

# CHAPTER 5

## ECDIS

### ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEMS

#### 500. The Importance of Electronic Charts

From the very beginning of the human quest to travel by water, the core desire of the navigator has always been to answer the fundamental question, “Where, exactly, is my vessel?” As navigators labored to answer this question through the ages, increasingly more sophisticated fix positioning methods were developed. Techniques matured from the simple use of plotting by visually observing objects ashore, to understanding how to mathematically translate the observed altitudes of celestial bodies, and eventually fix in a position using radio and satellite signals. Regardless the method, until the development of electronic charting technologies, the end result was always the same: calculate latitude and longitude, then plot the vessel’s position on a paper chart. Only then could they begin to assess the safety of the ship and its progress toward its destination. Far more time was spent taking fixes, working out solutions, and plotting the results than on making assessments; and the fix only indicated where the ship was at the time the fix was taken, not where the vessel was in real time. The navigator was always “behind the vessel.” On the high seas this may be of little importance, but near shore, it becomes vitally essential.

Electronic charts automate the process of integrating real-time positions with the chart display and allow the navigator to continuously assess the position and safety of the vessel. Further, the GPS/DGPS fixes are far more accurate and taken far more often than any navigator ever could using manual methods. A good piloting team is expected to take and plot a fix every three minutes. An electronic chart system can do it once per second to a standard of accuracy at least an order of magnitude better.

An Electronic Chart Display and Information System (ECDIS) allows the integration of other operational data, such as ship’s course and speed, depth soundings, automatic identification systems (AIS) information, and radar data into the display. Further, ECDIS allows automation of alarm systems to alert the navigator to potentially dangerous situations. Navigation with an ECDIS can also provide enhanced situational awareness of important events.

Finally, the navigator has a complete instantaneous picture of the instantaneous situation of the vessel and all charted dangers in the area. With a radar overlay, the tactical situation with respect to other vessels is clear as

well. This chapter will discuss the various types of electronic charts, the requirements for using them, and their characteristics, capabilities and limitations.

#### 501. Terminology

Before understanding what an electronic chart is and what it does, one must learn a number of terms and definitions. We must first make a distinction between official and unofficial charts. Official charts are those, and only those, issued officially by, or on the authority of, a Government authorized Hydrographic Office (HO), or other relevant government institution, and are designed to meet the requirements of marine navigation. Unofficial charts are produced by a variety of private companies and may or may not meet the same standards used by HO’s for data accuracy, currency, and completeness.

An **electronic chart system (ECS)** is a computer assisted navigation system capable of displaying electronic nautical charts and the vessel’s position in near real time. An ECS does not meet all the input, display and functionality of an Electronic Chart Display and Information System.

An **electronic chart display and information system (ECDIS)** is a navigation information system which with adequate back-up arrangements can be accepted as complying with the up-to-date chart required by the 1974 SOLAS Convention, by displaying selected information from a system electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and if required display additional navigation-related information.

An **electronic chart (EC)** is any digitized chart intended for display on a computerized navigation system.

An **electronic chart data base (ECDB)** is the digital database from which electronic charts are produced.

An **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. The ENC contains all the chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart (e.g. sailing directions) which may be considered necessary for safe navigation.

The **system electronic navigation chart (SENC)** means 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. It is this database that is actually accessed by ECDIS for the display generation and other navigational functions, and is the equivalent to an up-to-date paper chart. The SENC may also contain information from other sources.

A **raster navigation chart (RNC)** is a raster-formatted chart produced by a national hydrographic office.

A **raster chart display system (RCDS)** is a system which displays official raster-formatted charts on an ECDIS system. Raster charts cannot take the place of paper charts because they lack key features required by the IMO, so that when an ECDIS uses raster charts it operates in the ECS mode.

**Overscale** and **underscale** refer to the display of electronic chart data at too large and too small a scale, respectively. In the case of overscale, the display is “zoomed in” too close, beyond the standard of accuracy to which the data was digitized. Underscale indicates that larger scale data is available for the area in question. ECDIS provides a warning in either case.

**Raster** chart data is a digitized image of a chart comprised of millions of pixels. All data is in one layer and one format. The video display simply reproduces the picture from its digitized data file. With raster data, it is difficult to change individual elements of the chart since they are not separated in the data file. Raster data files tend to be large, since a data point with associated color and intensity values must be entered for every pixel on the chart.

**Vector** chart data is data that is organized into many separate files or layers. It contains graphics files and programs to produce certain symbols, points, lines, and areas with associated colors, text, and other chart elements. The navigator can selectively display vector data, adjusting the display according to voyage needs. Vector data supports the computation of precise distances between features and can provide warnings when hazardous situations arise.

## 502. Components of ECS and ECDIS

The terms ECS and ECDIS encompasses many possible combinations of equipment and software designed for a variety of navigational purposes. In general, the following components comprise an ECS or ECDIS.

- **Computer processor, software, and network:** These subsystems control the processing of information from the vessel's navigation sensors and the flow of information between various system components. Electronic positioning information from GPS or DGPS, contact information from radar, and digital compass data, for example, can be integrated with the electronic chart data.

- **Chart database:** At the heart of any ECS lies a database of digital charts. It is this dataset, or a portion of it, that produces the chart seen on the display screen.

- **System display:** This unit displays the electronic chart and indicates the vessel's position on it, and provides other information such as heading, speed, distance to the next waypoint or destination, soundings, etc. There are two modes of display, **relative** and **true**. In the relative mode the ship remains fixed in the center of the screen and the chart moves past it. This requires a lot of computer power, as all the screen data must be updated and re-drawn at each fix. In true mode, the chart remains fixed and the ship moves across it. The display may also be north-up or course-up, according to the availability of data from a heading sensor such as a digital compass.

- **User interface:** This is the user's link to the system. It allows the navigator to change system parameters, enter data, control the display, and operate the various functions of the system. Radar may be integrated with the ECDIS or ECS for navigation or collision avoidance, but is not required by SOLAS regulations.

## 503. Legal Aspects of Using Electronic Charts

Requirements for carriage of charts are found in SOLAS Chapter V, which states in part: “All ships shall carry adequate and up-to-date charts... necessary for the intended voyage.” As electronic charts have developed and the supporting technology has matured, regulations have been adopted internationally to set standards for what constitutes a “chart” in the electronic sense, and under what conditions such a chart will satisfy the chart carriage requirement.



Figure 503. USCG (NVIC 01-16) - Use of Electronic Charts and Publications in Lieu of Paper Charts, Maps and Publications. <http://www.dco.uscg.mil/Our-Organization/NVIC/>

An extensive body of rules and regulations controls the production of ECDIS equipment, which must meet certain high standards of reliability and performance. Only those systems identified by the U.S. Coast Guard can relieve the navigator of the responsibility of maintaining a corrected paper chart. Certain U.S. flagged vessels are subject to domestic chart and publication carriage requirements codified

in Titles 33 and 46 of the Code of Federal Regulations (C.F.R.). In February 2016, the U.S. Coast Guard issued Navigation and Vessel Inspection Circular (NVIC) 01-16, which states SOLAS-compliant equipment, three specific Radio Technical Commission for Maritime Services (RT-CM) classes of ECS, and certain publications, will be accepted as the equivalent of the requirements described in the aforementioned C.F.R.s. NVIC 01-16 can be found at the link provided in Figure 503.

The presence of an electronic chart system is not, however, a substitute for good judgment, sea sense, and taking

all reasonable precautions to ensure the safety of the vessel and crew.

An electronic chart system should be considered a navigational aid, one of many navigators might have at their disposal to help ensure a safe passage. While possessing revolutionary capabilities, it must be considered as a tool, not an infallible answer to all navigational problems. The rule for the use of electronic charts is the same as for all other navigational aids: The prudent navigator will never rely completely on any single one.

## CAPABILITIES AND PERFORMANCE STANDARDS

### 504. ECDIS Performance Standards

The specifications for ECDIS consist of a set of inter-related standards from three organizations, the International Maritime Organization (IMO), the International Hydrographic Organization (IHO), and the International Electrotechnical Commission (IEC). The IMO published a resolution in November 1995 to establish performance standards for the general functionality of ECDIS, and to define the conditions for its replacement of paper charts. It consisted of a 15-section annex and 5 original appendices. Appendix 6 was adopted in 1996 to define the backup requirements for ECDIS. Appendix 7 was adopted in 1998 to define the operation of ECDIS in a raster chart mode. Previous standards related only to vector data.

The IMO performance standards refer to IHO Special Publication S-52 for specification of technical details pertaining to the ECDIS display. Produced in 2014, the 6th edition of S-52 includes appendices includes the Presentation Library and specifies updating, display, color, and symbology of official electronic navigational charts (ENC), as well as a revised glossary of ECDIS-related terms. The IMO performance standards also refer to IEC International Standard 61174 for the requirements of type approval of an ECDIS. Published in 1998, the IEC standard defines the testing methods and required results for an ECDIS to be certified as compliant with IMO standards. Accordingly, the first ECDIS was given type approval by Germany's classification society (BSH) in 1999. Since then, multiple other makes of ECDIS have gained type approval by various classification societies.

The IMO performance standards specify the following general requirements: Display of government-authorized vector chart data including an updating capability; enable route planning, route monitoring, manual positioning, and continuous plotting of the ship's position; have a presentation as reliable and available as an official paper chart; provide appropriate alarms or indications regarding displayed information or malfunctions; and permit a mode of operation with raster charts similar to the above standards.

The performance standards also specify additional functions, summarized as follows:

- Display of system information in three selectable levels of detail
- Means to ensure correct loading of ENC data and updates
- Apply updates automatically to system display
- Protect chart data from any alteration
- Permit display of update content
- Store updates separately and keep records of application in system
- Indicate when user zooms too far in or out on a chart (over- or under-scale) or when a larger scale chart is available in memory
- Permit the overlay of radar image and ARPA information onto the display
- Require north-up orientation and true motion mode, but permit other combinations
- Use IHO-specified resolution, colors and symbols
- Use IEC-specified navigational elements and parameters (range & bearing marker, position fix, own ship's track and vector, waypoint, tidal information, etc.)
- Use specified size of symbols, letters and figures at scale specified in chart data
- Permit display of ship as symbol or in true scale
- Display route planning and other tasks
- Display route monitoring
- Permit display to be clearly viewed by more than one user in day or night conditions
- Permit route planning in straight and curved segments and adjustment of waypoints
- Display a route plan in addition to the route selected for monitoring
- Permit track limit selection and display an indication if track limit crosses a safety contour or a selected prohibited area
- Permit display of an area away from ship while

continuing to monitor selected route

- Give an alarm at a selectable time prior to ship crossing a selected safety contour or prohibited area
- Plot ship's position using a continuous positioning system with an accuracy consistent with the requirements of safe navigation
- Identify selectable discrepancy between primary and secondary positioning system
- Provide an alarm when positioning system input is lost
- Provide an alarm when positioning system and chart are based on different geodetic datums
- Store and provide for replay the elements necessary to reconstruct navigation and verify chart data in use during previous 12 hours
- Record the track for entire voyage with at least four hour time marks
- Permit accurate drawing of ranges and bearings not limited by display resolution
- Require system connection to continuous position-fixing, heading and speed information
- Neither degrade nor be degraded by connection to other sensors
- Conduct on-board tests of major functions with alarm or indication of malfunction
- Permit normal functions on emergency power circuit
- Permit power interruptions of up to 45 seconds without system failure or need to reboot
- Enable takeover by backup unit to continue navigation if master unit fails,

Before an IMO-compliant ECDIS can replace paper charts on vessels governed by SOLAS regulations, the route of the intended voyage must be covered completely by ENC data, that ENC data must include the latest updates, the ECDIS installation must be IMO-compliant including the master-slave network with full sensor feed to both units, and the national authority of the transited waters must allow for paperless navigation through published regulations. Certified training in the operational use of ECDIS is required as per STCW 2010 when an ECDIS is installed. The U.S. Coast Guard also requires training for ECS-A in U.S. waters. Certification may include alternate forms of the same ECDIS family, such as Multifunction Display, chart administration and route planning application, electronic logbook functionality, radar overlay functionality, VDR via Ethernet, and AIS keyboard plus display function.

The certifying agency issues a certificate valid for five years. For renewal, a survey is conducted to ensure that systems, software versions, components and materials used comply with type-approved documents and to review pos-

sible changes in design of systems, software versions, components, materials performance, and make sure that such changes do not affect the type approval granted.

Manufacturers have been willing to provide type-approved ECDIS to vessel operators, but in a non-compliant installation. Without the geographical coverage of ENC data, the expensive dual-network installation required by ECDIS will not eliminate the requirement to carry a corrected portfolio of paper charts. These partial installations range from approved ECDIS software in a single PC, to ECDIS with its IEC-approved hardware. In these instances, plotting on paper charts continues to be the primary means of navigation. NOAA has been providing an ENC data sets for all US waters since 2014; NGA supplies ENC data sets where NGA is the prime charting authority (See Section 517). In June 2009, IMO SOLAS Chapter V was approved and states ships engaged in international voyages must be fitted with ECDIS by July 2018. This is driving the need for readily available ENCs worldwide. As governments regulate paperless transits, vessel operators are upgrading their installations to meet full IMO compliance, making ECDIS the primary means of navigation.

### 505. ECS Standards

Although the IMO has declined to issue guidelines on ECS, in the United States the Radio Technical Commission for Maritime Services (RTCM) developed a voluntary, industry-wide standard for ECS. At the time of publication, the RTCM Standard recognized three classes of ECS that have varying levels of navigation functionality. This construct provided greater flexibility for manufacturers and provided the U.S. Coast Guard with the opportunity to allow an ECS, which meets the RTCM standard, to replace the paper charts (Navigation and Vessel Inspection Circular 01-16). The RTCM ECS standard follows the international standards for either raster or vector data display, and includes the requirement for simple and reliable updating of information, or an indication that the electronic chart information has changed. The three classes of ECS recognized by the U.S. Coast Guard are described in Table 505.

The term ECS, however, includes a multitude of systems, including highly complex charting systems that display vector charts issued by an authorized hydrographic office on an environmentally hardened box, to a software system displaying propriety charts on a user-selected hardware. Those ECS not adhering to the RTCM standard identified by U.S. Coast Guard policy to replace paper charts must be considered a navigational aid, and should always be used with a corrected chart from a government authorized hydrographic office.

Some classes of RTCM ECS do not meet the performance standards of either ECDIS or RCDS. But an ECDIS can operate in ECS mode when using raster charts or when using unofficial vector charts. When a type-approved ECDIS is installed without being networked to a backup ECDIS, or

USCG Recognized Classes of Electronic Chart Systems		
Class	Description/Purpose	Training
A	System is very similar to full ECDIS but does not meet full requirements. With required equipment interface (e.g. position fixing system, AIS, heading device, etc.), it can be primary means of navigation for non-SOLAS vessels.	Watch stander must have successful completion certificate from Coast Guard approved ECDIS course and endorsement on MMC.
B	Typically has less functionality than ECS 'A.' With required equipment interface (e.g. position fixing system, AIS, heading device, etc.), it can be primary means of navigation for non-SOLAS vessels operating within 12NM of territorial sea baseline.	Familiar with system prior to assuming watch duties.
C	Primarily designed as navigational aid to plot and monitor vessels position. With required equipment interface (e.g. position fixing system, AIS, heading device, etc.), it can be primary means of navigation for non-SOLAS vessels operating within 12NM of territorial sea baseline.	Familiar with system prior to assuming watch duties.

Table 505. RTCM ECS class type and description.

when it is using unofficial ENC data, or ENC data without updates, it can be said to be operating in an ECS mode. In this configuration, the system cannot be substituted for official, corrected paper charts.

### 506. Display Characteristics

While manufacturers of electronic chart systems have designed their own proprietary colors and symbols, the IMO Performance Standard requires that all IMO approved ECDIS and some RTCM ECS follow the International Hydrographic Organization (IHO) S-52 publication, Specifications for Chart Content and Display Aspects of ECDIS. These specifications are embodied in Annex A of S-52, the ECDIS Presentation Library, most recently updated in 2014. Their development was a joint effort between Germany, Canada, and Australia during the 1990s. In order for ECDIS to enhance the safety of navigation, every detail of the display should be clearly visible, unambiguous in its meaning, and uncluttered by superfluous information. Some ECS continue to be free to develop independent of IHO control. In general, they seek to emulate the look of the traditional paper chart.

To reduce clutter, the IMO Standard lays down a permanent display base of essentials such as depths, aids to navigation, shoreline, etc., making the remaining information selectable. The navigator may then select only what is essential for the navigational task at hand. A black background display for night use provides good color contrast

without compromising the mariner's night vision. Similarly, a "bright sun" color table is designed to output maximum luminance in order to be daylight visible, and the colors for details such as buoys are made as contrasting as possible.

The symbols for ENCs are based on the familiar paper chart symbols, with some optional extras such as simplified buoy symbols that show up better at night. Since ECDIS and ECS can be customized to each ship's requirements, new symbols were added such as a highlighted, mariner selectable, safety contour and a prominent isolated danger symbol. See Figure 506a and Figure 506b for an examples.

The Presentation Library is a set of colors and symbols together with rules relating them to the digital data of the ENC, and procedures for handling special cases, such as priorities for the display of overlapping objects. Every feature in the ENC is first passed through the look-up table of the Presentation Library that either assigns a symbol or line style immediately, or, for complex cases, passes the object to a symbology procedure. Such procedures are used for objects like lights, which have so many variations that a look-up table for their symbolization would be too long. The Presentation Library includes a Chart 1, illustrating the symbology. Given the IHO S-57 data standards and S-52 display specifications, a waterway should look the same no matter which hydrographic office produced the ENC, and no matter which manufacturer built the ECDIS.

The overwhelming advantage of the vector-based ECDIS or ECS display is its ability to remove cluttering

information not needed at a given time. By comparison, the paper chart and its raster equivalent is an unchangeable diagram. A second advantage is the ability to orient the display course-up when this is convenient, while the text remains screen-up.

Taking advantage of affordable yet high-powered computers, some ECDIS and ECS now permit a split screen display, where mode of motion, orientation and scale are individually selectable on each panel. This permits, for example, a north-up small-scale overview in true motion alongside a course-up large-scale view in relative motion. Yet another display advantage occurs with zooming, in that symbols and text describing areas center themselves automatically in whatever part of the area appears on the screen. None of these functions are possible with raster charts.

The display operates by a set of rules, and data is arranged hierarchically. For example, where lines overlap, the less important line is not drawn. A more complex rule always places text at the same position relative to the object it applies to, no matter what else may be there. Since a long name or light description will often over-write another object, the only solution is to zoom in until the objects separate from each other. Text is written automatically when the object it refers to is on the display. Because it causes so much clutter, and is seldom vital for safe navigation, it, text portrayal is an option under the “all other information” display level.

Flexibility in display scale requires some indication of distance to objects seen on the display. Some manufacturers use the rather restrictive but familiar radar range rings to provide this, while another uses a line symbol keyed to data's original scale. The ECDIS design also includes a one-mile scalebar at the side of the display, and an optionally displayed course and speed-made-good vector for own ship. There may be a heading line leading from the vessel's position indicating her future track for one minute, three minutes, or some other selectable time.

To provide the option of creating manual chart corrections, ECDIS includes a means of drawing lines, adding text and inserting stored objects on the display. These may be saved as user files, called up from a subdirectory, and edited on the display. Once loaded into the SENC, the objects may be selected or de-selected just as with other objects of the SENC.

Display options for ECDIS and ECS include transfer of ARPA-acquired targets and radar image overlay. IMO standards for ECDIS require that the operator be able to deselect the radar picture from the chart with a single operator action for fast “uncluttering” of the chart presentation.

In the 2014 Presentation Library update, several changes were made to include:

- A new “Detection and Notification of Navigational Hazard” section: For each ENC feature and its associated attributes, ECDIS will define the priority of an alert

to be raised when a navigational hazard is detected.

- A new “Detection of Areas, for which Special Conditions Exist” section: This lists the ENC features and attributes that will raise an indication or alert in the ECDIS as defined by the mariner.
- The ability to turn on and off isolated dangers in shallow water.
- New standardized symbols to identify where automatic ENC updates have been applied and indicate where features with temporal attributes are located.
- Display names of anchorage areas and fairways.
- A means for the mariner to insert a date or date range within the ECDIS to display date dependent features.

## 507. Units, Data Layers and Calculations

ECDIS uses the following units of measure:

- **Position:** Latitude and longitude will be shown in degrees, minutes, and decimal minutes, normally based on WGS-84 datum.
- **Depth:** Depths will be indicated in meters and decimeters.
- **Height:** Meters
- **Distance:** Nautical miles and tenths, or meters
- **Speed:** Knots and tenths

ECDIS requires data layers to establish a priority of data displayed. The minimum number of information categories required and their relative priority from highest to lowest are listed below:

- ECDIS warnings and messages
- Hydrographic office data
- *Notice to Mariners* information
- Hydrographic office cautions
- Hydrographic office color-fill area data
- Hydrographic office on demand data
- Radar information
- User's data
- Manufacturer's data
- User's color-fill area data
- Manufacturer's color-fill area data

As a minimum, an ECDIS system must be able to perform the following calculations and conversions:

- Geographical coordinates to display coordinates, and display coordinates to geographical coordinates.
- Transformation from local datum to WGS-84.
- True distance and azimuth between two geographical positions.
- Geographic position from a known position given distance and azimuth.
- Projection calculations such as great circle and rhumb line courses and distances.





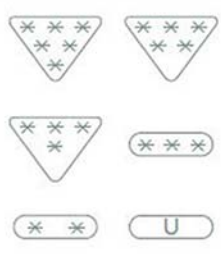
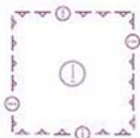
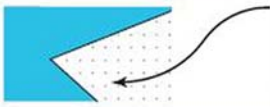




ENC Symbol	Explanation	Additional Information
	Generic isolated danger symbol – with less depth than user-selected safety contour or where the depth is unknown	Wreck, rock or obstruction
	Sounding of low accuracy	Equates to sounding of doubtful depth
	<p><b>6 stars A1</b> All significant seafloor features detected; very high accuracy survey</p> <p><b>5 stars A2</b> All significant seafloor features detected; high accuracy survey</p> <p><b>4 stars B</b> Uncharted features dangerous to navigation are not expected but may exist; medium accuracy survey</p> <p><b>3 stars C</b> Depth anomalies may be expected; low accuracy survey or passage soundings</p> <p><b>2 stars D</b> Large depth anomalies may be expected; poor quality data</p> <p><b>U</b> Quality of bathymetry yet to be assessed</p>	
	Caution area where a specific caution note applies	Refer to cursor enquiry to access additional information Refer to ECDIS Chart 1 for more examples
	Dredged area deeper than safety contour Darker blue indicates water shallower than safety contour	Refer to cursor enquiry for more information
	Vertical lines indicate areas of charted data at significantly smaller scale than main display	Zoom out until vertical lines disappear to view at scale appropriate to data
	Indicates boundary between IALA A and B buoyage systems	
	Isolated query indicates insufficient information to symbolise the feature Query associated with symbol indicates absence of a mandatory attribute, such as beacon shape, direction or orientation	Query may appear alone at a point, on a line or in a defined area. Further information may be obtained from cursor enquiry of the query
	Limit between area of unofficial vector data and official ENC data, marked by orange pecked line – pecks angled towards unofficial vector data	May be shown the other way around on older ECDIS. Within areas of non-ENC data, an alternative, official chart must be used for navigation

Figure 506a. Example of ENC symbology.

**508. Alerts and Indications**

Knowledge and ability to interpret and react to the ECDIS alarms requires the understanding the conditions that trigger alarms or indications. Appendix 5 of the IMO Performance Standard specifies that ECDIS must monitor the status of its systems continuously, and must provide

alarms and indications for certain functions if a condition occurs that requires immediate attention. Indications may be either visual or audible. An alarm must be audible and may be visual as well (It is important to note significant changes are coming to this crucial functionality in new ECDIS on August 1, 2017 and not currently reflected here).

ENC Symbol		Explanation	Additional Information
		Indicates that an additional information note or picture file is available	The information, note or graphic can be found using cursor enquiry
		Non-tidal current direction	
		Spring tide – Ebb Flood	
		Light vessel/lightfloat	
		Daymarks	
		New Object – Point New Object – Line New Object – Area	New type of feature not yet known to ECDIS – further information available by cursor enquiry
Symbol setting on ECDIS		For details of the IALA Maritime Buoyage System.	
Simplified	Traditional		
		Lateral beacons – red/green	IALA applicable system
		Lateral conical buoys – red/green, according to applicable IALA system	IALA applicable system
		Lateral can buoys – red/green	IALA applicable system
		Cardinal marks north/east/south/west (Cardinal mark north shown for Traditional)	
		Isolated danger marks	
		Safe water buoy	
		Special marks	Shape/topmarks are optional – colour yellow
		Special purpose buoys, for example; TSS lane markers	Shape/topmarks optional – colour yellow
		Buoy – mooring	

Figure 506b. Example of ENC symbology.



**An alarm is required for the following:**

- Exceeding cross-track limits
- Crossing selected safety contour
- Deviation from route
- Position system failure
- Approaching a critical point
- Chart on different geodetic datum from positioning system

**An alarm or indication is required for the following:**

- Largest scale for alarm (indicates that presently loaded chart is too small a scale to activate anti-grounding feature)
- Area with special conditions (means a special type of chart is within a time or distance setting)
- Malfunction of ECDIS (means the master unit in a master-backup network has failed)

**An indication is required for the following:**

- Chart overscale (zoomed in too close)
- Larger scale ENC available
- Different reference units (charted depths not in meters)
- Route crosses safety contour
- Route crosses specified area activated for alarms
- System test failure

As these lists reveal, ECDIS has been programmed to constantly “know” what the navigation team should know, and to help the team to apply its experience and judgment through the adjustment of operational settings.

This automation in ECDIS has two important consequences: First, route or track monitoring does not replace situational awareness; it only enhances it. The alarm functions, while useful, are partial and have the potential to be in error, misinterpreted, ignored, or overlooked.

Secondly, situational awareness must now include, especially when ECDIS is used as the primary means of navigation, the processes and status of the electronic components of the system. This includes all attached sensors, the serial connections and communication ports and data interfaces, the computer processor and operating system, navigation and chart software, data storage devices, and power supply. Furthermore, these new responsibilities must still be balanced with the traditional matters of keeping a vigilant navigational watch.

ECDIS or not, the windows in the pilothouse are still the best tool for situational awareness. Paradoxically, ECDIS makes the navigator’s job both simpler and more complex.

It is expected the **new ECDIS standards** when released and implemented (August 1, 2017) will provide better alarm management. Reducing alarm fatigue, the ECDIS will produce audible alarms for only three conditions:

Anti-grounding, anti-route, and anti-collision. Visual alerts and indications will display in four categories: Warning, Caution, Indication, and Permanent. Aiding the mariner with alarm privatization, the new ECDIS will use a color coding system:

- Red - visible and audible alarm that will require immediate action
- Orange - visual indication that needs attention
- Yellow - visual indication that needs to be addressed in time

Orange and yellow indications can be upgraded to red if not addressed.

**509. ECDIS Outputs**

During the past 12 hours of the voyage, ECDIS must be able to reconstruct the navigation and verify the official database used. Recorded at one minute intervals, the information includes:

- Own ship’s past track including time, position, heading, and speed
- A record of official ENC used including source, edition, date, cell and update history

It is important to note that if ECDIS is turned off, such as for chart management or through malfunction, voyage recording ceases, unless a networked backup system takes over the functions of the master ECDIS. In that case, the voyage recording will continue, including an entry in the electronic log for all the alarms that were activated and reset during the switchover. Voyage files consist of logbook files, track files and target files. The file structure is based on the date and is automatically created at midnight for the time reference in use. If the computer system time is used for that purpose, the possibility exists for overwriting voyage files if the system time is manually set back. Allowing GPS time as the system reference avoids this pitfall.

In addition, ECDIS must be able to record the complete track for the entire voyage with time marks at least once every four hours. ECDIS should also have the capability to preserve the record of the previous 12 hours of the voyage. It is a requirement that the recorded information be inaccessible to alteration. Preserving voyage files should follow procedures for archiving data. Unless radar overlay data is being recorded, voyage files tend to be relatively small, permitting backup onto low-capacity media, and purging from system memory at regular intervals. (This form of backing up should not be confused with the network master-slave backup system.)

Adequate backup arrangements must be provided to ensure safe navigation in case of ECDIS failure. This includes provisions to take over ECDIS functions so that an ECDIS failure does not develop into a critical situation, and a means of safe navigation for the remaining part of the voyage in case of complete failure.

### 510. Voyage Data Recorder (VDR)

The purpose of the voyage data recorder (VDR) is to provide accurate historical navigational data in the investigation of maritime incidents. It is additionally useful for system performance monitoring. A certified VDR configuration records all data points, as per IMO Resolution A.861(20) & EC Directive 1999/35/EC. Some of the voyage data can be relayed through ECDIS. A fully IEC compliant data capsule passes fire and immersion tests.

SOLAS chapter V, regulation 20 affects ships more than 3,000 gross tons sailing internationally. As of 2010, these ships are required to properly install a VDR or simplified Voyage Data Recorder (s-VDR). Ship owners may apply for an exemption through their Administration.

VDR features include:

- Navigation information recording: ship's position, date and time, current chart, last chart update, speed heading, radar data, Automatic Identification Sys-

tem data, echo depth sounder.

- Internal conditions recording: bridge audio, ship's alarm system, rudder order and response, engine order and response, hull openings (door) status, watertight and fire door status, accelerations and hull stress.
- External conditions recording: communications audio, wind speed and direction.
- Uninterruptible power supply (UPS): provided through battery operated UPS or through ship's emergency electrical power supply.
- Hardened fixed data capsule.
- Remote data recovery and shoreside playback: Options available in several systems.
- Annual system certification: The IMO requires that the VDR system, including all sensors, be subjected to an annual performance test for certification.

## DATA FORMATS

### 511. Official Vector Data

How ECDIS and ECS operate depends on what type of chart data is used. ENC's (electronic navigational charts) and RNC's (raster navigational charts) are approved for use in ECDIS. By definition both ENC's and RNC's are issued under the authority of national hydrographic offices (HO's). ECDIS functions as a true ECDIS when used with corrected ENC data, but ECDIS operates in the less functional raster chart display system (RCDS) mode when using corrected RNC data. When ECDIS is used with non-official vector chart data (corrected or not), it operates in the ECS mode.

In vector charts, hydrographic data is comprised of a series of files in which different layers of information are stored or displayed. This form of "intelligent" spatial data is obtained by digitizing information from existing paper charts or by storing a list of instructions that define various position-referenced features or objects (e.g., buoys, lighthouses, etc.). In displaying vector chart data on ECDIS, the user has considerable flexibility and discretion regarding the amount of information that is displayed.

An ENC is vector data conforming to the IHO S-57 ENC product specification in terms of content, structure and format. An ENC contains all the chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart. In general, an S-57 ENC is a structurally layered data set designed for a range of hydrographic applications. As defined in IHO S-57 Edition 3, the data is comprised of a series of points, lines, areas, features, and objects. The minimum size of a data set is a cell, which is a spherical rectangle (i.e., bordered by meridians and latitudes). Adjacent cells do not overlap. The scale of the data contained in

the cell is dependent upon the navigational purpose (e.g., general, coastal, approach, harbor).

Under S-57, cells have a standard format but do not have a standard coverage size. Instead, cells are limited to 5mb of data. S-57 cells are normally copy protected and therefore require a permit before use is allowed. These permits are delivered as either a file containing the chart permits or as a code. In both cases the first step is to install the chart permit into the ECDIS. Some hydrographic offices deliver S-57 cells without copy protection and therefore permits are not required.

Any regional agency responsible for collecting and distributing S-57 data, such as PRIMAR and IC-ENC, will also maintain data consistency. National hydrographic offices are responsible for producing S-57 data for their own country area. Throughout the world, hydrographic offices have been slow to produce sufficient quantities of ENC data. This is the result of standards that have been evolving over several years, and that vector data is much harder to collect than raster data.

Several commercial manufacturers have developed non S-57 vector databases beyond those that have been issued by official hydrographic offices. These companies are typically manufacturers of ECDIS or ECS equipment or have direct relationships with companies that do, and typically have developed data in proprietary format in order to provide options to raster charts in the absence of ENC data. HO-issued paper charts provide the source data for these formats, although in some cases non-official paper charts are used. In some cases, ECS manufacturers provide a regular updating and maintenance service for their vector data, resulting in added confidence and satisfaction among users. The manufacturer's source of the updates is through

the HO. Hence, these two particular non-official formats allow for a very high degree of confidence and satisfaction among mariners using this data.

ECS sometimes apply rules of presentation similar to officially specified rules. Thus information is displayed or removed automatically according to scale level to manage clutter. The same indications pertinent to overscaling ENC apply to private vector data. Since the chart data is not ENC, the systems must display that nonofficial status when used in an ECDIS.

## 512. IHO S-100

S-57, the current IHO Transfer Standard for Digital Hydrographic Data, adopted in 1992, was created to support multiple hydrographic data types and associated software. It is an encapsulation and encoding specification guide used for ENC and ECDIS. The S-57 limitations in flexibility stem not from updating the specifications, but from the manufacturer and shipping company update cycles; this potential time gap puts the mariner to sea with systems in non-compliance with current specification. In 2001, S-100, the IHO Universal Hydrographic Data Model, was put into the work plan of the IHO Transfer Standards Maintenance and Applications Development (TSMAD) Working Group. In 2010, it was adopted by the IHO and became an active international encapsulation standard. In order to ensure the mariner has the most up to date information that can be displayed properly, S-100 aligns with international geospatial standards, in particular ISO19100. This will allow easier integration of data and applications into GIS based solutions. S-100 will eventually replace the encapsulation segment S-57 while S-101 will replace the encoding segment of S-57.

S-100 supports a broader base of data sources, such as imagery, gridded data, high-density bathymetry, 3-D, and data with time variances. S-57 is limited with its fixed maintenance system and it cannot support future requirements without manufacturer development. One of the new features of S-100 will be the addition of the portrayal catalog, a rule set for depicting encoded features as graphics. This eliminates the dependency of updates to the specifications on manufacturer development. This allows the mariner access to the latest specification updates outside of bridge maintenance cycles. As geospatial information has become more and more prevalent in the maritime world, S-100 allows for a common encapsulation for the various data streams including charts, bathymetry, messages, and aids to navigation. Improvements and extensions will be developed with the help of the GIS domain, instead of isolated from it. S-100 will also allow government and commercial organizations to better support the applications, bringing the cost of upkeep lower and reaching a broader spectrum of clients and allow for data sharing. It will be well-suited for use with web-based applications to better acquire, process, analyze and present data.

### Benefits of S -100 include:

- Portrayal catalogs
- Feature catalogs
- Flexible version control
- Improved metadata storage
- Spatial geometry
- Use of imagery and gridded data
- Multiple encodings
- Standardized product specifications
- Continuous maintenance

From the S-100 framework, the S-101 ENC Product Specification is being developed. It will take several years before S-100 and S-101 are fully implemented; development of the S-101 test bed, ECDIS on-shore and sea trials, Original equipment manufacturer (OEM) development of ENC Production Systems are still in work. After S-101 is released for operational use, projected for 2019, conversion of data from S-57 to S-101 data will need to take place as well as Electro-optical multifunction system (EOMS) executing S-100 based ECDIS for use.

Additional information about S-100 is available for download from the web via the link provided in Figure 512.



Figure 512. IHO information on the S-100 Universal Hydrographic Data Model.

[https://www.iho.int/srv1/index.php?option=com\\_content&view=article&id=586&Itemid=1011&lang=en](https://www.iho.int/srv1/index.php?option=com_content&view=article&id=586&Itemid=1011&lang=en)

## 513. Raster Data

Raster navigational chart (RNC) data is stored as picture elements (pixels). Each pixel is a minute component of the chart image with a defined color and brightness level. Many new RNC are created from the vector data used for ENC and DNC. However, raster-scanned images are derived by scanning paper charts to produce a digital photograph of the chart. In either case, raster data may appear more familiar, but it presents many limitations to the user.

The official raster chart formats are:

- ARCS (British Admiralty)
- Seafarer (Australia)
- BSB (U.S., NOAA)

These charts are accurate representations of the paper chart with every pixel geographically referenced. Where applicable, horizontal datum shifts are included with each chart to enable referencing to WGS84. This permits compatibility with information overlaid on the chart. *Note: Not all available charts have WGS84 shift information.* Extreme caution is necessary if the datum shift cannot be determined exactly.

Raster nautical charts require significantly more computer memory than do vector charts to be displayed. Whereas a world portfolio of more than 7500 vector charts may occupy about 500mb, a typical coastal region in raster format may consist of just 40 charts and occupy more than 1000mb of memory. For practical reasons, most of a portfolio of raster charts should not be loaded into the ECDIS hard drive unless one is route planning or actually sailing in a given region. To update RNC the user typically must load a new version of the chart.

Certain non-official raster charts are produced that cover European and some South American waters. These are scanned from local paper charts. Additionally, some ECDIS and ECS manufacturers also produce raster charts in proprietary formats.

In 1998 the IMO's Maritime Safety Committee (MSC 70) adopted the Raster Chart Display System (RCDS) as Appendix 7 to the IMO Performance Standards. The IMO-IHO Harmonization Group on ECDIS (HGE) considered this issue for over three years. Where IHO S-57 Ed. 3 ENC data coverage is not available, raster data provided by offi-

cial HO's can be used as an interim solution. But this RCDS mode does not have the full functionality of an otherwise IMO-compliant ECDIS using ENC data. Therefore, RCDS does not meet SOLAS requirements for carriage of paper charts, meaning that when ECDIS equipment is operated in the RCDS mode, it must be used together with an appropriate portfolio of corrected paper charts.

Some of the limitations of RCDS compared to ECDIS include:

- Chart features cannot be simplified or removed to suit a particular navigational circumstance or task.
- Orientation of the RCDS display to course-up may affect the readability of the chart text and symbols since these are fixed to the chart image in a north-up orientation.
- Depending on the source of the raster chart data, different colors may be used to show similar chart information, and there may be differences between colors used during day and night time.
- The accuracy of the raster chart data may be less than that of the position-fixing system being used.
- Unlike vector data, charted objects on raster charts do not support any underlying information.
- RNC data will not trigger automatic alarms. (However, some alarms can be generated by the RCDS from user-inserted information.).
- Soundings on raster charts may be in fathoms and feet, rather than meters.

The use of ECDIS in RCDS mode can only be considered as long as there is a backup folio of appropriate up-to-date paper charts.

## INTEGRATED BRIDGE SYSTEMS

### 514. Description

An Integrated Bridge System (IBS) is a combination of equipment and software that use interconnected controls and displays to present a comprehensive suite of navigational information to the mariner. Rules from classification societies such as Det Norske Veritas (DNV) specify design criteria for bridge workstations. Their rules define tasks to be performed, and specify how and where equipment should be sited to enable those tasks to be performed. Equipment carriage requirements are specified for ships according to the requested class certification or notation. Publication IEC 61029 defines operational and performance requirements, methods of testing, and required test results for IBS.

Classification society rules address the total bridge system in four parts: technical system, human operator, man/machine interface, and operational procedures. The

DNV classifies IBS with three certifications: NAUT-C covers bridge design; W1-OC covers bridge design; instrumentation and bridge procedures; W1 augments certain portions of W1-OC.

An IBS generally consists of at least:

- Dual ECDIS installation – one serving master and the other as backup and route planning station
- Dual radar/ARPA installation
- Conning display with a concentrated presentation of navigational information (the master ECDIS)
- DGPS positioning
- Ship's speed measuring system
- Auto-pilot and gyrocompass system
- Full GMDSS functionality

Some systems include full internal communications, and a means of monitoring fire control, shipboard status alarms, and machinery control. Additionally, functions for the loading and discharge of cargo may also be provided.

An IBS is designed to centralize the functions of monitoring collision and grounding risks, and to automate navigation and ship control. Control and display of component systems are not simply interconnected, but often share a proprietary language or code. Several instruments and indicators are considered essential for safe and efficient performance of tasks, and are easily readable at the navigation workstation, such as heading, rudder angle, depth, propeller speed or pitch, thruster azimuth and force, and speed and distance log.

Type approval by Det Norske Veritas for the DNV-W1-ANTS (Automatic Navigation and Track-Keeping System) certification is given to ship bridge systems designed for one-man watch (W1) in an unbounded sea area. DNV also provides for the other two class notations, NAUT-C and W1-OC. The W1 specifications require the integration of:

- CDIS (providing the functions of safety-contour checks and alarms during voyage planning and execution)
- Manual and automatic steering system (including software for calculation, execution and adjustments to maintain a pre-planned route, and including rate of turn indicator)
- Automatic Navigation and Track-keeping System (ANTS)
- Conning information display
- Differential GPS (redundant)
- Gyrocompass (redundant)

- Radar (redundant) and ARPA
- Central alarm panel
- Wind measuring system
- Internal communications systems
- GMDSS
- Speed over ground (SOG) and speed through water (STW or Doppler log)
- Depth sounder (dual transducer >250m)
- Course alteration warnings and acknowledgment
- Provision to digitize paper charts for areas not covered by ENC data

The W1 classification requires that maneuvering information be made available on the bridge and presented as a pilot card, wheelhouse poster, and maneuvering booklet. The information should include characteristics of speed, stopping, turning, course change, low-speed steering, course stability, trials with the auxiliary maneuvering device, and man-overboard rescue maneuvers.

The W1-OC and W1 classifications specify responsibilities of ship owner and ship operator, qualifications, bridge procedures, and particular to W1, a requirement for operational safety standards. The W1 operational safety manual requires compliance with guidelines on bridge organization, navigational watch routines, operation and maintenance of navigational equipment, procedures for arrival and departure, navigational procedures for various conditions of confinement and visibility, and system fallback procedures. Both classifications also require compliance with a contingency and emergency manual, including organization, accident, security, evacuation, and other related issues.

## MILITARY ECDIS

### 515. ECDIS-N

In 1998, the U.S. Navy issued a policy letter for a naval version of ECDIS, called ECDIS-N, and included a performance standard that not only conforms to the IMO Performance Standards, but extends it to meet unique requirements of the U.S. Department of Defense.

A major difference from an IMO-compliant ECDIS is the requirement that the ECDIS-N SENC must be the Digital Nautical Chart (DNC) issued by the National Geospatial-Intelligence Agency (NGA). The DNC conforms to the U.S. DoD standard Vector Product Format (VPF), an implementation of the NATO DIGEST C Vector Relational Format.

The U.S. Navy uses the Voyage Management System (VMS) software as the ECDIS-N compliant system. Greater than 95% of the fleet is certified to operate without paper

charts. VMS was selected for use by the Navy in 2002, based on the large presence of VMS in the surface fleet Integrate Bridge Systems and in the submarine fleet BPS radar system. The current series of VMS software, the 9.x series, is being fielded in 2017. This will replace the 6.x, 7.x and 8.x versions in the fleet and reduce the number of fielded variants of VMS. In addition to VMS, many ships and combatant craft use the Common Geospatial Extensible Navigation Toolkit (COGENT) 2.4 software for electronic chart navigation situational awareness and mission support.

The Navy plans to replace the ECDIS-N with a new program of record called **Navy ECDIS**. Navy ECDIS will be based on the NATO Warship ECDIS (WECDIS) standard and also on a U.S. Navy specific Software Requirements Document (SRD). The Navy ECDIS software is being procured competitively and is expected to start fielding in 2019.

## 516. The Digital Nautical Chart

NGA produces DNC, a vector-based digital product housed in a global database designed to support marine navigation and Geographic Information Systems (GIS) applications. This product contains vector data and feature content thematically layered and relationally structured to support ECDIS. DNC is produced in the standard VPF, a non s-57 data format, and conforms to DNC (MIL-PRF-80923) specifications, which allows for modeling real world features in digital geographic databases. The database underlying the DNC portfolio uses a table-based georelational data model containing significant maritime features considered essential for safe marine navigation. It is designed to conform to the IMO Performance Standard and IHO specifications for ECDIS.

The DNC database is based on and developed with feature content from traditional paper charts produced by NGA and NOS. This content is updated regularly with both foreign partner charts and NOS charts to reflect the latest information from the various charting authorities. Although the majority of the DNC portfolio is unclassified, a significant portion is labeled Limited Distribution (LIMDIS) to protect the copyrights and sensitive feature data provided by NGA's foreign partners, therefore, DNC is primarily developed and maintained for use by Department of Defense (DoD) agencies and departments including, the U.S. Navy, U.S. Coast Guard, government agencies, and government/US military sponsored contractors. DNC data for U.S. waters is generally available for public use and is available for download from NGA's website.

DNC Library Categories		
Library Category	Scale	Purpose
General	> 1:500K	The smallest scale charts used for planning, fixing position at sea, and for plotting while proceeding on an ocean voyage. The shoreline and topography are generalized and only offshore soundings, the principal navigational lights, outer buoys, and land-marks visible at considerable distances are shown.
Coastal	1:75K - 1:500K	Intended for inshore coastwise navigation where the course may lie inside outlying reefs and shoals, for entering or leaving bays and harbors of considerable width, and for navigating large inland waterways.
Approach	1:25K - 1:75K	Intended for approaching more confined waters such as bays or harbors.
Harbor	1 < 1:50K	Intended for navigation and anchorage in harbors and small waterways
Browse Index	1:3,1000,000	Provides a global overview of the DNC coverage displaying geographical boundaries.

Table 516a. DNC library categories according to scale.

The DNC database consists of 29 DNC geographic regions that provide a worldwide footprint containing over 5,000 charts of varying scales resulting in global coverage between 84 degrees N and 81 degrees S. The 29 regions are further broken down by libraries. The DNC portfolio comprises some 3,800 or more DNC libraries created from over 8,600 Standard Nautical Charts (SNC). Each DNC library represents a different geographic area of interest and level of detail (i.e. scale). The libraries are organized as tiles according to the World Geodetic Reference System (GEOREF) tiling scheme. The libraries have been designed to support various navigation and piloting maneuvers as well as GIS applications.

The Horizontal datum in DNC is WGS 84 (considered

equivalent to NAD 83 in the U.S.). There are three vertical datums within the DNC database; two vertical datums related are topographic and the third is hydrographic. Topographic features are referenced to Mean Sea Level, and the shoreline is referenced to Mean High Water. Hydrography is referenced to a low water level most suitable for the region being charted. All measurements are metric.

The DNC data is stored in libraries; each library represents a different geographic area of interest and level of detail (i.e. scale). The libraries are as tiles according to the World Geodetic Reference System (GEOREF) tiling scheme. The DNC contains four library categories: Harbor, Approach, Coastal, and General, based on scale (from largest to smallest scale, respectively) and purpose. A Browse



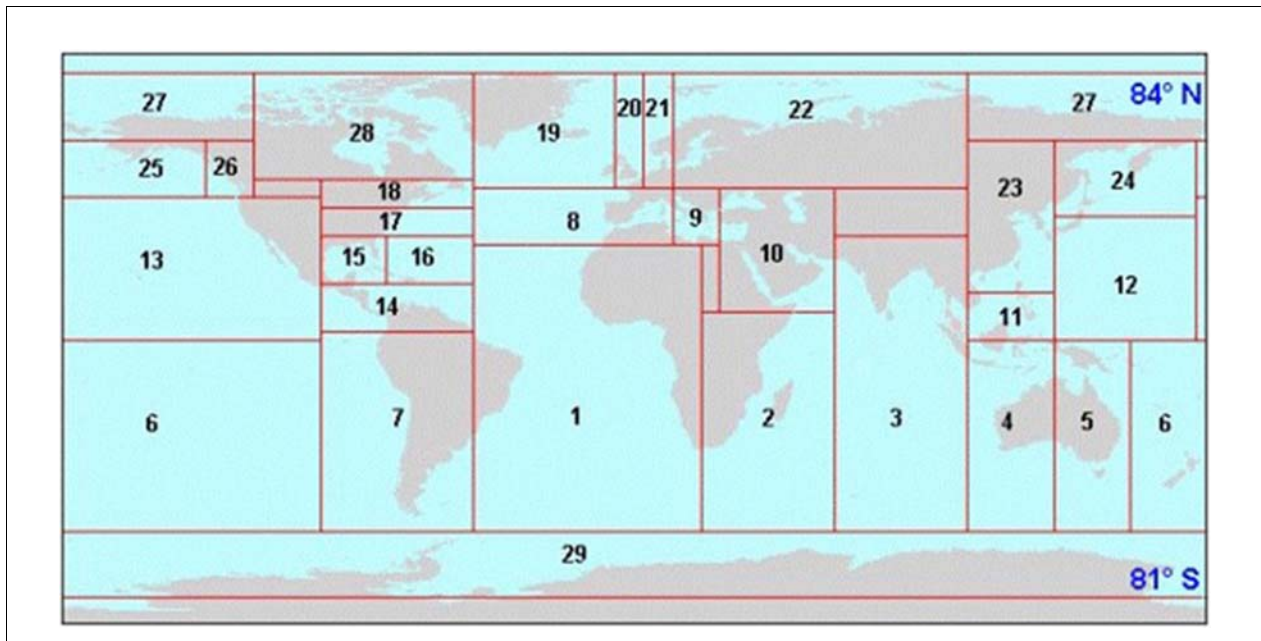


Figure 516a. DNC Regions graphic.

Index provides library names and footprints.

The DNC data is grouped and stored in the following five library scales in Table 516a. For voyage planning NGA provides a DNC Regions graphic, which is available on the DNC website (see Figure 516a).

The naming convention used for Harbor and Approach libraries are the same (e.g., H0145820 or A1708470). The first character signifies the category type (Harbor or Approach). The next two characters are the DNC geographic region number (e.g., 17 is the East Coast of the United States). The last five characters are the five-digit World Port Index (WPI) number.

The naming convention used for Coastal and General libraries start with a three letter code (COA or GEN) followed by the two-digit disc/geographic region number and a letter if the disc includes more than one library of that type (e.g., GEN1720a and GEN20b). The World Port Index reference is not included in the Coastal and General library naming convention.

DNC data is classified into and layered in 12 related feature class thematic layers:

- Cultural Landmarks (CUL)
- Data Quality (DQY)
- Earth Cover (ECR)
- Environment (ENV)
- Hydrography (HYD)
- Inland Waterways (IWY)
- Landcover (LCR)
- Limits (LIM)
- Aids to Navigation (NAV)
- Obstructions (OBS)
- Port Facilities (POR)
- Relief (REL)

Also, there are two additional layers found within the DNC data structure called Library Reference (LIBREF) and Tile Reference (TILEREF). These layers are used within the ECDIS-N to find the stored DNC data. DNC content is generally aligned to mirror what is found on a Standard Nautical Chart (SNC) printed on paper. However, one of the advantages of a digital product is the ability to provide the mariner with additional information when necessary to help them augment their understanding of the navigation space.

The publicly releasable DNC data is available for download at the following web location:

WWW: <https://dnc.nga.mil>

The full set of DNC data, to include the Limited Distribution information, is available via the following web locations:

NIPRNET: <https://dnc.geo.nga.mil>

SIPRNET: <http://dnc.nga.smil.mil>

JWICS: <https://dnc.nga.ic.gov>

**Tactical Ocean Data (TOD)** is an overlay to DNC. TOD data is bathymetric in nature and intended to support naval operations. Original TOD specifications provide for a total of six levels as outlined below:

**Level 0** - OPAREA, Range, and Naval Exercise Areas (NAVEX) charts

**Level 1** - Bottom Contour Charts (BC)

**Level 2** - Bathymetric Navigation Planning Charts (BNPC)

**Level 3** - Shallow Water Charts

**Level 4** - Hull Integrity Test Charts

**Level 5** - Strategic Straits Charts

In recent years, change in policy resulted in the combination of TOD levels 1, 3 and 5 into TOD Level 2. The current TOD Levels are referenced below:

**Level 0 - OPAREA, Range, and Naval Exercise Areas (NAVEX) charts**

- TOD0 provides worldwide databases of nautical information in Vector Product Format (VPF). The data content and coverage is intended to closely replicate NGA's Naval Operating Area (OPAREA) Chart, Range Chart, and Naval Exercise Area (NAVEX) Chart series.

**Level 2- Bathymetric Navigation Planning Charts (BNPC)**

- TOD2 provides worldwide databases of nautical information in Vector Product Format (VPF). The data content and coverage is intended to closely replicate NGA's Bathymetric Navigation Planning Chart (BNPC) series. includes data from:
  - Bottom Contour Charts (BC)
  - Shallow Water Charts
  - Strategic Straights Charts

**Level 4- - Hull Integrity Test Charts (HITS)**

- TOD4 is a vector-based digital product that portrays detailed bathymetric data for submarine Hull Integrity Test Sites (HITS) in a format suitable for computerized subsurface navigation. TOD4 data is designed for use during submarine hull integrity tests conducted as a part of builder's trials and after submarine hull maintenance. TOD4 data is provided primarily to support deep submergence rescue vessel operations and to enhance coordination between units during escorted test dives.

**517. Differences Between NOAA ENC and DNC**

The NOAA ENC is based on the International Hydrographic Organization Transfer Standard for Digital Hydrographic Data, Publication S-57 and is approved by the International Maritime Organization for SOLAS class vessels to use for navigation in an ECDIS. NOAA and the U.S. Army Corps of Engineers (USACE) are producing ENCs for the coastal and inland waters of the U.S. Most hydrographic offices throughout the world are producing vector charts in ENC format.

NGA produces ENC cells over areas where NGA is considered the charting authority such as Haiti, the Pacific Islands, and parts of Antarctica. In these areas, NGA is responsible for civilian shipping and is required to provide ENC to facilitate the International Maritime Organization (IMO) mandate for electronic charting. NGA ENC cells are available for download through the NOAA website.

DNC produced by the NGA, is unclassified, vector-based, digital database containing maritime significant

features essential for safe marine navigation. The DNC uses the Vector Product Format, which is a NATO standard for digital military map and chart data. NGA produces DNCs for worldwide coverage.

ENC was developed for civil navigation, with an initial emphasis on commercial navigation. DNC was developed for the military user for multiple roles; it can be combined with land, air and tactical data layers for various military uses such as littoral warfare.

During the creation of a NOAA ENC, high-resolution source information was used in portraying channels, aids to navigation, and other important features. Today, NOAA ENC data is updated by incorporating high resolution source information from a variety of sources. DNCs covering U.S. waters were created by digitizing paper NOAA charts.

The NOAA ENC files are updated using weekly USCG Local Notice to Mariners and NGA Notice to Mariners. DNCs are updated on a monthly basis using NGA Notice to Mariners. For US Waters, NGA updates the data inside the 12' contour by using USCG local notices.

**518. Warship ECDIS (WECDIS)**

WECDIS is defined by NATO Standard ANP-4564. WECDIS is a system which takes inputs from and provides information to disparate tactical sources (including the Command System), providing the user with a controllable set of information additions to overlay onto electronic charting and position displays for safety of navigation and enhanced tactical awareness. WECDIS is delivered via a dedicated user interface and chart display. When required by the user (for example in a benign tactical environment) WECDIS shall be capable of operation as an IMO compliant ECDIS. The primary function of WECDIS is to enhance military mission effectiveness by supporting safe and efficient navigation.

The IMO Performance Standards for ECDIS define the minimum requirements for functionality with respect to route planning, monitoring, alarms and voyage recording. However, warships can be operated under circumstances not anticipated by IMO, to include the core WECDIS capabilities of dived navigation, high speed navigation, waterspace management, integration of Additional Military Layers (AML) and the transfer of NATO User Defined Layers (NUDL) between NATO units. These circumstances impose additional requirements on WECDIS beyond those mandated by IMO.

WECDIS based solely on IMO specifications will not achieve the functionality required in a wartime scenario. Therefore NATO adds its own requirements in this WECDIS standard; these can be further expanded based on national requirements.

Although warships, naval auxiliaries, other ships owned or operated by a contracting government and

used only on governmental non-commercial service are exempt from the provisions of SOLAS Chapter V Regulations 18 and 19 (Ref A). WECDIS shall have the capability to be functionally compliant with the requirements of the latest IMO ECDIS performance and IHO chart presentation standards when selected by the user. Nations shall ensure that appropriate verification is completed to ensure functional compliance with IMO performance standards when operating in this mode.

Two operational modes, WECDIS mode and IMO compliant mode, categorize the requirements listed in this standard:

**WECDIS mode:** the system is operating in this mode when any of the currently activated system functionalities render it non ECDIS IMO compliant.

**IMO compliant mode:** the system is operating in this mode when all the currently activated system functionalities do not compromise ECDIS IMO regulations compliance.

## CORRECTING ELECTRONIC CHARTS

### 519. ECDIS Correction Systems

ECDIS software creates a database from the ENC data called the SENC and from this selects information for display. The ECDIS software meanwhile receives and processes serial data from navigational sensors and displays that textual and graphical information simultaneously with the SENC information.

It is the SENC that is equivalent to up-to-date charts, as stated by the Performance Standards. As originally conceived, ECDIS was designed to use internationally standardized and officially produced vector data called the ENC (electronic navigational chart). Only when using ENC data can ECDIS create a SENC, and thereby function in the ECDIS mode.

Updates for ENC are installed into the ECDIS separate from the ENC data itself. For the mariner, this involves activating a special utility accompanying the ECDIS and following the on-screen prompts. Within this same utility, update content and update log files in textual form can be viewed. Once the ECDIS software itself is reactivated, the update information is accessed in conjunction with the ENC data and the SENC database is created.

Just as ENC and updates are transformed into the SENC, so too are other data types accessed and combined. The user has the option to add lines, objects, text and links to other files supported by application. Referred to in the Performance Standards as data added by the mariner, these notes function as layers on the displayed chart. The user can select all or parts of the layers for display to keep clutter to a minimum. The mariner's own layers, however, must be called into the SENC from stored memory. As a practical matter, not only must the mariner take care to associate file names with actual content, such as with manually created chart corrections, but also must realize that the files themselves do not have the tamper-proof status that ENC and official updates have. Special care should be given when cells are canceled in the SENC database. These cells will not be subject to further updates and the cell will become out-of-date. The mariner should remove the ENC from the SENC when prompted to avoid accidental future use.

Within the SENC resides all the information available for the display. The Presentation Library rules such as Standard Display and Display Base define what levels of

information from the SENC can be shown. An ENC updating profile is contained within the IHO S-57 Edition 3.0 specification. This enables the efficient addition, removal or replacement of any line, feature, object or area contained within the ENC dataset. Guidance on the means and process for ENC updating is provided in IHO S- 52, Appendix 1. In terms of what is called for in the IMO Performance Standards, an ENC dataset being used in an ECDIS must also have an ENC updating service providing the most current information. The service permits the ENC and the SENC to be corrected for the intended voyage, and thus achieves an important component of SOLAS compliance..

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Accordingly, ECDIS must be capable of accepting official updates to the ENC data provided in conformity with IHO standard. Updated cells are stored in a file and transmitted by e-mail, floppy disk or CD-ROM, or satellite. For example, PRIMAR charts and updates are delivered on two CDs: the Base CD contains the PRIMAR database at the

time indicated on the label and the second CD contains the updates for those charts. However, the update CD also contains new charts issued since the base CD was printed. Since the operator must acquire the files and then initiate the update functions of the ECDIS software, this form of updating is referred to as semi-automatic. The two other types of updates include manual and automatic. Manual updating consists of the mariner entering printed NTMs, verbal communication or any other unformatted information. This method requires special attention to the reference-ellipsoid conformity and to conformity of the measurement units and the correction text. Automatic updating consists of updating the SENC through files obtained through electronic data communication lines, such as satellite.

ECDIS will reject updates if the update issuing authority is different from the cell issuing authority. It will also reject corrupted update files and files with an incorrect extension. ECDIS checks that updates are applied in the right sequence. If one update is missing the next update is rejected. An update CD-ROM should contain all available updates for all S-57 cells. Under normal circumstances, ECDIS will automatically run all updates in the right order for all cells.

For S-57 data, the content of updates in text form can be viewed from within the utility that permits the management of chart data. The utility can only be run when ECDIS is terminated. ECDIS is also capable of showing or hiding S-57 updates on a given chart or cell. The update should run via the chart utility. After restarting ECDIS, and after loading into the display the selected chart with the correction, the correction should be manually accepted. That enables the function in S-57 chart options to show or hide the symbol indicating the location of the correction.

#### **NGA DNC Corrections**

NGA produces the DNC Vector Product Format Database Update (VDU) to support worldwide DNC navigation requirements of the U.S. Navy, the Military Sealift Command (MSC), the U.S. Coast Guard, and certain foreign partners. Outside US Waters NGA does not distribute DNC to other than U.S. government agencies and foreign governments having data exchange agreements with NGA. The DNC maintenance system is able to apply new source materials such as bathymetry, imagery, Notice to Mariners, local notices, new foreign chart sources, etc. for inclusion in the DNC database. These updates are then provided to the mariner via the VDU process.

The VDU system works by performing a binary comparison of the corrected chart library with the previous latest released baseline edition version. The differences are then written to a binary "patch" file with instructions as to its exact location. The user then applies this patch file by specifying the proper path and

filename to their DNC on the ships ECDIS-N and the data is updated with the VDU patch file. These VDU patch files are cumulative so every new change incorporates all previous changes, so navigators are assured that, having received the latest change, they have all the changes issued to date. The mariner is not required to do weekly incremental updates to apply all the previous update information.

The VDU patch file sizes are small enough to support the bandwidth limitations of ships at sea, and require only one-way communication. The updated patch files are posted every four weeks in groups of seven to eight DNCs per week. The VDU patch files are available as either an individual library patch file, or a full edition patch file to update the whole DNC from the previous edition to the current edition. The DNC VDU patch files are available via the following web locations:

WWW: <https://dnc.nga.mil>

NIPRNET: <https://dnc.geo.nga.mil>

SIPRNET: <http://dnc.nga.smil.mil>

JWICS: <https://dnc.nga.ic.gov>

See Figure 519a for a screen capture from the VDU patch web portal.

A separate layer within DNC provides the user with identification of where changes have been made during the updating process.

#### **British Admiralty Raster and Vector Chart Corrections**

The Admiralty Raster Chart Service (ARCS) is the UKHO's paper chart portfolio presented in a digital format. The Admiralty Vector Chart Service (AVCS) is composed of official ENC delivered to industry standards (S-63/S-57) formats and compatible with ECDIS. All ENCs in AVCS satisfy the mandatory chart carriage requirements of SOLAS Chapter V. Both ARCS and AVCS provide worldwide coverage and have weekly online updating services. AN interface guides users through the process of selecting and downloading updates, which can then be transferred to an ECS or ECDIS on CD, DVD or USB memory stick. IN addition to the online update service, weekly CD and DVD update disks provide all the latest *Notice to Mariner* corrections.

#### **NOAA Corrections**

In the U.S., NOAA provides updates based on information from USCG, NGA, Canadian Hydrographic Service (CHS) notice to mariners and information that is ready for publication from other sources such as NOAA hydrographic surveys, NOAA shoreline surveys, USACE hydrographic surveys and other features submitted from federal, state and private organizations. Updates are available via the links provided in Figure 519b and Figure 519c.

Images

<Alabama To Texas Approaches> <Cuba, Cayman Islands And Jamaica Approaches>  
 <Mexico Approaches> <South Carolina To Florida Approaches> <Coastal Libraries>  
 <Alabama To Texas Harbors> <Cuba, Cayman Islands And Jamaica Harbors>  
 <Mexico Harbors> <South Carolina To Florida Harbors> <Browse> <General Libraries>

Number	Name	Download full library	Download VDU Patch (Windows)	Download VDU Patch (Unix)	Graphic
		<input type="checkbox"/> check all	<input type="checkbox"/> check all	<input type="checkbox"/> check all	
A1508500	Charleston Harbor, South Carolina	<input type="checkbox"/> Edition 036 (2.4 MB)	<input type="checkbox"/> Windows (550.6 KB)	<input type="checkbox"/> Unix (547.7 KB)	n/a
A1508530	Saint Helena Sound, Georgia	<input type="checkbox"/> Edition 036 (3.7 MB)	<input type="checkbox"/> Windows (58.6 KB)	<input type="checkbox"/> Unix (53.7 KB)	n/a
A1508540	Tybee Island to Doboy Sound, Georgia	<input type="checkbox"/> Edition 036 (1.7 MB)	<input type="checkbox"/> Windows (28.7 KB)	<input type="checkbox"/> Unix (23 KB)	n/a
A1508555	Doboy Sound, Georgia	<input type="checkbox"/> Edition 036 (1.5 MB)	<input type="checkbox"/> Windows (2 KB)	<input type="checkbox"/> Unix (1.7 KB)	n/a
A1508580	Saint Augustine, Florida	<input type="checkbox"/> Edition 036 (2.2 MB)	<input type="checkbox"/> Windows (578.7 KB)	<input type="checkbox"/> Unix (545.8 KB)	n/a
A1508595	Cape Canaveral, Florida	<input type="checkbox"/> Edition 036 (1.5 MB)	<input type="checkbox"/> Windows (1.1 MB)	<input type="checkbox"/> Unix (1 MB)	n/a

Figure 519a. DNC website screen capture.



Figure 519b. NOAA ENC Chart Downloader.  
<http://www.charts.noaa.gov/ENCs/ENCs.shtml>



Figure 519c. NOAA RNC Chart Downloader.  
<http://www.charts.noaa.gov/RNCs/RNCs.shtml>

**Commercial Systems**

There are a variety of ECS systems available for small craft, often found aboard fishing vessels, tugs, research vessels, yachts, and other craft not large enough to need SOLAS equipment but wanting the best in navigation technology. Given that these systems comprise a single navigation aid and do not represent a legal chart in any sense, it is probably not a critical point that correction systems for these products are not robust enough to support regular application of changes.

In fact, often the only way to make changes is to purchase new editions, although the more sophisticated ones allow the placement of electronic “notes” on the chart. The data is commonly stored on RAM chips of various types, and cannot be changed or without re-programming the chip from a CD-ROM or disk containing the data. If the data is on CD-ROM, a new CD-ROM is the update mechanism, and they are, for the most part, infrequently produced. Users of these systems are required to maintain a plot on a corrected paper chart.

## USING ELECTRONIC CHARTS

### 520. Digital Chart Accuracy

As is the case with any shipboard gear, the user must be aware of the capabilities and limitations of digital charts. The mariner should understand that nautical chart data displays possess inherent accuracy limitations. Because digital charts are primarily based on paper charts, many of these limitations have migrated from the paper chart into the electronic chart. Electronic chart accuracy is, for the most part, dependent on the accuracy of the features being displayed and manipulated. While some ECDIS and ECS have the capability to use large-scale data produced from recent hydrographic survey operations (e.g., dredged channel limits or pier/terminal facilities) most raster and vector-based electronic chart data are derived from existing paper charts.

Twenty years ago, mariners were typically obtaining position fixes using radar ranges, visual bearings or Loran. Generally, these positioning methods were an order of magnitude less accurate than the horizontal accuracy of the survey information portrayed on the chart. For example, a three-line fix that results in an equilateral triangle with sides two millimeters in length at a chart scale of 1:20,000 represents a triangle with 40-meter sides in real-world coordinates.

A potential source of error is related to the system configuration, rather than the accuracy of electronic chart data being used. All ECDISs and most ECSs enable the user to input the vessel's dimensions and GPS antenna location. On larger vessels, the relative position of the GPS antenna aboard the ship can be a source of error when viewing the "own-ship" icon next to a pier or wharf.

In U.S. waters, the Coast Guard's DGPS provides a horizontal accuracy of +/-10 meters (95 percent). However, with selective availability off, even the most basic GPS receiver in a non-differential mode may be capable of providing better than 10 meter horizontal accuracy. In actual operation, accuracies of 3-5 meters are being achieved. As a result, some mariners have reported that when using an electronic chart while moored alongside a pier, the vessel icon plots on top of the pier or out in the channel.

Similarly, some mariners transiting a range that marks the centerline of a channel report that the vessel icon plots along the edge or even outside of the channel. Mariners now expect, just as they did 20 years ago, that the horizontal accuracy of their charts will be as accurate as the positioning system available to them. Unfortunately, any electronic chart based on a paper chart, whether it is raster or vector, is not able to meet this expectation.

The overall horizontal accuracy of data portrayed on paper charts is a combination of the accuracy of the underlying source data and the accuracy of the chart compilation process. Most paper charts are generalized composite doc-

uments compiled from survey data that have been collected by various sources over a long period of time. A given chart might encompass one area that is based on a lead line and sextant hydrographic survey conducted in 1890, while another area of the same chart might have been surveyed in the year 2000 with a full-coverage shallow-water multi-beam system. In the U.S., agencies have typically used the most accurate hydrographic survey instrumentation available at the time of the survey.

While survey positioning methods have changed over the years, standards have generally been such that surveys were conducted with a positioning accuracy of better than 0.75 millimeters at the scale of the chart. Therefore, on a 1:20,000-scale chart, the survey data was required to be accurate to 15 meters. Features whose positions originate in the local notice to mariners, reported by unknown source, are usually charted with qualifying notations like position approximate (PA) or position doubtful (PD). The charted positions of these features, if they do exist, may be in error by miles.

In 2017, less than 30 percent of the depth information found on NOAA charts was based on hydrographic surveys conducted before 1940. Surveys conducted many years ago with lead lines or single-beam echo sounders sampled only a tiny percentage of the ocean bottom. Hydrographers were unable to collect data between the sounding lines. Depending on the water depth, these lines may have been spaced at 50, 100, 200 or 400 meters. As areas are re-surveyed and full-bottom coverage is obtained, uncharted features, some dangerous to navigation, are discovered quite often. These features were either: 1) not detected on prior surveys, 2) objects such as wrecks that have appeared on the ocean bottom since the prior survey or 3) the result of natural changes that have occurred since the prior survey.

In a similar manner, the shoreline found on most U.S. charts is based on photogrammetric or plane table surveys that are more than 20 years old. In major commercial harbors, the waterfront is constantly changing. New piers, wharves, and docks are constructed and old facilities are demolished. Some of these man-made changes are added to the chart when the responsible authority provides as-built drawings. However, many changes are not reported and therefore do not appear on the chart. Natural erosion along the shoreline, shifting sand bars and spits, and geological subsidence and uplift also tend to render the charted shoreline inaccurate over time.

Another component of horizontal chart accuracy involves the chart compilation process. For example, in the U.S. before NOAA's suite of charts was scanned into raster format, all chart compilation was performed manually. Projection lines were constructed and drawn by hand and all plotting was done relative to these lines. Cartographers graphically reduced large scale surveys or engineering drawings to chart scale. Very often these drawings were ref-



erenced to state plane or other local coordinate systems. The data would then be converted to the horizontal datum of the chart, for example, the North American Datum 1927 (NAD 27) or the North American Datum 1983 (NAD 83). In the late 1980s and early 1990s, NOAA converted all of its charts to NAD 83. In accomplishing this task, averaging techniques were used and all of the projection lines were redrawn.

When NOAA scanned its charts and moved its cartographic production into a computer environment, variations were noted between manually constructed projection lines and those that were computer generated. All of the raster charts were adjusted or warped so that the manual projection lines conformed to the computer-generated projection. In doing so, all information displayed on the chart was moved or adjusted.

Similar processes take place during NGA's digital chart production, but involving more complexity, since NGA cartographers must work with a variety of different datums in use throughout the world, and with hydrographic data from hundreds of official and unofficial sources. While much of NGA's incoming data was collected to IHO standards during hydrographic surveys, several sources are questionable at best, especially among older data.

Today, when survey crews and contractors obtain DGPS positions on prominent shoreline features and compare those positions to the chart, biases may be found that are on the order of two millimeters at the scale of the chart (e.g., 20 meters on 1:10,000-scale chart). High accuracy aerial photography reveals similar discrepancies between the true shoreline and the charted shoreline. It stands to reason that other important features such as dredged channel limits and navigational aids also exhibit these types of biases. Unfortunately, on any given chart, the magnitude and the direction of these discrepancies will vary by unknown amounts in different areas of the chart. Therefore, no systematic adjustment can easily be performed that will improve the inherent accuracy of the paper or electronic chart.

Some mariners have the misconception that because charts can be viewed on a computer, the information has somehow become more accurate than it appears on paper. Some mariners believe that vector data is more accurate than paper or raster data. Clearly, if an electronic chart database is built by digitizing a paper chart, it can be no more accurate than the paper chart.

Once ENC's are compiled, they may be enhanced with higher accuracy data over time. High resolution shoreline data may be incorporated into the ENC's as new photogrammetric surveys are conducted. Likewise, depths from new hydrographic surveys will gradually supersede depths that originated from old surveys.

## 521. Route Planning and Monitoring

The *IMO Guidelines for Voyage Planning Res. A.893(21)* state "the development of a plan for voyage or passage, as well as the close and continuous monitoring of

the vessel's progress and position during the execution of such a plan, are of essential importance for the safety of life at sea, safety and efficiency of navigation and protection of the marine environment." The use of ECDIS for route planning automates many navigational processes, from plotting legs between waypoints to the ability to scan the route for navigational hazards based on selected safety parameters and areas for which special conditions exist. The mariner now has greater control with the electronic chart over that of the paper chart with the selection of the display of safe and unsafe water along with other objects in the chart database. Ultimately, the revised *IMO Performance Standards for ECDIS MSC.232(82)* state that "it should be possible to carry out route planning and monitoring in a simple and reliable way."

Route planning with ECDIS takes place before the start of the voyage, except in situations where major changes or deviations in the route are required while the ship is underway. In either case, ECDIS allows the display of both small scale and large scale charts of the operating area and the selection of waypoints from those charts. The determination of the safety contour and safety depth by the mariner, which can be set similar to the minimum depth contour with paper charts, play a critical role during route planning and monitoring (See Section 1002, 1004, and 1018). The safety contour (in ECDIS, the contour related to the own ship, selected by the mariner from the contours provided for in the SENC) is to be used by ECDIS to distinguish on the display between safe and the unsafe water, and for generating anti-grounding alarms.

During route planning with ECDIS as per MSC.232(82):

- An indication is required if the mariner plans a route across an own ship's safety contour.
- An indication should be given if the mariner plans a route closer than a user-specified distance from the boundary of a prohibited area or geographic area for which special conditions exist...
- An indication should also be given if the mariner plans a route closer than a user-specified distance from a point object, such as a fixed or floating aid to navigation or isolated danger.
- It should be possible for the mariner to specify a cross track limit of deviation from the planned route at which an automatic off-track alarm should be activated.

While route or voyage planning encompasses many tasks and has many requirements, the following discussion generally focuses on the use of electronic charts through ECDIS. (Please review Vol. I - Chapters 6, 10, 27, and Vol. II - Chapter 3 for more detailed discussion on voyage planning.)

Based on the smaller relative size of the ECDIS screen as compared to equivalent paper charts, the mariner needs to be more accustomed to zooming (increasing or decreasing

ing the chart display scale) and scrolling about the electronic charts during route planning, but must also exercise care to not overuse the zoom function of electronic charts due to overscale and underscale considerations (see Section 501). The mariner has the ability to add, delete, and change the position of waypoints along the route. After the preliminary waypoints have been positioned, the largest scale charts with due regard to the chart's compilation scale are used to further refine the waypoints and resultant legs in between. Additionally, the placement of waypoints should also consider, but not be limited to, traffic patterns and integrated navigation components of visual and radar navigation.

The mariner may need to zoom in and out while reviewing and revising the waypoints along with the resultant route legs. This process should include reviewing the integrity of chart data along with the quality of the bathymetric data of the charts through the display of the category of zone of confidence in data (CATZOC) symbols. The ZOC provides the position and depth accuracy of the ENC cell seafloor coverage, and typical survey characteristics (see Section 428 for more information on ZOC for paper charts).

Accordingly, the accuracy of the areas within the electronic chart may differ from that of GPS/DGPS positioning; therefore, this information, coupled with the CATZOC, will assist in the determination of planned distances off navigational hazards, ECDIS safety settings and other risk management such as routing measures. The horizontal and vertical datum of the chart data must be closely inspected and noted as it may require increased positional cross check procedures. Since planning is normally conducted in advance of the voyage, ECDIS allows for the display of date-dependent objects. This assists the mariner by displaying future changes that may affect a route being planned, provided the new objects are in the database.

When reviewing and refining the position of waypoints, the cross-track distances (XTD) of each leg can be modified to take into consideration safe navigation through the areas of transit ranging from open sea to restricted waterways. The determination of these values should also consider, but not be limited to, ECDIS look-ahead functions through the alarm settings for deviation from route, crossing safety contour, areas with special conditions, indication settings for crossing isolated dangers, along with safe distances from dangers to navigation and other acceptable and approved distance values.

At each waypoint, a wheel over point/line can be displayed to visually indicate when to start a turn. ECDIS typically allows for the mariner to select and display a turn radius for each waypoint. The turn radius is instrumental in the placement and adjustment of waypoints. Accordingly, the mariner must consider at each waypoint involving a change of course whether to use a wheel over based on the advance and transfer calculated from the appropriate turning circle diagram or a constant radius turn (see Section 1002). The ECDIS also provides the capability for route

planning in both straight and curved segments such as rhumb lines and great circles. Depending on the capabilities of the respective ECDIS, the great circle route may require that the route be modified into rhumb line segments based on longitude and limiting latitude requirements (See Section 1206).

When the mariner is satisfied with the planned route, an automatic route check based on appropriate safety values should be conducted. Based on the results of this check, a closer inspection of route details and revisions may be necessary. Notwithstanding the automatic ECDIS route check function, a visual check of the entire route using the largest scale charts should be conducted. The use of the *All Other Information* display, aids the mariner in the display of dangers detected by the route check(s). The systematic and detailed visual check should also consider, but not be limited to, the compilation scale of the charts, alarm parameters, turn radius at each waypoint, critical points and areas along with the reviewing if the route crosses dangers of navigation such as safety contours, isolated dangers, and limits of prohibited and geographical areas for which special purpose areas exist based on the settings of cross-track distances. Upon completion of the visual check and after any route modifications, additional follow-up route checks should then be completed until the plan is finalized and approved.

ECDIS also provides the capability for creating schedules based on values such as ETD, speed, time zone and ETA. Scheduling features can vary among ECDIS manufacturers but ultimately allow for assisting in the calculations for speed of advance and safe speed(s) at various points along the route.

The ship's master should review, revise if necessary, and approve the ECDIS route prior to departure. The route should be saved according the bridge procedures or company policy onboard and properly annotated with any safety-related settings and other pertinent information.

After route planning is complete and prior to departure, the chart display should be set up for underway use to minimize clutter while balancing the need for information to maintain safe navigation. This could require the mariner to carefully select between the *Standard Display* and the on-demand features of the *All Other Information* display based on open sea and restricted waterway/pilotage requirements. Various members of the bridge team will be viewing the ECDIS for different navigational purposes such as route monitoring, looking ahead, and target tracking/monitoring. Accordingly, it must be set up to convey information that is useful and relevant for each bridge team member.

The ECDIS also allows for the display alternate routes as long as the monitored route is clearly distinguishable from the planned routes. The alternate routes display separate routes or passages that can be planned in advance and checked through both automatic and visual methods against the ship's safety parameters and maneuvering characteristics. For example, alternative routes can be created for

contingency or risk management procedures such as deviations or anchorages. See Chapter 10 Piloting and Chapter 41 Weather Routing for more information.

During route monitoring, the ECDIS shows the own ship's position whenever the display covers that area. Although the mariner may choose to "look-ahead" while in route monitoring, it is possible to return to own ship's position with a single operator action. Key information provided during route monitoring includes a continuous indication of vessel position, course, and speed. The display of own ship can be selected by the mariner of either true scale or as a symbol (see Figure 521a and Figure 521b). ECDIS can also provide distance right/left of intended track, planned course and speed to make good, distance to run, position and time of "wheel-over," and past track history.

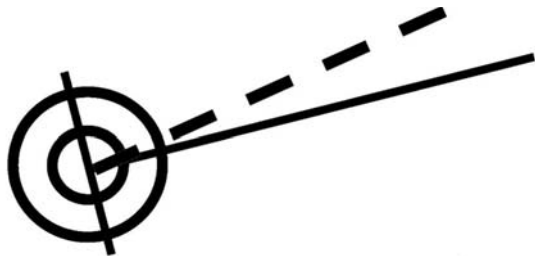


Figure 521a. Example of Own Ship symbol with speed vector (dashed line) and heading line (solid line) From IMO SN.1/Circ. 243/Rev.1 adapted with permission.

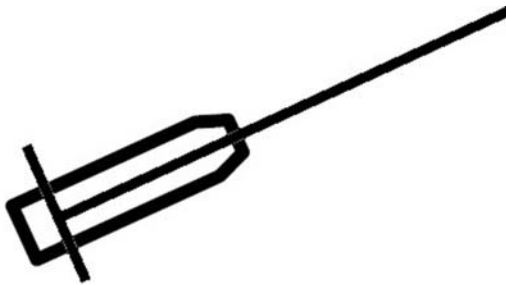


Figure 521b. Example of Own Ship True scale outline (symbol) oriented along own ship's heading. From IMO SN.1/Circ. 243/Rev.1 adapted with permission.

When own ship is approaching a waypoint, the mariner may need to zoom in on each waypoint if the chart scale from which it is selected is very small, such that the navigational picture in the area can be seen at a reasonable scale, while being careful not to overscale (Section 501). This can be done either manually or through automated ECDIS features.

To plot the ship's position by alternative means, the ECDIS offers manual position fixing capabilities as defined by MSC.232 (82). The functionality of this feature may vary based on the ECDIS manufacturer. Manually obtained lines of position (LOP) can span from visual bearings and

radar ranges to the input of position(s) calculated through celestial navigation. These positions can then be compared against the position provided by the GPS/DGPS. The ECDIS provides the capability to indicate discrepancies between the manual observations and that of the positions obtained by continuous positioning.

As specified in Appendix 5 of the MSC.232(82) *IMO ECDIS Performance Standards*, the ECDIS must provide an indication of the condition of the system and its components. An alarm must be provided if there is a condition that requires immediate attention. An indication can be visual, while an alarm must be either audible or both audible and visual.

The operator can control certain settings and functions, some of the most important of which are the parameters for certain alarms and indications, including:

- **Crossing safety contour:** As per MSC.232(82), "ECDIS should give an alarm if, within a specified time set by the mariner, own ship will cross the safety contour." The safety contour (shown as an extra thick line for the depth contour) is set to emphasize on the SENC the limits between safe and unsafe water. It is based on the available contours as provided for by the SENC. For example, when the mariner selects two-depth area shades to be displayed, the water deeper than the safety contour is shown in an off-white color while the water shallower than the safety contour is blue when using the day display mode (see Figure 521c).

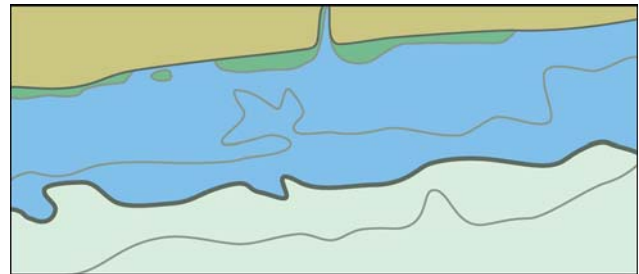


Figure 521c. Portrayal of depth areas with 2-color settings. Image courtesy of NOAA.

- **Area with special conditions:** As per MSC.232(82), "ECDIS should give an alarm or indication, as selected by the mariner, if, within a specified time set by the mariner, own ship will cross the boundary of a prohibited area or of a geographical area for which special conditions exist..." The areas for which special conditions exist are contained within Appendix 4 of MSC.232(82).
- **Deviation from route:** As per MSC.232, "An alarm should be given when the specified cross track limit for deviation from the planned route is exceeded." The value is determined as part of route planning,



Figure 521d. Isolated danger symbol. Image courtesy of NOAA.

and is the distance to either side of the route leg that the vessel is allowed to deviate before an alarm sounds.

- **Approach to critical point:** The ECDIS provides an alarm when the own ship will be within a specified time or distance to a critical point on the planned route. This alarm can be used for advanced notice of approaching a waypoint or based on a user added point, line, or area.
- **Different geodetic datum:** If the geodetic system used by the positioning system is not the same as the SENC, the ECDIS should give an alarm.
- **Isolated Dangers:** ECDIS can display small shoals, wrecks, rocks and other obstructions with a special symbol, different from their paper chart equivalents. The Isolated Danger symbol (see Figure 521d) is displayed to indicate dangers to navigation of a depth equal to or less than the safety contour and also lying within the 'safe' water defined by the safety contour. As per MSC.232(82), "an indication should be given to the mariner if, continuing on its present course and speed, over a specified time or distance set by the mariner, own ship will pass closer than a user-specified distance from a danger (e.g., obstruction, wreck, rock) that is shallower than the mariner's safety contour or an aid to navigation." It may also be displayed as selected by the mariner in the "unsafe" water between the displayed safety contour and zero meter contour. Additionally, the symbol will be displayed if the depth of the navigational danger is unknown.

The pick report or cursor picking of the ECDIS should be used to determine additional information about it and whether the danger might impact the safe navigation of the vessel. (For more information about the display of this symbol and that of other ENC data on ECDIS as specified by the IHO, consult U.S. Chart No 1, available online via the links provided in Figure 521e below.

Other settings that will affect the display of the electronic chart as compared to the paper chart include:

- **Safety depth:** This setting allows for soundings of equal to or less than the mariner-inputted safety depth value to be made more conspicuous than deeper soundings. Therefore, the mariner can use the safety depth setting to provide crucial depth infor-



Figure 521e. U.S. Chart No. 1.  
[https://msi.nga.mil/NGAPortal/MSI.portal?\\_nfpb=true&\\_st=&\\_pageLabel=msi\\_portal\\_page\\_62&pubCode=0004](https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_st=&_pageLabel=msi_portal_page_62&pubCode=0004)



Figure 521f. This image shows depth labels (with a light "halo" to set them apart) and soundings both deeper and shallower than the safety depth. Image courtesy of NOAA.

mation while sailing in proximity to and between the available contours (see Figure 521f). When using the safety depth feature the mariner is reminded that spot sounding are not included in the *Display Base* and *Standard Display*.

- **Four shades:** a shallow and deep contour, which defines additional depth areas for medium-deep and medium-shallow water can be selected by the mariner to add further detail to the chart display. This chart setting is useful during confined waterway transits such as harbor and coastal areas by providing enhanced awareness of the gradient of depth area.
  - **Shallow Contour:** This setting is usually set as the own ship's deep draft (plus calculated squat) to emphasize the contour shallower than the safety contour.

- **Deep Contour:** This setting is normally set to twice to ship's deep draft (plus calculated squat) to indicate areas where the vessel may experience squat.

When the four shades option is selected, the safety contour is displayed between the medium deep and medium shallow contours. Similar to the safety contour, if the SENC in use does not have a contour line equal to the selected shallow or deep contour, the ECDIS will default to the next deeper contour. Consequently, the mariner should carefully inspect the contour intervals and sounding data to determine the impact on the safe navigation of the vessel. See Figure 521g.

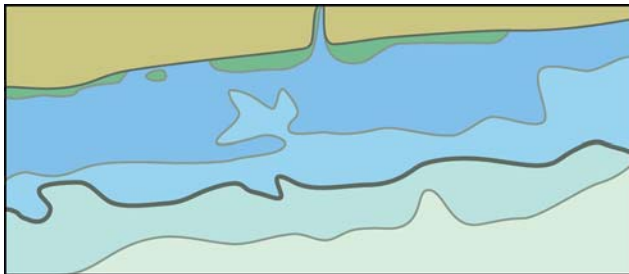


Figure 521g. Portrayal of depth areas with 4-color setting. Image courtesy of NOAA.

- **Areas Boundaries (Plain and Symbolized):** Because the ECDIS screen is smaller than the equivalent paper chart, the density of data must be considered. The plain area boundaries are intended for use at smaller scales as they can reduce the overall clutter of the charts against the backdrop of the other charted symbols. Symbolized area boundaries can be used on larger scales for display to aid in the identification of areas.
- **Chart Symbols (Traditional-Paper Chart and Simplified):** The selection of the chart symbols is the preference of the mariner based on operational considerations. The traditional symbols for point objects are most similar to paper chart symbols. See Figure 506b.

## 522. Waypoints and Routes

In the route planning mode, the ECDIS allows the entry of waypoints alphanumerically as coordinates of latitude and longitude or the selection of waypoints by moving a cursor around on the charts. It allows the creation and storage of numerous pre-defined routes, which can be combined in various ways to create complex voyages (review Chapter 27 Navigation Processes).

Routes created from berth to pilot station (or pilot station to berth) should also take into account the maneuvering characteristics of the vessel in restricted and/or confined waterways (review Chapter 10 Piloting). Turn radius used

at each waypoint must be closely inspected to insure acceptable clearance throughout the turn with reference to “unsafe” water and other dangers to navigation. During these transits, depending on the availability of contour intervals in the SENC, the mariner with the display of the safety depth has the ability to add additional no-go areas with the mariner's navigational objects or user chart function. Additionally, notes and features can include: Ship Reporting Systems, VTS call-in points, speed limits, expected traffic areas, clearing bearings, DR and EP positions, etc., along with contingency plans such as anchorages, abort and point(s) of no-return.

Coastal and open sea routes can be developed using the vessel's characteristics for route monitoring in addition to using autopilot along with track control (if fitted) considerations. Depending on the sophistication of the autopilot system and integration with other bridge equipment, some ECDIS units, in conjunction with GPS, compare the ship's observed position with that of the intended leg. The units with proper weather, rudder and rate of turn settings then determine the level of compensation for wind and current to ensure the heading and COG are appropriate to maintain the ship on track. The cross-track distance may be set to consider the vessel's operating procedures concerning leeway and course XTD allowance. Berth to sea buoy and coastal/open sea routes can be combined or linked with the ECDIS to establish integrated routes from berth to berth. Route checking and scanning procedures still apply to the newly created route to insure that the routes linked at the appropriate waypoint and other safety settings are considered as discussed in Section 521.

Company procedures regarding **cyber-security** will normally apply to the transferring of data between ECDIS and other computers with internet access. Virus scanning of USBs and other approved media along with the organization of update and route files in paramount. Route files and user chart/notes should be saved and backed up to external media to help insure availability in the event of ECDIS malfunction, failure, transfer to backup system and after a restart/reboot. Based on the individual ECDIS manufacturer, the options for adding notes and descriptions to each saved route can vary. Naming conventions for route names differ based on the operational procedures but can include voyage number, UN/LOCODE for ports, and current year. For example, a voyage between San Francisco and Honolulu could be named 17Voy1USSFOtoUSHNL.

Regardless of whether the route is planned for confined/restricted waterways or open sea, each plan must take into account the principles of safe navigation (review Chapter 10, 27, and in Vol II - Chapter 3).

## 523. Training and Simulation

The STCW Code as amended in 1995 first introduced the concept of ECDIS being considered within the term “charts.” The 2010 Manila Amendments to the STCW



further revised the ECDIS training requirements, which are included in Tables A-II/1, A-II/2 and A-II/3. The training and assessment in the operational use of ECDIS should also conform to revised guidelines as defined by Table B-I and B-II assessment in navigational watchkeeping and evaluation of competence of the STCW Code. Specifically, the 2010 amendments added ECDIS competency requirements for chief mates, masters and officers in charge of a navigational watch on vessels 500 gross tons (GT) or more.

The current curriculum guidance for USCG course approval of ECDIS states the “course should be at least 35 hours and be substantially similar to IMO Model Course 1.27 The Operational Use of the Electronic Chart Display and Information System (ECDIS) (2012 Edition).” The course should also include the “applicable assessments of competence for STCW endorsements for Officer in Charge of a Navigational Watch (OICNW) and Chief Mate and Master.” The ECDIS course should include the Table A-II Column 1 Competencies, which also contains Column 2 Knowledge, Understanding and Proficiency components:

- Knowledge of the capability and limitations of ECDIS, and sub-topics 1 through 3
- Proficiency in the operation, interpretation, and analysis of information obtained from ECDIS, and subtopics 1 through 6
- Management of operational procedures, system files and data, and subtopics 1 through 7

Current training requirements for mariners on ECDIS-equipped vessels includes both generic and familiarization components. The generic training currently follows the ECDIS IMO Model Course 1.27 (2012) Edition. The ECDIS course is typically designed to emphasize the application and learning of ECDIS in the underway context. There are five primary stages of the ECDIS Course:

1. Elements of ECDIS
2. Watchkeeping with ECDIS
3. ECDIS Route Planning
4. ECDIS Charts, Targets & System
5. ECDIS Responsibility

As per Section B-I/12 of the STCW Code, as amended, ECDIS training should be structured to include the theory and demonstration of the principal types of ECDIS and their display characteristics, risks of over-reliance on ECDIS, detection of misrepresentation of information and factors affecting system performance and accuracy. Simulator exercises of the ECDIS training further demonstrate and, through practical opportunities, allow the trainee to attain knowledge and skills in the setup and maintenance of display, operational use of electronic charts, route planning, route monitoring, alarm handling, manual correction of a ship's position and motion parameters, records in the ships' log, chart updating, operational use of ECDIS where ra-

dar/ARPA is connected, operational use of ECDIS where AIS is connected, operational warnings, their benefits and limitations, and system operational tests.

The training requirements for the use of the ECS to meet US domestic paper chart requirements are currently found in Navigation and Vessel Inspection Circular (NVIC) 01-16 as follows:

- “RTCM class 'A' training is met through the successful completion of a USCG-Approved ECDIS course and having an the appropriate endorsement on their Merchant Mariner Credential (MMC)
- “RTCM class 'B' and 'C' training is through the familiarization requirement of 46 CFR 15.405. As per NVIC 01-16, this familiarity can be accomplished through the company following the manufacturer's standards, user's manuals, and company policies to document competency.

While ECDIS can be viewed from a standardized perspective due to the IMO Performance Standards and other IHO and IEC requirements, individual manufacturers have some degree of freedom in their menu structure and terminology used for required functions. This particular aspect and specific installations underlies the need for familiarization to specific ECDIS equipment. Additionally, familiarization with the ECDIS should include reviewing the backup arrangements, sensors and related peripherals. Conversely, generic training in ECDIS has a broader focus on the theory and operational use of ECDIS in the context of navigation.

Familiarization requirements follow STCW Regulation A-I/14 Responsibilities of Companies, International Safety Management (ISM) 6 Resources and Personnel 6.3, 6.5 and 46 CFR 15.405.

Due to advances in navigational technologies, mariners are encouraged to consult USCG, IMO, IHO and manufacturer websites to stay abreast of electronic chart and ECDIS developments. Links to additional information are provided in Figure 523a, Figure 523b and Figure 523c.



Figure 523a. USCG - Navigation Center.  
<http://www.navcen.uscg.gov/>





Figure 523b. NOAA Nautical Charts.  
<https://www.nauticalcharts.noaa.gov/index.html>

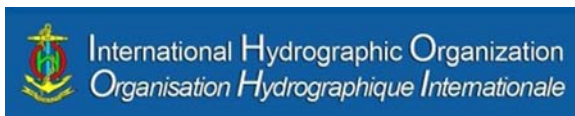


Figure 523c. IHO homepage. Select the ENC's, ECDIS & S-100 tab for more information.  
<https://www.iho.int/srv1/index.php?lang=en>

## 524. Reference Note

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