Chapter 7

Electronic charts

7.1 Introduction

Ever since man first went to sea there has been a requirement for some form of recognition of the sea-going environment to assist in the safe passage to the required destination. Knowledge of the coastline, safe channels for navigation which avoid wrecks, sandbanks etc., and tidal information all play their part in assisting the navigator. Paper charts giving information about particular areas have been around for centuries and hydrographers from various countries have explored the world's oceans to produce up-to-date charts which are an invaluable aid to the seafarer whether they are aboard commercial vessels plying their trade around the world or leisure craft sailing for pleasure and recreation.

In 1683 an official survey of British waters was initiated by Royal Command, although the surveys that were published some 10 years later were produced at the surveyor's expense. In the 18th century much hydrographic work around the world was done by British hydrographers, although they still had to have their work published at their own expense, gaining recompense only by selling the results of their efforts privately. It was not until 1795 that the office of Hydrographer to the Board of Admiralty was established, the French having established their Hydrographic Office some 75 years earlier. The United Kingdom Hydrographic Office (UKHO), as it is now called, has an enviable reputation as a supplier of high quality charts and provides worldwide coverage with a folio of some 3300 charts. The UKHO is a member of the International Hydrographic Organization (IHO), a body set up to co-ordinate the activities of national hydrographic offices, promote reliable and efficient hydrographic surveys and ensure uniformity of chart documentation.

It was in 1807 that the Office of Coast Survey was set up in the United States for the purpose of surveying the US coast. Various name changes followed over the years, becoming the National Ocean Survey under the newly established National Oceanic and Atmospheric Administration (NOAA) in 1970. In 1982 a further name change produced the National Ocean Service (NOS) which contained an Office of Charting and Geodetic Services which was renamed as the Coast and Geodetic Survey (C&GS) in 1991. C&GS disappeared in a 1994 restructuring but the former subordinate division, the Nautical Charting Division, re-emerged as the present Office of Coast Survey (OCS), responsible for NOAA's mapping and charting programmes. Divisions within the OCS include the Marine Chart Division, which collects the data to enable the production of nautical charts, and the Hydrographic Surveys Division, which is responsible for all areas of hydrographic survey operations.

The OCS produces about 1000 nautical charts and is also a member of the IHO and, together with the National Imagery and Mapping Agency (NIMA) share responsibilities associated with IHO membership. The IHO presently consists of 67 member states. Most of these chart only their own waters but there are three nations that can supply chart folios of the world and two more that have coverage that extends outside their own waters. The IHO is a force for chart standardization throughout the world and this is an important feature of the move towards digital production of chart data.

At the present time most hydrographic offices still operate with the paper chart as the basis of their operations. However, over the past few years electronics has moved into the sphere of charting and now digital chart data is becoming more popular and is likely to be the mainstay product of the hydrographic offices in the years to come. With this new technology the seafarer is provided with a means of viewing a chart using a monitor that can display, in colour, all the information present on a paper chart. The chart information is contained on a memory device such as a CD-ROM and can be stored on a computer hard disk. Suitable navigational software can enable the chart data to be viewed for the purpose of 'safe and efficient navigation'. The electronic chart is one where chart data is provided as a digital charting system and it is capable of displaying both geographical data and text to assist the navigator. An electronic chart may fall into one of two categories.

- Official, which describes those electronic charts which are issued by, or on the authority of, a national hydrographic office. The hydrographic offices are government agencies and are legally liable for the quality of their products regardless of whether those products are paper or digital. Such charts are updated at regular intervals in order to conform to the SOLAS (Safety of Life at Sea) requirement that charts should be 'adequate and up-to-date for the intended voyage'.
- Non-official, which describes those electronic charts which are issued by commercial organizations which may use data owned by a hydrographic authority but are not endorsed by that authority.

An electronic chart may be constructed using either of two types of data, raster or vector.

7.1.1 Raster data

Raster data is produced by scanning a paper chart. This process produces an image that is an exact replica of the paper chart and which comprises a number of lines that are composed of a large number of coloured dots, or pixels. This technique does not recognize individual objects, such as a sounding, which limits its ability to conform to certain international guidelines. However, the use of what is termed a vector overlay, which can display specified user data such as waypoints and system data such as radar overlays etc., can overcome this deficiency. The advantages of raster charts can be summarized as follows.

- User familiarity since they use the same symbols and colours as paper charts.
- They are exact copies of the paper charts with the same reliability and integrity.
- The user cannot inadvertently omit any navigational information from the display.
- Cost of production is less than their vector counterpart.
- Wide availability of official raster charts. ARCS charts, for example, have near worldwide coverage.
- By using vector overlays together with appropriate software, raster charts can be used for all standard navigational tasks normally undertaken using paper charts. They can also emulate some of the functions of an electronic display and information system (ECDIS).

Disadvantages of raster charts can be summarized as follows.

- The user cannot customize the display.
- When using vector overlays the display may appear cluttered.
- They cannot be interrogated without an additional database with a common reference system.

- They cannot, directly, provide indications or alarms to indicate a warning to the user.
- Unless data content is the same, more memory is required to store data compared to a vector chart.

7.1.2 Vector data

Apart from the electronic navigational chart (ENC), which is compiled using raw data, vector data may also be produced by scanning a paper chart. However, the raster image is then vectorized by digitally encoding individual charted objects and their attributes (structured encoding) and storing such data, together with the object's geographical location, in a database. The ENC is the designated chart for the ECDIS system and is discussed in the next section. Chart features may be grouped together and stored in thematic layers that individually categorize each group. For example, the coastline could form one layer while depth contours are found on another layer etc. The system operator can thus optimize the display to show only that data of interest and avoid the display becoming cluttered with unwanted data. The vector chart is intelligent in that it can provide information that allows a warning of impending dangers to be generated.

The process of producing vector charts is time consuming and expensive while verification of chart data is more complicated than its raster counterpart. The advantages of vector charts can be summarized as follows.

- Chart information is in layers which allows selective display of data.
- The display may be customized to suit the user.
- Chart data is seamless.
- It is possible to zoom-in without distorting the displayed data.
- Charted objects may be interrogated to give information to the user.
- Indications and alarms can be given when a hazardous situation, such as crossing a safety contour, occurs.
- Objects may be shown using different symbols to those used on paper or raster charts.
- Chart data may be shared with other equipment such as radar and ARPA.
- Unless data content is the same, less memory is required to store data compared to a raster chart.

Disadvantages of the vector chart can be summarized as follows.

- They are technically far more complex than raster charts.
- They are more costly and take longer to produce.
- Worldwide coverage is unlikely to be achieved for many years, if ever.
- It is more difficult to ensure the quality and integrity of the displayed vector data.
- Training in the use of vector charts is likely to be more time consuming and costly compared to that needed for raster charts.

The vehicle for the delivery of electronic chart data is the Electronic Chart Display and Information System (ECDIS) which is a navigation hardware/software information system using official vector charts. Such a system must conform to the internationally agreed standard adopted by the International Maritime Organization (IMO) as satisfying a vessel's chart-carrying requirements under SOLAS. The ECDIS hardware could be simply a computer with graphics capability or a graphics workstation provided as part of an integrated bridge system. The system has inputs from other sources, namely position sensors such as GPS or loran, course indication from the gyrocompass, speed from the ship's log etc.

The information is transmitted to the ECDIS using National Marine Electronics Association (NMEA) interfacing protocols. Radar information can also be superimposed using either raw data from a raster scan radar or as synthetic ARPA (automatic radar plotting aid) data. The ECDIS software must comprise a user interface and a component that allows charts to be displayed and data read. The chart data component of ECDIS is the electronic navigational chart (ENC) which must comply with ENC production specifications under the IHO's S-57 edition 3 data transfer standard. More details of this system can be found in Section 7.3.

7.2 Electronic chart types

There are many different types of electronic charts available that use different formats, different levels of content and attribution, and may, or may not, be official charts. As described above, all presently available electronic charts are either vector or raster. For the former, the chart may be based on the IHO S-57 format or some other format. Only if the level of content and attribution of the chart conforms to the IHO ENC product specification and is produced by, or on the authority of, a government authorized hydrographic office, can the chart be considered an ENC as defined by the IMO ECDIS performance standards.

Official vector charts issued by the relevant hydrographic offices should conform to the ENC product specification based on the IHO S-57 format. Privately produced vector charts (non-official) may, or may not, conform to the ENC product specification. However, the use of unofficial ENCs will render an ECDIS non-compliant. Finally, it is possible to obtain charts that do not use the IHO S-57 format and do not conform to the ENC product specification.

7.2.1 Privately produced vector charts

These are generally made from scanned hydrographic office paper charts. The image produced is then digitized by tracing lines and features on the chart. This vectorization process stores chart features in 'layers' which can be redrawn automatically at an appropriate size if the chart is zoomed into. Categories of data, such as spot depths, navigation marks etc., can be added/deleted as required. In some systems specific chart items can be interrogated to obtain more information.

The nature of the vector display is such that the chart data is not displayed electronically as it was compiled in its paper chart form. Most systems automatically decide on the information to be displayed, depending on the level of zoom, to avoid the image being cluttered. Thus a new operational regime has to be developed to take account of the implications of:

- adding/deleting layers of data
- zooming and seeing more/less data appear according to the level of zoom
- displaying the chart at a larger scale than the source paper chart.

One of the principal producers of digital format electronic charts is C-MAP of Norway with worldwide coverage of 7500 charts on a CD-ROM. Data is coded in a System Electronic Navigational Chart (SENC) format called CM-93/3 which is compliant with the IHO S-57 format. C-MAP 93/3 displays a -U- (for unofficial) on their privately produced S-57 compliant charts. Details of the use of a SENC in an ECDIS is discussed in Section 7.3.

7.2.2 Official raster chart

There are two official raster chart formats.

- BSB raster charts, which contain all the data found in NOAA paper charts, with updates published weekly. These updates are available via the Internet and are in-sync with the US Coast Guard (USCG), NIMA and Canadian notices. NOAA has 1000 official charts and all have been available in raster form since 1995. These raster charts are produced jointly by NOAA and Maptech Inc. under a co-operative research and development agreement. The growth of computer-based navigation systems, together with GPS and other positioning systems, has meant an increase in the sale of raster charts and today approximately twice as many raster charts are sold compared to paper charts. The raster charts are available in CD-ROM form with each CD-ROM containing about 55 charts together with other relevant navigational facilities.
- UKHO ARCS and Australian Hydrographic Office (AHO) Seafarer both produced in the UKHO's proprietary hydrographic chart raster format (HCRF). ARCS is updated weekly using a CD-ROM with the same information as the weekly Notice to Mariners used to correct paper charts. Seafarer is updated monthly on a similar basis. ARCS has near worldwide coverage with 2700 charts available on CD-ROM.

ARCS/Seafarer charts are produced from the same process used to print paper charts, i.e. a rasterized process is used either to print a paper chart or produce a raster chart. They are accurate representations of the original paper chart with every pixel referenced to a latitude and longitude. Where applicable, horizontal datum shifts are included with each chart to enable the chart, and any information overlaid on it, to be referenced back to WGS-84. Not all available charts have WGS-84 shift information and such charts must be used with caution when a GPS position fix is applied. Chart accuracy is discussed further in Section 7.4.

The UKHO ARCS production system involves the use of a raster base maintenance and on-line compilation system (ABRAHAM) which is used to update, manage and plot navigational chart bases. The ARCS production system is integrated with ABRAHAM as is shown in Figure 7.1.

In its simplest terms ABRAHAM is all processes that are necessary to create and maintain the high-resolution (25 μ/1016 dpi) monochrome raster bases from which paper charts are produced, and ARCS is all processes that turn the ABRAHAM bases into ARCS CD-ROMs including:

- processing bases into lower resolution (200 μ/127 dpi) colour images
- adding header and catalogue information
- quality assurance checks
- encrypting the data
- ending a CD-ROM master to a pressing plant
- checking the stock returned by the pressing plant.

The ARCS CD-ROM production can be subdivided into periodic processing cycles.

- Weekly. Updates for all charts affected by Notice to Mariners are generated, checked and placed on the weekly ARCS update CD-ROM. New charts and new editions published that week are also included on the update CD, as is the text of temporary and preliminary Notices to Mariners.
- Periodic. To prevent the update CD from filling up, accumulated updates are periodically moved onto reissues of the ARCS chart CD-ROMs. This results in the production of a reissued chart CD at the same time as the weekly update CD. Nominally, one chart CD requires to be reissued each

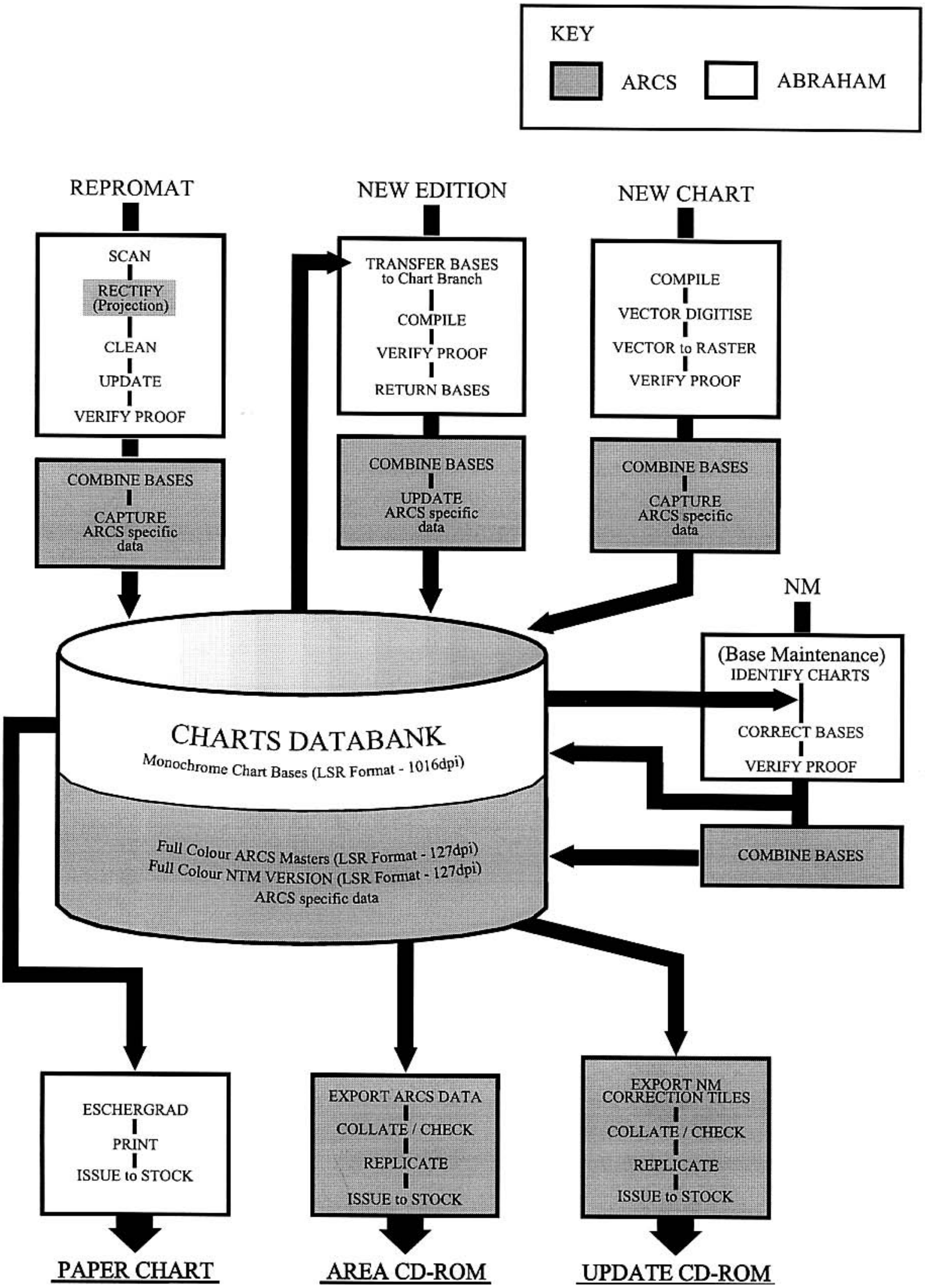

Figure 7.1 ARCS/ABRAHAM production system. (Reproduced with the permission of the Controller of HMSO and the United Kingdom Hydrographic Office.)

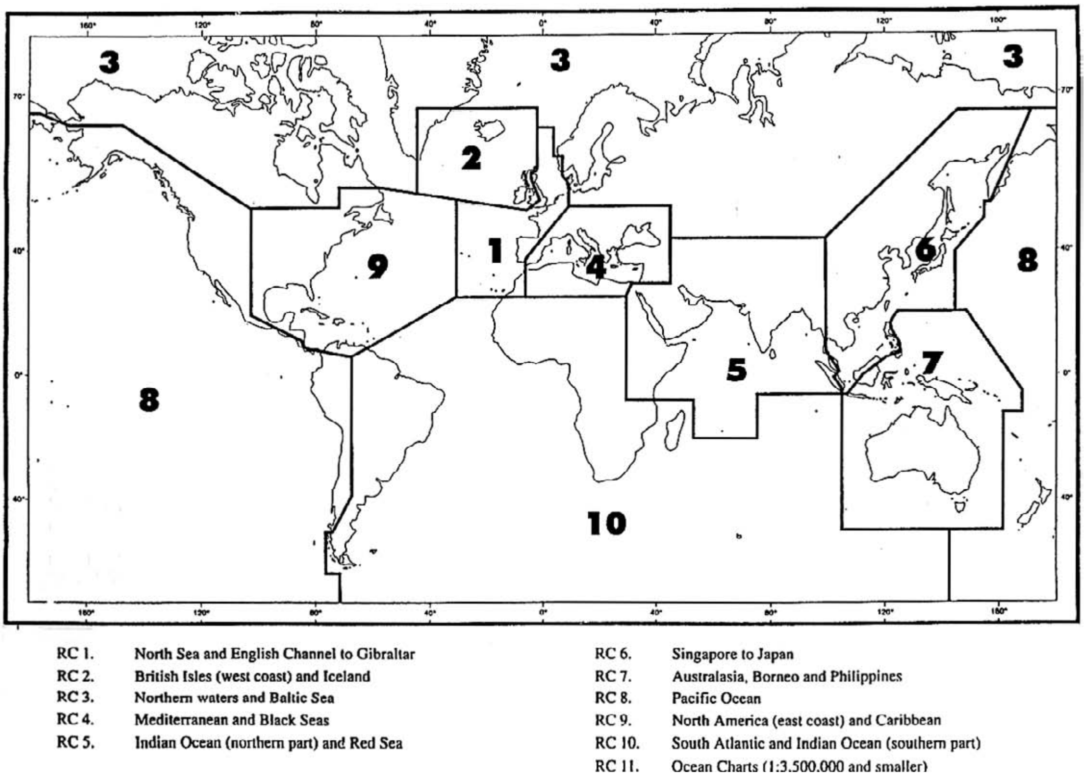

Figure 7.2 Regional coverage of ARCS CD-ROMs. (Reproduced with the permission of the Controller of HMSO and the United Kingdom Hydrographic Office.)

month, but the schedule varies according to the number of corrections outstanding and the number of chart CDs in stock.

- Monthly. Cross-checks are carried out against the data held on the Sales Order Processing System and the Chart Information System (CIS).

The UKHO provides a near worldwide coverage with 2700 charts available as ARCS CD-ROMs. The regional coverage of these charts is shown in Figure 7.2.

Table 7.1 gives a comparison between the BSB and ARCS raster types.

7.2.3 Electronic navigational charts (ENC)

These are the designated charts for the ECDIS system and they possess a single universal data format. Such charts use vector data based on the IHO Special Publication S-57, edition 3, IHO Transfer Standard for Digital Hydrographic Data. Some of the major points which identify the unique property of these charts are as follows.

- They are issued by or on the authority of a government-authorized hydrographic office.
- Items on the chart must be attribute-coded and must be able to be interrogated to provide information.

Table 7.1 Comparison between different raster chart types. (Reproduced courtesy of D. Edmonds of PC Maritime, UK)

Feature	*BSB*	*ARCS*
Government authorized	Yes	Yes
Entire catalogue always up to date to latest notice to mariner	Yes	Yes
Update service	Weekly	Weekly
Original scan from:	Stable mylar film originals used for printing paper charts	Stable colour separates used for printing paper charts
Scan resolution	762 dpi	1016 dpi
Chart resolution	256 dpi	127 dpi
Anti-aliasing	Yes	Yes
No of points used to relate the chart images to Lat/Long conversion	10–20, pixel to location conversions are also provided, accuracy depends on the printed chart	Pixel to position conversion is by calculation and is accurate to 1 pixel
Geodetic datum shifts	Yes	Yes
Integrity checks	Byte checksums are included in chart file	32-bit CRC check on original and updated image
Liability	US government accepts liability for errors on NOAA charts	UK government accepts liability on UKHO products

- The data is delivered in cells to provide seamless data for the task in hand. The cell structure changes according to the data set used.
- All chart data is referenced to a global geodetic datum, WGS-84, which is the datum used by GPS.

The data is fully scaleable and it only needs a view area to be defined for an appropriate level of data to be automatically presented to the operator. If it is required to add/delete data then information can be grouped into layers and turned on/off as required. Zooming can allow the chart image to be enlarged to provide greater ease of use. Zooming with a raster chart clearly shows when an image is presented at a scale greater than the compilation scale since the text and navigational symbols would be larger than their normal size rendering the chart unsafe for navigation. Over-scaling with an ENC has the problem that the navigational symbols remain the same size regardless of the scale used and this could cause a potential navigation hazard. The ECDIS is required to display an over-scale warning automatically if it has used zooming to produce an image beyond the compilation scale of the chart.

Individual contour lines can be defined as safety contours with anti-grounding warnings given based on the ship's closeness to them. Alarms will be generated automatically if the ECDIS detects a conflict between the vessel's predicted track and a hydrographic feature within the ENC that represents a potential hazard to the vessel.

The ECDIS can offer different chart information by displaying all ENC content, a subset of the ENC content (known as standard display) or a minimum permitted subset of ENC content (known as display base). The first two categories permit information to be added/deleted while the display base cannot have information deleted since it is stipulated as the minimum required for safe navigation. A System Electronic Navigational Chart (SENC) is that database obtained by the transformation of the ENC data, including any updates and data added by the user, by the ECDIS prior to display. It is the SENC that forms the basis for the display and the user decides what part of the SENC database is required for the display. It is a requirement that the ENC database must remain unaltered so that the SENC database could be reconstructed should it be debased in any way during operations.

The availability of ENCs will depend on key factors that affect the NHOs producing them. These factors include the following.

- Production experience. The rate of production should increase as staff gain more experience in the production of these charts.
- Data quality. Software tools necessary to underpin the quality assurance of the digital database have to be developed to ensure compliance with S57, edition 3 requirements. This will take time.
- Uniformity of data. There is a need for all hydrographic offices to ensure their ENCs are produced with consistency in the interpretation of the standard and to product specification. The use of regional co-ordinating centres is of use in facilitating this.
- Geographical cover. By concentrating on the geographical areas most used by shipping companies it should be possible to deliver the required charts ahead of others.

As an example of the development of ENCs, the UKHO awarded a contract to the Indian company, IIC Technologies, for data capture work in February 2000. This is the first step in the production of ENCs with the data sets produced by IIC to be quality assessed by the UKHO to ensure compliance with the required standards. The UKHO will also concentrate on stitching together the data set cells and matching the edges to produce a seamless ENC database. The contract is an enabling contract of up to four and a half years allowing the UKHO to request data sets in tranches with continuity of production.

The regional co-ordinating centres are an important means of distributing the ENCs to potential customers. The International Hydrographic Organization (IHO) proposed a system for supplying ENCs to be known as Worldwide ENC Database (WEND). Using this concept the world is divided into Regional ENC Co-ordinating Centres (RENCs). At present only one RENC has been set up,

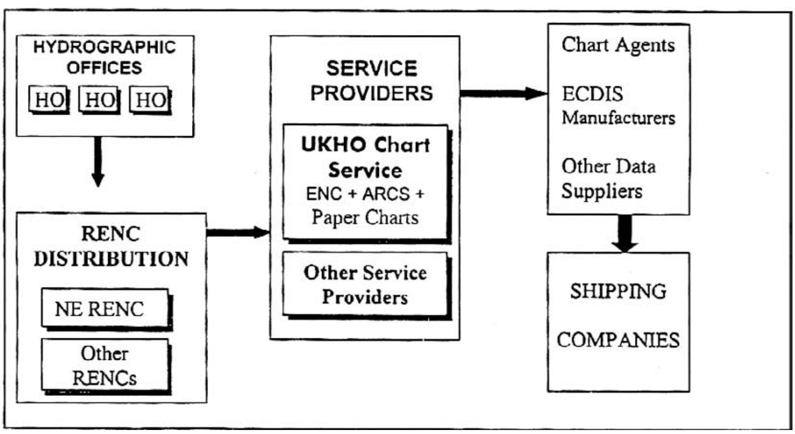

Figure 7.3 RENC distribution system. (Reproduced with the permission of the Controller of HMSO and the UK Hydrographic Office.)

Table 7.2 Equivalence to the paper chart. (Reproduced courtesy of D. Edmonds of PC Maritime, UK)

Privately produced vector charts	*Official raster (RNCs)*	*ENCs*
Generally a copy of the paper chart	An exact replica of paper chart	All data merged into cells
A different image to the original paper chart is presented at all levels of zoom and scale	The same image as the paper chart is always presented. The chart is more equivalent to the paper chart than any vector chart including ENCs	No resemblence to the paper chart
Symbols and colour vary with manufacturer	Symbols and colour are the same as the paper chart equivalent	The IHO publication S–52 defines new colours and symbols for ENCs
Accuracy, reliability and completeness vary with manufacturer	RNCs are as accurate, reliable and complete as the paper version	ENCs should eventually be more accurate and reliable than the paper version
A new operational regime is required	The same operational regime as paper charts is followed. There are some changes, if only because of screen size	A new operational regime is required

Table 7.3 Chart integrity. (Reproduced courtesy of D. Edmonds of PC Maritime, UK)

Privately produced vector charts	*Official raster (RNCs)*	*ENCs*
Produced by private companies	Produced by, or under the authority of government authorised hydrographic offices	Produced by, or under the authority of government authorised hydrographic offices
Unofficial	Official	Official
Generally no responsibility is accepted	Responsibility is accepted for chart data in terms of its completeness and accuracy in comparison with the equivalent paper chart	Responsibility is accepted for chart data in terms of its completeness and accuracy
Is unlikely to become legally equivalent to the paper chart	Is unlikely to become legally equivalent to the paper chart	Is legally equivalent to the paper chart
It may be possible to change original chart data	The chart data is tamper proof	The chart data is tamper proof
Charts can be zoomed (i.e., the display of a single chart is magnified or reduced without restriction. Chart detail varies depending on the level of zoom)	Chart zoom should be limited to a level that does not break up the image. Information displayed on the chart remains unaltered	Charts can be zoomed in or out without restriction. Chart detail varies depending on the level of zoom
Quality control varies with manufacturer	Quality control is government standard	Quality control is government standard

Table 7.4 Chart corrections. (Reproduced courtesy of D. Edmonds of PC Maritime, UK)

Privately produced vector charts	*Official raster (RNCs)*	*ENCs*
Up-to-dateness of charts varies with manufacturer	Charts are up-to-date at the point of sale	Charts will be up-to-date at the point of sale
It is difficult to determine the up-dating policy of manufacturers	Chart data is maintained up-to-date to clearly stated standards	Chart data is maintained to a clearly defined standard
Varies with manufacturer	On demand updates for leisure users	Not applicable
Varies with manufacturer	Subscription updates for commercial users	Subscription updates available
Varies with manufacturer	Automatic integration of chart updates	Automatic integration of chart updates

Table 7.5 Safety. (Reproduced courtesy of D. Edmonds of PC Maritime, UK)

Privately produced vector charts	*Official raster (RNCs)*	*ENCs*
Geodetic datum shift to WGS-84 may not be provided	Chart data includes geodetic datum shift to WGS-84, if known	All data is referenced to WGS-84
Chart data can be removed from the display. Significant navigation information may be inadvertently removed	Chart data cannot be removed from the display. The user cannot inadvertently remove significant navigation information	Chart data can be removed from the display. Significant navigation information may be inadvertently removed

namely the Northern Europe RENC known as PRIMAR. This is a co-operative arrangement between most of the national hydrographic offices in northern and western Europe. To date the hydrographic offices of Denmark, Finland, France, Germany, Netherlands, Norway, Portugal, Poland, Sweden and UK have signed the formal co-operation arrangement and other hydrographic offices have expressed an interest in joining. PRIMAR is operated by the UK Hydrographic Office and the Norwegian Mapping Authority's Electronic Chart Centre.

The ENCs will be sold through a network of distributors and should be able to provide worldwide cover by exchange of data with other RENCs once these are established in other parts of the world. A block diagram showing the RENC concept is shown in Figure 7.3.

Tables 7.2 to 7.5 summarize the features of each chart type in relation to each other.

7.3 Electronic chart systems

7.3.1 Electronic Chart Display and Information System (ECDIS)

There are several types of electronic chart systems available but only one performance standard has been approved by the International Maritime Organization (IMO) in November 1995. The IMO resolution A817(19) states that the ECDIS should 'assist the mariner in route planning and route monitoring and, if required, display additional navigation-related information'. The system approved is known as the Electronic Chart Display and Information System (ECDIS) and applies to vessels governed by Regulation V, Chapter 20 of the 1974 Safety of Life at Sea (SOLAS) convention. It complies with the carriage requirement for charts with an ECDIS system using Electronic Navigational Charts (ENCs). ECDIS is a navigational information system comprising hardware, display software and official vector charts and must conform to the ECDIS performance standards; amongst other aspects these performance standards govern chart data structure, minimum display requirements and minimum equipment specifications. Chart data used in an ECDIS must conform to the Electronic Navigational Chart (ENC) S-57, edition 3.0 specification and the performance standard for this was agreed by the International Hydrographic Organization (IHO) in February 1996. Any ENC must be issued on the authority of a government-authorized hydrographic office.

Back-up arrangements for ECDIS were agreed by the IMO in November 1996, becoming Appendix 6 to the Performance Standards and allowing ECDIS to be legally equivalent to the charts required under regulation V/20 of the 1974 SOLAS convention. It is an IMO requirement that the National Hydrographic Offices (NHOs) of Member Governments issue, or authorize the issue of, the ENCs, together with an updating service, and that ECDIS manufacturers should produce their systems in accordance with the Performance Standards. Other notable milestones leading to the ECDIS specification include the following.

- IHO Special Publication S-52 which specifies chart content and display of ECDIS. This includes appendices specifying the issue, updating and display of ENC, colour and symbol specification. The IHO Special Publication S-52 was produced in December 1996.
- IEC International Standard 61174. In this publication the International Electrotechnical Commission describes methods of testing, and the required test results, for an ECDIS to comply with IMO requirements. The standard was officially published in August 1998 and is to be used as the basic requirement for type approval and certification of an ECDIS which complies with the IMO requirements.

Some ECDIS definitions are summarized below.

- **Electronic Chart Display and Information System (ECDIS)** means a navigation system which, with adequate back-up arrangements, can be accepted as complying with the up-to-date chart required by regulation V/20 of the 1974 SOLAS Convention, by displaying selected information from a System Electronic Navigational Chart (SENC) with positional information from navigational sensors to assist the mariner in route planning, route monitoring and displaying additional navigational-related information if required.
- **Electronic Navigational Chart (ENC)** is the database, standardized as to content, structure and format, issued for use with ECDIS on the authority of government-authorized hydrographic offices.
- **System Electronic Navigational Chart (SENC)** is a database resulting from the transformation of the ENC by ECDIS for appropriate use, updates to the ENC by appropriate means, and other data added by the mariner.
- **Standard Display** means the SENC information that should be shown when a chart is first displayed on an ECDIS. The level of information provided for route planning and route monitoring may be modified by the mariner.
- **Display Base** means the level of SENC information which cannot be removed from the display, consisting of information which is required at all times in all geographical areas and all circumstances.

The basic ECDIS requirements can be summarized as follows.

- **ENC data.** This is to be supplied by government-authorized hydrographic offices and updated regularly in accordance with IHO standards.
- **Colours/Symbols.** These must conform to the specification outlined in IHO Special Publication S-52. Symbol size and appearance are specified and the mariner should be able to select colour schemes for displaying daylight, twilight and night-time conditions.
- **Own Ship's Position.** The ECDIS should show own ship's position on the display. Such a position is the result of positional input data received from suitable sensors and should be continuously updated on the display.
- **Change Scale.** The use of zoom-in and zoom-out should allow information to be displayed using different scales. ECDIS must display a warning if the information shown is at a scale larger than that contained in the ENC or if own ship's position is produced by an ENC at a larger scale than that shown by the display.
- **Display Mode.** The mariner should be able to select a 'north-up' or 'course-up' mode. Also the display should be able to provide true motion, where own ship symbol moves across the display, or relative motion where own ship remains stationary and the chart moves relative to the ship.
- **Safety Depth/Contour.** The mariner can select safety depth, whereby all soundings less than or equal to the safety depth are highlighted, or safety contour whereby the contour is highlighted over other depth contours.
- **Other Navigational Information.** Radar or ARPA data may be added to the display.

As emphasized earlier, one of the key requirements for ECDIS is to assist the user to plan a route and monitor the route while under way. This and other functions are listed below.

- **Route Planning.** The mariner should be able to undertake the planning of a suitable route, including the provision of waypoints which should be capable of being amended as required. It should be possible for the mariner to specify a limit of deviation from the planned route at which activation of an automatic off-track alarm occurs.
- **Route Monitoring.** ECDIS should show own ship's position when the display covers the area involved. The user should be able to 'look-ahead' while in this mode but be able to restore own ship's position using a 'single operator action'. The data displayed should include continuous indication of ship's position, course and speed and any other information, such as time-to-go, past track history etc., considered necessary by the user. Indication/alarms should feature using parameters set by the mariner.
- **Indication/Alarm.** ECDIS is required to give information about the condition of the system or a component of the system; an alarm should be provided when a condition requires urgent attention. An indication could be visual whereas an alarm could be visual but must also be audible. Indications should include, among others, information overscale, different reference system, route planned over a safety contour etc. Alarms should include, among others, system malfunction, deviation from route, crossing safety contour etc.
- **Record of Voyage.** ECDIS must be capable of recording the track of an entire voyage with timings not exceeding 4-hourly intervals. Also ECDIS should keep a record of the previous 12 h of a voyage; such a record should be recorded in such a way that the data cannot be altered in any way. Also during the previous 12 h of a voyage ECDIS must be capable of reproducing navigational data and verifying the database used. Information such as own ship's past track, time, position, speed and heading and a record of official ENC data used, to include source, edition, date, cell and update history, should be recorded at 1-min intervals.

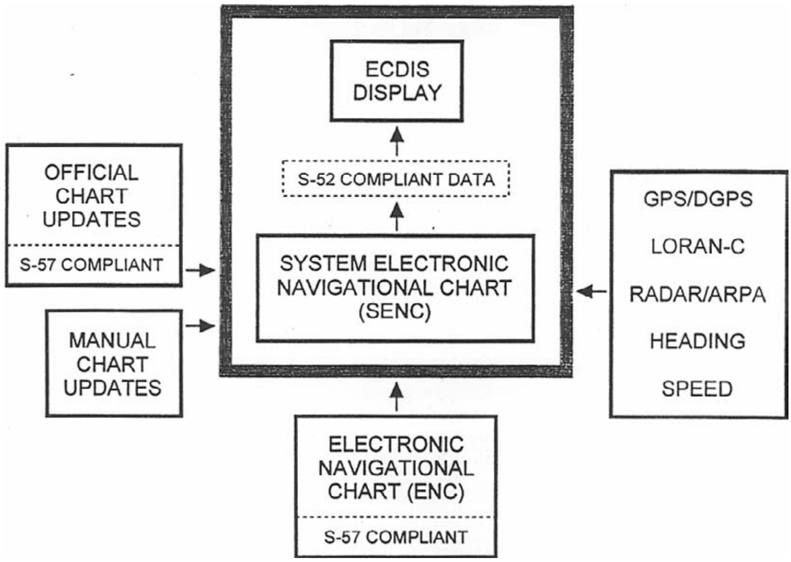

Figure 7.4 Block diagram of an ECDIS. (Reproduced courtesy of Warsash Maritime Centre.)

- **Back-up Arrangements.** This is required in case of an ECDIS failure. The back-up system should display in graphical (chart) form the relevant information of the hydrographic and geographic environment necessary for safe navigation. Such a system should provide for route planning and monitoring. If the back-up system is electronic in form it should be capable of displaying at least the information equivalent to the standard display as defined by the performance standard.

A block diagram of an ECDIS is shown in Figure 7.4.

The production of ENCs is proceeding but it is a lengthy and costly business and it is likely that widespread coverage will not be available for some time and certain regions may never be covered at all. Because of the delay likely in implementing ECDIS, hydrographic offices around the world have proposed an alternative official chart solution that uses the raster chart and is known as the Raster Chart Display System (RCDS).

7.3.2 Raster Chart Display System (RCDS)

This is a system capable of displaying official raster charts that meets the minimum standards required by an appendix to the ECDIS Performance Standard. The raster nautical chart (RNC) is a digital facsimile of the official paper chart and provides a geographically precise, distortion-free image of the paper chart.

The IHO proposed a raster chart standard that 'should form a part of the ECDIS performance standards where it would logically fit'. This was approved by the IMO's Maritime Safety Committee in December 1998 as a new appendix to the existing ECDIS Performance Standard, entitled 'RCDS Mode of Operation'. It is now permissible for ECDIS to operate in RCDS mode using official RNCs when ENCs are not available. The use of ECDIS in RCDS mode can only be considered providing there is a back-up folio of appropriate up-to-date paper charts as determined by national administrations.

Raster charts for these systems have been developed in recent years by major hydrographic offices and include the British Admiralty Raster Chart Service (ARCS) and the NOAA's BSB raster chart. The United States started raster scanning in 1991 and evaluated a prototype of the scheme in 1992. NOAA began converting its charts to raster format in 1993 and completed the task in 1994. The United Kingdom Hydrographic Office (UKHO) started the raster scanning of its Admiralty charts in 1994 and shipboard trials of ARCS began in 1995; the service becoming commercial in 1996. Other nations have also developed their own RCDS charts.

Raster charts are offered as an interim measure while awaiting the arrival of the ENCs and are designed to offer a performance specification that closely follows that of the ENCs and includes important requirements such as:

- continuous chart plotting and chart updating
- at minimum, the same display quality as the hydrographic office paper chart
- extensive checking, alarms and indicators relating to the integrity and status of the system
- route planning and voyage monitoring.

The IMO has drawn mariners' attention to the fact that the RCDS mode of operation lacks some of the functionality of ECDIS. Some of the limitations of RCDS mode compared to ECDIS mode include the following.

- The raster navigational chart (RNC) data will not itself trigger automatic alarms although some alarms can be generated by the RCDS from information inserted by the user.
- Chart features cannot be altered or removed to suit operational requirements. This could affect the superimposition of radar/ARPA.
- It may not be possible to interrogate RNC features to gain additional information about charted objects.
- An RNC should be displayed at the scale of the paper chart and RCDS capability could be degraded by excessive use of the zoom facility.
- In confined waters the accuracy of the chart data may be less than that of the position fixing system in use. ECDIS provides an indication in the ENC that permits determination of the quality of the data.

7.3.3 Dual fuel systems

Because of the adoption by the IMO of the amendments to the performance standards for ECDIS to include the use of RCDS, an ECDIS is now able to operate in two modes:

- ECDIS mode when ENC data is used
- RCDS mode when ENC data is unavailable.

Thus the dual fuel system is one that is either an ECDIS or RCDS depending on the type of chart data in use. At the present there are only few ENCs so the ability to use ECDIS is restricted. RNCs are plentiful and can provide two vital functions:

- provide official electronic chart coverage for areas not covered by ENCs
- provide link coverage between the ENCs that are available.

7.3.4 Electronic chart systems (ECS)

Where a system does not conform to either ECDIS or RCDS performance standards it is classified as an ECS system. There are no official performance standards for this system. The IMO had been considering the production of advisory guidelines but at the 1998 meeting of the IMO Navigation Safety Subcommittee it was decided that guidelines for ECS were not necessary and the matter will not be pursued further. As a general rule, a system is an ECS if:

- it uses data which is not issued under the authority of a government-authorized hydrographic office
- vector chart data is not in S-57 format
- the system does not meet the standards of either ECDIS or RCDS performance standards.

An ECS may not be used as a substitute for official paper charts, and ships fitted with an ECS are legally required to carry suitable up-to-date official paper charts. Examples of ECS include radar systems incorporating video maps, stand-alone video plotters and all systems while using commercial raster charts and vector charts systems.

7.4 Chart accuracy

Any chart is only as good as the original survey data allows and the accuracy with which that data is recorded on the chart by the cartographer. A navigational chart is referenced to two data: horizontal, for latitude and longitude; and vertical, for depth and height.

Since the beginning of mapmaking, local maps were based on the earth's shape in that area and, since the earth is not a perfect sphere, the shape does vary from location to location. Figure 7.5 shows a representation of a vertical slice through the earth. The diagram shows an uneven surface to the

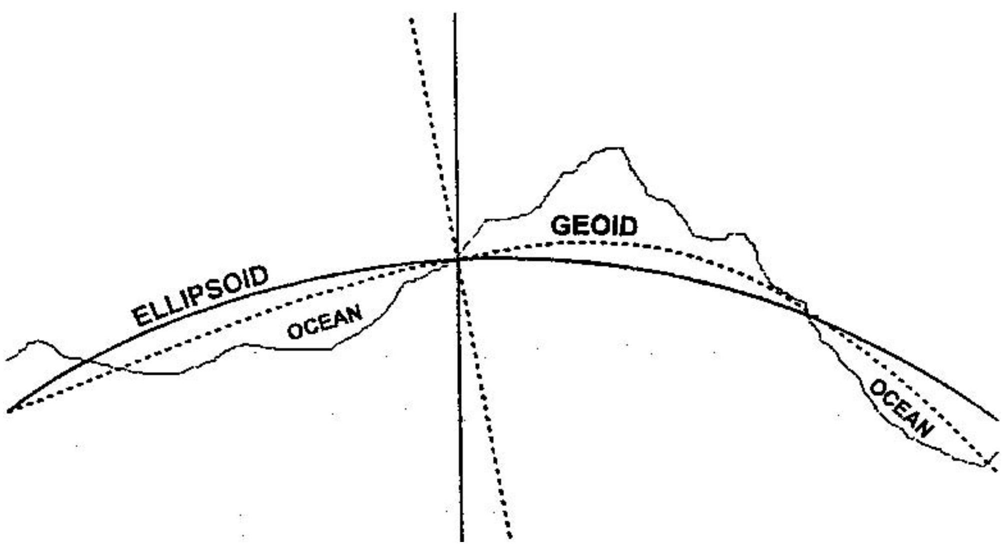

Figure 7.5 View of the earth's surface showing the geoid and ellipsoid. (Reproduced courtesy of Warsash Maritime Centre.)

earth, a dotted line representing a geoid and a solid line representing an ellipsoid. The geoid represents a surface with equal gravity values and where the direction of gravity is always perpendicular to the ground surface. For mapping purposes it is necessary to use a geodetic datum which is a specifically orientated reference ellipsoid. The surface of a geoid is irregular while that of an ellipsoid is regular.

Many different ellipsoids have been used to represent the best fit to the geoid in a particular area. The use of an ellipsoid for positional calculations must first be referenced to the geoid and that relationship defines what is known as a datum. The accuracy of a particular datum may be fine for the local area for which it was intended but the accuracy may suffer as the deviation from that area increases. There are scores of different data such as Ordnance Survey Great Britain 1936 (OSGB36), the European Datum 1950 (ED50), the Australian Geodetic System 1984, North American Datum 1983 (NAD83), etc. Charts drawn for a particular area therefore may contain datum information that is localized.

The use of satellite systems has involved the use of a global datum and GPS uses the World Geodetic System 1984 (WGS-84) which uses a model of the complete earth. The ellipsoid for this system is centred on the Earth's centre of mass and, over the earth as a whole, is a better fit to the geoid than other ellipsoids, although the local datum may give a better fit within their own small area. Ideally all charts should be referenced to WGS-84 but this is not expected to occur for many years to come. Reasons for the delay include:

- the time necessary to replace current charts with new versions using WGS-84
- lack of data necessary to calculate datum shifts and, in some cases, the datum used for the chart is either unknown or poorly defined.

As far as the UKHO is concerned, about 20% of its charts are referenced to the WGS-84 datum, a further 40% use datum when the shift is known, while some 40% use unknown datum. When the shift to WGS-84 is known the UKHO charts have a 'Satellite Derived Positions' note that provides shift values in minutes of latitude and longitude which allows GPS-determined positions, referenced to WGS-84, to be correctly adjusted before they are plotted on the chart. Currently about 40% of the UKHO charts contain shift values.

Electronic chart systems using raster chart displays can use the datum shift values indicated in the 'Satellite Derived Positions' note on the chart to convert the WGS-84 co-ordinates to the local datum. The shift values are mean values for the area covered by the chart but the shift variation across the chart is within manual plotting tolerance at the scale of the chart and can be ignored. However, the quoted shift values on an adjacent chart could well be different.

For electronic chart systems using vector charts it is a requirement that the charts are referenced directly to WGS-84. Since so few official paper charts are referenced directly to WGS-84 it follows that vector chart producers must use a mathematical model to shift the data on certain charts to WGS-84. Users of the system should always check to see whether the official paper chart is referenced directly to WGS-84. If the official chart has a 'Satellite Derived Positions' note giving datum shift values then it could safely be assumed that errors introduced by the conversion to WGS-84 will be small at the scale of the official chart. If WGS-84 shift values do not appear on the paper chart it would suggest that the existing data is insufficient to establish accurate datum shifts and GPS-derived positions cannot be used with confidence.

With ECDIS and the use of ENCs, all references are to WGS-84 so there should be no problem with datum shifts. However, as discussed earlier, there could be a problem of geodetic datum shifts using paper charts, RNCs and privately produced vector charts if positional information is received based on one datum and such data is plotted on a chart which is based on another datum. Figure 7.6

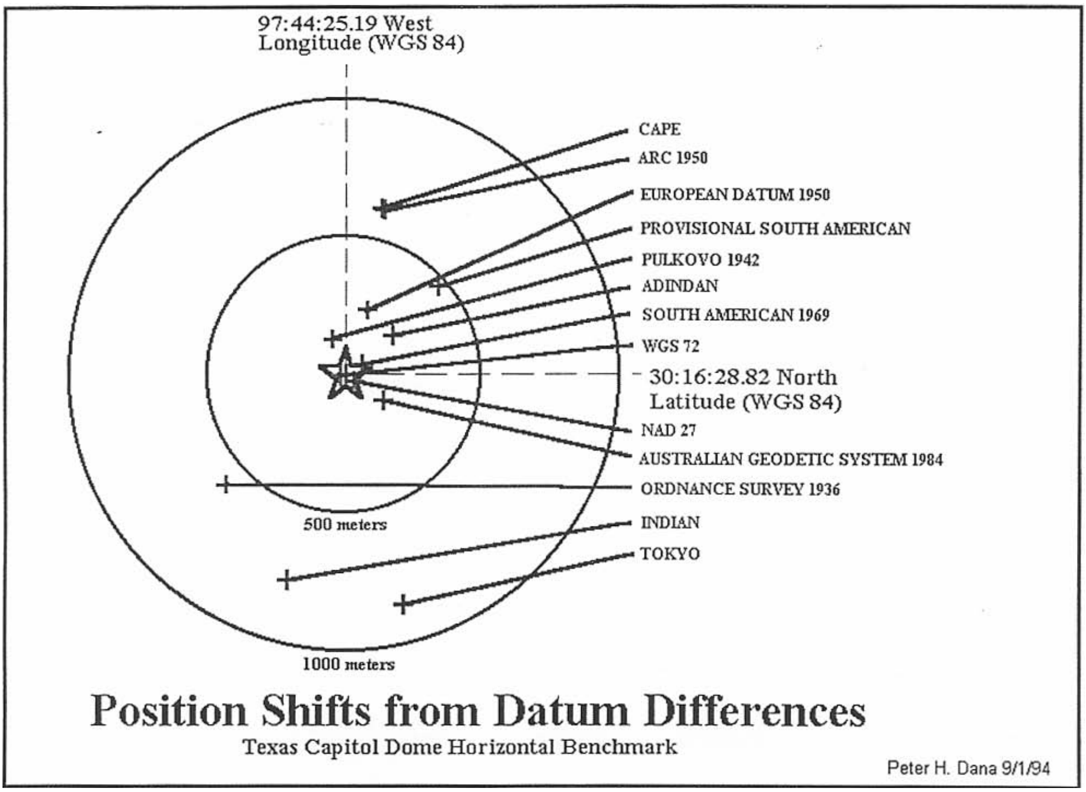

Figure 7.6 World geodetic datums. (Reproduced courtesy of PC Maritime.)

illustrates the variation in latitude and longitude positions that could be derived for the same real location depending on the datum used.

Consider another example of datum differences in the English Channel. The Admiralty charts covering the English coastline are in OSGB36 whereas the Admiralty charts covering the French coastline are in ED50. The OSGB36 datum is used for charts covering the coastline of England, Wales and Scotland while the ED50 was developed for military mapping in Central Europe. UKHO charts covering both sides of the channel tend to be in OSGB36. Thus if an operator working in the channel plotted a position on an OSGB36 chart and then moved to a European 1950 chart without allowing for a datum shift, there will be a positional error as indicated in Figure 7.7.

In some regions of the world the difference between WGS-84 and the local datum can be quite large and this is illustrated in Figure 7.8.

The solution to the problem is obviously to obtain positional information in WGS-84 and to apply the published shift every time a change of paper chart is made. It must be remembered that GPS accuracy has tolerance values and any inaccuracy derived from GPS may be exacerbated by plotting charts of different datum. Most GPSs have built-in datum transformations so that the system can output positions in a local datum but this has certain disadvantages.

- Because there are no standards applicable to the transformation formulae, two different GPSs may use different formulae and give different results. The solutions produced are averaged over a wide

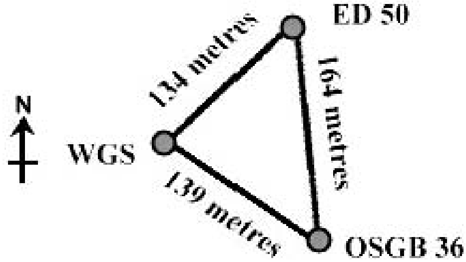

Figure 7.7 An example of datum shift in the English Channel. (Reproduced courtesy of PC Maritime.)

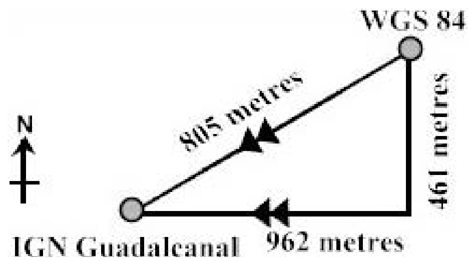

Figure 7.8 An example of datum shift in the Pacific. (Reproduced courtesy of PC Maritime.)

area and any transformation error may range from, say 25 m to much more at the fringes of the area covered by the datum.

- It is difficult to ensure the GPS is switched to the correct datum every time a chart is changed.
- GPS positions may be fed simultaneously to other equipment, such as ARPA, autopilot etc., which expect to receive data in WGS-84 co-ordinates.
- Some GPSs apply the data transformation to all waypoint positions held in memory when a datum other than WGS-84 is selected for the display of positions.

It may be better to maintain the output of GPS in WGS-84. As stated earlier, for the UKHO paper charts, a shift from WGS-84 to the local datum is printed on the chart. Any figure printed on the chart indicates that the original survey has been referenced to WGS-84 and the published shifts can be used with confidence. If the chart contains no shift data then no referencing to WGS-84 has been made and any plotted positions made must be treated with caution because of possible shift errors.

An advantage of modern charts and the use of software is that the management of datum shifts can be automated. A system such as ARCS has the shift data included and thus an RCDS can keep track of the data of positions of all types, including vessel position and track, waypoints and any other overlaid points on the chart, and adjust them all to the local geodetic datum as required.

7.5 Updating electronic charts

As mentioned on page 228 with reference to the UKHO's ARCS system, updates for all charts affected by Notice to Mariners (up to about 200 a week) are generated, checked and placed on a weekly ARCS Update CD-ROM which includes temporary and preliminary notices. This provides error-free automatic corrections and provides cumulative updates with only the latest update CD-ROM required. The CD-ROMs are sent to chart agents who then send them to shipping companies as required.

NOAA provides continuous updating to all 1000 charts using information from the USCG, NIMA and the Canadian Hydrographic Service, and Maptech makes the necessary raster chart updates. Maptech uses modern technology to update only those parts of a chart identified as needing correction. This so-called 'patch' technique compares the existing chart file and its corrected counterpart on a pixel-by-pixel basis. A difference file is produced which can be manipulated so that it registers exactly with the existing raster file to which it applies. A raster chart can therefore be updated by displaying it, using the relevant CD-ROM, and using the patch file to alter the pixels on the old chart as necessary to incorporate the corrections.

The updating service became available on subscription in January 2000. Customers receive a weekly e-mail that contains a hot link to the update computer server. Clicking on the hot link begins the transmission of the update patches to the computer; the updates in the transmission are cumulative updates for all charts on a CD-ROM. Downloading takes from a few seconds to up to 5 min depending on the modem speed. Once the file reception is completed the charts may be corrected and stored on the computer's hard drive. It is anticipated that dynamic updating should soon be available. With this technique the charts and patches are kept separate and the patch is applied to the chart in real time allowing the user to see the changes produced by the patch.

Dynamic patching is the preferred method under the international standards for ECDIS where it is a requirement that mariners should not change the original data files. It is expected that in future single chart updates may be made available rather than a complete CD's worth and that the procedure will be extended to ENCs when they become available.

7.6 Automatic Identification System (AIS)

Automatic Identification System (AIS) is a shipborne transponder system capable of broadcasting continuously, using the VHF marine band, information about the ship. Such information could include:

- ship identification data, i.e. ship name, call sign, length, breadth, draught etc.
- type of cargo carried and whether it was hazardous in nature
- course and manoeuvring data
- position to GPS accuracy limits.

Such broadcast information would be capable of reception by other AIS-equipped ships and by shore sites such as Vessel Traffic System (VTS) stations within broadcast range. Data received by a ship or shore station could be relayed to an ECS and AIS targets could be displayed, with GPS or DGPS accuracy, with a velocity vector indicating speed and heading. By 'clicking' on a target, other information such as ship identification data etc. could be displayed. A typical AIS scenario is illustrated in Figure 7.9.

An AIS transponder system requires a GPS or DGPS receiver, a VHF transmitter, two VHF TDMA receivers, a VHF DSC receiver and a standard marine electronic communications connection to the ship's display system. Position and timing information is derived from the GNSS (GPS) receiver. Information, such as ship's heading, course and speed over ground, is normally broadcast using AIS but other information such as destination, ETA etc. could also be promulgated if available.

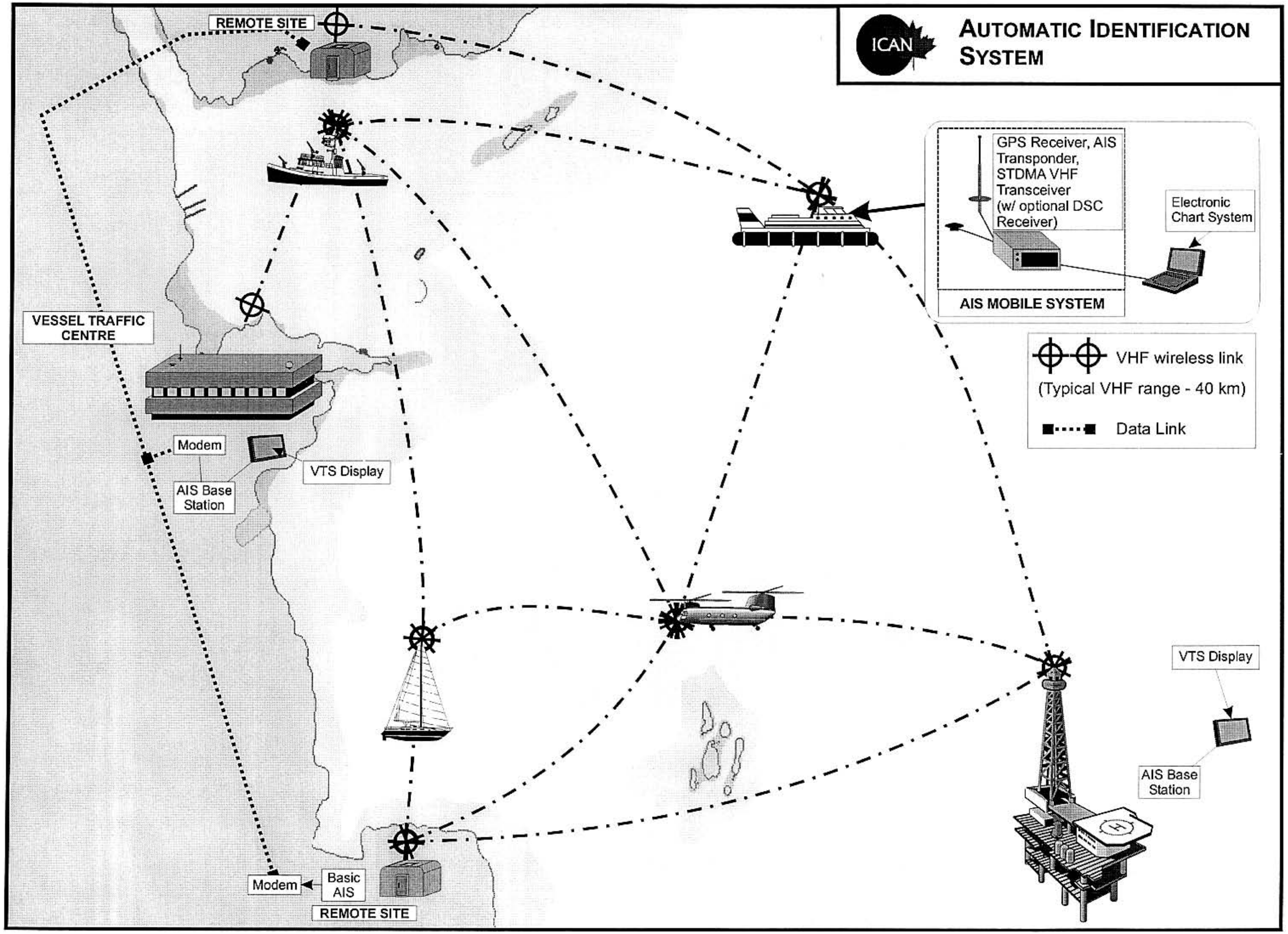

Figure 7.9 Automatic Identification System (AIS). (Reproduced courtesy of ICAN.)

The AIS transponder transmits using 9.6 kbyte GMSK (Gaussian minimum shift keying) FM modulation over 25 kHz or 12.5 kHz channels using HDLC packet protocols. The channel bandwidth of 25 kHz is for use on the high seas and the 12.5/25 kHz channel bandwidth used as defined by the appropriate authority in coastal waters. There are two radio channels available for transmission/ reception that minimize RF interference, provide increased capacity and allow channels to be shifted without loss of communication from other ships. The ITU has allocated frequencies with AIS channel 1 using 161.975 MHz (ch87B) and AIS channel 2 using 161.025 MHz (ch88B).

Each transponder self-allocates time slots for its position reports and such reports occur at time intervals that correspond to the traffic situation. This method of communication is known as self-organizing time division multiple access (SOTDMA). The SOTDMA broadcast mode allows the system to be overloaded by up to 500% while still providing nearly 100% communication capacity for ships within 10 nautical miles of each other in ship-to-ship mode. If system overload tends to occur, then targets at the longer ranges will tend to drop out of the system leaving only closer range targets, which are the ones of greater interest to the navigator. There are 2250 time slots established every 60 s for each AIS channel; this gives a time slot duration of 26.67 ms and as each slot has 256 bits the data transmission rate is 9600 bit s^{-1}.

AIS stations continuously synchronize with other stations to obviate any slot transmission overlap. Slot selection by an AIS station is randomized within a defined interval and triggered with a random timeout of between 0 and 8 frames. When a station changes its slot assignment the new location and associated timeout is pre-announced, thus allowing new stations to be received.

Although the AIS concept has been around for many years and trials have taken place at many geographical locations, there is still much work to be done to produce an internationally-agreed standard. Some of the detail of what has been achieved to date is listed below.

IMO Resolution MSC.74(69). Annex 3, Recommendation on Performance Standards for a Universal Shipborne Automatic Identification System (AIS)

The 43rd session of the IMO Navigation Subcommittee, which met in July 1997, completed a draft performance standard on shipborne automatic identification systems (transponders). This performance standard describes the operational requirements for the device but does not define the telecommunications protocol the device must use. The 69th session of the IMO Maritime Safety Committee formally adopted the standard without change in May 1998.

A report from the Subcommittee on Safety of Navigation on its 45th session included the following items.

1 All ships of 300 gross tonnage and upwards (engaged on international voyages), cargo ships of 500 gross tonnage and upwards (not engaged on international voyages), and passenger ships, irrespective of size, shall be fitted with AIS, as follows:

- 1.1 ships constructed on or after 1 July 2002;
- 1.2 ships engaged on international voyages constructed before 1 July 2002;
- 1.2.1 in the case of passenger ships irrespective of size and tankers of all sizes, not later than 1 July 2003;
- 1.2.2 in the case of ships, other than passenger ships and tankers, of 50000 gross tonnage and upwards, not later than 1 July 2004;
- 1.2.3 in the case of ships, other than passenger ships and tankers, of 10000 gross tonnage and upwards but less than 50000 gross tonnage, not later than 1 July 2005;
- 1.2.4 in the case of ships, other than passenger ships and tankers, of 3000 gross tonnage and upwards but less than 10000 gross tonnage, not later than 1 July 2006;

1.2.5 in the case of ships, other than passenger ships and tankers, of 300 gross tonnage and upwards but less than 3000 gross tonnage, not later than 1 July 2007; and
1.3 ships not engaged on international voyages constructed before 1 July 2002, not later than 1 July 2008.

2 The Administration may exempt ships from the application of the requirements of this paragraph when such ships will be taken permanently out of service within two years after the implementation date specified in paragraph 1.

3 AIS shall:
3.1 provide automatically to appropriately equipped shore stations, other ships and aircraft information, including the ship's identity, type, position, course, speed, navigational status and other safety-related information;
3.2 receive automatically such information from similarly fitted ships;
3.3 monitor and track ships; and
3.4 exchange data with shore-based facilities, the requirements of this paragraph shall not be applied to cases where international agreements, rules or standards provide for the protection of navigational information. AIS shall be operated taking into account the guidelines adopted by the Organization.

ITU-R Recommendation M.1371, Technical Characteristics for a Universal Shipborne Automatic Identification System Using Time Division Multiple Access in the Maritime Mobile Band

The International Telecommunications Union Sector for Radiocommunication (ITU-R) met in March 1998 to define the technology and telecommunications protocol for this device. The draft recommendation completed by Working Party 8B was approved by Study Group 8, which met in July 1998. The recommendation was formally adopted in November 1998 and the publication is now available for a fee (see website www.itu.org). The International Association of Lighthouse Authorities (IALA) has been the main organization co-ordinating the development of the Universal AIS Transponder and a revision of this standard is being prepared by IALA for submission to the ITU-R Working Party 8B in October 2000. If adopted it will become ITU-R Recommendation M.1371–1.

IEC Standard 61993–2 on AIS

In July 1998, the International Electrotechnical Commission TC80/WG8-U.AIS started work on the performance, technical, operational and testing standard for the Universal AIS Transponder. The working group is expected to meet regularly and complete its work during the year 2000 with an expected publication date for the standard of December 2001. This standard will supersede IEC Standard 61993–1 on digital selective calling AIS transponders. This new standard will define testing and interfacing requirements for AIS systems. Commercially-produced systems should meet all the three standards described above.

ICAN have developed an AIS module which is an add-on to their 'Aldebaran' Electronic Charting System. The module has been developed for use with Saab TransponderTechs AIS hardware for which ICAN is the exclusive Canadian agent. The AIS module enables ICAN's ECS to display broadcast AIS information on screen in InfoPanels and as overlays. A typical screen display with this feature is shown in Figure 7.10.

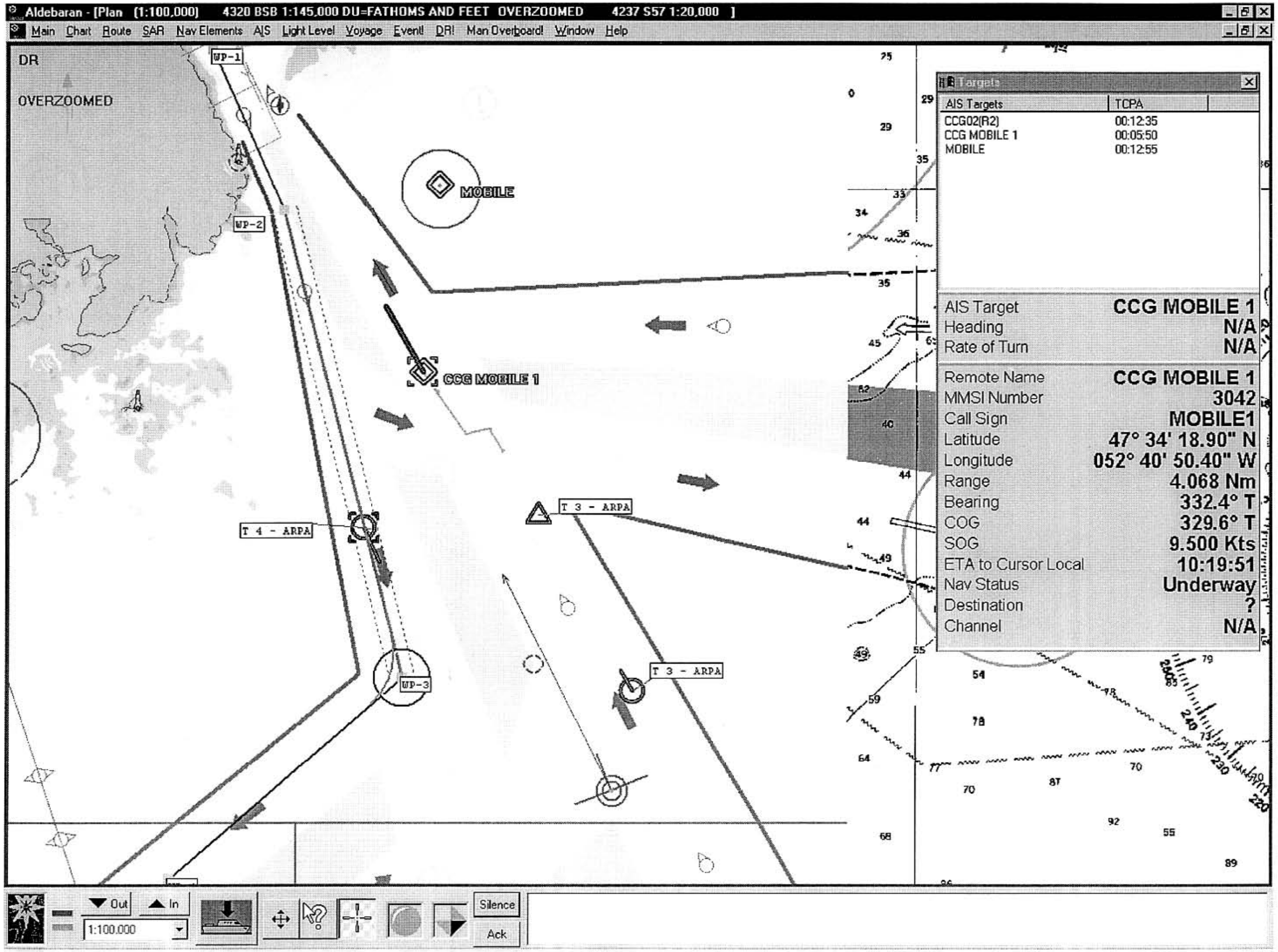

Figure 7.10 Display showing AIS target information. (Reproduced courtesy of ICAN.)

Features of the ICAN AIS module are as follows.

1 AIS Target Monitoring
- Unlimited on-screen AIS targets.
- AIS Tracking InfoBox sorted based on TCPA and RCPA.
- Targets can be individually centred on screen.
- Single target activation.
- Messages can be addressed or sent via broadcast as binary or ASCII data on specific channels.
- Automatic (scheduled) and manual data transmissions.
- Binary transmissions include: man overboard, ARPA, markers and points of interest (SAR, waypoints, routes and zones).
- Displayed AIS transponder channels.
- On screen CPA display.
- Alarms and indications based on configurable CPA properties.

2 Long Range AIS Monitoring
- Microsoft's MAPI (Mail Application Programming Interface) based mail set-up.
- Office and remote monitoring through Inmarsat terminal or service provider.
- Filtered sender information.
- Multiple e-mail address transmissions (single Inmarsat message).
- Configurable gateway formats.

3 AIS Module Configuration
- Remote target properties (shape, labels).
- Name, call sign, ship type, MMSI, IMO no., draught, trip, destination and ETA to destination.
- Own ship transponder transmission information (Nav sensor, antenna location, UTC date time and channel designation).
- Distinguishable transponder characteristics (R2 vs R3 labelling).
- ECS back-up positioning device (transponder GPS).
- Transponder GNSS status.
- Closest point of approach (time and range based).
- Channel polygons.

4 Data logging and Distribution
- Unfiltered logging of serial inputs, including AIS transponder information.
- File-based distribution of logged data.
- TCP/IP distribution of serial inputs.
- Playback of recorded data.

5 ICAN ECS Environment
- Seamless display of charts of S-57, NTX, BSB and MRE formats (other formats in development include ARCS and CM-93).
- Point-of-interest feature allows constant update of range/bearing to any point, marker or waypoint (station keeping).
- Ability to add other software modules including high resolution radar overlay, useful for coastline mapping (scanner up to 120 rpm, 8-bit radar image, raw radar data recording capable).

Information on this AIS module and other useful products offered by ICAN are available on their website www.ican.nf.net.

7.7 Navmaster Electronic Navigation System

There are a multitude of suppliers of software suitable for implementing an electronic navigation system, requiring only the hardware and suitable electronic charts to produce an ECDIS or an ECDIS in RCDS mode. The ‘Navmaster Professional’ from PC Maritime of Plymouth, UK is used as a basis for showing how the software can assist the navigator in passage planning, position logging and navigation management, providing as it does a continuous display of vessel positions received from GPS and plotted on official electronic charts. The minimum system requirements for Navmaster are: a computer operating with a Pentium 133, or better, processor; Windows 95/98/NT/2000; 10-Mbyte hard drive for minimum installation; CD-ROM and floppy-disk drives; 32-Mbyte RAM; and a monitor with 800×600 resolution with 256 colours or more. Input/output requirements are one serial and one parallel port. The software is supplied on a CD-ROM. The system uses electronic chart data, which is the copyright of various national hydrographic offices; chart data is protected by a security key that allows access to the charts only via a user PIN number.

Once the software has been loaded into the computer then starting with Navmaster the display will be similar to the one shown in Figure 7.11.

The toolbars and side panels can be moved around the screen, hidden and displayed as required. The main window contains the following.

Title bar

The title bar displays the program control icon, the activation or active image title and the standard minimize/maximize/restore/close buttons.

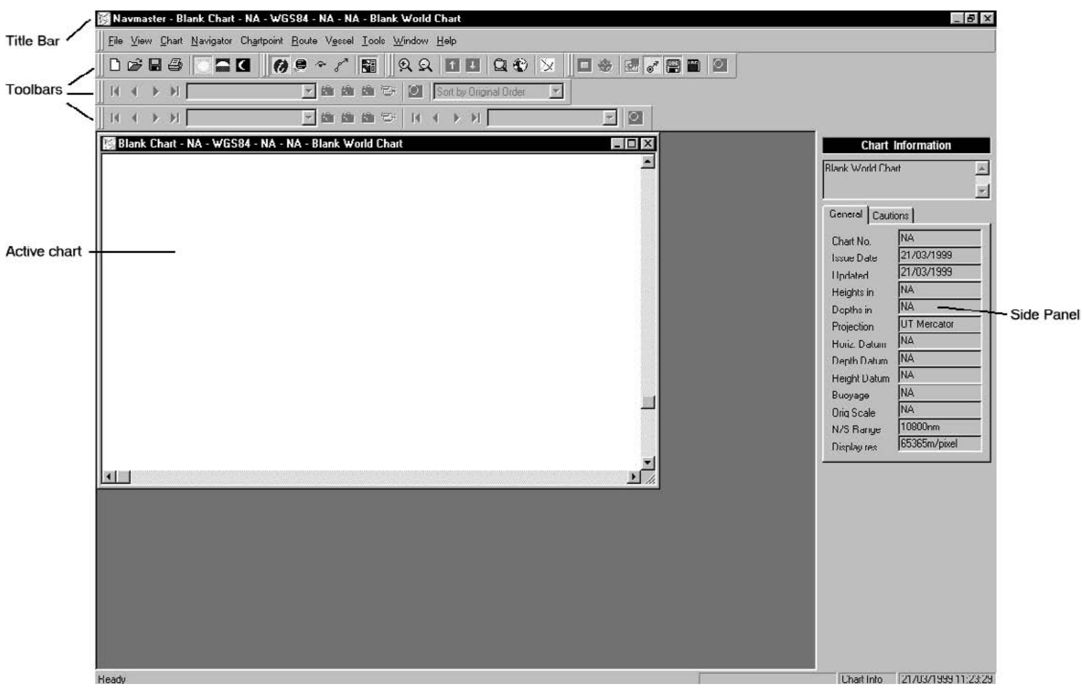

Figure 7.11 The Navmaster start-up window. (Reproduced courtesy of PC Maritime.)

Figure 7.12 Navmaster menu bar headings. (Reproduced courtesy of PC Maritime.)

Menu bar

The menu bar displays the menu headings as shown in Figure 7.12. These are as follows.

- File. Contains standard menu commands for file management, printing and workspace, opening charts, and opening and saving chartpoint and route databases.
- Edit. Provides standard menu commands.
- View. Provides menu commands to select modes of operation, turn on or off the toolbars, side panel and status bar.
- Chart. Provides menu commands to change the chart display, install chart permits and updates, set the location of charts and updates and set chart-related options.
- Navigator. Provides menu commands to: turn position plotting on or off and set DR parameters; turn position logging on or off and make log entries; upload routes and waypoints to GPS; access diagnostic windows for equipment interfacing; open the Autoscroll monitor window; set position and navigation-related options.
- Target. Provides menu commands to Activate/Deactivate ARPA and Tender tracking and set related options.
- Chartpoint. Provides menu commands related to chartpoints.
- Route. Provides menu commands related to routes.
- Vessel. Provides menu commands to enter vessel information for use when calculating plans.
- Tools. Provides menu commands to display tidal atlas and activate the Range and Bearing tool, customize toolbars and set workspace and tidal atlas options.
- Window. Provides menu commands to manipulate windows.
- Help. Provides Help and information on obtaining technical support.

Toolbars

The toolbars provide buttons that access some of the frequently used commands in the menus. If a command is unavailable, its button appears greyed-out. Toolbars and their button functions are shown in Figure 7.13.

Side panels

These panels represent each of the main functions of the Navmaster system, i.e. monitoring position, storing chartpoints and creating and calculating routes. Switching between functions is achieved by pressing a button on the display toolbar or by selecting an item in the View menu.

1 Monitor mode. In this mode it is possible to monitor and plot the vessel's passage. The screen consists of three main areas: the chart area, the side panel and the toolbars. The chart area provides a view of the current chart, which may be manipulated as required. A typical side panel in monitor mode is shown in Figure 7.14.

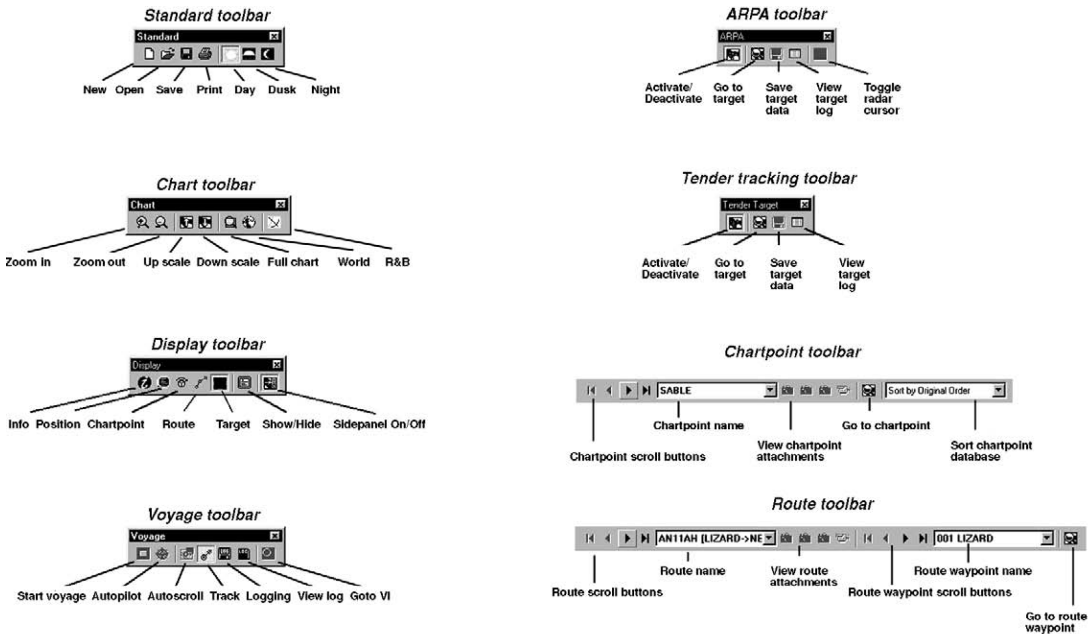

Figure 7.13 Toolbars used in the Navmaster display. (Reproduced courtesy of PC Maritime.)

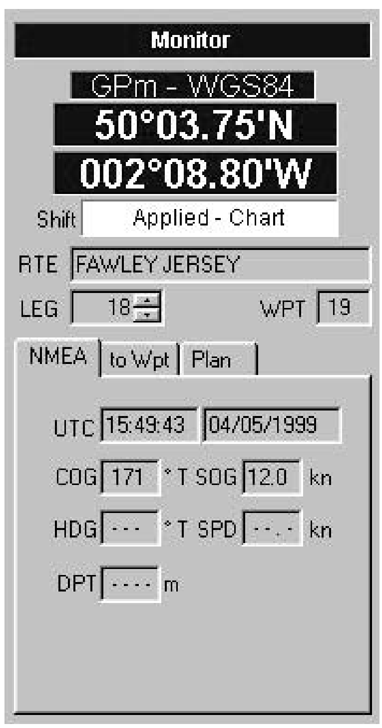

Figure 7.14 Navmaster monitor mode side panel. (Reproduced courtesy of PC Maritime.)

The panel repeats the position obtained from the GPS, provides information on any datum shift that has been applied, and displays the current route name and active leg. Three tabs provide further information:

NMEA	repeats information from electronic instruments;
to Wpt	provides calculated information from current position to the next waypoint in the route;
Plan	repeats information for the leg from the passage plan if one has been calculated.

The Autocheck box activates/deactivates automatic leg advance.

2 Chartpoint mode. In this mode it is possible to add, delete, edit or save chartpoints. A chartpoint is the latitude and longitude of a geographical position stored in a database; a chartpoint on a chart is shown as a blue circle. Each chartpoint has database fields which allow the user to add other information which may be of assistance. Any number of chartpoint databases can be created and each database can contain any number of chartpoints. To enter chartpoint mode, the chartpoint button on the display toolbar (see Figure 7.13) is pressed and, provided side panel display is activated, the chartpoint side panel will be displayed (see Figure 7.15). The panel provides information about the current chartpoint. Each field within the panel can be edited.

Figure 7.15 Navmaster chartpoint mode side panel. (Reproduced courtesy of PC Maritime.)

Navmaster stores chartpoints in WGS-84 co-ordinates where possible and, provided a selected chartpoint is on the currently selected chart, it is possible to view and edit the chartpoint to match the local chart datum. A chartpoint can simply be used as a marker on a chart or, if used to indicate points on a route, they are known as waypoints.

3 Route mode. This mode enables the user to create new routes, edit existing routes and copy or reverse routes. A route is a sequence of waypoints built up from previously stored chartpoints or created by clicking on a chart. The route is drawn on the chart for evaluation and possible amendment. Routes are stored in databases and there can be many routes stored.

Route mode can be accessed by pressing the route button on the display toolbar (see Figure 7.13). The route side panel will be displayed, provided the side panel is switched on. Routes may be created, and edited, using waypoints from a chartpoint database or by drawing the route directly on the screen chart, or by a combination of both methods. Whatever route method is used, each waypoint in the route is inserted into the box on the route side panel and a line will connect the route waypoints on the chart. This line can be adjusted depending on whether the user adds, deletes or moves waypoints using the route side panel.

Routes are stored in a route database and any number of route databases can be created, containing any number of routes. A typical side panel in route mode is shown in Figure 7.16.

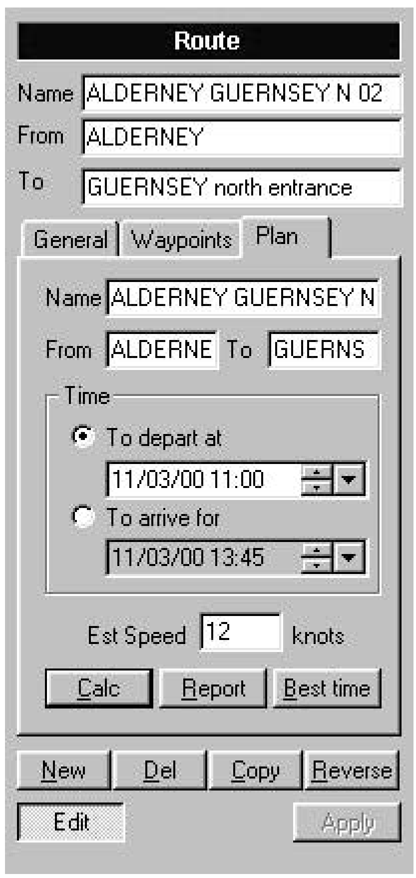

Figure 7.16 Navmaster route mode side panel. (Reproduced courtesy of PC Maritime.)

Three tabs provide further information:

General	enables the user to enter and display a textual note relating to the route;
Waypoints	lists the waypoints in the route and provides a means to select waypoints for amendment or deletion or to locate a new waypoint;
Plan	gives the ability to calculate a passage plan based on the route which the user can print or view on the screen.

Other side panels, which are available but not illustrated, are Target Tracking, which provides information on ARPA and Tender targets, and Information which gives information on the selected chart.

7.7.1 Installing charts

Navmaster supports the UKHO ARCS and the Australian Hydrographic Office Seafarer charts and will support ENC charts by the end of 2000. To install these charts the user needs:

- the floppy disk containing a licence file and chart permit file
- one (or more) chart CD-ROM
- one update CD-ROM with the latest chart corrections.

Each chart CD-ROM contains all the charts available for a particular region. A chart permit is a code that unlocks a specific chart. Charts can be installed from the chart permit disk or by entering the chart permit number manually. The user PIN number must be entered before a chart can be loaded or installed. When Navmaster loads a chart it also applies any chart updates at that time. A chart can be displayed without its update but a warning will be displayed indicating the fact that corrections are missing.

The ARCS or Seafarer chart is supplied as two, independent images namely a low-resolution (LR) image and a high-resolution (HR) image. The LR image provides an overview of the chart while the HR image is the one recommended for navigation and is updated with Notice to Mariner corrections. Navmaster provides further zooming in and out of the LR and HR images to give five levels of display for each chart.

The chart can be manipulated so that it is centred on a selected cursor position and the chart can be panned by using the scroll bars at the sides of the chart window.

Table 7.6 The five levels of display for each chart

Resolution	*Zoom level*	*Warning*
Low resolution	Zoom out (LR-out)	Underscale
	Normal (LR)	Underscale
High resolution	Zoom out (HR-out)	Underscale
	Normal (HR)	None
	Zoom in (HR-in)	Overscale

7.7.2 Using Navmaster

When using Navmaster the recommended sequence to follow is:

- create chartpoints
- create a route
- calculate a plan
- monitor by plotting track, viewing data in the Navigation Monitor panel and comparing progress with the plan.

Navmaster is a multi-window application. Charts, the log, waypoint lists etc. all have their own window and windows can be tiled, cascaded or kept in the background as required. Turning on Autoscroll opens a dedicated window which displays the vessel's position in the centre of a chart. For safety reasons the Autoscroll window cannot be minimized so that the user is fully aware of the vessel's position. However, the window can be resized to allow more room for other charts, or it can be covered by a maximized window.

If the Autoscroll window is closed then Autoscroll is turned off. The remaining windows give complete flexibility to organize the charts to suit the task in hand. For example, new chart windows could be opened to:

- look ahead by displaying the vessel's position on a smaller scale chart than the Autoscroll chart
- view charts for other segments of the route
- view the approaches or harbour charts for intended destination
- plan new routes or chartpoints.

While the above is going on it is still possible to view a continuously updating vessel position on the largest scale chart available.

The maximum number of chart windows that can be opened is limited to three plus the Autoscroll window. The number can be increased but the default value of three is chosen to prevent users inadvertently opening too many windows.

The Chart Information panel in Navmaster displays information on the selected chart and indicates the following.

- Chart Description. The Hydrographic Office description of the chart.
- Chart No. The Hydrographic Office chart number.
- Orig Scale. The scale of the paper version of the chart.
- Edition Date. The date the chart was first issued.
- Updated. The date of the last update.
- Heights In. The units of height used.
- Depths In. The units of depth used.
- Projection. The type of projection used in the production of the chart.
- Horiz Datum. The geodetic datum of the chart. EG OSGB36 – The Ordnance Survey of Great Britain (1936) datum.
- Depth Datum. The datum to which depths are referred.
- Height Datum. The datum to which heights are referred.
- Buoyage. The buoyage system in use on the chart.
- N/S Range. The vertical distance in nautical miles of the portion of the chart currently displayed in the chart window.
- Display Resolution. The number of metres represented by each pixel on the computer display, which will alter depending on the zoom level of the chart.

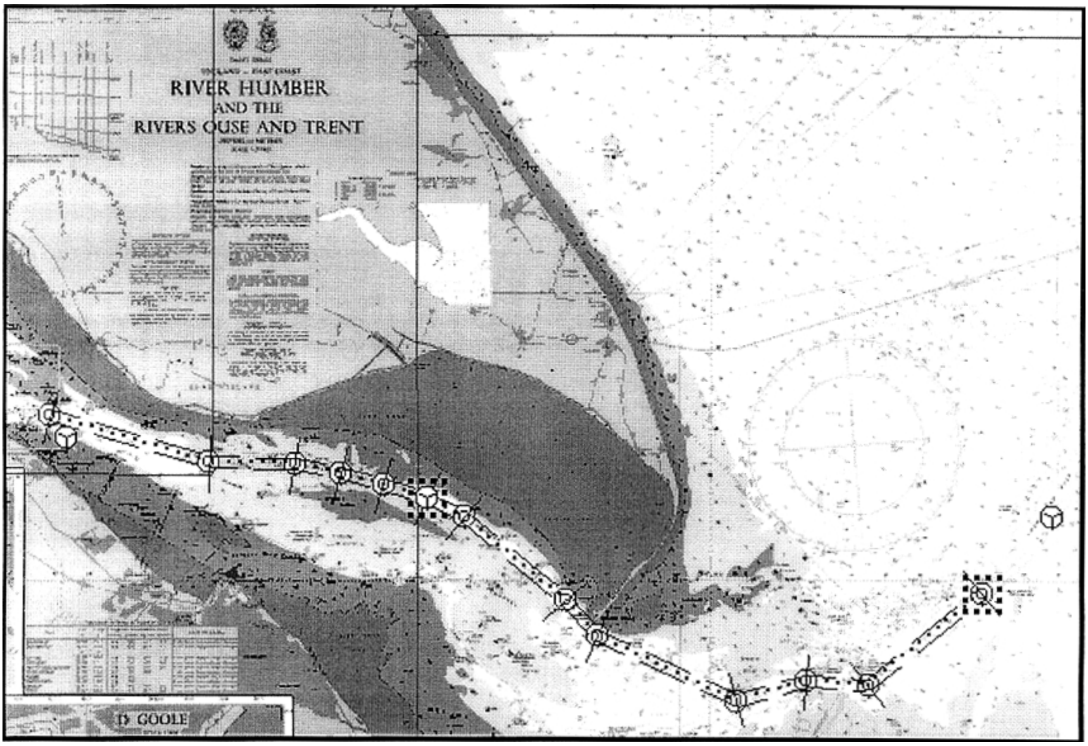

Figure 7.17 ARCS chart 109, River Humber and the Rivers Ouse and Trent OSGB36. (Reproduced courtesy of PC Maritime.)

Passage plans

Having created a route, the user can enter estimated speed, desired departure/arrival times and calculate for each leg of the route:

- course to steer, allowing for variation, deviation and tidal stream (if required)
- distance
- estimated time.

The user can view the plan on screen, change variables as required and then print a copy of the plan. As an example of a chart overlaid with a route Figure 7.17 shows ARCS chart 109, with a route approaching the Humber River, illustrating waypoints entered for the planned route.

Route monitoring options can be chosen so that it is possible to:

- automatically increment route legs as the vessel passes through waypoints so that Navmaster calculations on range and bearing to the next waypoint are relevant, and up-to-date information is sent to the Autopilot
- monitor the vessel's progress against the planned route.

Other options include the following.

- Automatic leg advance. Choosing this option allows the route legs to increment automatically as the vessel passes through the waypoint detection parameters set by the user.

- Waypoint detection. Choosing this option and setting a radius for the route leg to increment to the next leg when vessel position enters the circle. On entry a warning is given. The position and time of entry, and waypoint name are recorded in the log. See Figure 7.18.
- Passing perpendicular. Choosing this option allows the route leg to increment to the next leg when vessel position crosses a line drawn at right angles to the current leg. On passing, a warning is given. Position, time of entry and waypoint name are entered in a log. See Figure 7.18.
- Limits of deviation. Choosing this option allows a deviation limit to be set. If the vessel position exceeds this limit a warning message is displayed and remains until the vessel returns inside the

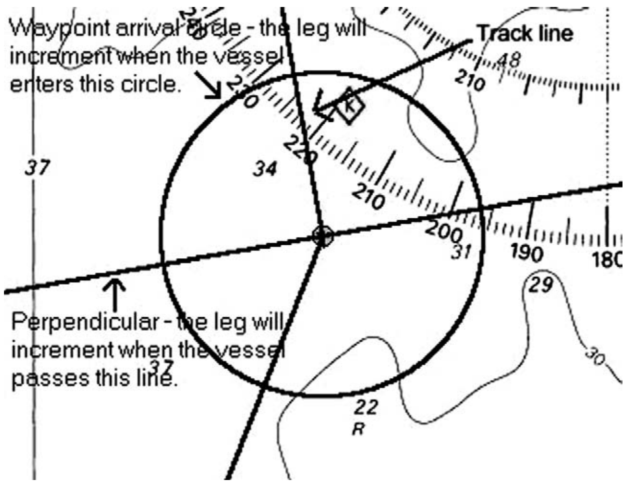

Figure 7.18 Use of waypoint arrival circle and passing perpendicular. (Reproduced courtesy of PC Maritime.)

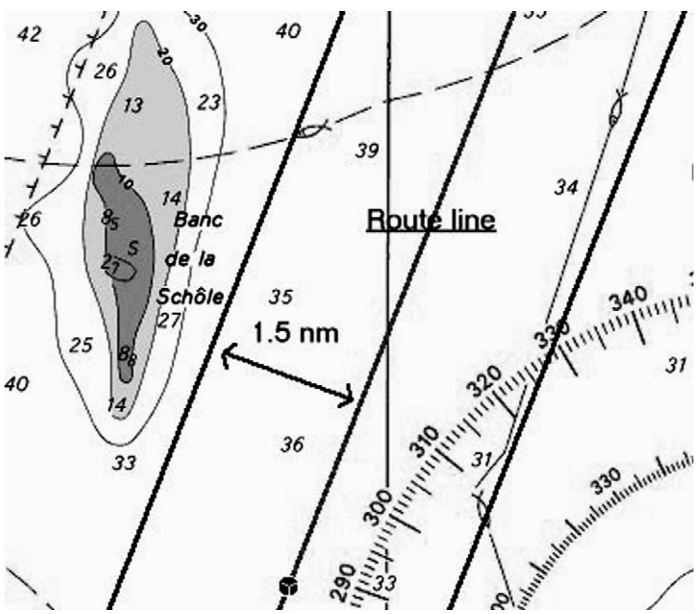

Figure 7.19 Use of limits of deviation. (Reproduced courtesy of PC Maritime.)

Your Company Name

Your company logo

Passage Plan Report

FROM : SPURN APPROACHES
TO : IMMINGHAM

Vessel	:		Options :	Tides [Off]
Estimated speed	: 5.0 knots			Variation [Off]
Passage distance	: 18.0 nm			Deviation [Off]
Passage time	: 000:03:35		Calculated	: 11:52:13 / 6/24/00
Route name	: HARBOUR ENTRY		Viewed	: 12:16:52P 24/06/2000

Rte Wpt No	Datum	Time	Elap Time (ddd:hh:mm)	Name	Position	Crse (°T)	Leg (nm)	Accum (nm)	To Go (nm)
1	WGS84	11:52:13 6/24/00	000:00:00	SPURN HEAD APPROACHES	53°34.80'N 000°17.70'E	231	2.51	0.00	18.0
2	WGS84	12:22:20 6/24/00	000:00:30	SPURN LIGHTSHIP	53°33.22'N 000°14.43'E	274	1.05	2.51	15.4
3	WGS84	12:34:57 6/24/00	000:00:43	SE CHEQUER	53°33.29'N 000°12.67'E	254	1.26	3.56	14.4
4	WGS84	12:50:02 6/24/00	000:00:58	NO 3 CHEQUER	53°32.95'N 000°10.64'E	295	2.64	4.82	13.1
5	WGS84	1:21:40 6/24/00	000:01:29	SUNK CHANNEL	53°34.06'N 000°06.63'E	319	0.83	7.46	10.5
6	WGS84	1:31:36 6/24/00	000:01:39	HAWKE	53°34.68'N 000°05.71'E	309	2.25	8.29	9.67
7	WGS84	1:58:38 6/24/00	000:02:06	HAWKE S4	53°36.11'N 000°02.79'E	296	0.74	10.5	7.42
8	WGS84	2:07:27 6/24/00	000:02:15	HAWKE S5	53°36.43'N 000°01.68'E	287	0.78	11.3	6.68
9	WGS84	2:16:48 6/24/00	000:02:25	SUNK S6	53°36.66'N 000°00.43'E	285	0.75	12.1	5.90
10	WGS84	2:25:50 6/24/00	000:02:34	SUNK S7	53°36.86'N 000°00.79'W	281	0.82	12.8	5.15
11	WGS84	2:35:38 6/24/00	000:02:43	SUNK S8	53°37.01'N 000°02.14'W	272	1.47	13.6	4.33
12	WGS84	2:53:17 6/24/00	000:03:01	SUNK SPIT	53°37.05'N 000°04.61'W	286	2.86	15.1	2.86
13	WGS84	3:27:35 6/24/00	000:03:35	IMMINGHAM OIL TERMINAL	53°37.85'N 000°09.22'W	000	0.00	18.0	0.00

Pre-departure check list
Navmaster Raster Chart Display System

1: Navmaster system on ☐
2: Correct chart displayed ☐
3: Folio mode and Autoscroll on ☐
4: This route displayed on chart ☐
5: Position logging on ☐
6: Logging on ☐

On completion of pre-departure checks this form is to be signed by the responsible officer and handed to the master.

Port.................................. Signed..................................
Date....................................

Figure 7.20 Passage plan for a route into Immingham on the River Humber. (Reproduced courtesy of PC Maritime.)

limit. When the vessel exceeds the limit a log entry is made, with time and position. A further log entry is made when the vessel returns inside the limit. See Figure 7.19.

Creating a passage plan

A passage plan can be created as follows.

1 Prepare the route.
2 Select the plan tab on the Route panel (a typical Route side panel is shown in Figure 7.16).
3 Enter departure/arrival time and estimated speed.
4 Set any options required.
5 Click on Calc.
6 Click on Report to see the plan.

A typical passage plan report for the route of Figure 7.17 is shown in Figure 7.20.

Because Navmaster calculates routes almost instantly it is a simple matter to change parameters such as vessel speed, date and options.

The above has been extracted, with permission, from the Navmaster User Guide and only gives a very limited overview of the facilities available with the system. More detail can be obtained from the manufacturers PC Maritime, Brunswick House, Brunswick Road, Plymouth PL4 0NP, UK. E-mail: marketing@pcmaritime.co.uk and website: www.pcmaritime.co.uk.

7.8 Glossary

AHO	Australian Hydrographic Office.
AIS	Automatic Identification System, see Transponder.
ARCS	Admiralty Raster Chart Service. The UKHO proprietary RNC.
ARPA	Automatic Radar Plotting Aid.
Chart cell	The smallest unit for geographical data. Each cell has a unique address in memory and may possess different data volume and size characteristics.
Chart symbol	A graphical representation of an object or characteristic.
CIS	Chart Information System.
'Course-up' display	A display where the heading of own ship is upwards on the screen and the chart moves relative to own ship.
CPA	Closest Point of Approach.
Database	A set of stored data used for a particular application which can be assessed as required.
Datum	See Geodetic datum.
DGPS	Differential Global Positioning System.
ECDIS	Electronic Chart Display and Information System. The performance standard approved by the IMO and defined in publications from the IHO (Special Publications S-52 and S-57) and IEC document 1174.
ECS	Electronic Chart System. A system that, unlike ECDIS, has no obligation to conform to the ECDIS performance standards.
Ellipsoid	A regular geometric shape which closely approximates to the shape of a geoid, having a specific mathematical expression, and can be used for geodetic, mapping and charting purposes.

ENC	Electronic Navigational Chart. Charts, manufactured for use with ECDIS, which meet the ECDIS performance standards and are issued by or on the authority of government-authorized hydrographic offices.
ETA	Estimated time of arrival.
Geodetic datum	A specifically orientated reference ellipsoid requiring typically eight parameters to define it. Two parameters relate to the dimensions of the ellipsoid, three parameters specify its centre with respect to the Earth's centre of mass while the remainder specify ellipsoid orientation with respect to the average spin axis of the Earth and Greenwich reference meridian. Provides a horizontal datum.
Geoid	An undulating but smooth representation of equal values of the Earth's gravitational field coinciding most closely with mean sea level. The geoid is the primary reference surface for heights.
GMSK	Gaussian Minimum Shift Keying.
GNSS	Global Navigation Satellite System. The use of GPS for civilian purposes.
GPS	Global Positioning System. A satellite navigation system designed to provide continuous position and velocity data in three dimensions and accurate timing information globally.
Hardware	The physical part of a computer system that provides the processing capability; includes peripheral devices and cabling.
HCRF	Hydrographic Chart Raster Format. Developed by the UKHO and used by them for the Admiralty Raster Chart Service (ARCS) and by the AHO for its Seafarer Chart Service. Other HOs are expected to adopt the format.
HDLC	High-Level Data Link Control, specified by ISO/IEC 3309, 5th edition 1993.
IEC	International Electrotechnical Commission. The organization which produces world standards in the area of electrical and electronic engineering.
IHO	International Hydrographic Organization. A grouping of national hydrographic offices responsible for promoting international standards in the fields of hydrographic surveying and chart production.
IMO	International Maritime Organization. A specialized agency of the United Nations and responsible for promoting maritime safety and navigational efficiency.
ITU-R	International Telecommunications Union Sector for Radiocommunication.
MMSI	Maritime Mobile Service Identities. An international system of automatic identification for all ships.
NHO	National Hydrographic Office.
NIMA	National Imagery and Mapping Agency.
NMEA	National Marine Electronics Association. An organization comprising manufacturers and distributors. Responsible for agreeing standards for interfacing between various electronic systems on ships. NMEA 0183 version 2.3 is the current standard.
NOAA	National Oceanic and Atmospheric Administration.
'North-up' display	A display configuration where north is always in the up direction. This corresponds to the orientation of nautical charts and is the normal display for an ECDIS.
Notice to Mariners	A notice issued by hydrographic offices, on a periodic or occasional basis, relating to matters that affect nautical charts, sailing directions, light lists and other nautical publications.

NOS	National Ocean Service.
OCS	Office of Coast Survey.
Own ship	Used to define the vessel on which the electronic chart system is operating.
Performance standard	Used to define the minimum performance requirements for a system to meet the requirements of the SOLAS Convention.
Pixel	An abbreviation for picture element. It is the smallest element that can be resolved by electronic raster devices such as a scanner, display and plotter.
PRIMAR	A series of regional distribution centres (RENCs) will be set up for the distribution of ENCs, and PRIMAR is the first of these centres.
RCDS	Raster Chart Display System. A navigation system which can be accepted as complying with the paper version of the up-to-date chart requirements of regulation V/20 of the SOLAS Convention, by displaying RNCs with position information from navigation sensors to assist the mariner in route planning and route monitoring, and if required display additional navigation related material.
RCPA	Range to closest point of approach.
RENC	Regional ENC Co-ordinating Centre.
RNC	Raster navigational chart. A facsimile of a paper chart. Both the paper chart and the RNC are originated by, or distributed on the authority of, a government authorized-hydrographic office.
Route monitoring	A function required of an ECDIS whereby own ship present position can be displayed on the chart and viewed relative to the chart data.
Route planning	A function required of an ECDIS whereby the mariner can study the intended route on a display and select an intended track, marking it with waypoints and other navigational data.
S-52	IHO Special Publication S-52. Specification for chart content and display aspects of ECDIS.
S-57	IHO Special Publication S-57. IHO transfer standard for digital hydrographic data, edition 3. It describes the data model and format to be used for ENCs.
Safety contour	The contour selected by the mariner, using the SENC data, to determine soundings which, relative to own ship's draught, provide safe water channels. The ECDIS can use the information to generate anti-grounding alarms.
Safety depth	The depth, selected by the mariner, which defines own ship's draught plus under-keel clearance which can be used by the ECDIS to indicate soundings on the display which may be equal or less than the defined value.
SENC	System Electronic Navigational Chart. This is the database produced by chart suppliers which meets the requirements of the IHO Special Publication S-57.
Software	This includes all the programs that can be used on a computer. Software can be subdivided into the operational software required for the computer to function and the application software developed for specific user applications.
SOLAS	Safety of Life at Sea. The International Convention for the Safety of Life at Sea Chapter V Safety of Navigation, Regulation 20, Nautical Publications requires that 'All ships shall carry adequate and up-to-date charts, sailing directions, lists of lights, notices to mariners, tide tables and all other nautical publications necessary for the intended voyage'. SOLAS does not apply universally and some vessels, such as ships of war, cargo ships of less than 500 GRT, fishing vessels etc are exempt from the SOLAS requirements.

SOTDMA Self-organizing time division multiple access. Used by mobile stations operating in autonomous and continuous mode. The protocol offers an access algorithm that quickly resolves conflicts without intervention from controlling stations.

Standard display The SENC information that should be displayed when a chart is first accessed by the ECDIS. The level of data contained can be customized to suit the mariner.

TCPA Time to closest point of approach.

TDMA Time division multiple access.

Transponder (AIS) A shipborne transmit/receive system which broadcasts continuously, on VHF frequencies, details about ship's identity, ship characteristics, type of cargo, destination, course and speed. The ECDIS can be used to display AIS targets together with their speed and course vectors.

UKHO United Kingdom Hydrographic Office.

USCG US Coast Guard.

UTC Co-ordinated universal time. Developed to meet the requirements of scientists to provide a precise scale of time interval and navigators surveyors and others requiring a time scale directly related to the earth's rotation.

VTS Vessel Traffic System. A system for managing shipping traffic in congested areas such as ports and inland waterways.

Waypoint A point entered into a computer and used as a reference point for navigational calculations. Planned voyages would have a series of waypoints indicating legs of the voyage. A modern computer is capable of storing multiple waypoints.

WEND Worldwide ENC database. A model, developed by the IHO, to act as a distribution network to supply ENCs to ECDIS compliant ships.

WGS-84 World Geodetic System 1984. A global datum system for horizontal datum used as a standard in ECDIS.

Zoom A method of changing the scale of the displayed chart information on the screen. Zoom-in or zoom-out facilities are usually provided at the touch of a button.

7.9 Summary

- An electronic chart is one where chart data is provided as a digital charting system capable of displaying both geographical data and text.
- An electronic chart is 'official' if it is issued by or on the authority of a national hydrographic office. All other charts are 'non-official'.
- An electronic chart may use raster data or vector data.
- Delivery of electronic chart data is via an Electronic Chart Display and Information System (ECDIS) which is a navigational information system, comprising hardware, software and official vector charts and must conform to ECDIS Performance Standards.
- Chart types available include privately produced vector, official raster and Electronic Navigational Chart (ENC). The ENC is the designated chart system for ECDIS.
- A Raster Chart Display System (RCDS) is one that displays official raster navigational charts (RNCs).

- A dual fuel system is one that operates as an ECDIS or RCDS mode according to the type of chart data in use.
- Chart accuracy may depend on local datum that may differ from that used by satellite systems which use a global datum, e.g. WGS-84. Corrections may be necessary before a position is plotted on a chart.
- Electronic charts are updated regularly to ensure conformity with the SOLAS requirement that charts should be 'adequate and up-to-date for the intended voyage'.
- Automatic Identification System (AIS) is a shipborne transponder system that broadcasts information about a ship fitted with the system. The data generated may be used by other AIS-fitted ships and/or shore stations and such data may be passed to an electronic charting system where AIS-fitted ships could appear as 'targets' on the electronic chart. Such targets could be interrogated to generate information such as ship's speed, heading and other data.
- For any ECDIS system to operate, suitable software must be available to enable the function of an ECDIS system to meet performance standards as laid down by the regulatory bodies. A particular system examined is the Navmaster Electronic Navigation System of PC Maritime.

7.10 Revision questions

1. What do you understand by the term 'electronic chart'? What is the definition of an 'official' electronic chart?
2. Explain briefly the difference between a chart produced using raster data and one produced using vector data. Give advantages/disadvantages associated with each type of chart.
3. Explain briefly what defines an electronic navigational chart (ENC) used with ECDIS. What are the advantages of an ENC in terms of chart information that can be displayed?
4. Describe what you understand by the term Electronic Chart Display and Information System (ECDIS). What are the basic requirements of an ECDIS?
5. Describe what you understand by the term Raster Chart Display System (RCDS) and state briefly how a RCDS could be used in a dual fuel system.
6. Explain why there may be a difference between local datum used for a particular chart and the global datum used in ECDIS. How would a position, determined from a GPS or DGPS input, be affected if plotted on a chart based on a different datum?
7. Describe briefly the concept of an Automatic Identification System (AIS). Explain the advantages to be gained by fitting ships and specific shore stations with AIS.
8. The Navmaster Electronic Navigation System (Section 7.7) uses on-screen side panels that represent main functions of the system. Describe briefly the function of the following side panels:
   (a) monitor mode
   (b) chartpoint mode
   (c) route mode.
9. Using the Navmaster Electronic Navigation System (Section 7.7) describe how charts may be installed in the system. What information is displayed in the chart information panel for a selected chart?
10. Using the Navmaster Electronic Navigation System (Section 7.7) as a basis, describe the recommended sequence to be followed for route planning and monitoring. Define what is meant by a chartpoint and describe how chartpoints could be used in route planning.