision avoidance" system. The Performance Standard that has been developed by IMO and IHO includes a total requirement for eight alarms and seven indications to advise the navigator of unsatisfactory situations [5]. These warn the navigator, in addition to crossing the safety contour, of such matters as undesirable navigation situations as well as equipment failures.

It is clear that ECDIS designed to meet the IMO Standard provides the navigator with a far greater range of possibilities than the paper chart and consequently, if properly designed, should lead to much greater safety than that provided by the paper chart.

A particular feature of ECDIS is the ability of the navigator to be able to design his own chart. It is recognized that the paper chart is a compromise in satisfying its many users. Not only will the needs of the Supertanker navigator be quite different from the needs of the small yacht skipper but there is an increasing number of different kinds of users [6]. The chart is not only used for navigation but by all those who wish to exploit or protect the sea. As a consequence of these many needs it has been difficult to prevent the paper chart becoming congested or cluttered. ECDIS provides a possibility for each user to display only that information that concerns his needs. It should be emphasized from the start that what is included in the data base and what may appear on the display are two different things, although the displayed information will always be a subset of the data base contents. A recent paper [7] has used the term "stripping" with respect to the navigator's capability to remove information that he considers that he does not need on the display. Early work on ECDIS Standards suggested that the manufacturers of ECDIS had a responsibility to ensure that the navigator always had on display a complete set of information but navigators themselves have rejected this need and have stated that they wish to control all the information themselves. The Standard now refers to a Standard Display which is a limited set of information text which will always appear on switching on the System but may have information added or subtracted by the navigator and to a Display Base which is a level of critical information which is required at all times and cannot be removed from the display. In spite of these precautions, the navigator using ECDIS will be in a position of selecting his information in a manner that has never before been possible. A failure to call up a critical piece of information which is in the system data base could lead to a most dangerous situation which has yet to be fully examined in terms of the legal liability of all parties concerned.

Another feature of ECDIS to be considered is that of maintaining it up to date as required for the charts in SOLAS V/20. Without doubt, the hand correction of paper charts is heartily disliked by navigators and a source of extra work and consequent cost to shipowners. The possibility of automatic application of chart corrections, or updates as they are termed in connection with ECDIS, is clearly one of the bonus points of ECDIS but it requires technical and organizational development for it to take place accurately and reliably. ECDIS development is taking place during a period of considerable progress in communications development. As a consequence, the possibilities of updating ECDIS using satellite or other telecommunications media are being studied. At the present time the Notices to Mariners, which include the chart corrections, are sent by mail by Hydrographic Offices to their chart agents around the world. Ships only receive the Notices to Mariners when they arrive at port and normally at intervals of no more often than once a week. Urgent changes to charts may be sent by radio message at any time as part of the Navigational Warning Service but they will be repeated later in the Notices to Mariners if they are of a permanent nature. The association of telecommunications with ECDIS presents the possibility that all updates may be relayed instantly to ships at sea. At this time the question becomes primarily one of economy due to the costs associated with telecommunications and is being examined carefully. A publication providing guidance on ECDIS updating is to be issued shortly by the International Hydrographic Organization [8].

One final observation may be made on the potential of ECDIS concerning its contribution to navigation. This is its potential to be designed in a way that permits the navigator to interrogate the information provided. On a paper chart it is often necessary to provide a complex symbol or a lengthy written text to describe an object used by the navigator. For example a navigational buoy may have a symbol of a certain shape and colour to describe the buoy itself. There will then be a magenta flash to show that it is lit at night, a short abbreviated text will then describe the characteristics of the light e.g. Fl. .. 5 secs. It may be stated that it has a fog signal and its characteristics, if relevant, and finally there may be a symbol to show that it has a radar reflector. Using the possibilities of ECDIS and, in particular, the availability of an object oriented database, it is possible, instead of showing all the information of the display, as on a paper chart, to use a generic symbol for all buoys of a class and then to interrogate all the other information when it is needed [9]. The two approaches are a subject of contention between navigators, some of whom who wish to see the electronic chart appear just like the paper chart and some who feel that unless generic symbols are used the electronic chart will become cluttered.

At this stage the full contribution of electronic charts, in particular the contribution of ECDIS, has yet to be realized. SOLAS V/20 requires not only charts, be they paper or electronic, but "Sailing Directions, Lists of Lights, Notices to Mariners, Tide Tables and all other nautical publications necessary for the intended voyage", to be carried. The IMO Performance Standard addresses only the chart and the Notices to Mariners, but it is clear that ECDIS should be able to include much of the other information provided it is provided in the database. Further study is needed on how to communicate text information, such as included in the Sailing Directions. Obviously some automatic referencing of text to the chart area on display is required, but is there a need to convert the text into some form of pictorial or audible media that permits more effective cerebral communication?

The list of lights is basic to an object-oriented approach and must be an element of any intelligent ECDIS. In Australia, this has been carried one step further. using a multi-media approach in a test bed system designed for the Australian Hydrographic Office [10] which shows the navigator pictures of an aid to navigation in view form, as it would appear to him by day. Tide data may either be shown as a digital display with the tide tables stored in a special area of the system data base or tides may be predicted for the area of interest with the harmonic constants only being stored. This procedure is already used in several PC based systems for which the software has been produced by national HOs and commercial companies. A more far seeing use of tidal data is the possibility that soundings appearing on an ECDIS display may be reduced in real time by tidal heights to provide the actual depth, rather than the depth below the tidal datum as provided on paper charts such an approach is being taken with electronic charts covering the St. Lawrence Seaway. The difficulty of this possibility is twofold. One, the need to provide very accurate and reliable tidal data, the other is that unless a very dense set of sounding data is available it will not be possible to redraw the depth contours to satisfy a changing tidal correction.

Looking further afield into the potential of ECDIS it is possible to see the inclusion of information other than that provided by the chart and nautical publication [11]. This would include other parameters such as meteorological and perhaps ocean seafloor physical parameters to satisfy the needs of fishermen or other specialist users.

A DATA BASE TO SATISFY THE REQUIREMENTS

Some of the more developed Hydrographic Offices have been working to introduce computer assistance to their cartographic operations for over thirty years [12] and during the last fifteen years have been developing digital data bases [13], [14]. One of the questions has always been what depth of detail should be included? Should it be just the information from the paper chart or should it be a database of all the basic information, including the results of the surveys? Commercial companies developing electronic charts and realizing the lack of digital data available from the Hydrographic Offices started by digitizing the information on the paper chart. When national HOs entered the fray to produce digital data for ECDIS, it was thought at first that, as they possessed all the data, they could provide a data base of all the basic data. This would have required the ECDIS to compile the chart by performing such operations as automatic contouring and generalization when small scale chart images were to be shown. The difficulty of developing such detailed data bases as well as the extent of expert system control that would be needed in the ECDIS were quickly realized. As a result, much of the attention in developing digital data has so far been given to digitizing paper charts. However some HOs are developing digital flowlines in which the paper chart and the digital data for ECDIS are prepared simultaneously. Although this method is obviously efficient and economic it inhibits the speed at which the ECDIS data can be produced. Some HOs are developing digital data for ECDIS by recovering the digital data from several sources of government data, such as land contours from the land survey organization, the details of aids to navigation from the national lighthouse authority and the bathymetry from their own hydrographic sources. The requirement here is that all these data bases must be available in digital form and may be technically transferred into the ECDIS database.

The technology of digitizing from graphics has been substantially improved in recent years by the development of V-Track line following. Such technology is now in use by several HOs and commercial companies. The graphic, ideally the printing separations, is raster scanned. This raster image can then be displayed on a computer screen and an interactive line following technique can be used to quickly capture the digital coordinates of the line information. This, unfortunately, is only part of the job because the codification of the objects and attributes remains a time-consuming operation, with considerable quality control needed. Nevertheless, some of the pessimistic earlier estimates of time to produce digital data for ECDIS have now been reduced significantly.

A particular concern for HOs producing digital data is the quality of the original data as appearing on the paper charts. This has two dimensions. One is the inaccuracy of many of the earlier surveys from which the charts were compiled, particularly with respect to horizontal position of the data, the other is the fact that the majority of existing charts are not referenced to the WGS-84 reference datum [15]. It would be desirable, but quite impractical, to do all the surveys again and recompile the charts referenced to WGS-84. This is being done for certain limited areas where high quality digital data is essential but for most of the world such a procedure would not provide the data in time for the demand. It is felt that very little can be done to improve the quality of the data on a worldwide basis but it may be possible to apply some corrections to adjust the reference to WGS-84. Unfortunately, there are some charts where not even a local horizontal datum is provided and these areas will require field work if they are to be referenced to WGS-84.

It would be desirable to have a seamless data base [16]. The use of paper charts as a data source provides artificial boundaries which are not needed in a digital database. Paper charts are normally compiled on a range of scales with large scales generally being used where the water is shallower and the navigation complex. Small scales are normally used for the larger ocean areas where most of the water is deep and safe. As a move to assemble digital ECDIS data in a more systematic way, it was decided to assemble the data in cells which, like the paper charts, would cover progressively smaller areas as the data available became more dense. Unlike paper charts they would not overlap and would cover unique areas which would be standardized in dimensions. A problem yet to be overcome is the cartographic capability of ECDIS, if it is to provide "seamless" chart displays it will need to be capable of automatic generalization when the navigator wishes to view an area of densely populated data base at a smaller scale. The process of generalization will require that spot depths and irrelevant meanders of lines are omitted as the scale is reduced. Groups of features, such as small rocks and islets, may be combined into single features. The logic required for such an automatic operation is complex and a total dependence on a safe solution is essential. Various researchers have attempted to find solutions for cartographic generalization but to date no solution for ECDIS appears to be acceptable.

Another feature of a digital database for ECDIS is the inclusion of topology that allows the ECDIS to colour fill areas. This requires that all polygons must be complete. If they are not, the computer will be faced with the uncertainty of where one colour begins and another ends. As in the assembly on international data bases the data must be passed between HOs, this requirement for topology must be included in the digital data transfer standard so that the relationships may be passed accurately and completely.

A matter that was addressed in the requirements section of this paper is the desirability of fully describing each object and its attributes in the data base in order that they may be interrogated both for the purpose of providing information to the navigator and for identifying objects that the system needs to consider in order to provide alarms and warnings.

An important decision to be made is whether the database should be produced in raster or vector form [17]. The raster form involves a much greater amount of data than the vector form and consequently may require a more powerful computer in the electronic chart system. On the other hand the data is relatively simple to capture and provided that the pixel size is kept small it provides a faithful reproduction of the document that was scanned. Therefore when equivalence is desired, as discussed earlier, the raster image really can provide a digital equivalent to the paper product. As many artists have found, visual communication is sometimes most effective when just a few critical lines are drawn rather than when the viewer is overwhelmed with patterns and different colours. This may be the situation for the navigator and particular care must be taken not to overwhelm him with visual information especially when it is shown on a computer display screen, which is normally much smaller in dimensions than the paper chart. Vector data provides him with the tools to identify and select only those chart elements that are needed for the navigational task in hand. This feature is not possible with raster data which must display all or nothing. This is not to paint an entirely black picture of raster data because, in addition to giving a complete representation of all the data that has been scanned, it is possible to combine it with vector data overlays that will allow specific objects to be addressed. It also may be used to provide information on non-critical areas of the chart, such as the deep ocean areas on the land topography, which are not important to the navigator equipped with a precise positioning system and probably do not interfere with the navigator's viewing of critical navigable areas.

THE TECHNICAL APPROACH OF THE IHO

Accuracy. Metadata is required to describe the accuracy of data included in the database. A Working Group continues to study the matter of digital data quality and how it should be displayed. The exchange standard makes provision for including metadata.

HO supplied data. It is required by the IMO Performance Standard that all data be approved by government authorized Hydrographic Offices and furthermore be delivered using the IHO Transfer Standard for Digital

Hydrographic Data S-57 [18]. The possibility that additional data might be required to be displayed in ECDIS is recognized. Such data might include data from very large scale harbour or channel plans. However the fact that this is unofficial data must be clearly identified [19].

Scale ranges and Cells. As, for the time being, most of the data will be derived from paper chart sources or at least compilations intended to produce paper charts, the data density in the data base will normally be a function of the scale of the paper charts. It is convenient to organize data in cells, both for data manipulation in ECDIS and for chart correction. The cell size should be a function of the amount of data that will typically appear in a cell. This has led to the design of a uniform generic cell system as follows:

Class. of chart	Scale	Cell size
Plan	1:10 000 and larger	7.5 min x 7.5 min
Harbours	1:10 001 - 1:40 000	15 min x 15 min
Approach	1:40 001 - 1:80 000	30 min x 30 min
Coastal	1:80 001 - 1:300 000	1 degr x 1 degr
General	1:300 001 - 1:2 250 000	5 degr x 5 degr
World	1:2 250 000 and smaller	10 degr x 10 degr

Priority Layers. Besides arranging the data in cells it is also convenient to arrange it in priority layers. It is planned at present to have eleven layers.

Language. A debated issue has been whether the database should be in English only or if other languages should be included. It has been decided that the language should be English but other languages may be used as a supplementary option. Non-English alphabets may be used when necessary.

The Exchange Standard. Prior to the advent of ECDIS the IHO had realized the need for an exchange standard for the transfer of digital data between HOs for the production of paper charts. In 1986 it formed a Committee on the Exchange of Digital Data (CEDD) and approved the CEDD Exchange Standard at the XIIIth IH Conference in 1987 [20]. However, after examining the requirements for exchanging ECDIS data it was realized that the standard had to be re-designed. In particular, it was found necessary to include topology and a complete Object code. The new standard, known by its publication number S-57, has now gone through some refinement and Version 2.0 was published in 1993. Although there has been an increasing interest in extending the standard to raster data, it was initially decided to address vector data only. It is planned to include raster data requirements in a future version. It may be noticed that S-57 is an exchange standard and not a product standard. Data being passed by a manufacturer to an ECDIS user may use other formats, if they lead to greater efficiency.

Updating. It is essential that a data base for use with ECDIS must be regularly updated if ECDIS is to meet the requirements of SOLAS V/20. Although this matter has been realized for several years, it is only recently that the necessary research has been tackled. An IHO working group is at present working on Updating Guidance. Its conclusions are that there should be automatic and semi-automatic methods of updating available. For the former, updates may be passed from a HO to a distributing centre and then to the ECDIS by means of INMARSAT or other telecommunications media. In the latter the updates may be passed to the ECDIS user on a diskette or other form of magnetic media. Several experiments in updating are going on at present but no results have so far been published.

Quality Control. As for all hydrographic products, great concern is expressed for the data quality. This requirement is connected both with the overall reputation of government HOs and of their legal liabilities for their products. Several of the HOs now involved in database development have introduced some form of Quality Assurance, with ISO 9000 being considered as a relevant standard to be considered.

Database Contents. In spite of all the thought that has been given so far to the database design there remains some contention as to how the database is to be populated and what data will actually be included. Essentially, if an ECDIS is to be equivalent to the paper chart it must include all the data shown on the paper sheet. However, the fact that ECDIS will almost certainly be integrated with a very precise positioning system, such as DGPS or at least GPS, makes the requirement to show some of the features on the chart, that are required for visual navigation, redundant. It is also clear that some information on the chart is more important than other information and that in populating the database it may be more expeditious to first populate all the database area with the critical data and then progressively add the data in order of priority. This approach is being taken in Canada and Sweden.

Limited experience with electronic charts to date shows that there is an interest in having much more detailed information available than is provided on the published paper charts. Such information is particularly helpful in docking and navigating long narrow ship channels [21]. Therefore, a later stage of database development will need to provide this detail where needed; at present, it is only available from engineering drawings that are not authorized by HOs as sources of data.

THE ADMINISTRATIVE APPROACH OF THE IHO

There are several parallels between the development of a worldwide service providing digital data for ECDIS and the development of a worldwide service of international paper charts. While it would be possible for each national HO to provide international shipping with paper charts or to provide a database for its national waters it is more efficient to distribute the data, be it on paper or in digital form from a limited number of points. The convenience of "one stop shopping" is recognized by the service provided to international shipping in providing a worldwide coverage of paper charts by the UK Hydrographic Office, by the US Defense Mapping Agency and by the Russian Naval Hydrographic Office. It is the view of the IHO Special Committee on WEND (Worldwide Electronic Navigational Chart Database) that a similar arrangement to provide worldwide coverage of digital chart data should be a goal, although national shipping can be provided with digital chart data from its own national HO.

In 1991 the Norwegian Hydrographic Service proposed to the IHO that it should develop and provide a worldwide coverage of digital chart data and the associated service to maintain it. This was discussed at a Seminar at which the Chilean HO proposed an alternative regional approach [22]. The result of the Seminar, which was passed to the XIVth IH Conference in 1992 and subsequently approved, was to encourage Norway to develop a pilot scheme for Northwest Europe and for the IHO to establish a Special Committee. This body was to study the need for a Worldwide Electronic Nautical Chart Database (WEND) and to look into its administration and legal matters associated with it.

The Special Committee has recently completed its work and issues its final report [23]. It proposes that there be a network of interconnected Regional ENC Coordinating Centres [RECCs] [24]. Individual HOs will develop digital data and pass it to the RECC covering its geographic area. The RECC will integrate the data into a regional data base. Although it has yet to be firmly established, it has been proposed that the RECCs communicate with each other, so that a navigator can obtain digital data covering more that one RECC region from a single source. This should assist international shipping in obtaining all the digital data needed for a voyage. It is planned that updates to the database follow a similar pattern. Each HO will initiate the updating of its own digital data. These updates will be sent to the RECCs, where they will be integrated to provide a single set of updates for the entire region.

For the concept of RECCs to work it is necessary for the RECCs to establish bilateral agreements with the individual HO's within the Region. Such agreements will cover the conditions of making the data available, including technical matters and the reimbursement for the use of data. Norway, which is establishing the first formal RECC for Northwest Europe, has now established the form of this agreement and is busily setting up bilateral relationships. The Japanese Hydrographic Department has agreed to establish a RECC for East Asia and is discussing the details of its formation with its neighbouring countries. Several countries are now actively preparing digital information at a national level in order that it may be passed to the relevant RECC.

The legal liability associated with electronic charts is of considerable concern both to navigators and hydrographers. An earlier symposium to discuss this matter concluded that the electronic chart posed no significantly different legal issues than the paper chart. However the concern remains and a Conference is to be held at Tulane University, in the USA, next year to examine the matter further.

While the Special Committee on WEND has now recommended approaches to the administrative organization and other committees are steadily resolving technical issues associated with data base development, an outstanding question is how long it will take to develop and populate a worldwide data base for ECDIS. It is reported that Norway, France, Japan, the USA and Canada will all have developed substantial regional or national data bases by about 1996 but there remain areas of the world where the future progress is uncertain. There have been proposals to develop a regional data base for the Western Mediterranean by Italy and its neighbouring countries but no HO has yet proposed to develop a data base for the important shipping routes through the Red Sea and the Persian Gulf. In both South America and Australia there is considerable activity in developing the technology but no firm plans have been announced for data base development. From all these clues one may predict that a data base covering the world's main shipping routes will not be available until the early years of the next century.

ALTERNATIVE APPROACHES TO DATABASE DEVELOPMENT

The IMO Performance Standards state unequivocally that "the chart information to be used in ECDIS should be the latest edition of that originated by a Government Hydrographic Office, and conforms to IHO Standards". It is of considerable significance that two of the three HOs that produce worldwide paper chart coverage are producing digital data that does not meet these criteria. The US Defense Mapping Agency is producing worldwide coverage of digital data but is producing it in the Vector Product Format (VPF). This is one of the DIGEST family of Standards. DMA has reportedly chosen this route because of its needs to provide digital charts in a format that is acceptable to all branches of the US Armed Services. At this time it is stated that the digital data base is only to be made available to the armed services but should it be decided at a later date to market it to civilian customers there will be two Standards in use, which is undesirable, particularly when it comes to updating. Work is going on to try to make the S-57 and DIGEST Standards as compatible as possible, in order that, if necessary, data in one standard may be translated into another standard.

The UK HO has announced its plans to develop a raster data base covering all the world's main shipping routes. This is to be called the Admiralty Raster Chart Service (ARCS). Although it stresses that it is a product of an authorized Hydrographic Office and therefore fulfills the first criterion of the IMO Performance Standard, it does not conform to IHO Standard and therefore fails on that point. However the UK HO points out that it is intended as an interim product until the

S-57 database is available. It is in fact a by-product of the process of preparing S-57 data and the organization and technology needed to ensure its regular updating will no doubt resolve many of the issues yet to be faced in distributing the S-57 data and its updates. The UK ARCS data base is in fact more equivalent to the paper chart than S-57 as it will appear identical to the paper chart. It will also be much easier to ensure quality control than with the S-57 data. But unless it is developed to include complementary vector overlays, it appears at this time that it will not allow the electronic charts to perform some of the required functions, such as to provide alarms. Nevertheless the fact that it appears just like the much respected Admiralty paper chart and the ease and speed of development will make it very attractive to electronic chart manufacturers and to navigators. Whether the market will be prepared to wait and then to pay the additional cost required for a database that will make ECDIS more functional remains to be seen.

Yet another option for database development is offered by several commercial companies which are developing digital data. In the early days of electronic chart development some commercial companies started to digitize data from charts as it was not available from HOs. These and other companies produced simple electronic charts and simple data bases to be used with them. Their market was primarily recreational craft and commercial fishing vessels. In recent years some of these companies have seen a market in providing systems and the relevant data bases for larger commercial vessels and have begun to develop data which approaches the sophistication of the S-57 Standard. Their problem is that the data is not originated by a Government authorized Hydrographic Office and so does not meet the IMO Performance Standard. In order to take advantage of the quality control that can be provided by a government authorized HO and the productive capability of a commercial company several consortiums between government and industry are being developed. The exact arrangements tend to vary but this approach may lead to an overall faster delivery of S-57 data than had previously been estimated.

CONCLUSIONS

With the IMO Performance Standards being expected to be approved in 1995, there is an increasing interest in ECDIS. Experience to date with electronic chart systems on commercial vessels has shown their potential as an important element of future integrated bridge systems. The Achilles heel at this time is the uncertainties associated with the development of a suitable digital data base. The IHO and its Member States have moved purposefully to resolve the technical and administrative problems and several Member States are placing high priority on the development of digital data. The further development of the national data sets into regionally and, perhaps globally, integrated packages remains further into the future and therefore the exact course that will be taken remains uncertain.

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