U.S. Department of Homeland Security

United States Coast Guard

BOAT CREW HANDBOOK – Navigation and Piloting

Captain John A. Henriques

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General Characteristics of Short-Range AtoN

A.4. Description

Aids to navigation have many different characteristics. An aid's color, size, light, and sound signify what mariners should do when they see it. Characteristics of short-range aids used in the U.S. are described in the following paragraphs.

A.5. Type

The location and the intended use determine which one of the two types of AtoN will be placed in a spot or waterway:

(01) Floating (buoy).
(02) Fixed (beacon).

A.6. AtoN Identification (Numbers and Letters)

Solid red AtoN buoys and beacons bear even numbers and all solid green AtoN bear odd numbers. No other AtoN are numbered. When proceeding from seaward toward the direction of conventional navigation, the numbers increase. Numbers are kept in approximate sequence on both sides of the channel. Letters may be used to augment numbers when lateral AtoN are added to channels with previously completed numerical sequences. For instance, a buoy added between R"4" and R"6" in a channel would be numbered R"4A". Letters will also increase in alphabetical order.

Not every buoy or beacon is numbered. Preferred channel, safe water marks, isolated danger, special marks, and information/regulatory AtoN use only letters."

A.7. Color

During daylight hours, the color of an AtoN indicates the port or starboard side of a channel, preferred channels, safe water, isolated dangers, and special features. Only red or green buoys, or beacons fitted with red or green dayboards, have lateral significance.

A.8. Shape

Shapes of buoys and beacons help identify them from a distance or at dawn or dusk, when colors may be hard to see. Like other characteristics of AtoN, mariners should not rely solely on shape to identify an aid.

A.8.a. Cylindrical Buoys (Can)

Cylindrical buoys, often referred to as “can buoys,” are unlighted AtoN. When used as a lateral mark, they indicate the left side of a channel or of the preferred channel when returning from seaward. They are painted solid green or have green and red horizontal bands; the topmost band is always green. Can buoys are also used as unlighted special marks and will be colored based on their use (**Figure 2-2**).

A.8.b. Conical Buoys (Nun)

Conical buoys, often referred to as “nun buoys,” are unlighted AtoN. When used as a lateral mark, nun buoys indicate the right side of a channel or of the preferred channel when returning from seaward. They are painted solid red or red and green with horizontal bands and always with a red topmost band. Nun buoys are also used as unlighted special marks and will be colored based on their use (**Figure 2-2**).

CAN BUOY (LEFT) NUN BUOY (RIGHT)

Figure 2-2
Can and Nun Buoys, “When Returning From Sea”

A.8.c. Miscellaneous Buoys

The Coast Guard and other agencies place (station) specialty buoys for operational and developmental uses, and for research purposes. In many instances, the buoy used is a standard buoy modified for specialized use. There are several examples of specialty buoys:

(01) Fast water buoys.
(02) Discrepancy buoys.
(03) Weather/oceanographic buoys.
(04) Mooring buoys.

A.15. Marking Port Side

Green buoys and beacons with square shaped green dayboards mark the port side of a channel when returning from seaward.

A.16. Marking Channel Junction or Bifurcation

Red and green, or green and red, horizontally banded buoys and beacons are called preferred-channel marks. They are used to indicate a channel junction or bifurcation (point where a channel divides or where two tributaries meet). They may also mark wrecks or obstructions and may be passed on either side. When returning from sea, and the topmost band is:

(01) Green: keep the aid to port to follow the preferred channel.

(02) Red: keep the aid to starboard to follow the preferred channel.

A.17. Safe Water Marks

Safe water marks are buoys with alternating red and white vertical stripes, and beacons with red and white vertically striped dayboards (**Figure 2-5**). They also mark a mid-channel, fairway, channel approach points and the "In" and "Out" channels of a "Traffic Separation Scheme." See buoy "N" in **Figure 2-5**. If lighted, they will display a white light with the characteristic Morse Code "A". Safe water buoys (lighted or not) should be fitted with a red sphere as a visually distinctive top mark. Safe water marks are not laterally significant.

Figure 2-5
Safe-Water Mark

A.18. Isolated Danger Marks

Black and red horizontally banded buoys are called "Isolated Danger Marks". They are used to mark isolated dangers (wrecks or obstructions) which have navigable water all around. Isolated danger marks display a white light with a "group-flashing" characteristic; and are fitted with a visually distinctive topmark, consisting of two black spheres, one above the other (**Figure 2-11**).

NOTE ✍ This buoy marking system is not used in the Western River System.

A.19. Special Marks

Yellow buoys and beacons are called "special marks". They mark anchorages, dredging/spoil areas, fishnet areas, and other special areas or features. When lighted, special marks will display a yellow light with a Fixed ("F") or Flashing ("Fl") characteristic. Special marks may also be used to mark the center of the traffic separation scheme.

A.20. Marking Regulated Areas

Information and regulatory buoys and beacons indicate various warnings or regulatory matters. They are colored with white and orange shapes (**Figure 2-11**). They will only display a white light and may display any light rhythm except quick flashing.

A.21. Marking Outside Normal Channels

Beacons with no lateral significance may be used to supplement lateral AtoN outside normal routes and channels. Daymarks for these aids are diamond shaped and will either be red and white, green and white, or black and white (**Figure 2-11**).

Buoys

A.22. Identification Markings

Buoys are floating AtoN anchored at a given position to provide easy identification by mariners. The significance of an unlighted buoy can be determined by its shape. These shapes are only laterally significant when associated with laterally significant colors such as green or red. Buoys are useful AtoN, but should never be relied upon exclusively for navigation.

When a buoy is "watching properly", it is marking its charted position "on Station" and properly displaying all other distinguishing characteristics. Heavy storms, collisions with ships, and severe ice conditions may move a buoy "off Station". Heavy storms may also shift the shoal a buoy marks into the channel. It is important to remember, even heavily anchored buoys fail.

Beacons

A.23. Beacon Types

Beacons are fixed AtoN structures attached directly to the earth's surface. The design, construction, and characteristics of these beacons depend on their location and relationship to other AtoN in the area. Strictly defined, a beacon is any fixed unlighted AtoN (daybeacon) or minor light (lighted) AtoN of relatively low candlepower. The following types of beacons are used in the U.S.:

(01) Daybeacons.
(02) Lighted beacons (minor lights).
(03) Major lights.
(04) Light towers.

Automated Identification System (AIS)

C.2. Automated Identification System (AIS) AtoN

The Automated Identification System (AIS) is an internationally adopted radio communication protocol that enables the autonomous and continuous exchange of navigation safety related messages amongst vessels, lifeboats, aircraft, shore stations, and aids to navigation. AIS equipped aids and stations broadcast their presence, identity (9-digit Marine Mobile Service Identity (MMSI) number), position, and status at least every three minutes or as needed. All three AIS AtoN variants can be received by any existing AIS mobile device, but they would require an external system for their portrayal (i.e., ECDIS, ECS, radar, PC). **Table 2-2** provides amplifying information AIS AtoN electronic charting symbols now in use.

How they are portrayed currently varies by manufacturer, but the future intention is for the portrayal to be in accordance with forthcoming International Standards

There are numerous applications of virtual aids to navigation. They are used not only to mark specific locations like beacons or buoys do, but also to mark lines, areas and other forms. They are not intended to replace physical aids to navigation, but to complement or supplement existing marks to improve the safety of navigation.

C.3. Real and Synthetic AIS AtoN

A 'Real' AIS AtoN Station is a physical aid to navigation fitted with an AIS device.

For practical or economic reasons it may not be appropriate to fit an AIS to an AtoN. In this case, the 'Synthetic' AIS approach may be taken. There are two types of synthetic AIS AtoN, 'Monitored' and 'Predicted'.

(01) A 'Monitored Synthetic AIS AtoN' is transmitted from an AIS Station that is located remotely. The AtoN physically exists and there is a communication link between the AIS Station and the AtoN. The communication between the AtoN and AIS shall confirm the location and status of the AtoN.

(02) A 'Predicted Synthetic AIS AtoN' is transmitted from an AIS Station that is located remotely. The AtoN physically exists but the AtoN is not monitored to confirm its location or status. Predicted Synthetic AIS AtoN should not be used for floating aids to navigation.

C.4. Virtual AIS AtoN

A Virtual AIS AtoN is transmitted from an AIS station to establish an aid to navigation that does not physically exist. In this case, a digital information object will appear on the navigational system for a specified location, even though there is no physical AtoN. A nearby base station or AtoN station could broadcast this message. The AIS message will clearly identify this as a Virtual AIS AtoN.

C.5. AIS AtoN Limitations

A Virtual AtoN will not be visible on the displays of many ships and, if visible, the symbols may differ from one display to another. The consequences may be confusion, lack of information for the user and the undermining confidence in ECDIS, the chart and other systems.

Other limitations include:

(01) GNSS vulnerability,

(02) Susceptibility to spoofing and jamming.

Purpose of Virtual Aid	Definition	Electronic Chart Portrayal	Paper Chart Portrayal
North Cardinal	A virtual object that indicates navigable water lies northwards		
East Cardinal	A virtual object that indicates navigable water lies eastwards		
South Cardinal	A virtual object that indicates navigable water lies southwards		
West Cardinal	A virtual object that indicates navigable water lies westwards		
Port lateral (IALA A)	A virtual object marking the port side of a channel		
Starboard Lateral (IALA A)	A virtual object marking the starboard side of a channel		
Port lateral (IALA B)	A virtual object marking the port side of a channel		
Starboard Lateral (IALA B)	A virtual object marking the starboard side of a channel		
Isolated Danger	A virtual object marking an isolated danger		
Safe Water	A virtual object marking safe water		
Special Purpose	A virtual object used to mark an area or feature referred to in nautical documents		
Emergency Wreck Marking	A virtual object marking a wreck		

Table 2-2
AIS or Virtual Aids to Navigation (AtoN)

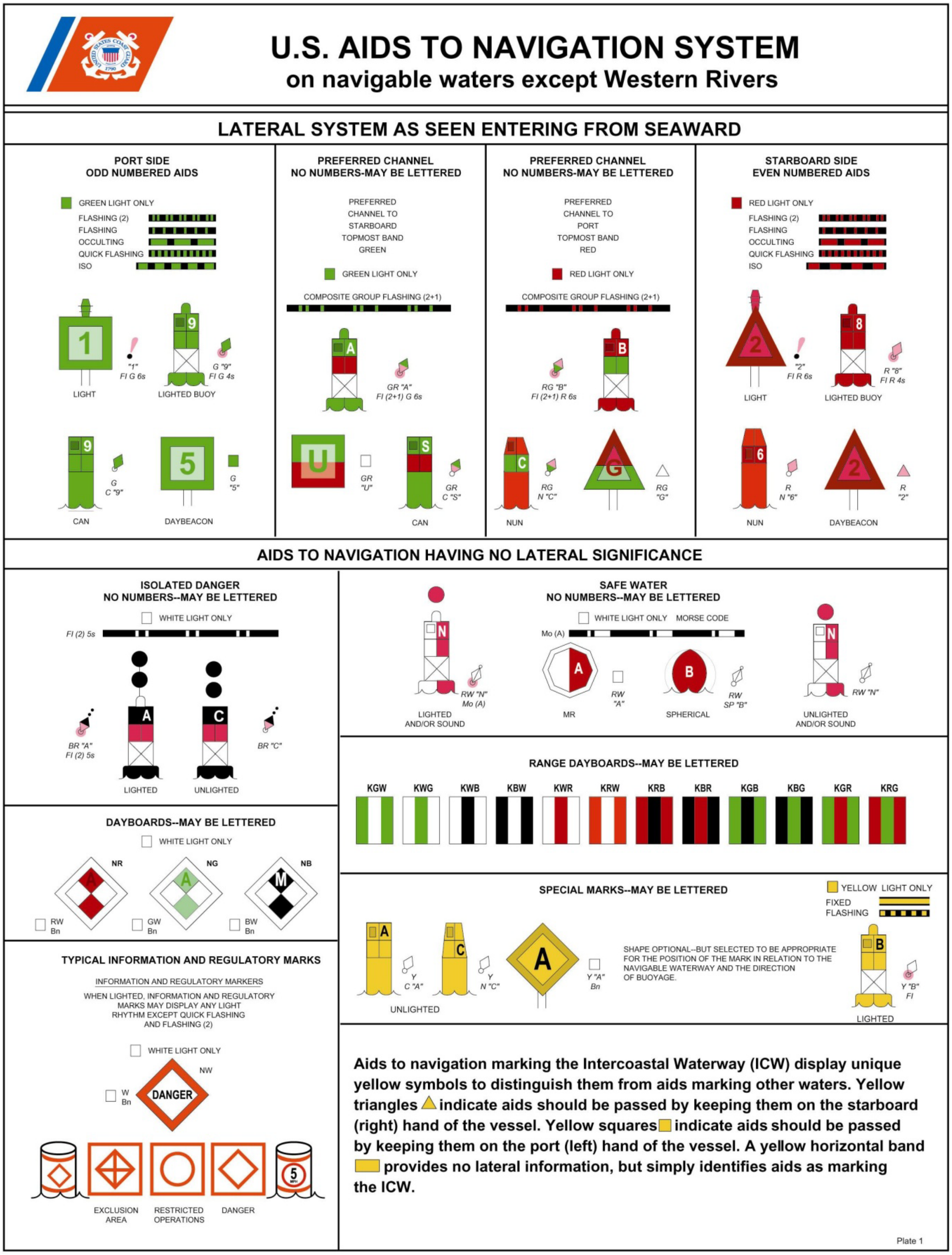


Figure 2-11
U.S. Aids to Navigation System on Navigable Waters, Except the Western River System

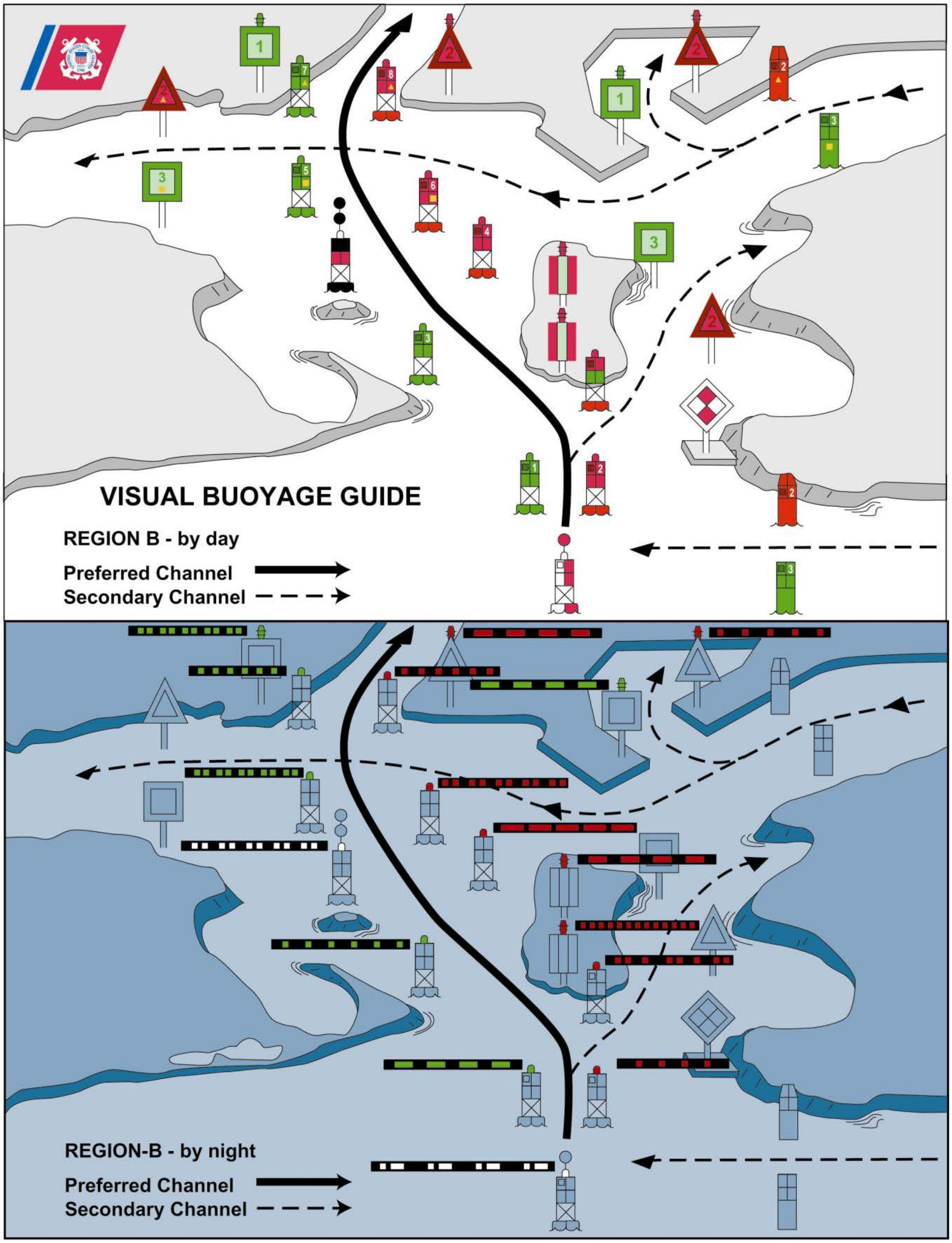


Figure 2-12
Visual Buoyage Guide

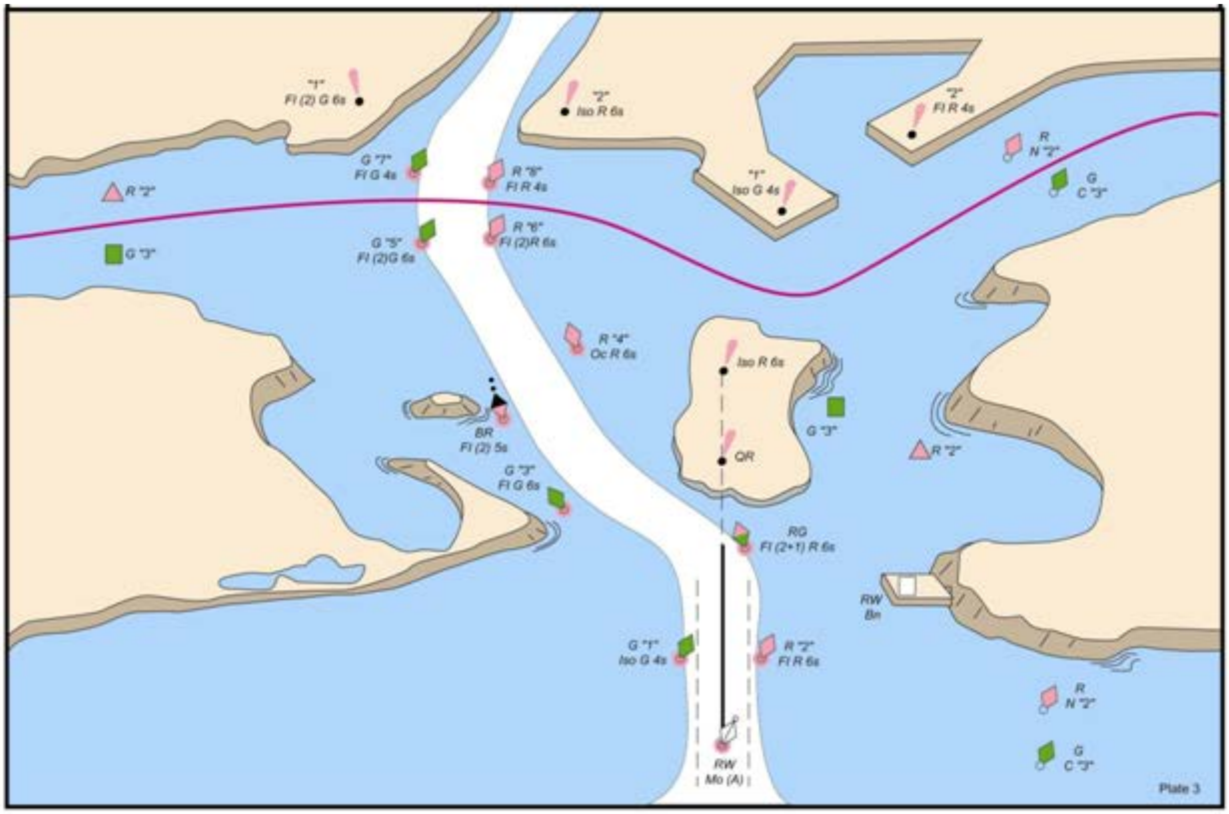


Figure 2-13
How the Visual Guide Would Appear on a Nautical Chart (Example)

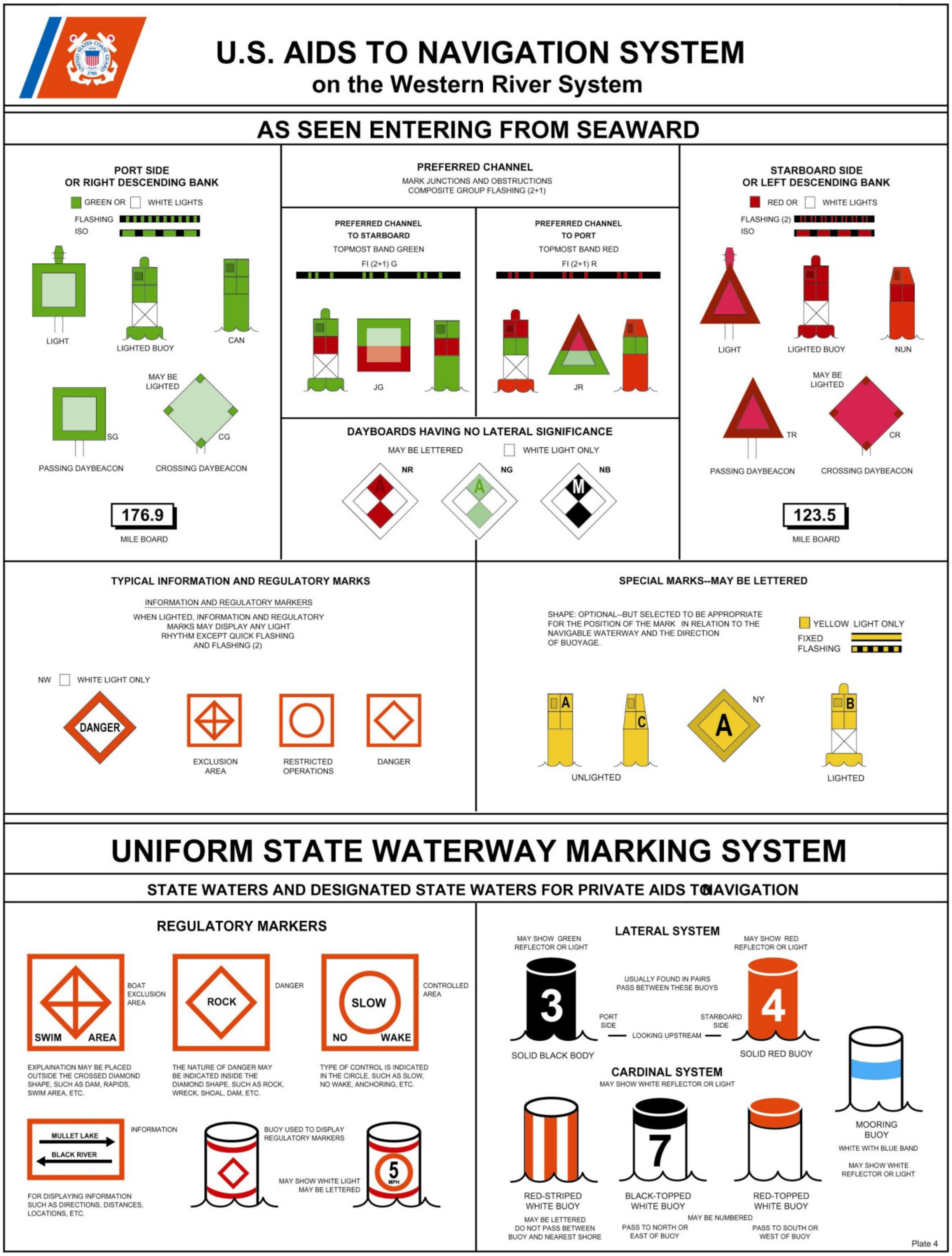


Figure 2-14
U.S. Aids to Navigation System on the Western River System and the Uniform State Waterway Marking System

Electronic Charts

B.7. Electronic Chart Types

There are two general types of electronic chart data: vector and raster. See reference (b) for more detailed information concerning electronic chart data and updates.

(01) **Vector Charts.** These charts include Electronic Navigation Charts (ENC), Inland Electronic Navigation Charts (IENC), and Digital Nautical Charts (DNC). Vector charts consist of points, lines, and area data that represent real world objects. Since each object is separate, it allows for more information than can be displayed for each object to be stored in the chart data, allowing the user to query the chart. It also allows the navigation system to test each object for grounding or height alarms. Based on zoom level and operator preference the charting system can hide or display certain vector chart objects. System constantly display a set of base information, but the user must add other filters and objects to ensure safe navigation. The user can save these filters as part of the Profiles feature to ensure constant display of preferred objects.

(02) **Raster Charts.** Raster charts (RNC) are digital images of paper charts. Each paper chart has a corresponding raster chart that is its digital equivalent. Users cannot query raster chart data for more information or use raster data for alarms. Over-scaling is readily apparent on a raster chart and accuracy is lost.

NOTE ✍

> Commercial proprietary formats (e.g. Vega, C-MAP) present a unique appearance from RNC or ENC charts. Charting symbols vary by system and and zoom will not afford denser data.

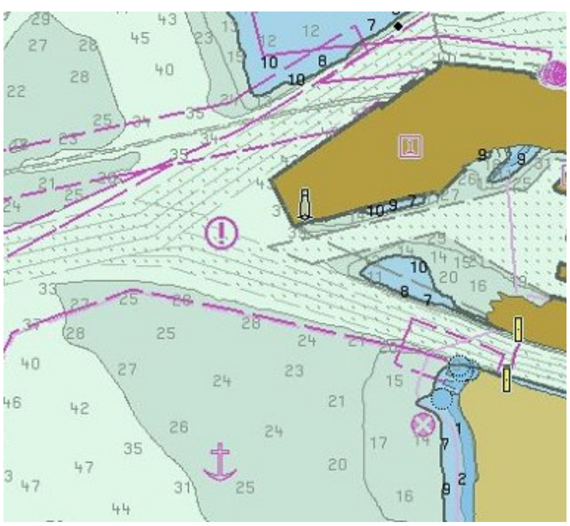


Figure 3-14
Vector Chart (ENC)

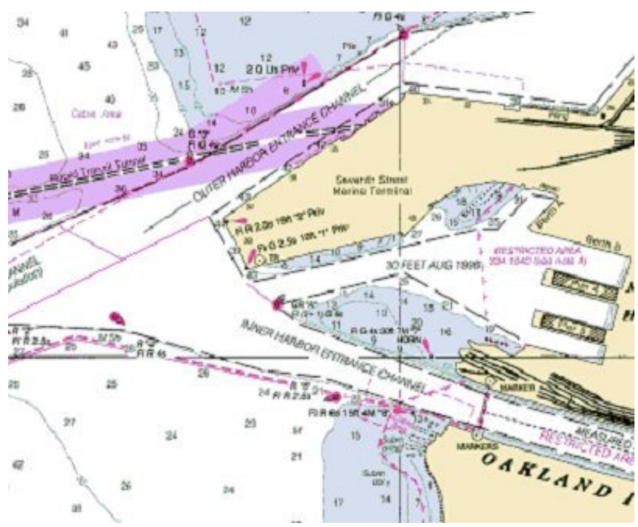


Figure 3-15
Raster Chart (RNC)

B.7.a. AIS or Virtual Aids to Navigation	Addition information on Automated Identification Systems (AIS) is contained in Chapter 2, Section C, Automated Identification System (AIS).

Specific Components

C.3. Multi-Function Displays

Electronic navigation systems are characterized by Multi Function Displays (MFD) that serve to present information from a variety of sources in a graphic format displayed on multiple screens **(Figure 3-16).** Capabilities of these systems vary widely, but all have similar characteristics in that they draw information from a variety of sources. Electronic chart plotters integrate radar and electronic navigational charts into their display **(Figure 3-17)**.

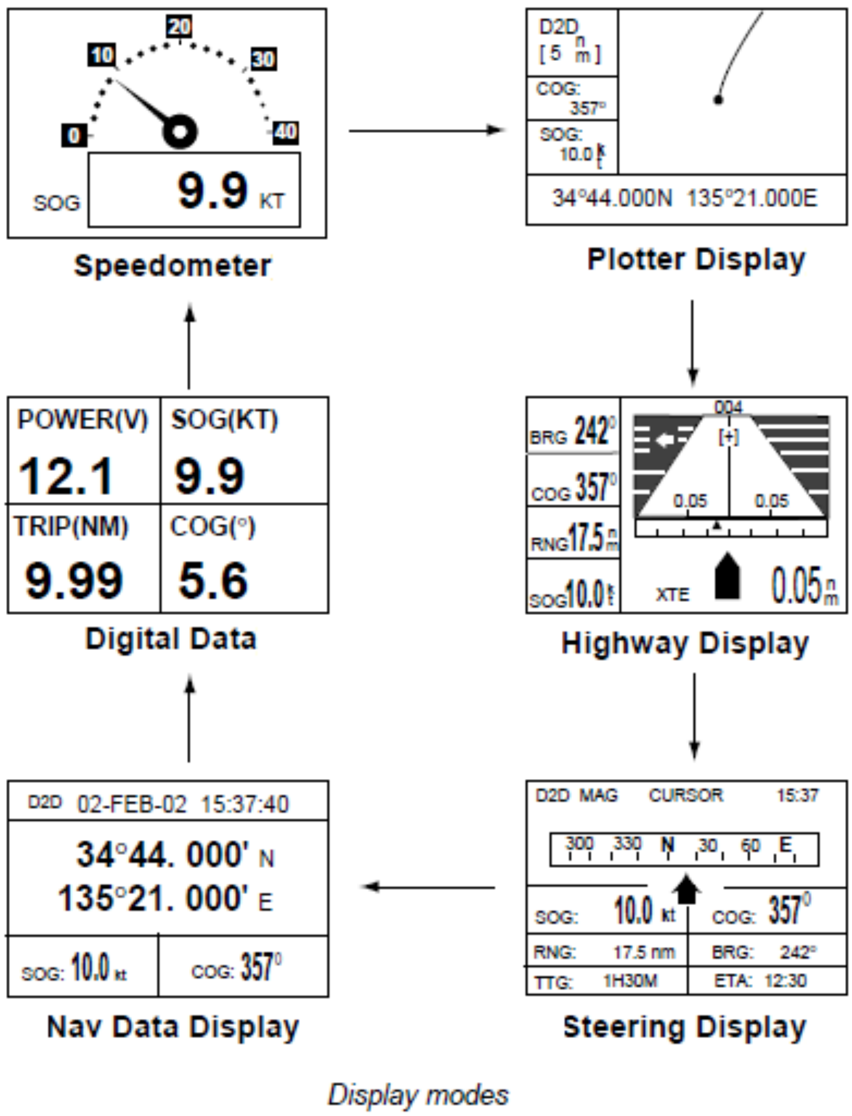


Figure 3-16
Multi-Function Display Screens

Figure 3-17
Multi-Function Display / Electronic Chart Plotter (Example)

C.4. Electronic Chart Plotter

Chart plotters are now a primary maritime navigation tool. In most case, they have all but replaced paper charts. They use electronic charts and are interfaced with GPS to allow for a rapid, reliable plot of the boat's position. Chart plotters allow you to see, from an electronic perspective, where your boat is, where you were (trackline history), and where you are heading. Additionally they can display a wide variety of data that the operator may find useful. The chart plotter becomes particularly useful when strict navigational tolerance is needed such as with low visibility situations or when transiting through hazardous areas. When combined with other electronics and sound navigation practices, safer navigation is possible. Features of these plotter systems include:

(01) Know your current location at a quick glance
(02) View your track history,
(03) Show AtoN(Aids to Navigation), hazards, obstructions, wrecks, etc.,
(04) Show water depth in a given location,
(05) Store waypoints / routes (Including MOB),
(06) Interface with GPS and autopilot for automatic steering,
(07) Determine travel time (ETA),
(08) View tide and current data(if equipped).

C.4.a. Electronic Chart Overlays

The MFD can incorporate a variety of data and display it in the form of overlays on the electronic chart. The availability of these overlays depends on whether the data is loaded onto the MFD or whether the devices that receive the data are active. Typical overlays include radar, satellite imagery, depth shading, tidal and current data, and weather.

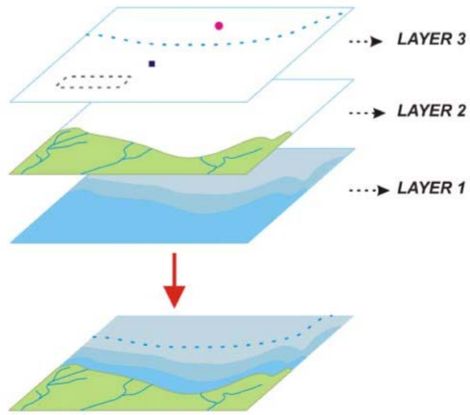


Figure 3-18
Electronic Chart Overlays

C.4.b. Scaling

Electronic chart data is most accurate when displayed at its source scale. Scaling/zooming in or out distorts the visually perceived relative distance between chart objects. In addition, cursor-indicated positions for charted features vary when scaling the chart.

C.4.c. Display Matching

Display matching ensures displayed information is consistently oriented to the viewer, thereby preventing errors in interpretation. When the system displays radar and electronic chart data together in overlay mode, the display must match in scale, orientation, and projection. For example, scaling out the radar to 24 NM when the electronic chart scale is at 3 NM can cause misinterpretations.

C.4.d. Boat Position Symbol

Chart plotters display the boat's position as an icon. The heading line originates at the boat icon and continues to the edge of the screen. The course/speed vector indicator will appear as a separate line.

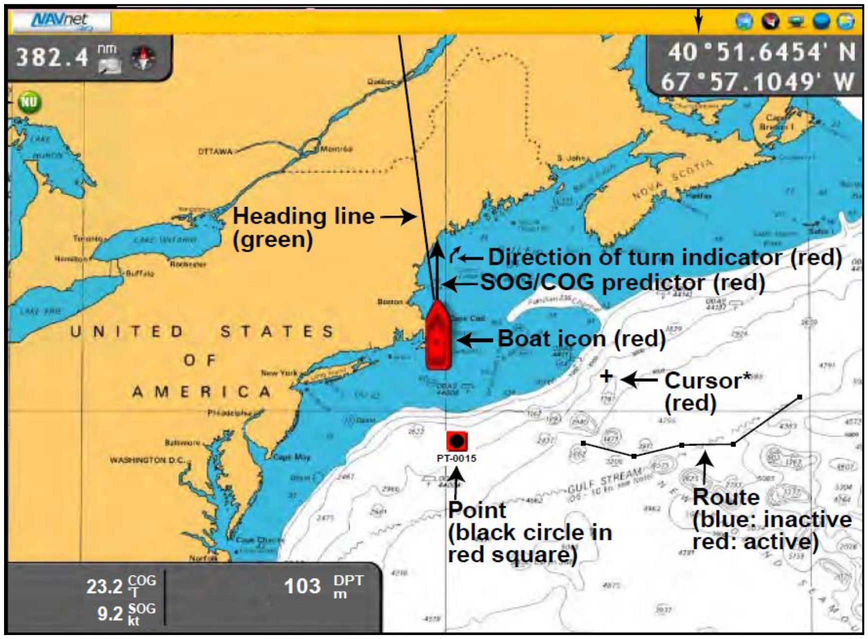


Figure 3-19
Boat Position Symbol

C.4.e. Display Orientation

There are varying displays that can be configured, the crew must understand the differences and understand which display works best for them. Unless directed by your unit or parent command otherwise, there is no "correct" display orientation. These are usually considered personal preference. For example, someone may like north up because of their affinity to a paper chart, while others may like to see their course as it relates to the electronic chart. Take time to learn what your particular model has available and become comfortable with using them.

(01) Course-Up – The course-up mode is preferred for monitoring your progress towards a waypoint. The destination is at the top of the screen when a destination is set. When no destination is set, the course or heading is at the top of the screen at the moment the course up mode is selected. If there is an auto-course feature, it will automatically adjust the screen to keep the course up pointing at the top of the screen. The adjustment is based on an arbitrary number of degrees and once exceeded it will rotate the screen to keep the course at the top of the screen. Some operators find this distracting when making large course changes as the screen tends to "change" a lot for some operators.

(02) North-Up – North (000°) is always oriented at the top of the display screen. This mode is useful for navigation planning and when the boat is stationary. It can be helpful when executing a search pattern and determining course changes in relation to next turn and course. It is also beneficial when the operator is used to operating with a paper chart that is normally oriented with North at the top.

C.4.f .Tracks

In comparison to a route, a track is the path along which the boat travels and is plotted on the chart plotter with position data. The track function records where the boat has been and displays the path as a line on the electronic chart. Tracks can be shown if the information is helpful or necessary and can also be hidden if the data is no longer needed or clutters the chart.

C.4.g. Common Functions

While all systems are different, you should refer to your specific operator's manual for specific guidelines for operation, however, many share the same characteristics as follows:

(01) Power / Brilliance – In general this button controls the power to the unit, either turning the plotter on and off or allowing the user to adjust the brilliance (how bright the display is).

(02) Range In/Out – The range is the distance that will be displayed on the screen. Common ranges for boat systems are from .125 NM to 24 NM or 48 NM. The area of operation will determine the best range to use. For example, if operating offshore the user may want to have the range set to 12 NM but when entering a harbor, a scale of 1.5 NM might be more appropriate. A smaller range usually includes more detail such as hazards, depths and AtoN.

(03) Center/Home – This brings the boat to the center of the screen.

(04) Offset –Allows for the boat icon to be moved from the center of the screen and placed at a specific location so other more relevant information can be shown. This may be advantageous when operating at higher speeds.

C.4.h. Navigation Data

Steering displays like the one below can be used to show navigational data when transiting to a waypoint. This tool displays information such as cross track error, heading, course over ground (COG), estimated time of arrival (ETA), and more.

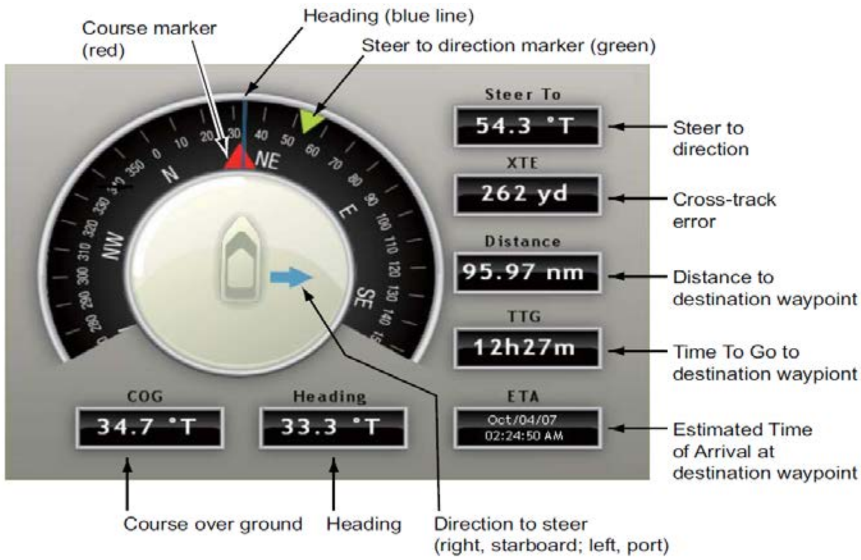


Figure 3-20
Navigation Data

C.4.i. Data Boxes

When a route is active, navigation data boxes are displayed on the screen. These can be fully customized to display information such as distance-to-waypoint, course-to-steer, time-to-go, and cross track error.

C.4.j. Tidal Data

Many electronic chart plotters are equipped with tide and current information that can be accessed through menu options.

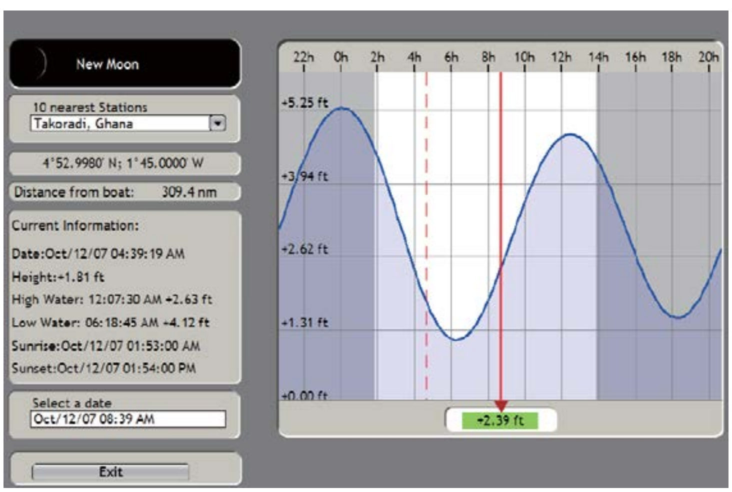


Figure 3-21
Tidal Data

C.5. Heading Sensor/Fluxgate Compass

Heading is the direction in which the vessel is pointing at any given moment. Electronic heading sensors have largely replaced the magnetic compass as the primary means of determining a vessel's heading, with the magnetic compass normally serving only as an emergency backup. An electronic heading sensor is installed on most modern boats and is normally mounted low on the centerline. The sensor detects terrestrial magnetism and produces heading data, which is utilized by electronic navigation system components that need accurate and stable heading input such as an electronic charting system and radar.

Heading accuracy of these sensors is typically ±1°. Heading data is shown in three figure notation (ie. 000°) and can be adjusted to display as either True or Magnetic, depending on user preference and standard operating procedures.

Though used by larger vessels, the gyrocompass will not be discussed since it is not commonly used by boats.

C.6. Global Positioning System (GPS)

The Global Position System (GPS) is a radionavigation system of 24 satellites operated by the DoD. It is available 24 hours per day, worldwide, in all weather conditions. Each GPS satellite transmits its precise location, meaning position and elevation. In a process called "ranging," a GPS receiver on the boat uses the signal to determine the distance between it and the satellite. Once the receiver has computed the range for at least four satellites, it processes a three-dimensional position that is accurate to about 33 meters. GPS provides **two levels of service - SPS for civilian users, and PPS for military users.**

Figure 3-22
GPS Screen

C.6.a. Selective Availability

GPS signals accessible to the general population have historically been deliberately degraded by the US government as it sought to retain the advantage of a more accurate signal. Termed selective availability, this intentional error ensured accuracy was no better than 100 meters 95% of the time. This system has been switched off, but may be reintroduced by the U.S. government without warning and at any time.

C.6.b. Differential Global Positioning System (DGPS)

DGPS employs a local fixed reference receiver to correct errors in standard GPS signals. These corrections are then broadcast from the reference receiver to any DGPS capable receiver. The corrections are applied within the user's receiver, providing mariners with a position that is accurate to within 3 meters, with 99.7% probability.

To receive DGPS signals the GPS receiver must be coupled with a DGPS receiver and be within range of a fixed reference station, normally 200 miles. DGPS was becoming common with general users until selective availability was turned off and GPS signals returned to their inherent 15 meter accuracy.

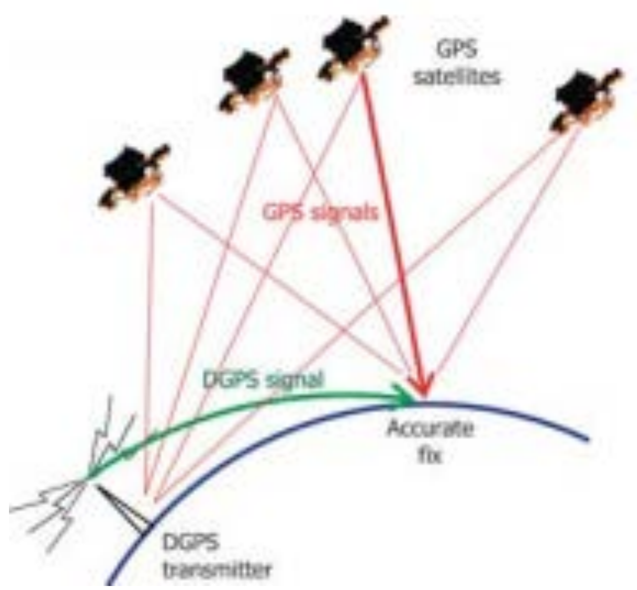


Figure 3-23
Differential Global Positioning System (DGPS)

C.6.c. Wide Area Augmentation System (WAAS)

Wide Area Augmentation Service (WAAS) uses a network of ground stations to monitor accuracy of GPS positions. Error corrections are reported to two master stations which relay the data to the network of satellites for further distribution to all WAAS enabled GPS receivers. This process reduces the 95% error to an accuracy of approximately 3 meter.

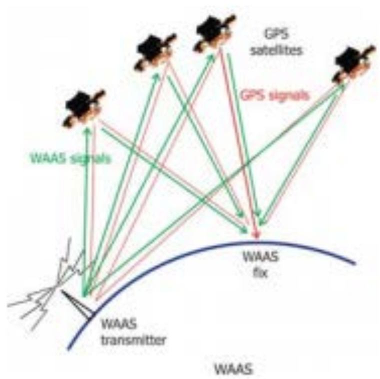


Figure 3-24
Wide Area Augmentation System (WAAS)

C.6.d. Equipment Features

GPS receivers are small, have small antennas, and need little electrical power. Hand-held units are available. Positional information is shown on a liquid crystal display (LCD) screen as geographical coordinates (latitude and longitude readings). These receivers are designed to be interfaced with other devices such as autopilots, EPIRBs and other distress alerting devices, to automatically provide positional information.

Navigational features available in the typical GPS receiver include:

(01) Entry of waypoints and routes in advance.
(02) Display of course and speed made good.
(03) Display of cross-track error.
(04) Availability of highly accurate time information.

NOTE

Over-reliance on eNav systems can cause tunnel vision or ignorance of fundamental signs of danger. To prevent this, it is critical to understand system functions and use foundational navigation skills to properly prepare these systems and detect errors.

C.6.e. Signal Strength & Accuracy

The state of reception of GPS depends upon the strength of GPS signals. The greater the signal strength, the more stable the reception status is. State of reception depends upon the number of satellites tracked for positioning. If the number of the tracked satellites is great, GPS positioning becomes greater, but if there are fewer satellites tracked for positioning, it become difficult to generate a GPS position.

Determining GPS satellite signal strength at specific intervals is critical to ensuring displayed positioning data is accurate for navigation. (e.g. before getting underway and entering restricted waters, daily, etc). All navigation systems with GPS capability have a means for determining signal strength within their internal software (**Figure 3-25**). Consult the equipment's manufacturer guidelines to determine how to access and review signal strength data.

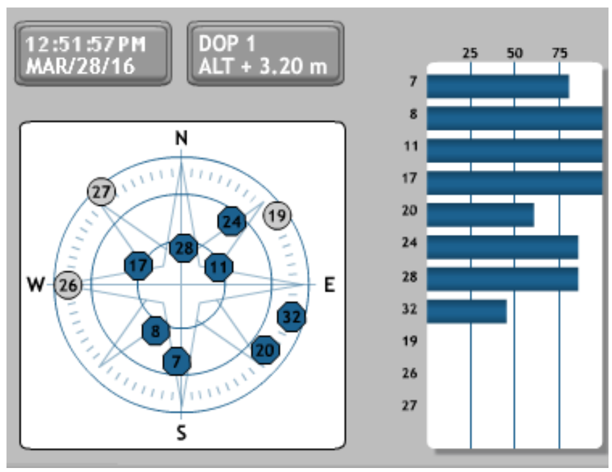


Figure 3-25
GPS Signal Strength

When accessing signal strength data, GPS units generally provide the below information:

(01) DOP (Dilution of Precision) describes the geometric strength of satellite configuration on GPS accuracy. When visible satellites are close together in the sky, the geometry is weak and the DOP value is high, when the satellites are far away from one another, the geometry is strong and the DOP value is low.

(02) ALT is the height of your GPS antenna above the surface of the water.

(03) Estimated position of each GPS satellite.

(04) Satellites used to find position.

(05) Satellites not used to find position.

(06) The strength of the RX signal from each satellite is shown with a bar. If the signal level of a satellite is high, that satellite's signal was used to find your position.

C.6.f. Read Latitude and Longitude

GPS units present latitude (Lat) and longitude (Long) readings in three ways:

(01) Degrees, minutes, seconds: 40° 26′ 46″ N, 79° 58′ 56″ W,

(02) Degrees, minutes, tenths of minutes: 40° 26.767′ N, 79° 58.933′ W,

(03) Decimal degrees: 40.446° N 79.982° W.

C.6.g. Course Over Ground (COG)

Course over ground/course made good (COG/CMG), is direction of movement from one point to another with regard to wind and current.

C.6.h. Speed Over Ground (SOG)

Speed over ground (SOG), or Speed Made Good, is the speed of travel of a boat along the track, expressed in knots.

C.7. Radar

Radar uses radio waves to identify the location, course, and speed of objects. The center of the radar screen represents the position of the boat. When used properly, the radar enables you to identify land masses and other vessels, determine the distance from your vessel to contacts (range), and determine direction from your vessel to contacts, even in restricted visibility (bearing).

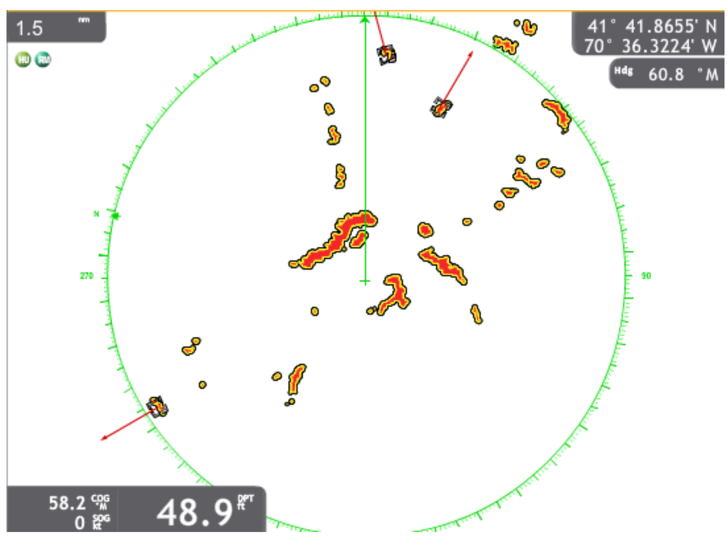


Figure 3-26
Radar

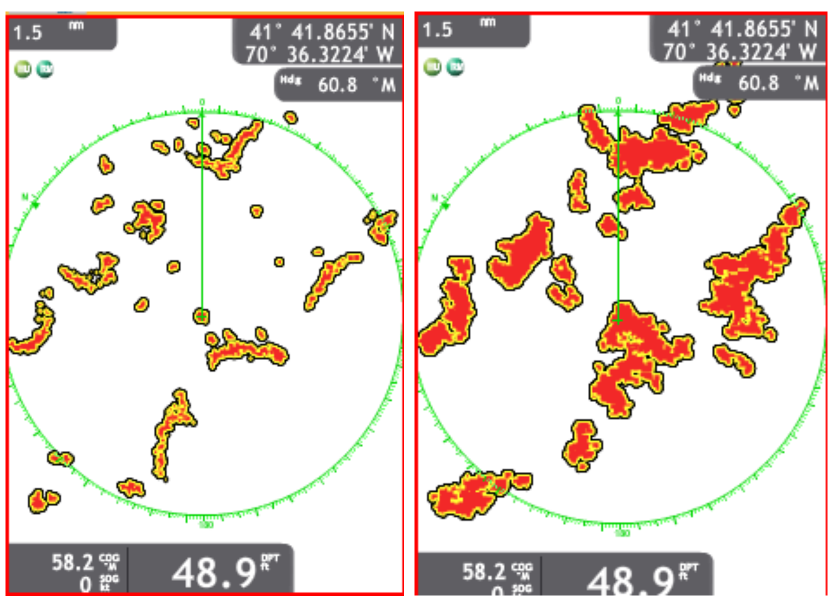
A radar’s pedestal transmits pulses of radio waves, then receives those wave that bounce off objects. The returns are processed and contacts are displayed on the radar screen in intensities according to echo strength. Images on a radar screen differ from what is seen visually by the naked eye. This is because some contacts reflect radio waves (radar beams) better than others Familiarity with the operating area helps to identify images that are displayed. The radar does not paint a detailed picture of an object. Instead, all objects displayed on the radar screen as indistinct masses of color. Knowing the location of land masses and man-made structures-such as bridges, docks, and navigational aids-helps differentiate those objects from other vessels on the radar.

C.7.a. Standby/ Transmit

Often combined with the on/off button, the standby/transit control switches the radar between a standby mode in which it is ready for use and transmit mode in which it is fully operational.

C.7.b. Gain

Gain on the radar is how well a contact or target appears. By increasing gain, the amount of echo returned is increased and the contact is seen much easier. If you adjust the gain too high however, excessive background noise can hide contacts from view. Conversely, the less gain, the less likely the contact will be seen. If you adjust the gain too low, objects with weak echos do not display on the screen, increasing the risk of collision. The gain is set correctly when some background noise displays on the screen.



Low Gain High Gain

Figure 3-27
Gain

C.7.c. Display Mode

(01) **Head Up:** Available with no compass input as the heading mark points straight upwards. It has the advantage of displaying a target on the port side of the boat as a contact on the left side of the screen while those on the starboard side of the boat appear on the right hand side. The disadvantage is that, as the boat yaws, the picture yaws in response, causing the objects on the screen to move.

C.7.k. Echo Trails

Echo trails are images on the radar that show the previous positions of radar contacts over a present period of time. Echo trails show the movements of radar contacts and help alert to possible collisions. The disadvantage of using echo trails is that over a period of time, returns from land can paint a band across the screen that may obscure weak contacts.

Echo trails display on the radar for a specific amount of time, then the trails are erased and restarted. Echo trail time can be set from seconds to continuous. The longer the echo trail time, the longer the trail that displays on the screen.

C.7.l. Heading Mark

The straight line outstretched from the center of the screen indicates the direction the boat is pointing.

C.7.m. Fixed Range Rings

Range rings are used to estimate the distance from the boat to a contact. Range rings display as concentric solid circles emanating out from the center of the screen. The number of rings is automatically determined by the selected range scale. The distance between range rings (interval) is displayed on the screen.

Major range scales are indicated in miles and are then subdivided into range rings. Typical range scales for a boat radar are ½, 1, 2, 4, 8, and 16 NM. Typical number of range rings for a particular range scale are shown as follows:

Scale/Miles	Rings	NM Per Ring
½	1	½
1	2	½
2	4	½
4	4	1
8	4	2
16	4	4

To measure the range to a target using range rings:

Step	Procedure
1	Count the number of rings between the center of the display and the contact.
2	Multiply the number of rings by the range ring interval.
3	Estimate the distance from the contact to the nearest inner ring, and add that number to the range ring distances.

C.7.n. Variable Range Marker (VRM)

Variable Range Markers (VRM) measure the distance from the boat to a contact. The VRM displays as a ring around the boat on the radar. Data for the selected VRM is displayed on the screen. Adjusting the size of the ring until it touches the contact will give the distance to the target.

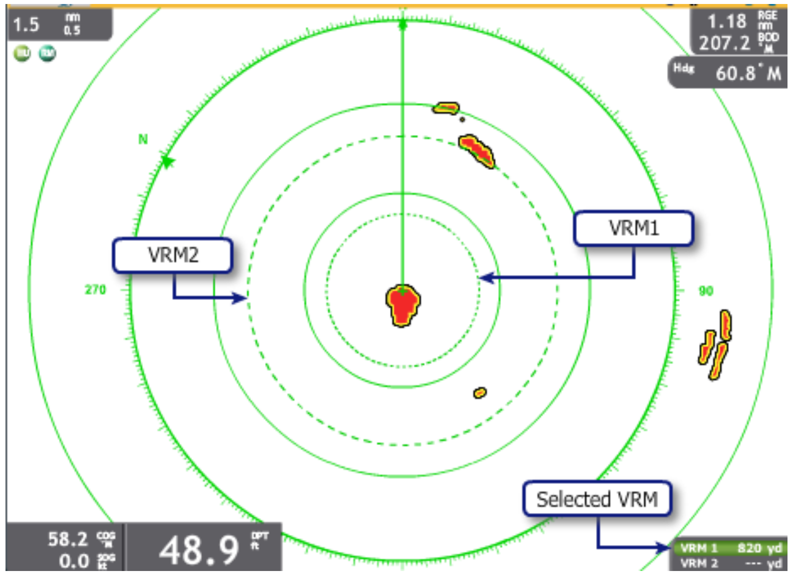


Figure 3-28
Variable Range Marker (VRM)

C.7.o. Electronic Bearing Lines

Electronic Bearing Lines (EBL) measure the bearing from the boat to a contact. Radar bearings can be measured in true, magnetic, or relative direction. To obtain a target bearings, the EBL is adjusted until the line crosses the target.

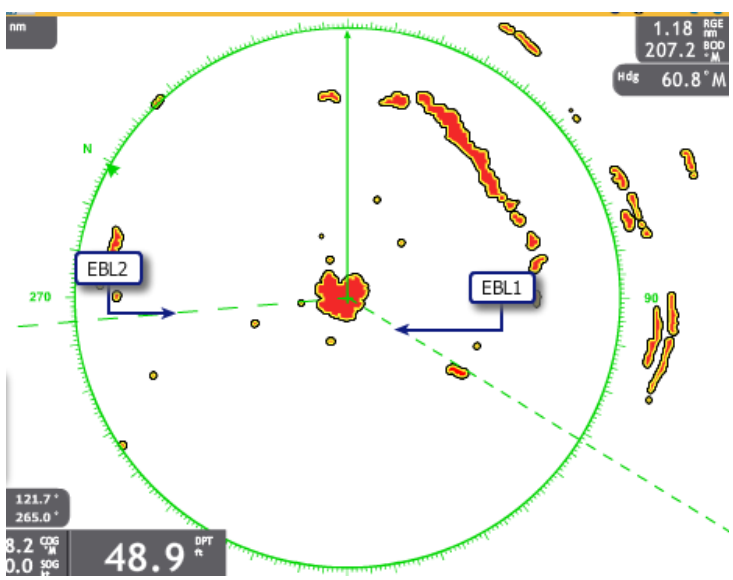


Figure 3-29
Electronic Bearing Line

C.7.p. Automatic Radar Plotting Aid (ARPA)

The Automatic Radar Plotting Aid (ARPA) is a feature that allows you to track the movement of up to 30 radar contacts. ARPA also provides information about each tracked contact, such as Course Over Ground (COG), speed, range, bearing, and Closest Point of Approach (CPA). Targets can be acquired manually, or an ARPA acquisition area can be established so any contact that enters the area is automatically acquired and tracked.

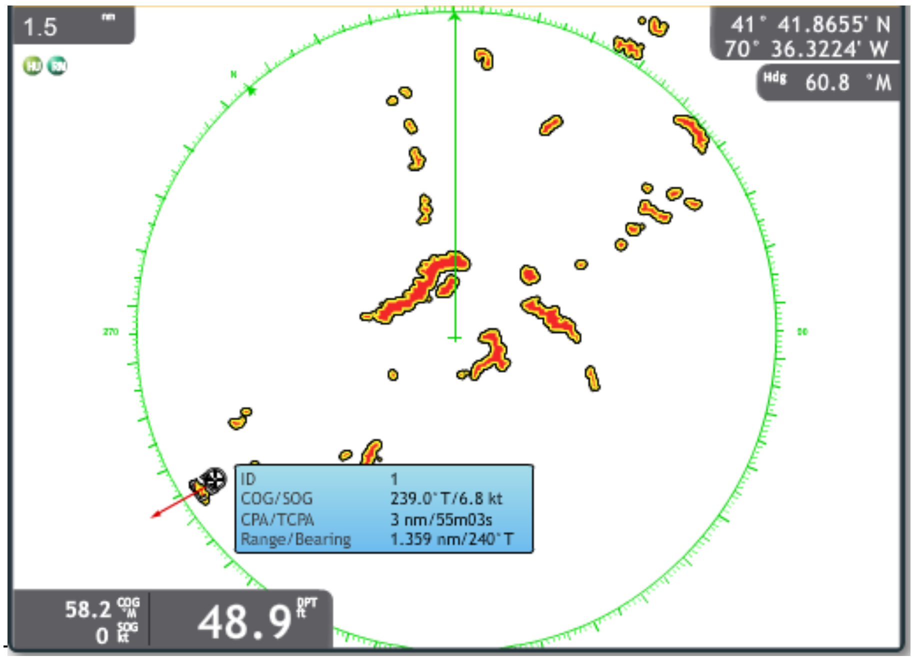


Figure 3-30
Automatic Radar Plotting Aid (ARPA)

C.7.q. Collision Avoidance

Your own vessel is always at the center of the radar screen, unless the user inputs an offset. If you are moving toward a stationary object, such as a day beacon, the radar picture will give the impression that you are stationary and the day beacon is moving toward you. This is known as relative motion as the radar shows the day beacon is changing position relative to your own vessel rather than its fixed position on the surface of the Earth. When considered with a moving object the relative motion depends on the movement of both your vessel and the tracked object. The movement of a contact across a radar screen is seldom an accurate representation of the target's movement across the Earth.

C.7.r. Assessing Risk

Constant bearing associated with a risk of collision can be determined by using the EBL. If the contact is another vessel and appears to slide straight along the EBL the implication is that it is on a constant bearing and there is a risk of collision. Unless someone takes action to change the situation the contact will continue along the EBL until it reaches the center of the screen, the position occupied by your boat.

C.8. Depth Sounder

There are several types of depth sounders, but they operate on the same principle. The depth sounder is the most accurate way to determine the depth of water. The depth sounder transmits a high frequency sound wave that reflects off the bottom and returns to the receiver. The “echo” is converted to an electrical impulse and can be read on a depth sounder display. It shows only the depth of water the vessel is in. Depth sounders can be set to fathoms (one fathom = 6 feet), feet, or meters. Ideally the units displayed should be the same as those of the chart being used.

C.8.a. Transducer

The transducer is the part of the depth sounder that transmits the sound wave. It is usually mounted permanently in the bottom or under the transom on the centreline. Transducers, if installed, are not always located at the lowest point of a boat. The distance from the transducer to the lowest point of the hull must be known. This distance must be subtracted from the depth sounding reading to determine the actual depth of water available.

Example: Depth sounder reading is 6 feet. The transducer is 1 foot above the lowest point of the hull - the boat extends 1 foot below the transducer. This 1 foot is subtracted from the reading of 6 feet, which means the boat has 5 feet of water beneath it.

C.8.b. Offset

Offset is a function available in most depth sounders. Its purpose is to compensate for the display of available depth from the sensor location on the hull to the actual lowest point of the vessel (**Figure 3-32**). When the offset value is reading correctly, zero ft beneath the keel means the lowest part of the vessel is touching the bottom, even though the actual transducer location may be several feet from the bottom.

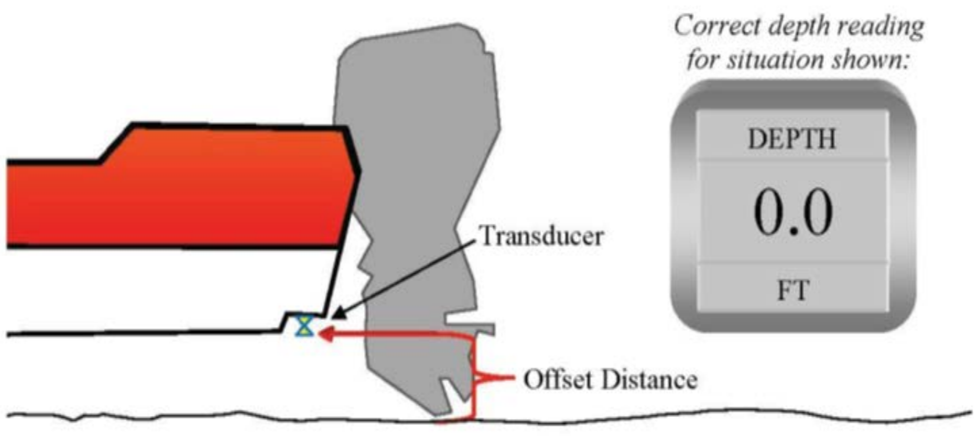


Figure 3-31
Offset

C.8.c. Depth Sounder / Transducer in Aerated Waters

The accuracy of even the best transducers can be severely impacted, or rendered completely useless, in aerated water. This is likely to occur when operating in heavy seas, high speeds, during turns, backing down, or when station keeping on waterjet powered boats. In these conditions the depth sounder should not be relied upon for accurate readings.

When operating at high speeds, it is unlikely that a coxswain will be able to react to avoid grounding if relying solely on the depth sounder to determine depth of water. When in doubt slow down to improve the quality of water flow past the transducer and allow more time to react to a change in depth.

Coxswain should always take advantage of other means to verify water depth, such as charts or chart plotter.

C.8.d. Alarms

Depth sounders are equipped with audible and visual alarms triggered at a specified depth of water. How close to bottom should a vessel get before an alarm sounds? The answer is based on the amount of reaction gap needed to address and respond to the situation. Establishing a navigational draft, meaning a depth of water that serves as the threshold for operations, is a prudent step to ensure timely warning and response prior to a portion of the boat making contact with the bottom. In determining an appropriate navigational draft the following conditions should be considered:

(01) Too small of a value results in an alarm that sounds when the vessel is already in peril, or does not allow for reaction to avoid peril.

(02) Too large of a value results in over-alarms, becomes a nuisance, and erodes confidence in alarm value by surpassing your alarm threshold.

Ideally a specified navigational draft will be the total vessel draft (including appendages in displacement mode) plus a safety margin. Factoring negative height of tide may also be needed in some situation. **Figure 3-32** indicates the concept in greater detail.

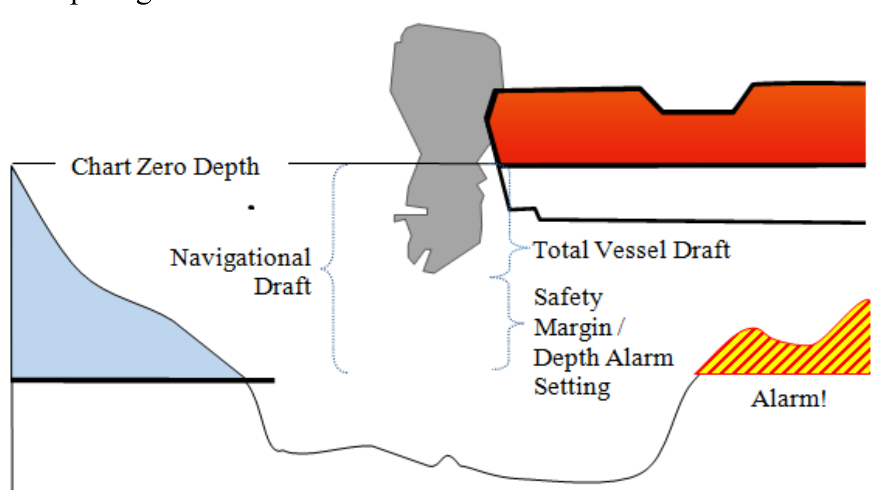


Figure 3-32
Navigational Draft

C.9. Automatic Identification System (AIS)

The Automatic Identification System (AIS) provides timely vessel identification and collision avoidance information to vessels within Very High Frequency (VHF) range. AIS transmits and receives detailed static, dynamic, voyage related, and safety information. AIS integrated into radar or an electronic chart display includes a symbol at the position of every significant ship transmitting AIS within radio range, along with an associated velocity vector indicating the boat's speed and heading and maneuvering information including closest point of approach (CPA) and time to closest point of approach (TCPA).

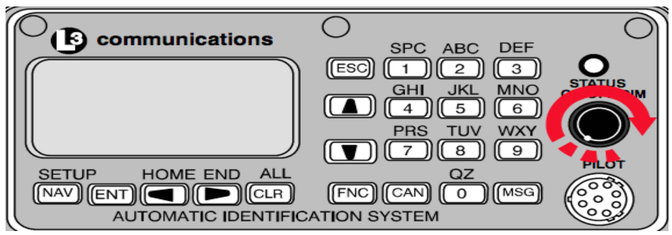


Figure 3-33
AIS Receiver

C.9.a. Maritime Mobile Service Identities (MMSIs)

Maritime Mobile Service Identities (MMSIs) are nine digit numbers used by AIS and other integrated navigation and communication equipment to uniquely identify a vessel, coast radio station, or aid to navigation. MMSI greatly aids efforts to communicate with other vessels by allowing boat crews to immediately identify a vessel by name and hail them directly via VHF-FM or DSC enabled radio instead of a typical radio call out to the "ship off my starboard bow" or other broad non-specific means.

C.9.b. Operating Modes

CLASS-A is the standard mode, which complies with the internationally accepted mode of operation.

TX Disabled is a receiving only mode. It allows users in this mode the ability to view others but not allows other vessels to view operators using TX Disabled.

Secure TX is primary mode of operation for most government boats. It allows users to view vessels operating within Class-A mode, but does not allow those vessels to view Secure TX vessels. Vessels using this mode can view others using the same mode.

E.2. Plotting Symbols on a Paper Chart

The plotter should clearly mark an electronic fix with a triangle or a visual fix with a circle. The time of each fix should be clearly labelled. A visual running fix should be circled, marked "R Fix" and labelled with the time of the second LOP. Maintain the chart neat and uncluttered when labelling fixes.

See **Figure 3-49** for examples of the plotting symbols on a paper chart.

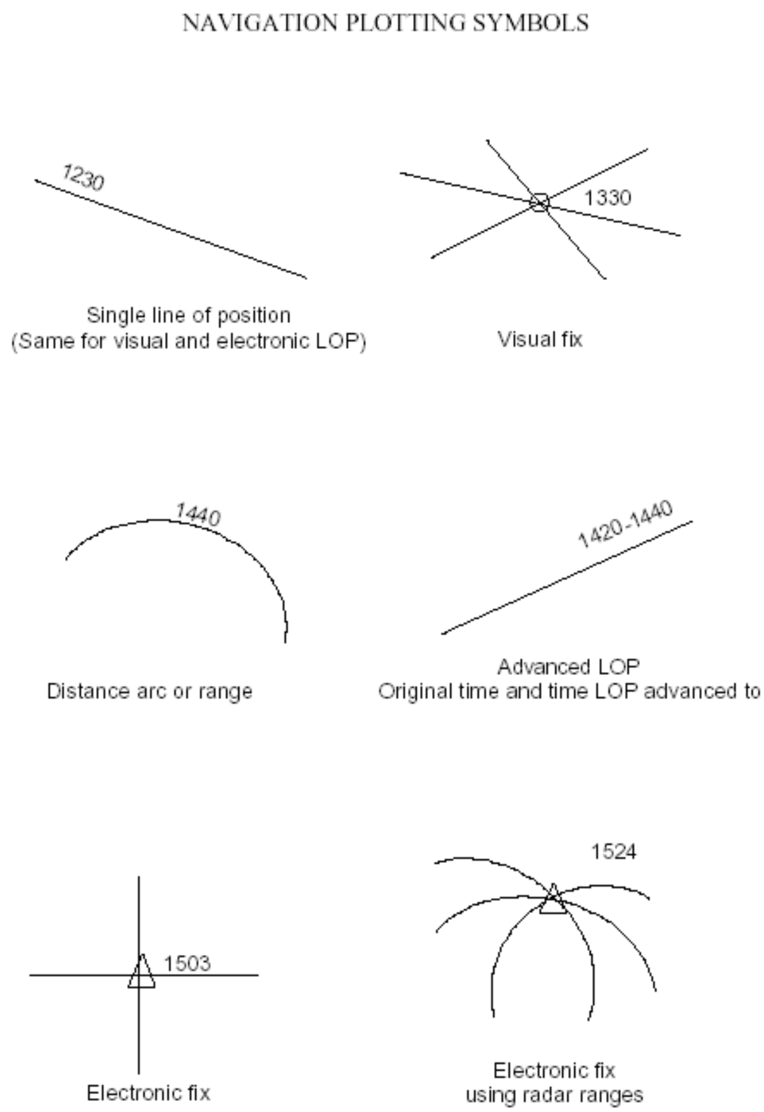


Figure 3-49
Plotting Symbols

Tools

E.3. Paper Chart Plotting Tools

In order for a crew to make good use of a paper chart, tools such as compasses, dividers, parallel rulers, and papers must be available.

E.3.a. Pencils

It is important to use a correct type of pencil for plotting. A medium or mechanical pencil (No. 2) is best. Pencils should be kept sharp; a dull pencil can cause considerable error in plotting a course due to the width of the lead.

E.3.b. Dividers

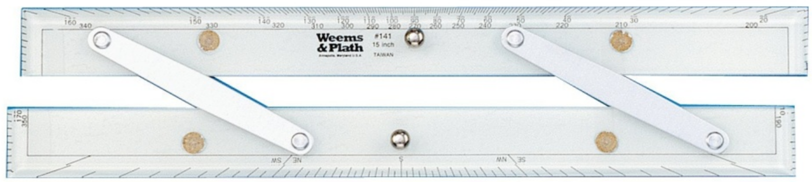
Dividers are instruments with two pointed legs, hinged where the upper ends join. Dividers are used to measure distance on a scale and transfer them to a chart.

E.3.c. Drafting Compass

The drafting compass is an instrument similar to the dividers. One leg has a pencil attached. This tool is used for swinging arcs and circles.

E.3.d. Parallel Rulers

Parallel rulers are two rulers connected by arms that allow the rulers to separate while remaining parallel. They are used in chart work to transfer directions from a compass rose to various plotted courses and bearing lines and vice versa. Parallel rulers are always walked so that the top or lower edge intersects the compass rose center to obtain accurate courses.



E.3.e. Course Plotter

A course plotter may be used for chart work in place of the parallel rulers discussed above. It is a rectangular piece of clear plastic with a set of lines parallel to the long edges and semi-circular scales. The center of the scales is at or near the center of one of the longer sides and has a small circle or bull’s eye. The bull’s eye is used to line up on a meridian so that the direction (course or bearing) can be plotted or read off of the scale. A popular model is the “Weems Plotter” that is mounted on a roller for ease of moving.

E.4. Finding Latitude of a Position

The drafting compass is an instrument similar to the dividers. One leg has a pencil attached. This tool is used for swinging arcs and circles.

To find the latitude coordinate of a position, use a drafting compass or navigators' dividers, and the scale markings on the side of the nautical chart. Follow these instructions in **Figure 3-50** to determine the latitude of a randomly chosen position marked point A. Notice position A is above the solid black horizontal latitude line.

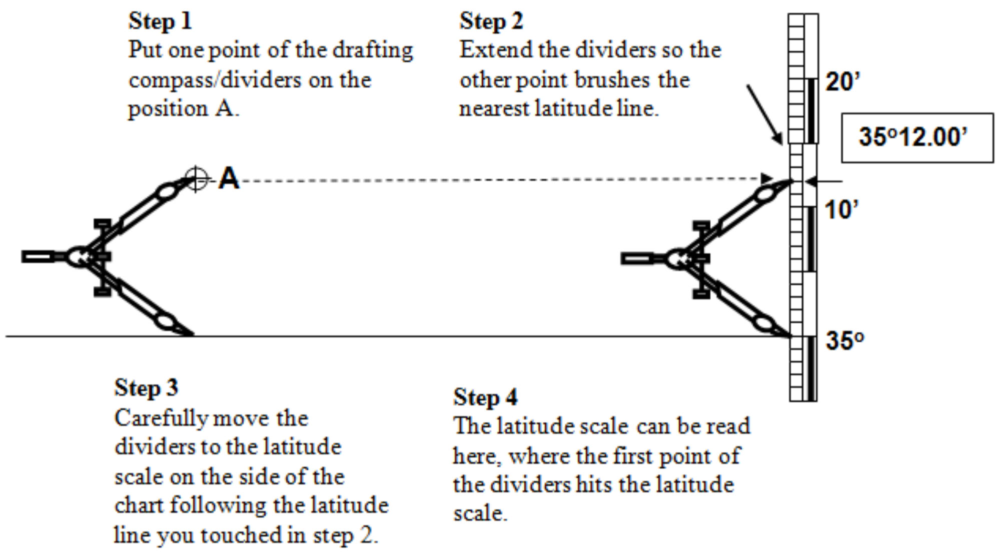


Figure 3-50
Finding Latitude of a Position

Notice that latitude is recorded with the degrees number 35 with the degrees (o) symbol, and the minutes of latitude number 12.0 is written with the minutes (') symbol. In this example, the 12.0 has a decimal point followed by 0. This shows that this scale is in tenths of a minute. But when there is no tenths of a minute zero is recorded. If there is no tenths or hundredths of a minute fill in this space with zeros.

The above final position above would read: 35° 12.00' N

E.8.d. Measuring Distance Using Latitude

Latitude is measured between the horizontal lines along a meridian; the length of 1 minute of latitude is the same as 1 nautical mile or 2,000 yards anywhere on the latitude scale.

Care should be taken to measure the distance using the latitude scale in the same general area you are working in on the nautical chart, especially when using sailing charts (small scale covering a large area). The measurement of 1 degree of latitude is not the same on the northern corner of the small scale chart as it is in the southern corner.

Remember, the chart is a flat surface depicting a round surface, so measurements will not be quite exact.

E.8.d.1. Measuring Distance Using Latitude Examples

1° of latitude is equal to 60 nautical miles. Look at 0° at the equator in the (**Figure 3-54**) below.

(01) **Example 1:** If you travelled from 0° at the equator to 1° north or south latitude, you would have gone 60 nautical miles. 1° x 60 = 60 NM.

(02) **Example 2:** If you travelled from 0° at the equator to 20° north or south latitude, you would have travelled 1,200 nautical miles. 20° x 60 = 1,200 NM.

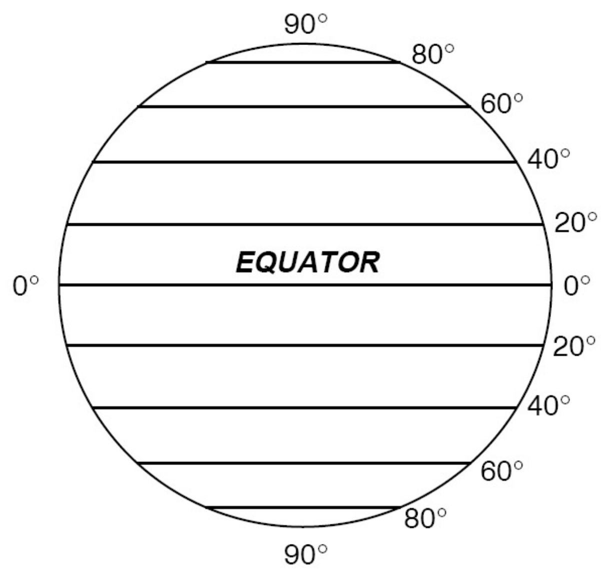


Figure 3-54
Measuring Distance Using Latitude Example

E.8.d.2. Measuring Distance Using the Latitude Scale

Step	Action
1	Place one end of a pair of dividers at each end of the distance to be measured being careful not to change the span of the dividers.
2	Transfer them to the latitude scale closest to the latitude being measured. Read the distance in minutes then convert to NM or yards.

Figure 3-55 relates to steps 1 and 2 above by showing the distance between two lights, transferred to latitude scale.

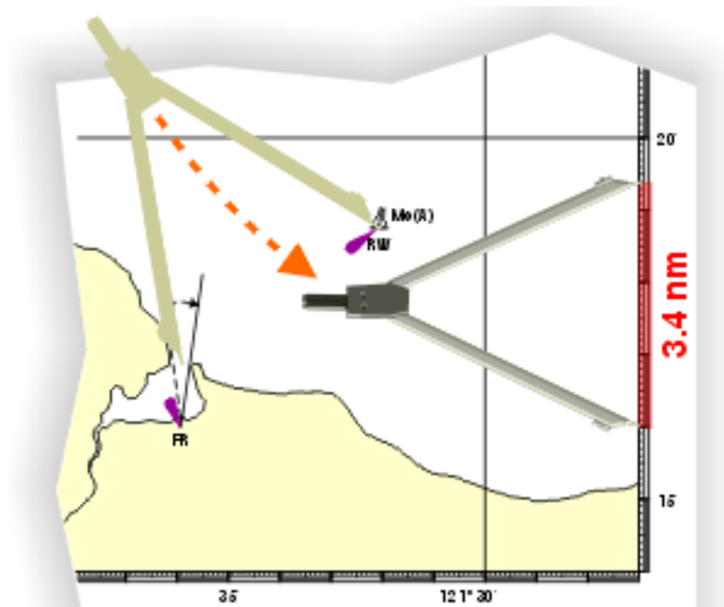


Figure 3-55
Latitude Scale Distance Measurement

Step	Action
3	When the distance being measured is greater than the span of the dividers, the dividers can be set at a certain distance. Take the known distance and starting at the first point continue marking on your line, and then total the distance (**Figure 3-56**).

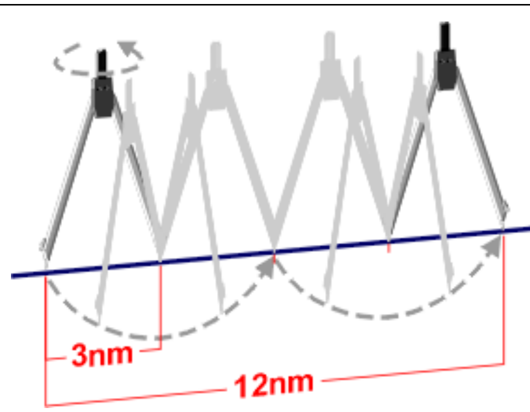


Figure 3-56
Marking Distance

4	The last span of the measurement, if not equal to that setting on the dividers, must be separately measured. To do this, step the dividers once more, closing them to fill the distance.
5	Measure the distance on the scale and add it to the sum of the other measurements.
6	The latitude scale nearest the middle of the line to be measured should be used.

E.8.e. Measuring Distance Using Graphic Scale

If provided, the graphic scale is found on the top and bottom of the charts. It will provide you with both nautical miles and yards. The top scale is for measuring nautical miles and the bottom is used for measuring yards. Either NM or Yards can be used, depending on the unit of measure you desire.

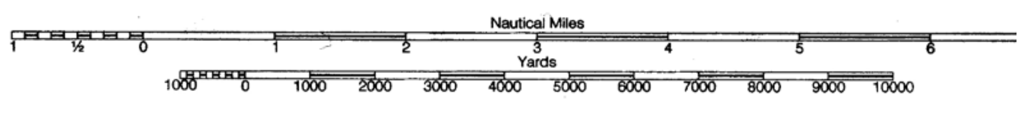


Figure 3-57
Graphic Scale

Using a compass, place the pointed end on the large number to the right, and the lead will fall in the section on the left, which is broken down in smaller units. Read the large number on the right and add the additional miles/yards from the left.

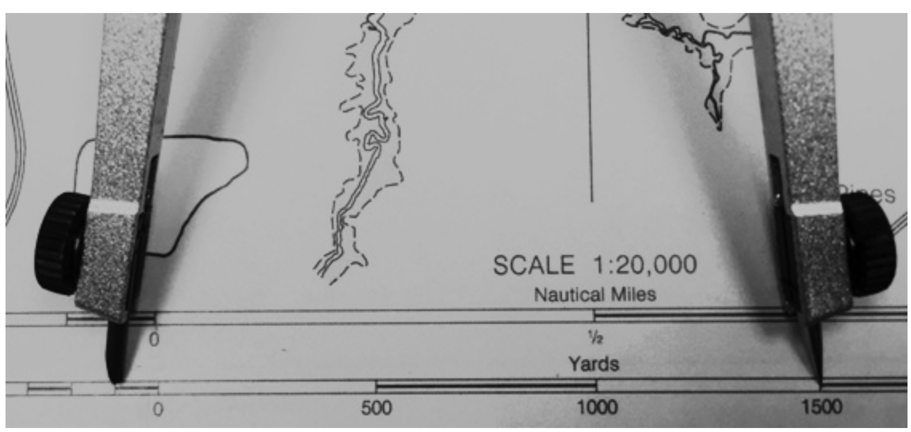


Figure 3-58
Graphic Scale Distance Measurement

E.9. Lines of Position

Bearings are obtained primarily by using a magnetic compass (compass bearings) or radar (relative bearings). Bearings of fixed, known, objects are the most common sources for LOPs in coastal navigation. When using a compass to take bearings, the object should be sighted across the compass.

To begin fixing position with this information the bearing to the object is recorded, converted to magnetic or true direction as needed, and plotted. The line drawn on the chart is called a Line of Position (LOP). A single observation gives an LOP, not a position, meaning all that is known is the boat is located somewhere along that LOP.

For example, if a standpipe and a flagstaff in a line are observed, the boat is somewhere on the line drawn from the standpipe through the flagstaff and towards the boat. This line may also be referred to as a visual range (**Figure 3-59**).

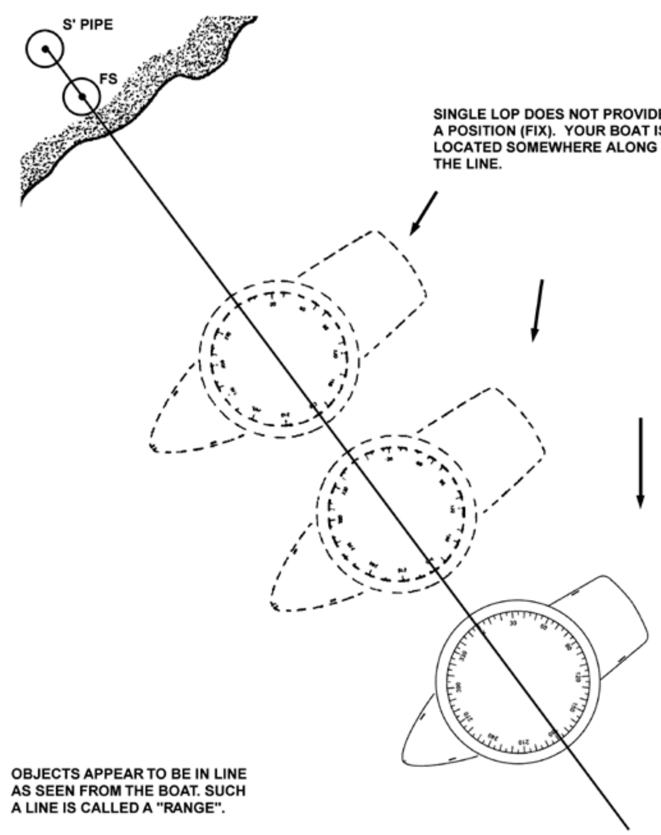


Figure 3-59
Line of Position

G.6. Electronic Charting System

Crews employing an electronic charting system to follow a navigation plan should take the following steps:

Step	Procedure
1	Ensure planned waypoints and tracklines are entered into the electronic chart plotter.
2	Verify system navigation calculations against chart work or backup system (i.e. GPS).
3	Assign helmsman and lookout.
4	Verify displayed position using radar, depth sounder, terrestrial ranges, and AtoN.
5	Activate route.
6	Verify Cross Track Error Alarm is set.
7	Verify depth alarms are set in accordance with unit navigation standards.
8	Provide initial and revised ETA as conditions change. Begin transit at planned speed.
9	Direct helmsman toward next waypoint using system navigation data, visual and radar information to make good estimated times along the planned track.
10	Conduct frequent reports of the navigation situation to crew (i.e. distance left/right of track, time to go to turn, nearest hazard to navigation, depth below keel, recommended course). Verify displayed position using radar, depth sounder, terrestrial ranges, and AtoN.
11	Make turns on-time to maintain trackline.
12	Adjust navigation plan and update remaining ETAs as needed due to traffic, safe speed, sea conditions, etc.

G.6.a. Cross Track Error

Cross Track Error (XTE) is an automatic navigation alarm function found in many electronic charting systems and GPS receivers that alerts users upon deviation from the intended trackline. When the vessel's position has exceeded the maximum allowable XTE, the system triggers an alarm. This alarm serves to prompt the operator to immediately address the situation. In **Figure 3-75** the vessel has exceeded the maximum allowable XTE value. Desired reaction-gap determines the value of the XTE alarm, with the intent being to provide vessel operators enough time to correct errors prior to mishap.

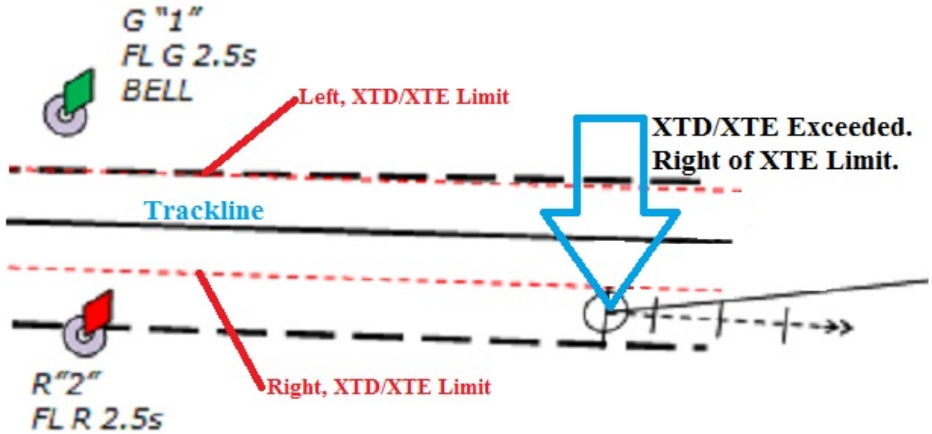


Figure 3-75
Cross Track Error (XTE)

ACRONYM	DEFINITION
UTS	Unit Travel System
UV	Ultraviolet
VHA	Variable Housing Allowance
VHF	Very High Frequency
VRM	Variable Range Marker
VRO	Variable Ratio Oiler
VRP	Vessel Response Plan
VS	Sector Search
VSC	Vessel Safety Check
VTS	Vessel Traffic Services
WP	Working Punt
WAAS	Wide Area Augmentation System
WAMS	Waterways Analysis and Management System
WC	Wellness Coordinator
WLIC	Construction Tender
WLL	Working Load Limit
WPB	Patrol Boat
WR	Wellness Representative
WWM	Waterways Management
XO	Executive Officer
XPO	Executive Petty Officer
XTE	Cross Track Error