“NAVIGATIONAL AND NAUTICAL EQUIPMENT”

ΑΚΑΔΗΜΙΑΕΜΠΟΡΙΚΟΥΝΑΥΤΙΚΟΥ
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ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΡΙΑ: ΠΑΝΑΓΟΠΟΥΛΟΥ ΜΑΡΙΑ

ΘΕΜΑ:

NAVIGATIONAL AND NAUTICAL EQUIPMENT

ΤΗΣ ΣΠΟΥΔΑΣΤΡΙΑΣ: ΣΚΕΠΕΤΑΡΗ ΙΩΑΝΝΑ

Α.Γ.Μ: 3432

Ημερομηνία ανάληψης της εργασίας:

Ημερομηνία παράδοσης της εργασίας:

Α/Α	Ονοματεπώνυμο	Ειδικότης	Αξιολόγηση	Υπογραφή
1				
2				
3				
ΤΕΛΙΚΗ ΑΞΙΟΛΟΓΗΣΗ				

Ο ΔΙΕΥΘΥΝΤΗΣ ΣΧΟΛΗΣ :

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INTRODUCTION

Navigational instruments refers to the instruments used by nautical navigators and pilots as tools of their trade. The purpose of navigation is to ascertain the present position and to determine the speed, direction etc. to arrive at the port or point of destination.

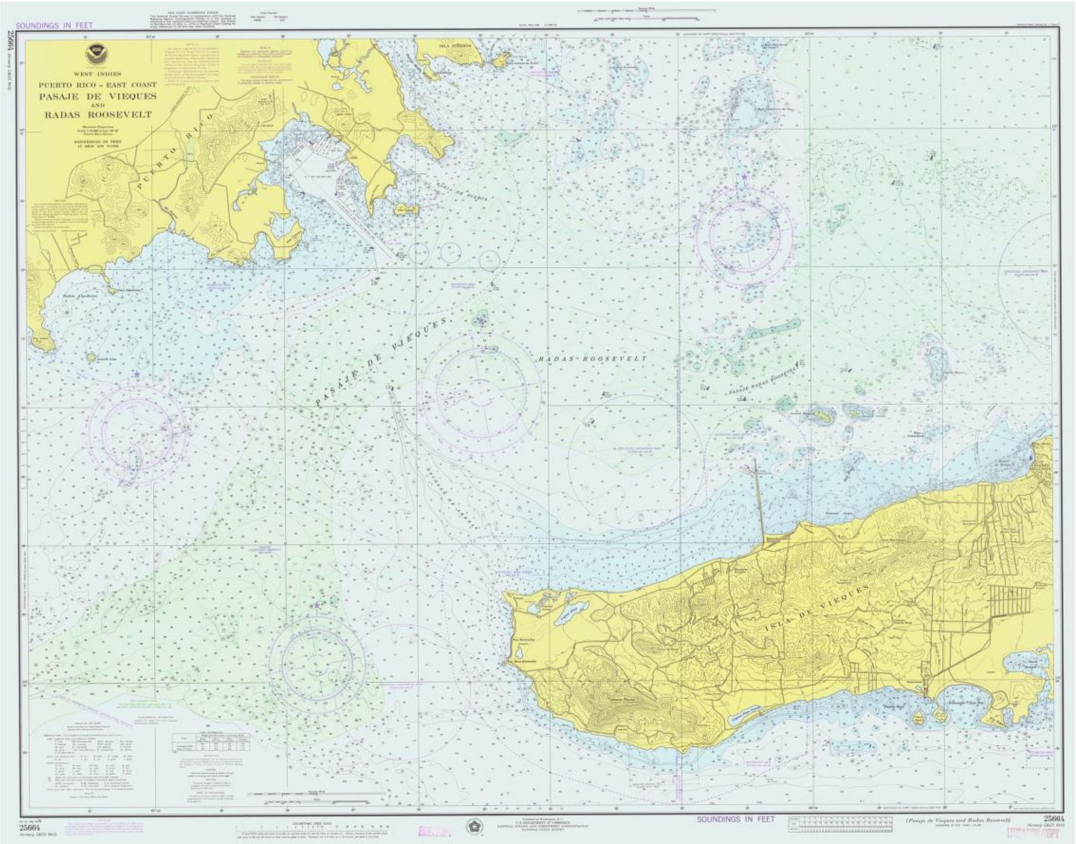
The days when a ship navigation officer had to take help of unconventional ways to plan and navigate a voyage at sea are long gone. Today, a ship officer has myriad of marine navigation equipment which makes his life a lot simpler, thanks to the advancement in technology. Moreover, the present-day seafarers are trained so as to know the functioning and operation of all modern day navigational equipment that has made the journey at sea smoother and safer.

With modern day facilities and automation, a ship today has several advanced navigation equipment systems which give accurate data for the voyage.

Chapter 1 - Charts and drafting instruments

1.1 Nautical chart

A nautical chart is a graphic representation of a maritime area and adjacent coastal regions. Depending on the scale of the chart, it may show depths of water and heights of land (topographic map), natural features of the seabed, details of the coastline, navigational hazards, locations of natural and human-made aids to navigation, information on tides and currents, local details of the Earth's magnetic field, and human-made structures such as harbours, buildings and bridges. Nautical charts are essential tools for marine navigation, many countries require vessels, especially commercial ships, to carry them. Nautical charting may take the form of charts printed on paper or computerized electronic navigational charts. Recent technologies have made available paper charts which are printed "on demand" with cartographic data that has been downloaded to the commercial printing company as recently as the night before printing. With each daily download, critical data such as Local Notice to Mariners is added to the on-demand chart files so that these charts will be up to date at the time of printing.



(https://en.wikipedia.org/wiki/)

Nautical charts are based on hydrographic surveys. As surveying is laborious and time-consuming, hydrographic data for many areas of sea may be dated and not always reliable. Depths are measured in a variety of ways. Historically the sounding line was used. In modern times, echo sounding is used for measuring the seabed in the open sea. When measuring the safe depth of water over an entire obstruction, such as a shipwreck, the minimum depth is checked by sweeping the area with a length of horizontal wire. This ensures that difficult to find projections, such as masts, do not present a danger to vessels navigating over the obstruction.

Nautical charts are issued by power of the national hydrographic offices in many countries. These charts are considered "official" in contrast to those made by commercial publishers. Many hydrographic offices provide regular, sometimes weekly, manual updates of their charts through their sales agents. Individual hydrographic offices produce national chart series and international chart series. Coordinated by the International Hydrographic Organization, the international chart series is a worldwide system of charts ("INT" chart series), which is being developed with the goal of unifying as many chart systems as possible.

There are also commercially published charts, some of which may carry additional information of particular interest, e.g. for yacht skippers.

1.1.1 Chart correction

The nature of a waterway depicted by a chart may change, and artificial aids to navigation may be altered at short notice. Therefore, old or uncorrected charts should never be used for navigation. Every producer of nautical charts also provides a system to inform mariners of changes that affect the chart. In the United States, chart corrections and notifications of new editions are provided by various governmental agencies by way of Notice to Mariners, Local Notice to Mariners, Summary of Corrections, and Broadcast Notice to Mariners. In the U.S., NOAA also has a printing partner who prints the "POD" (print on demand) NOAA charts, and they contain the very latest corrections and notifications at the time of printing. To give notice to mariners, radio broadcasts provide advance notice of urgent corrections.

A good way to keep track of corrections is with a Chart and Publication Correction Record Card system. Using this system, the navigator does not immediately update every chart in the portfolio when a new Notice to Mariners arrives, instead creating a card for every chart and noting the correction on this card. When the time comes to use the chart, he pulls the chart and chart's card, and makes the indicated corrections on the chart. This system ensures that every chart is properly corrected prior to use. A prudent mariner should obtain a new chart if he has not kept track of corrections and his chart is more than several months old.

Various Digital Notices to Mariners systems are available on the market such as Digitrace, Voyager, or ChartCo, to correct British Admiralty charts as well as NOAA charts. These systems provide only vessel relevant corrections via e-mail or web downloads, reducing the time needed to sort out corrections for each chart. Tracings to assist corrections are provided at the same time.

The Canadian Coast Guard produces the Notice to Mariners publication which informs mariners of important navigational safety matters affecting Canadian Waters. This electronic publication is published on a monthly basis and can be downloaded from the Notices to Mariners (NOTMAR) Web site. The information in the Notice to Mariners is formatted to simplify the correction of paper charts and navigational publications.

Various and diverse methods exist for the correction of electronic navigational charts.

Limitations

In 1973 the cargo ship MV Muirfield (a merchant vessel named after Muirfield, Scotland) struck an unknown object in waters charted at a depth of greater than 5,000 metres (16,404 ft), resulting in extensive damage to her keel In 1983, HMAS Moresby, a Royal Australian Navy survey ship, surveyed the area where Muirfield was damaged, and charted in detail a previously unsuspected hazard to navigation, the Muirfield Seamount.

The dramatic accidental discovery of the Muirfield Seamount is often cited as an example of limitations in the vertical geodetic datum accuracy of some offshore areas as represented on nautical charts, especially on small-scale charts. A similar incident involving a passenger ship occurred in 1992 when the Cunard liner Queen Elizabeth 2 struck a submerged rock off Block Island in the Atlantic Ocean. More recently, in

2005 the submarine USS San Francisco ran into an uncharted sea mount about 560 kilometres (350 statute miles) south of Guam at a speed of 35 knots (40.3 mph; 64.8 km/h), sustaining serious damage and killing one seaman. In September 2006 the jack-up barge Octopus ran aground on an uncharted sea mount within the Orkney Islands (United Kingdom) while being towed by the tug Harold. £1M worth of damage was caused to the barge and delayed work on the installation of a tidal energy generator prototype. As stated in the Mariners Handbook and subsequent accident report "No chart is infallible. Every chart is liable to be incomplete".

1.1.2 Map projection, positions, and bearings

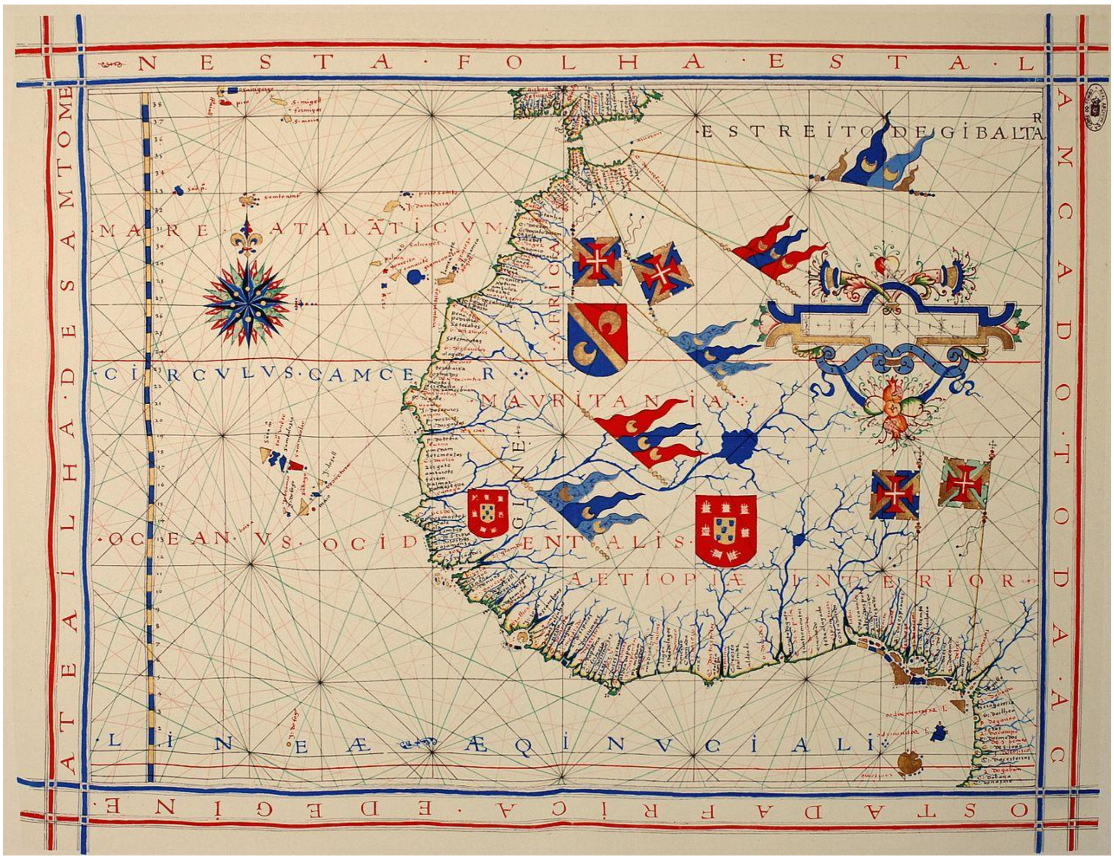
The Mercator projection is used on the vast majority of nautical charts. Since the Mercator projection is conformal, that is, bearings in the chart are identical to the corresponding angles in nature, courses plotted on the chart may be used directly as the course-to-steer at the helm.

The gnomonic projection is used for charts intended for plotting of great circle routes. NOAA uses the polyconic projection for some of its charts of the Great Lakes, at both large and small scales.

Positions of places shown on the chart can be measured from the longitude and latitude scales on the borders of the chart, relative to a geodetic datum such as WGS 84.

A bearing is the angle between the line joining the two points of interest and the line from one of the points to the north, such as a ship's course or a compass reading to a landmark. On nautical charts, the top of the chart is always true north, rather than magnetic north, towards which a compass points. Most charts include a compass rose depicting the variation between magnetic and true north.

However, the use of the Mercator projection is not without its drawbacks. Mercator's technique was to make the lines of longitude parallel. On the real globe, the lines of longitude converge as one goes north or south away from the equator, until they meet at the pole. This distortion means that horizontal distances are exaggerated. Mercator's solution, imperfect as it might be, was to increase the distance between lines of latitude in proportion; in a Mercator's projection map, a square is a square no matter where you are on the chart, but a square on the Arctic Circle is much bigger than a square at the equator, even though both occupy the same number of degrees on the globe. The result of this is that scale in a nautical chart is dependent on latitude. In practical use, this is less of a problem than it sounds. One minute of latitude is, for practical purposes, a nautical mile. Distances in nautical miles can therefore be measured on the latitude gradations printed on the side of the chart.



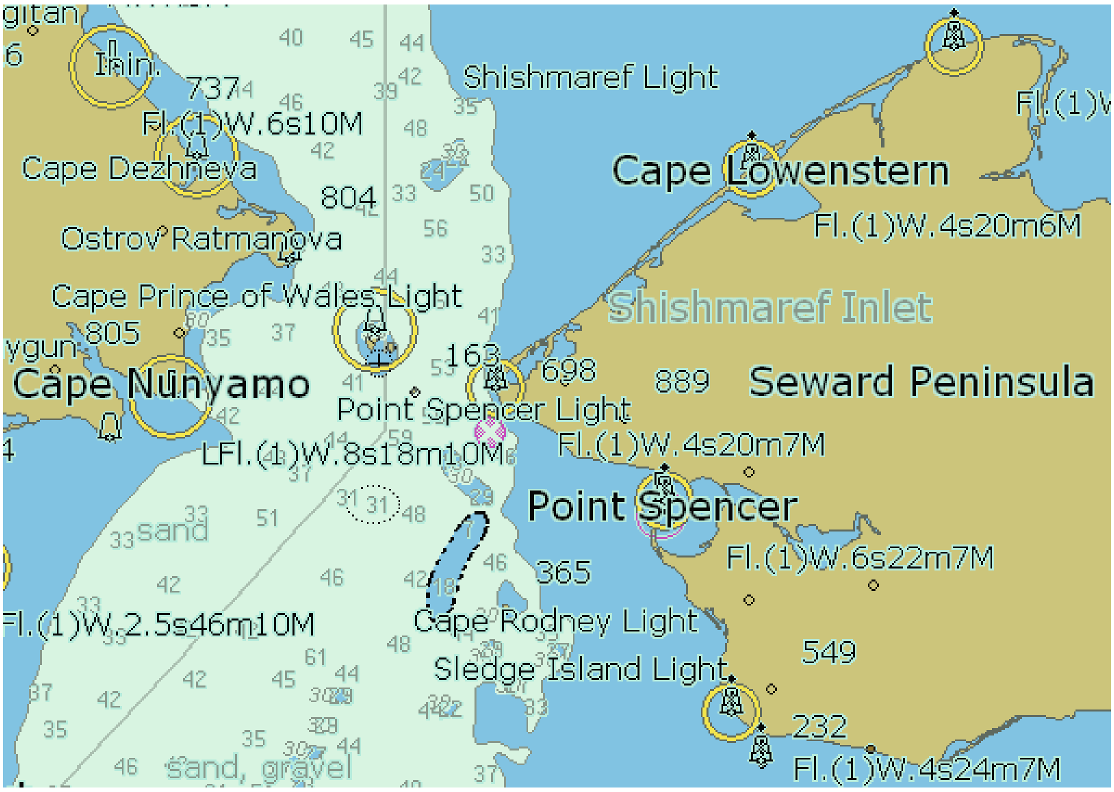
A pre-Mercator nautical chart of 1571, from Portuguese cartographer Fernão Vaz Dourado (c. 1520–c.1580). It belongs to the so-called plane chart model, where observed latitudes and magnetic directions are plotted directly into the plane, with a constant scale, as if the Earth's surface were a flat plane (Portuguese National Archives of Torre do Tombo, Lisbon)

1.1.3 Electronic and paper charts

Conventional nautical charts are printed on large sheets of paper at a variety of scales. Mariners will generally carry many charts to provide sufficient detail for the areas they might need to visit. Electronic navigational charts, which use computer software and electronic databases to provide navigation information, can augment or in some cases replace paper charts, though many mariners carry paper charts as a backup in case the electronic charting system fails.

Labeling nautical charts

Nautical charts must be labeled with navigational and depth information. There are a few commercial software packages that do automatic label placement for any kind of map or chart.



Portion of an electronic chart of the Bering Strait

1.1.4 Details on a nautical chart

Many countries' hydrographic agencies publish a "Chart 1", which explains all of the symbols, terms and abbreviations used on charts that they produce for both domestic and international use. Each country starts with the base symbology specified in IHO standard INT 1, and is then permitted to add its own supplemental symbologies to its domestic charts, which are also explained in its version of Chart 1. Ships are typically required to carry copies of Chart 1 with their paper charts.

Pilotage information

The chart uses symbols to provide pilotage information about the nature and position of features useful to navigators, such as sea bed information, sea mark, and landmarks. Some symbols describe the sea bed with information such as its depth, materials as well as possible hazards such as shipwrecks. Other symbols show the position and characteristics of buoys, lights, lighthouses, coastal and land features and structures that are useful for position fixing. The abbreviation "ED" is commonly used to label geographic locations whose existence is doubtful.

Colours distinguish between man-made features, dry land, sea bed that dries with the tide, and seabed that is permanently underwater and indicate water depth.

Depths and heights

Depths which have been measured are indicated by the numbers shown on the chart. Depths on charts published in most parts of the world use metres. Older charts, as well as those published by the United States government, may use feet or fathoms. Depth contour lines show the shape of underwater relief. Coloured areas of the sea emphasise shallow water and dangerous underwater obstructions. Depths are measured from the chart datum, which is related to the local sea level. The chart datum varies according to the standard used by each national Hydrographic Office. In general, the move is towards using lowest astronomical tide (LAT), the lowest tide predicted in the full tidal cycle, but in non-tidal areas and some tidal areas Mean Sea Level (MSL) is used.

Heights, e.g. a lighthouse, are generally given relative to mean high water spring (MHWS). Vertical clearances, e.g. below a bridge or cable, are given relative to highest astronomical tide (HAT). The chart will indicate what datum is in use.

The use of HAT for heights and LAT for depths, means that the mariner can quickly look at the chart to ensure that they have sufficient clearance to pass any obstruction, though they may have to calculate height of tide to ensure their safety.

Tidal information

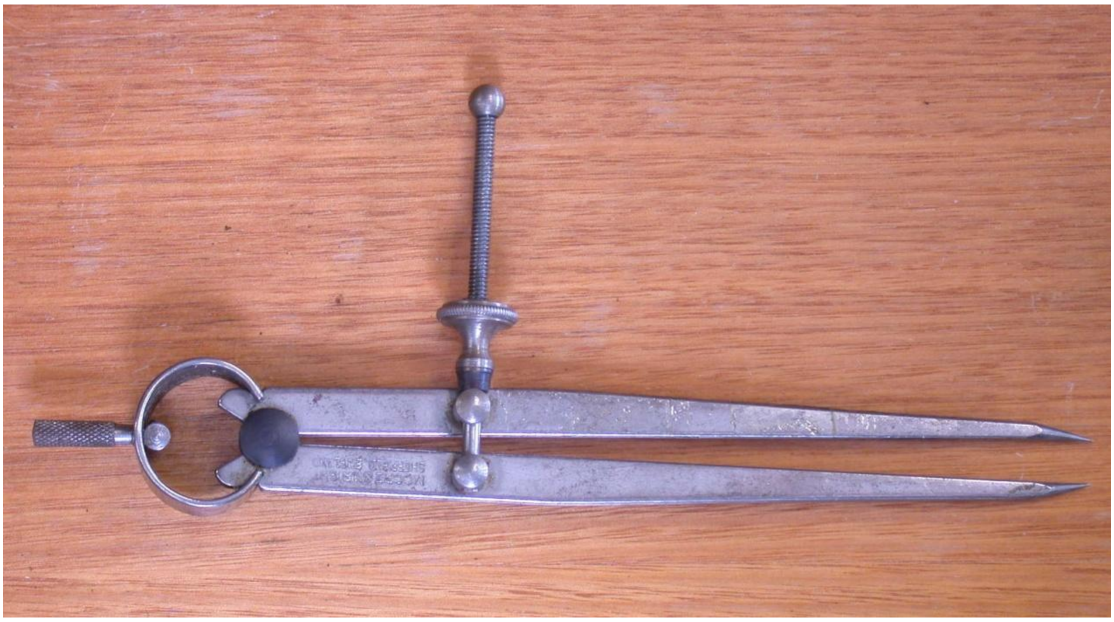
Tidal races and other strong currents have special chart symbols. Tidal flow information may be shown on charts using tidal diamonds, indicating the speed and bearing of the tidal flow during each hour of the tidal cycle.

1.2 Divider caliper

In the metalworking field, a divider caliper, popularly called a compass, is used in the process of marking out locations. The points are sharpened so that they act as scribers, one leg can then be placed in the dimple created by a center or prick punch and the other leg pivoted so that it scribes a line on the workpiece's surface, thus forming an arc or circle.

A divider caliper is also used to measure a distance between two points on a map. The two caliper's ends are brought to the two points whose distance is being measured. The caliper's opening is then either measured on a separate ruler and then converted to the actual distance, or it is measured directly on a scale drawn on the map. On a nautical chart the distance is often measured on the latitude scale appearing on the sides of the map: one minute of arc of latitude is approximately one nautical mile or 1852 metres.

Dividers are also used in the medical profession. An ECG (also EKG) caliper transfers distance on an electrocardiogram; in conjunction with the appropriate scale, the heart rate can be determined. A pocket caliper versions was invented by cardiologist Robert A. Mackin.



A pair of dividers

1.3 Nautical almanac

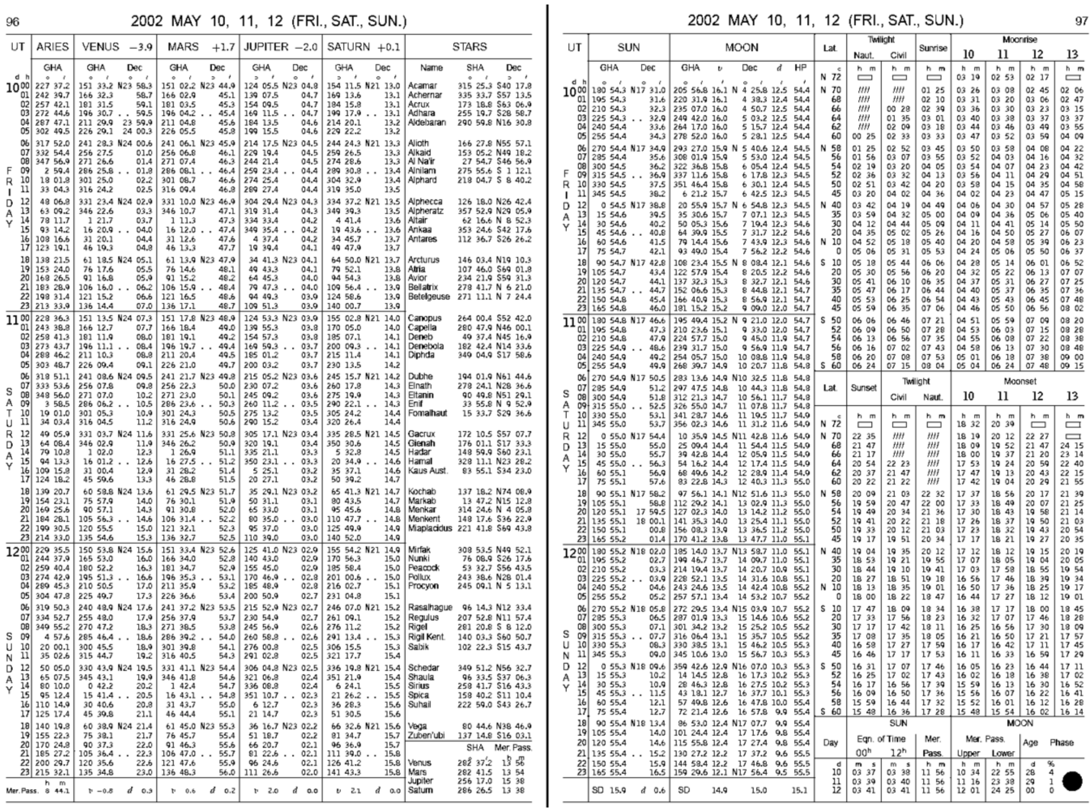
A nautical almanac is a publication describing the positions of a selection of celestial bodies for the purpose of enabling navigators to use celestial navigation to determine the position of their ship while at sea. The Almanac specifies for each whole hour of the year the position on the Earth's surface (in declination and Greenwich hour angle) at which the sun, moon, planets and first point of Aries is directly overhead. The positions of 57 selected stars are specified relative to the first point of Aries.

In Great Britain, The Nautical Almanac has been published annually by HM Nautical Almanac Office, ever since the first edition was published in 1767. In the United States, a nautical almanac has been published annually by the US Naval Observatory since 1852.Since 1958, the USNO and HMNAO have jointly published a unified nautical almanac, for use by the navies of both countries.[2] Almanac data is now available online from the US Naval Observatory.

Also commercial almanacs were produced that combined other information. A good example would be Brown's — which commenced in 1877 – and is still produced annually, its early twentieth century subtitle being "Harbour and Dock Guide and Advertiser and Daily Tide Tables". This combination of trade advertising, and information "by permission... of the Hydrographic Department of the Admiralty" provided a useful compendium of information. More recent editions have kept up with the changes in technology – the 1924 edition for instance had extensive advertisements for coaling stations. Meanwhile the Reeds Nautical Almanac, published by Adlard Coles Nautical, has been in print since 1932, and in 1944 was used by landing craft involved in the Normandy landings.

The "Air Almanac" of the United States and Great Britain tabulates celestial coordinates for 10-minute intervals for the use in aerial navigation. The Sokkia Corporation's annual "Celestial Observation Handbook and Ephemeris" tabulated daily celestial coordinates (to a tenth of an arc second) for the Sun and nine stars, it was last published for 2008.

To find the position of a ship or aircraft by celestial navigation, the navigator measures with a sextant the apparent height of a celestial body above the horizon, and notes the time from a marine chronometer. That height is compared with the height predicted for a trial position; the arcminutes of height difference is how many nautical miles the position line is from the trial position.



Two sample pages of the 2002 Nautical Almanac published by the U.S. Naval Observatory

1.4 Parallel rulers

Parallel rulers are a drafting instrument used by navigators to draw parallel lines on charts. The tool consists of two straight edges joined by two arms which allow them to move closer or further away while always remaining parallel to each other.

Parallel rule in plastic with aluminum arms.

The parallel ruler was invented in about 1584 by Fabrizio Mordente, but it was not in common use until the 18th century.

Captain Field's Improved Parallel Rule

In the 19th century a retired sea captain, Captain William Andrew Field (c. 1790/1 - 1870) of Fold Farm, Herbrandston in Pembrokeshire, improved the design by adding a protractor-style scale to the upper edge of one rule, and compass points to the opposing edge, which made reading bearings easier. Examples exist of boxwood, ivory or ebony, usually with brass hinges. The instrument usually had two links, but longer models sometimes had three, and sometimes the links were scissored. Another variation is the "roller" model which included a cylindrical roller for ease of use.

In February 1833 the same Capt. William Andrew Field rescued 14 sailors from the Sicilian brig, Felicita which was wrecked on rocks at the entrance to Sandy Haven in Milford Haven for which he received a Silver Medal from the RNLI and a medal from the Royal Humane Society.

Chapter 2 - Direct measuring

2.1 Chip log

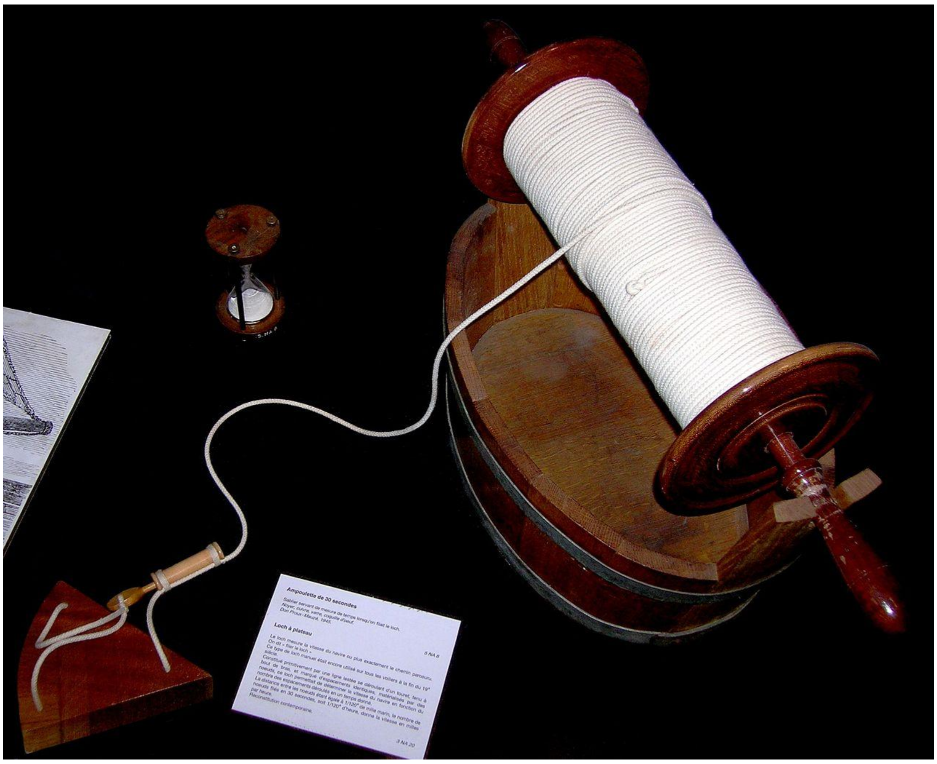
A chip log, also called common log, ship log, or just log, is a navigation tool which mariners use to estimate the speed of a vessel through water. The word knot, means nautical mile per hour, derives from this measurement method.

All nautical instruments that measure the speed of a ship through water are known as logs. This nomenclature dates back to the days of sail, when sailors tossed a log attached to a rope knotted at regular intervals off the stern of a ship. Sailors counted the number of knots that passed through their hands in a given time to determine the ship's speed. Today, sailors and aircraft pilots still express speed in knots.

A chip log consists of a wooden board attached to a line (the log-line). The log-line has a number of knots at uniform intervals. The log-line is wound on a reel so the user can easily pay it out.

Over time, log construction standardized. The shape is a quarter circle, or quadrant, and the log-line attaches to the board with a bridle of three lines that connect to the vertex and to the two ends of the quadrant's arc. To ensure the log submerges and orients correctly in the water, the bottom of the log is weighted with lead. This provides more resistance in the water, and a more accurate and repeatable reading. The bridle attaches in such a way that a strong tug on the log-line makes one or two of the bridle's lines release, so a sailor can retrieve the log.

A navigator who needed to know the speed of the vessel had a sailor drop the log over the ship's stern. The log acted as a drogue, remaining roughly in place while the vessel moved away. The sailor let the log-line run out for a fixed time while counting the knots that passed over. The length of log-line passing (the number of knots) determined the reading.



Ampoulette de 30 secondes

Sablier servant de mesure de temps lorsqu'on filait le loch.
Noyer, cuivre, verre, coquille d'oeuf.
Don Proux-Mauzé, 1945.

5 NA 8

Loch à plateau

Le loch mesure la vitesse du navire ou plus exactement le chemin parcouru.
On dit « filer le loch »
Ce type de loch manuel était encore utilisé sur tous les voiliers à la fin du 19e siècle.
Constitué primitivement par une ligne lestée se déroulant d'un touret, tenu à bout de bras, et marqué d'espacements identiques, matérialisés par des noeuds, ce loch permettait de déterminer la vitesse du navire en fonction du nombre des espacements déroulés en un temps donné.
La distance entre les noeuds étant égale à 1/120e de mille marin, le nombre de noeuds filés en 30 secondes, soit 1/120e d'heure, donne la vitesse en milles par heure.
Reconstitution contemporaine.

3 NA 20

Ship log and associated kit. The reel of log-line is clearly visible. The first knot, marking the first nautical mile is visible on the reel just below the centre. The timing sandglass is in the upper left and the chip log is in the lower left. The small light-coloured wooden pin and plug form a release mechanism for two lines of the bridle. From the Musée de la Marine, Paris.

2.2 Hourglass

An hourglass (or sandglass, or sand timer, or sand clock) is a device used to measure the passage of time. It comprises two glass bulbs connected vertically by a narrow neck that allows a regulated trickle of material (historically sand) from the upper bulb to the lower one. Factors affecting the time interval measured include sand quantity, sand coarseness, bulb size, and neck width. Hourglasses may be reused indefinitely by inverting the bulbs once the upper bulb is empty.

Hourglasses were an early dependable and accurate measure of time. The rate of flow of the sand is independent of the depth in the upper reservoir, and the instrument will not freeze in cold weather.[5] From the 15th century onwards, hourglasses were being used in a range of applications at sea, in the church, in industry, and in cookery.

During the voyage of Ferdinand Magellan around the globe, 18 hourglasses from Barcelona were in the ship's inventory, after the trip being authorized by emperor Charles V. It was the job of a ship's page to turn the hourglasses and thus provide the times for the ship's log. Noon was the reference time for navigation, which did not depend on the glass, as the sun would be at its zenith. A number of sandglasses could be fixed in a common frame, each with a different operating time, e.g. as in a four-way Italian sandglass likely from the 17th century, in the collections of the Science Museum, in South Kensington, London, which could measure intervals of quarter, half, three-quarters, and one hour (and which were also used in churches, for priests and ministers to measure lengths of sermons).

Modern practical uses

While they are no longer widely used for keeping time, some institutions do maintain them. Both houses of the Australian Parliament use three hourglasses to time certain procedures, such as divisions.

The sandglass is still widely used as the kitchen egg timer; for cooking eggs, a three-minute timer is typical, hence the name "egg timer" for three-minute hourglasses. Egg timers are sold widely as souvenirs. Sand timers are also sometimes used in games such as Pictionary and Boggle to implement a time constraint on rounds of play.

2.3 Depth sounding

Depth sounding refers to the act of measuring depth. It is often referred to simply as sounding. Data taken from soundings are used in bathymetry to make maps of the floor of a body of water, and were traditionally shown on nautical charts in fathoms and feet. The National Oceanic and Atmospheric Administration (NOAA), the agency responsible for bathymetric data in the United States, still uses fathoms and feet on nautical charts. In other countries, the International System of Units (meters) has become the standard for measuring depth.

"Sounding" derives from the Old English sund, meaning swimming, water, sea. It is not related to the word sound in the sense of noise or tones, but to sound, as a geographical term.

Traditional terms for soundings are a source for common expressions in the English language, notably "deep six" (a sounding of 6 fathoms): see John Ehrlichman. On the Mississippi River in the 1850s, the leadsmen also used old-fashioned words for some of the numbers; for example instead of "two" they would say "twain". Thus when the depth was two fathoms, they would call "by the mark twain!". The American writer Mark Twain, a former river pilot, likely took his pen name from this cry. The term lives on in today's world in echo sounding, the technique of using sonar to measure depth.

(According to “http://en.m.wikipedia.org/wiki/Depth_sounding”)

Chapter 3 - Position finding instruments

Celestial navigation instruments

These instruments are used primarily to measure the elevation or altitude of a celestial object.

3.1 Backstaff

The backstaff is a navigational instrument that was used to measure the altitude of a celestial body, in particular the sun or moon. When observing the sun, users kept the sun to their back (hence the name) and observed the shadow cast by the upper vane on a horizon vane. It was invented by the English navigator John Davis who described it in his book Seaman's Secrets in 1594.

Backstaff is the name given to any instrument that measures the altitude of the sun by the projection of a shadow. It appears that the idea for measuring the sun's altitude using back observations originated with Thomas Harriot. Many types of instruments evolved from the cross-staff that can be classified as backstaves. Only the Davis quadrant remains dominant in the history of navigation instruments. Indeed, the Davis quadrant is essentially synonymous with backstaff. However, Davis was neither the first nor the last to design such an instrument and others are considered here as well.

Captain John Davis invented a version of the backstaff in 1594. Davis was a navigator who was quite familiar with the instruments of the day such as the mariner's astrolabe, the quadrant and the cross-staff. He recognized the inherent drawbacks of each and endeavoured to create a new instrument that could reduce those problems and increase the ease and accuracy of obtaining solar elevations.

One early version of the quadrant staff is shown in Figure 1. It had an arc affixed to a staff so that it could slide along the staff (the shape is not critical, though the curved shape was chosen). The arc (A) was placed so that it would cast its shadow on the horizon vane (B). The navigator would look along the staff and observe the horizon through a slit in the horizon vane. By sliding the arc so that the shadow aligned with the horizon, the angle of the sun could be read on the graduated staff. This was a simple quadrant, but it was not as accurate as one might like. The accuracy in the instrument is dependent on the length of the staff, but a long staff made the instrument more unwieldy. The maximum altitude that could be measured with this instrument was 45°.

The next version of his quadrant is shown in Figure 2. The arc on the top of the instrument in the previous version was replaced with a shadow vane placed on a transom. This transom could be moved along a graduated scale to indicate the angle of the shadow above the staff. Below the staff, a 30° arc was added. The horizon, seen through the horizon vane on the left, is aligned with the shadow. The sighting vane on the arc is moved until it aligns with the view of the horizon. The angle measured is the sum of the angle indicated by the position of the transom and the angle measured on the scale on the arc.

The instrument that is now identified with Davis is shown in Figure 3. This form evolved by the mid-17th century.[4] The quadrant arc has been split into two parts. The smaller radius arc, with a span of 60°, was mounted above the staff. The longer radius arc, with a span of 30° was mounted below. Both arcs have a common centre. At the common centre, a slotted horizon vane was mounted (B). A moveable shadow vane was placed on the upper arc so that its shadow was cast on the horizon vane. A moveable sight vane was mounted on the lower arc (C).

It is easier for a person to place a vane at a specific location than to read the arc at an arbitrary position. This is due to Vernier acuity, the ability of a person to align two line segments accurately. Thus an arc with a small radius, marked with relatively few graduations, can be used to place the shadow vane accurately at a specific angle. On the other hand, moving the sight vane to the location where the line to the horizon meets the shadow requires a large arc. This is because the position may be at a fraction of a degree and a large arc allows one to read smaller graduations with greater accuracy. The large arc of the instrument, in later years, was marked with transversals to allow the arc to be read to greater accuracy than the main graduations allow.

Thus Davis was able to optimize the construction of the quadrant to have both a small and a large arc, allowing the effective accuracy of a single arc quadrant of large radius without making the entire instrument so large. This form of the instrument became synonymous with the backstaff. It was one of the most widely used forms of the backstaff. Continental European navigators called it the English Quadrant.

A later modification of the Davis quadrant was to use a Flamsteed glass in place of the shadow vane; this was suggested by John Flamsteed. This placed a lens on the vane that projected an image of the sun on the horizon vane instead of a shadow. It was useful under conditions where the sky was hazy or lightly overcast; the dim image of the sun was shown more brightly on the horizon vane where a shadow could not be seen.

Davis quadrant, made in 1765 by Johannes Van Keulen. On display at the Musée national de la Marine in Paris.

In order to use the instrument, the navigator would place the shadow vane at a location anticipating the altitude of the sun. Holding the instrument in front of him, with the sun at his back, he holds the instrument so that the shadow cast by the shadow vane falls on the horizon vane at the side of the slit. He then moves the sight vane so that he observes the horizon in a line from the sight vane through the horizon vane's slit while simultaneously maintaining the position of the shadow. This permits him to measure the angle between the horizon and the sun as the sum of the angle read from the two arcs.

Since the shadow's edge represents the limb of the sun, he must correct the value for the semidiameter of the sun.

The Elton's quadrant derived from the Davis quadrant. It added an index arm with spirit levels to provide an artificial horizon.

3.2 Jacob's staff

The term Jacob's staff, also known as cross-staff, a ballastella, a fore-staff, is used to refer to several things. In its basic form, a Jacob's staff is a stick or pole with length markings, most staffs are much more complicated than that, and usually contain a number of measurement and stabilization features. The two most frequent uses are:

- in astronomy and navigation for a simple device to measure angles, later replaced by the more precise sextants
- in surveying (scientific fields that use surveying techniques, such as geology and ecology) for a vertical rod that penetrates or sits on the ground and supports a compass or other instrument.

The simplest use of a Jacob's staff is to make qualitative judgements of the height and angle of an object relative to the user of the staff

In navigation the instrument is also called a cross-staff and was used to determine angles, for instance the angle between the horizon and Polaris or the sun to determine a vessel's latitude, or the angle between the top and bottom of an object to determine the distance to said object if its height is known, or the height of the object if its distance is known, or the horizontal angle between two visible locations to determine one's point on a map.

The Jacob's staff, when used for astronomical observations, was also referred to as a radius astronomicus. With the demise of the cross-staff, in the modern era the name "Jacob's staff" is applied primarily to the device used to provide support for surveyor's instruments.

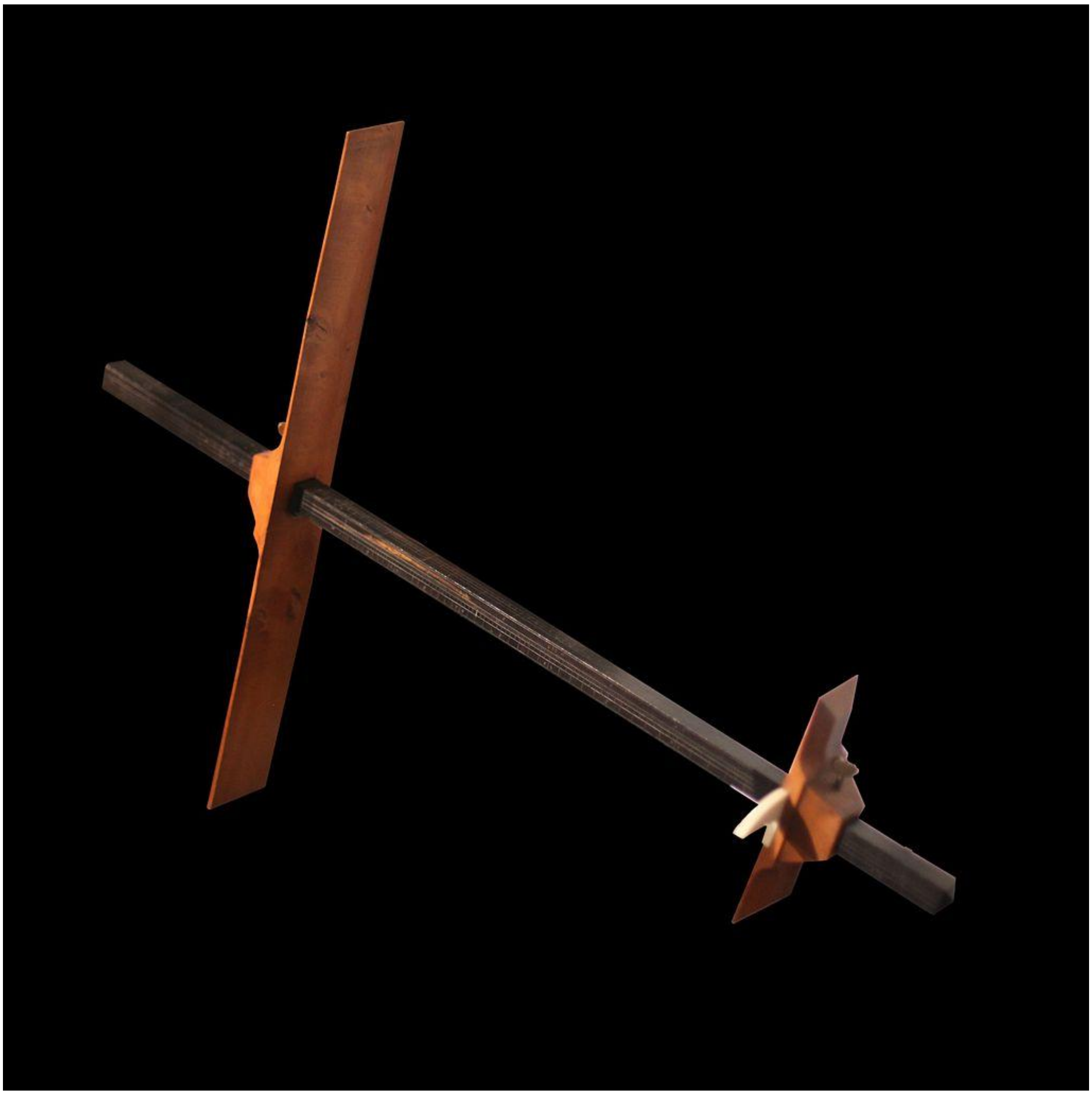
The original version was not reported to be used at sea, until the Age of Discoveries. Its use was reported by João de Lisboa in his Treatise on the Nautical Needle of 1514. Johannes Werner suggested the cross-staff be used at sea in 1514 and improved instruments were introduced for use in navigation. John Dee introduced it to England in the 1550s. In the improved versions, the rod was graduated directly in degrees. This variant of the instrument is not correctly termed a Jacob's staff but is a cross-staff.

The cross-staff was difficult to use. In order to get consistent results, the observer had to position the end of the pole precisely against his cheek. He had to observe the horizon and a star in two different directions while not moving the instrument when he shifted his gaze from one to the other. In addition, observations of the sun required the navigator to look directly at the sun. This could be a painful exercise and made it difficult to obtain an accurate altitude for the sun. Mariners took to mounting smoked-glass to the ends of the transoms to reduce the glare of the sun.

As a navigational tool, this instrument was eventually replaced, first by the backstaff or quadrant, neither of which required the user to stare directly into the sun, and later by the octant and the sextant. Perhaps influenced by the backstaff, some navigators modified the cross-staff to operate more like the former. Vanes were added to the ends of the longest cross-piece and another to the end of the main staff. The instrument was reversed so that the shadow of the upper vane on the cross piece fell on the vane at the end of the staff. The navigator held the instrument so that he would view the horizon lined up with the lower vane and the vane at the end of the staff. By aligning the horizon with the shadow of the sun on the vane at the end of the staff, the elevation of the sun could be determined. This actually increased the accuracy of the instrument, as the navigator no longer had to position the end of the staff precisely on his cheek.

Another variant of the cross-staff was a spiegelboog, invented in 1660 by the Dutchman, Joost van Breen.

Ultimately, the cross-staff could not compete with the backstaff in many countries. In terms of handling, the backstaff was found to be more easy to use.However, it has been proven by several authors that in terms of accuracy, the cross-staff was superior to the backstaff. Backstaves were no longer allowed on board Dutch East India Company vessels as per 1731, with octants not permitted until 1748.



Nautical cross-staff dated 1776, on display at Musée national de la Marine, Paris.

3.3 Kamal

A kamal is a celestial navigation device that determines latitude. The invention of the kamal allowed for the earliest known latitude sailing, and was thus the earliest step towards the use of quantitative methods in navigation. It originated with Arab navigators of the late 9th century,[and was employed in the Indian Ocean from the 10th century. It was adopted by Indian navigators soon after, and then adopted by Chinese navigators some time before the 16th century.

A simple wooden kamal.

3.4 Mariner's astrolabe

The mariner's astrolabe, also called sea astrolabe, was an inclinometer used to determine the latitude of a ship at sea by measuring the sun's noon altitude (declination) or the meridian altitude of a star of known declination. Not an astrolabe proper, the mariner's astrolabe was rather a graduated circle with an alidadeused to measure vertical angles. They were designed to allow for their use on boats in rough water and/or in heavy winds, which astrolabes are ill-equipped to handle. In the sixteenth century, the instrument was also called a ring.

In order to use the astrolabe, the navigator would hold the instrument by the ring at the top. This caused the instrument to remain in a vertical plane. The navigator would then align the plane of the astrolabe to the direction of the object of interest. The alidade was aligned to point at the object and the altitude was read off the outer degree scale.

If observing a dim object such as a star, the navigator would observe the object directly through the alidade. If observing the sun, it was both safer and easier to allow the shadow of one of the alidade's vanes to be cast onto the opposite vane.

The mariner's astrolabe needed to be suspended vertically in order to measure the altitude of the celestial object. This meant it could not be used easily on the deck in windy conditions. It could not easily be used to measure the angle between two objects, which was necessary for longitude calculations by the lunar distance method (though that technique was not used when the instrument was developed).

Another limitation was that the instrument's angular accuracy was directly proportional to the length of the alidade, which was not very long.

Mariner's astrolabe from circa 1600.

3.5 Quadrant

A quadrant is an instrument that is used to measure angles up to 90°. Different versions of this instrument could be used to calculate various readings, such as longitude, latitude, and time of day. It was originally proposed by Ptolemy as a better kind of astrolabe. Several different variations of the instrument were later produced by medieval Muslim astronomers.

The term “quadrant”, meaning one fourth, refers to the fact that early versions of the instrument were derived from astrolabes. The quadrant condensed the workings of the astrolabe into an area one fourth the size of the astrolabe face; it was essentially a quarter of an astrolabe.

The geometric quadrant is a quarter-circle panel usually of wood or brass. Markings on the surface might be printed on paper and pasted to the wood or painted directly on the surface. Brass instruments had their markings scribed directly into the brass.

For marine navigation, the earliest examples were found around 1460. They were not graduated in degrees but rather had the latitudes of the most common destinations directly scribed on the limb. When in use, the navigator would sail north or south until the quadrant indicated he was at the destination's latitude, turn in the direction of the destination and sail to the destination maintaining a course of constant latitude. After 1480, more of the instruments were made with limbs graduated in degrees.

In order to measure the altitude of a star, the observer would view the star through the sights and hold the quadrant so that the plane of the instrument was vertical. The plumb bob was allowed to hang vertical and the line indicated the reading on the arc's graduations. It was not uncommon for a second person to take the reading while the first concentrated on observing and holding the instrument in proper position.

The accuracy of the instrument was limited by its size and by the effect the wind or observer's motion would have on the plumb bob. For navigators on the deck of a moving ship, these limitations could be difficult to overcome.

3.6 Octant

The octant, also called reflecting quadrant, is a measuring instrument used primarily in navigation. It is a type of reflecting instrument.

The name octant derives from the Latin octans meaning eighth part of a circle, because the instrument's arc is one eighth of a circle.

Reflecting quadrant derives from the instrument using mirrors to reflect the path of light to the observer and, in doing so, doubles the angle measured. This allows the instrument to use a one-eighth of a turn to measure a quarter-turn or quadrant.

Use and adjustment of the octant is essentially identical to the navigator's sextant.

The octant provided a number of advantages over previous instruments.

The sight was easy to align because the horizon and the star seem to move together as the ship pitched and rolled. This also created a situation where the error in observation was less dependent on the observer, as he could directly see both objects at once.

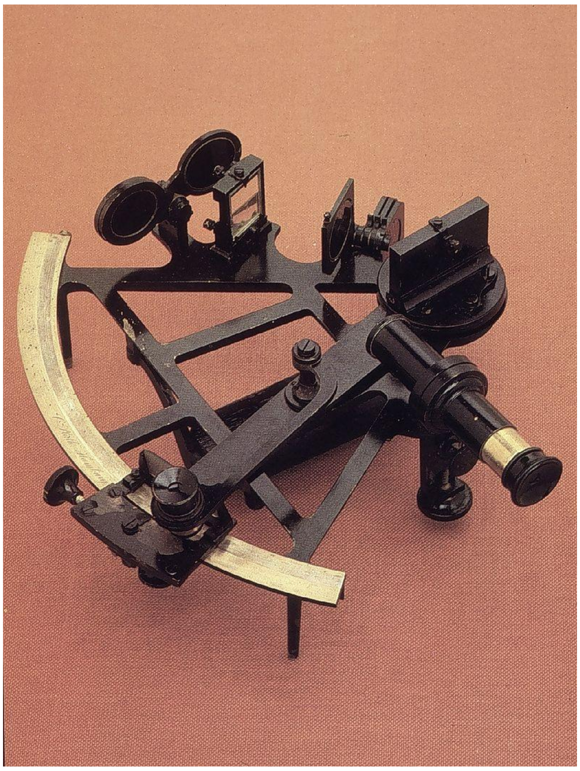
With the use of the manufacturing techniques available in the 18th century, the instruments were capable of reading very accurately. The size of the instruments was reduced with no loss of accuracy. An octant could be half the size of a Davis quadrant with no increase in error.

Using shades over the light paths, one could observe the sun directly, while moving the shades out of the light path allowed the navigator to observe faint stars. This made the instrument usable both night and day.

By 1780, the octant and sextant had almost completely displaced all previous navigational instruments.

3.7 Sextant

A sextant is a doubly reflecting navigation instrument that measures the angular distance between two visible objects. The primary use of a sextant is to measure the angle between an astronomical object and the horizon for the purposes of celestial navigation. The estimation of this angle, the altitude, is known as sighting or shooting the object, or taking a sight. The angle, and the time when it was measured, can be used to calculate a position line on a nautical or aeronautical chart—for example, sighting the Sun at noon or Polaris at night (in the Northern Hemisphere) to estimate latitude. Sighting the height of a landmark can give a measure of distance off and, held horizontally, a sextant can measure angles between objects for a position on a chart. A sextant can also be used to measure the lunar distance between the moon and another celestial object (such as a star or planet) in order to determine Greenwich Mean Time and hence longitude. The principle of the instrument was first implemented around 1731 by John Hadley (1682–1744) and Thomas Godfrey (1704–1749), but it was also found later in the unpublished writings of Isaac Newton(1643–1727). Additional links can be found to Bartholomew Gosnold (1571 - 1607) indicating that the use of a sextant for nautical navigation predates Hadley's implementation. In 1922, it was modified for aeronautical navigation by Portuguese navigator and naval officer Gago Coutinho.



Like the Davis quadrant, the sextant allows celestial objects to be measured relative to the horizon, rather than relative to the instrument. This allows excellent precision. However, unlike the backstaff, the sextant allows direct observations of stars. This permits the use of the sextant at night when a backstaff is difficult to use. For solar observations, filters allow direct observation of the sun.

Since the measurement is relative to the horizon, the measuring pointer is a beam of light that reaches to the horizon. The measurement is thus limited by the angular accuracy of the instrument and not the sine error of the length of an alidade, as it is in a mariner's astrolabe or similar older instrument.

A sextant does not require a completely steady aim, because it measures a relative angle. For example, when a sextant is used on a moving ship, the image of both horizon and celestial object will move around in the field of view. However, the relative position of the two images will remain steady, and as long as the user can determine when the celestial object touches the horizon the accuracy of the measurement will remain high compared to the magnitude of the movement.

The sextant is not dependent upon electricity (unlike many forms of modern navigation) or anything human-controlled (like GPS satellites). For these reasons, it is considered an eminently practical back-up navigation tool for ships.

Bearing instruments

3.8 Pelorus

In marine navigation, a pelorus is a reference tool for maintaining bearing of a vessel at sea. It is a "dumb compass" without a directive element, suitably mounted and provided with vanes to permit observation of relative bearings.

In appearance and use, a pelorus resembles a compass or compass repeater, with sighting vanes or a sighting telescope attached, but it has no directive properties. That is, it remains at any relative direction to which it is set. It is generally used by setting 000° at the lubber's line. Relative bearings are then observed. They can be converted to bearings true, magnetic, grid, etc., by adding the appropriate heading. The direct use of relative bearings is sometimes of value. A pelorus is useful, for instance, in determining the moment at which an aid to navigation is broad on the beam. It is also useful in measuring pairs of relative bearings which can be used to determine distance off and distance abeam of a navigational aid.

If the true heading is set at the lubber's line, true bearings are observed directly. Similarly, compass bearings can be observed if the compass heading is set at the lubber's line, etc. However, the vessel must be on the heading to which the pelorus is set if accurate results are to be obtained, or else a correction must be applied to the observed results. Perhaps the easiest way of avoiding error is to have the steersman indicate when the vessel is on course. This is usually done by calling out "mark, mark, mark" as long as the vessel is within a specified fraction of a degree of the desired heading. The observer, who is watching a distant object across the pelorus, selects an instant when the vessel is steady and is on course. An alternative method is to have the observer call out "mark" when the relative bearing is steady, and the steersman note the heading. If the compass is swinging at the moment of observation, the observation should be rejected. The number of degrees between the desired and actual headings is added if the vessel is to the right of the course, and subtracted if to the left. Thus, if the course is 060° and the heading is 062° at the moment of observation, a correction of 2° is added to the bearing.

The instrument was named for one Pelorus, said to have been the pilot for Hannibal, circa 203 BC.

Pelorus aboard HMS Belfast

Compasses

3.9 Magnetic compass

The magnetic compass is the most familiar compass type. It functions as a pointer to "magnetic north", the local magnetic meridian, because the magnetized needle at its heart aligns itself with the horizontal component of the Earth's magnetic field. The magnetic field exerts a torque on the needle, pulling the North end or pole of the needle approximately toward the Earth's North magnetic pole, and pulling the other toward the Earth's South magnetic pole. The needle is mounted on a low-friction pivot point, in better compasses a jewel bearing, so it can turn easily. When the compass is held level, the needle turns until, after a few seconds to allow oscillations to die out, it settles into its equilibrium orientation.

In navigation, directions on maps are usually expressed with reference to geographical or true north, the direction toward the Geographical North Pole, the rotation axis of the Earth. Depending on where the compass is located on the surface of the Earth the angle between true north and magnetic north, called magnetic declination can vary widely with geographic location. The local magnetic declination is given on most maps, to allow the map to be oriented with a compass parallel to true north. The location of the Earth's magnetic poles slowly change with time, which is referred to as geomagnetic secular variation. The effect of this means a map with the latest declination information should be used. Some magnetic compasses include means to manually compensate for the magnetic declination, so that the compass shows true directions.

Modern compasses usually use a magnetized needle or dial inside a capsule completely filled with a liquid (lamp oil, mineral oil, white spirits, purified kerosene, or ethyl alcohol are common). While older designs commonly incorporated a flexible rubber diaphragm or airspace inside the capsule to allow for volume changes caused by temperature or altitude, some modern liquid compasses utilize smaller housings and/or flexible capsule materials to accomplish the same result.[14] The liquid inside the capsule serves to damp the movement of the needle, reducing oscillation time and increasing stability. Key points on the compass, including the north end of the needle are often marked with phosphorescent, photoluminescent, or self-luminous materials to enable the compass to be read at night or in poor light. As the compass fill liquid is non-compressible under pressure, many ordinary liquid-filled compasses will operate accurately underwater to considerable depths.

Many modern compasses incorporate a baseplate and protractor tool, and are referred to variously as "orienteering", "map compass" or "protractor" designs. This type of compass uses a separate magnetized needle inside a rotating capsule, an orienting "box" or gate for aligning the needle with magnetic north, a transparent base containing map orienting lines, and a bezel (outer dial) marked in degrees or other units of angular measurement. The capsule is mounted in a transparent baseplate containing a direction-of-travel (DOT) indicator for use in taking bearings directly from a map.

Other features found on modern orienteering compasses are map and romer scales for measuring distances and plotting positions on maps, luminous markings on the face or bezels, various sighting mechanisms (mirror, prism, etc.) for taking bearings of distant objects with greater precision, gimbal-mounted, "global" needles for use in differing hemispheres, special rare-earth magnets to stabilize compass needles, adjustable declination for obtaining instant true bearings without resorting to arithmetic, and devices such as inclinometers for measuring gradients.[17]The sport of orienteering has also resulted in the development of models with extremely fast-settling and stable needles utilizing rare-earth magnets for optimal use with a topographic map, a land navigation technique known as terrain association.

The military forces of a few nations, notably the United States Army, continue to issue field compasses with magnetized compass dials or cards instead of needles. A magnetic card compass is usually equipped with an optical, lensatic, or prismatic sight, which allows the user to read the bearing or azimuth off the compass card while simultaneously aligning the compass with the objective (see photo). Magnetic card compass designs normally require a separate protractor tool in order to take bearings directly from a map.

The U.S. M-1950 military lensatic compass does not use a liquid-filled capsule as a damping mechanism, but rather electromagnetic induction to control oscillation of it magnetized card. A "deep-well" design is used to allow the compass to be used globally with a card tilt of up to 8 degrees without impairing accuracy. As induction forces provide less damping than fluid-filled designs, a needle lock is fitted to the compass to reduce wear, operated by the folding action of the rear sight/lens holder. The use of air-filled induction compasses has declined over the years, as they may become inoperative or inaccurate in freezing temperatures or extremely humid environments due to condensation or water ingress.

Some military compasses, like the U.S. M-1950 (Cammenga 3H) military lensatic compass, the Silva 4b Militaire, and the Suunto M-5N(T) contain the radioactive material tritium ($_1H^3$) and a combination of phosphors. The U.S. M-1950 equipped with self-luminous lighting contains 120 mCi (millicuries) of tritium. The purpose of the tritium and phosphors is to provide illumination for the compass, via radioluminescent tritium illumination, which does not require the compass to be "recharged" by sunlight or artificial light. However, tritium has a half-life of only about 12 years, so a compass that contains 120 mCi of tritium when new will contain only 60 when it is 12 years old, 30 when it is 24 years old, and so on. Consequently, the illumination of the display will fade.

Mariners' compasses can have two or more magnets permanently attached to a compass card, which moves freely on a pivot. A lubber line, which can be a marking on the compass bowl or a small fixed needle, indicates the ship's heading on the compass card. Traditionally the card is divided into thirty-two points (known as rhumbs), although modern compasses are marked in degrees rather than cardinal points. The glass-covered box (or bowl) contains a suspended gimbal within a binnacle. This preserves the horizontal position.

3.10 Gyrocompass

A gyrocompass is a type of non-magnetic compass which is based on a fast-spinning disc and the rotation of the Earth (or another planetary body if used elsewhere in the universe) to find geographical direction automatically. Although one important component of a gyrocompass is a gyroscope, these are not the same devices; a gyrocompass is built to use the effect of gyroscopic precession, which is a distinctive aspect of the general gyroscopic effect. Gyrocompasses are widely used for navigation on ships, because they have two significant advantages over magnetic compasses:

- they find true north as determined by the axis of the Earth's rotation, which is different from, and navigationally more useful than, magnetic north, and
- they are unaffected by ferromagnetic materials, such as in a ship's steel hull, which distort the magnetic field.

Aircraft commonly use gyroscopic instruments (but not a gyrocompass) for navigation and altitude monitoring; for details, see Flight instruments and Gyroscopic autopilot.

Timekeeping

3.11 Marine chronometer

A marine chronometer is a timepiece that is precise and accurate enough to be used as a portable time standard; it can therefore be used to determine longitudeby means of celestial navigation. When first developed in the 18th century, it was a major technical achievement, as accurate knowledge of the time over a long sea voyage is necessary for navigation, lacking electronic or communications aids. The first true chronometer was the life work of one man, John Harrison, spanning 31 years of persistent experimentation and testing that revolutionized naval (and later aerial) navigation and enabling the Age of Discovery and Colonialism to accelerate.

The term chronometer was coined from the Greek words chronos (meaning time) and meter (meaning counter) in 1714 by Jeremy Thacker, an early competitor for the prize set by the Longitude Act in the same year.[1] It has recently become more commonly used to describe watches tested and certified to meet certain precision standards. Timepieces made in Switzerland may display the word "chronometer" only if certified by the COSC (Official Swiss Chronometer Testing Institute).

A marine chronometer by Charles Frodsham of London, shown turned upside down to reveal the movement. Chronometer circa 1844-1860.

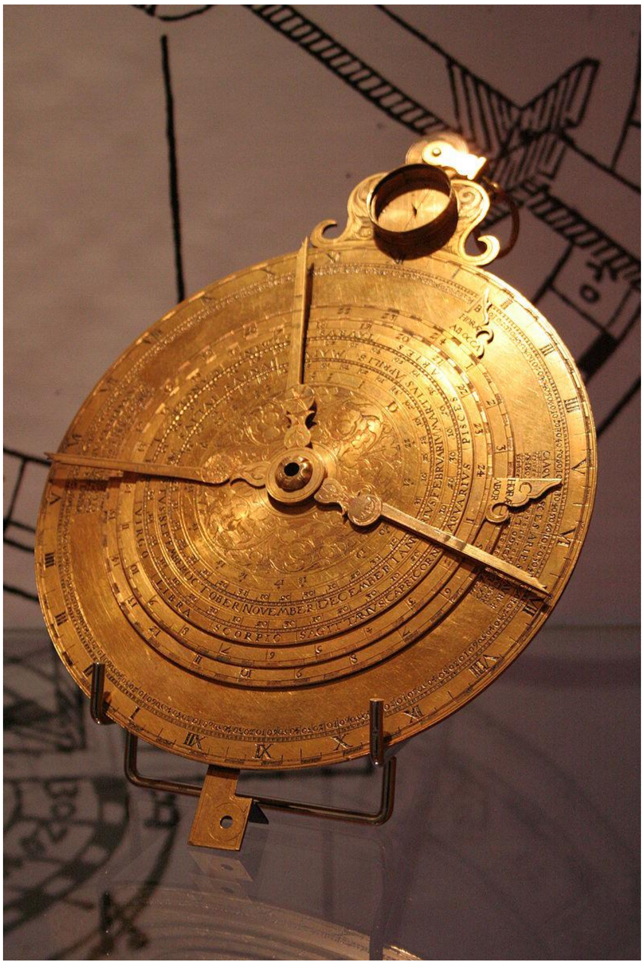
3.12 Nocturnal

A nocturnal is an instrument used to determine the local time based on the relative positions of two or more stars in the night sky. Sometimes called a "horologium nocturnum" (time instrument for night) or nocturlabe (in French and occasionally used by English writers), it is related to the astrolabe and sun dial. Knowing the time is important in piloting for calculating tides and some nocturnals incorporate tide charts for important ports.

Even if the nightly course of the stars has been known since antiquity, the mentions of a dedicated instrument for its measurement are not found before the Middle Ages. The earlier image presenting the use of a nocturnal is in a manuscript dated from the 12th century. Raymond Lull repeatedly described the use of a sphaera horarum noctis ou astrolabium nocturnum.

With Martín Cortés de Albacar's book Arte de Navegar, published in 1551 the name and the instrument gained a larger popularity.

It was described also c. 1530 by Peter Apianus in his Cosmographicus Liber republished later by Gemma Frisius with a widely circulated illustration of the instrument while being used by an observer.



A nocturnal made in Vienna.

A nocturnal is a simple analog computer, made of two or more dials, that will provide the local time based on the time of year and a sighting of Polaris and one or more other stars. In the northern hemisphere, all stars will appear to rotate about the North Star (known as Polaris) during the night, and their positions, like the progress of the sun, can be used to determine the time. The positions of the stars will change based on the time of year.

The most commonly used reference stars are the pointer stars from the Big Dipper (Ursa Major) or Kochab from the Little Dipper (Ursa Minor). The star Shedar in Cassiopeia may also be used, since it is on the opposite side of the sky from Ursa Major.

The inner disc is rotated so that the mark for the chosen reference star points to the current date on the outer disc. The north star is sighted through the center of the device, and the pointer arm is rotated to point at the chosen reference star. The intersection of the pointer arm with the hour markings on the inner disc indicates the time. The instrument must be held upright, and should have a handle or similar hint as to which direction is down.

It is not possible to convert the local time to a standard time such as UTC without accurate knowledge of the observer's longitude. Similarly, it is not possible to determine longitude unless the observer also knows the standard time from a chronometer.

3.13 Ring dial & astronomical ring

Ring dial or astronomical ring used to measure the height of a celestial body above the horizon. It could be used to find the altitude of the sun or determine local time. It let sunlight shine through a small orifice on the rim of the instrument. The point of light striking the far side of the instrument gave the altitude (or tell time).

In a ring dial (also known as an Aquitaine or a perforated ring dial), the ring is hung vertically and oriented sideways towards the sun. A beam of light passes through a small hole in the ring and falls on hour-curves that are inscribed on the inside of the ring. To adjust for the equation of time, the hole is usually on a loose ring within the ring so that the hole can be adjusted to reflect the current month.

All those mentioned were the traditional instruments used until well into the second half of the 20th century. After World War II electronic aids to navigation developed very rapidly and, to a great extent, replaced more traditional tools. Electronic speed and depth finders have totally replaced their older counterparts. Radar has become widespread even in small boats. Some Electronic aids to navigation like LORAN have already become obsolete themselves and have been replaced by GPS.

3.14 Global Positioning System

Global Positioning System (GPS) is a global navigation satellite system (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites, owned by the United States. GPS Receiver is a display system used to show ship's location with the help of Global positioning satellite in the Earth's orbit. The GPS was originally developed for use by the United States military, but in the 1980s, the United States government allowed the system to be used for civilian purposes. Though the GPS satellite data is free and works anywhere in the world, the GPS device and the associated software must be bought or rented. According to the initial design, for determining the position of the satellite receiver, the satellites of the GPS system emit the following coded signals:

- Coarse Acquisition Code (C/A), that concerns the recognition of satellites and the determination of satellite receiver distances, for civil users,
- Precision code (P), to determine the receiver's distances from the satellites, for military users,
- Data code (D-Code) or maritime message, to determine the position of the satellites with their tracking elements and the data of the exact time that it contains.

http://www.nauticexpo.com/prod/navis-usa-llc/product-28504-370383.html

3.15 Automatic Identification System

Automatic Identification System (AIS) is an automatic exchange of digital signals between ships in VHF frequency. This system provides for the mutual information of all ships operating in an area on the movements of the remaining vessels, their identity, their cargo, the port of departure and the port of arrival and other useful information.

The objective purpose of AIS is:

- to improve/promote the safer sailing level
- to enable safer and more efficient shipping
- to identify targets
- to assist in the pursuit of objectives
- to simplify the communication/exchange information between ships
- to provide additional information for a good assessment of the marine environment

An information of AIS contains three individual types of parameters:

- The static information (there are structural and technical details of the ship and its identity, this information is updated every six minutes) which are:
  - ➢ MMSI Number
  - ➢ IMO Number
  - ➢ Name of ship and Call Sign
  - ➢ Dimensions of the ship
  - ➢ Type of ship
  - ➢ The position of the ship
  - ➢ The type of GPS

- The dynamic information (there are motion information. This information is constantly being updated because it refers to ever-changing elements), which are:
  - ➢ Position of ship
  - ➢ Universal Time of Coordination (UTC)
  - ➢ True Course using gyrocompass (0-359)
  - ➢ Course over Ground (COG)
  - ➢ Speed over Ground (SOG)
  - ➢ Navigation status (“at anchor”, “onboard” etc.)
  - ➢ Rate of turn (0-720/min)

- The travel information (these information refers to data that apply to the particular travel), which are:
  - ➢ Draught of ship (0.1 meter to 25.5 meters)
  - ➢ Destination (maximum 20 characters)
  - ➢ Estimated Time of Arrival (ETA)
  - ➢ Type of cargo

3.16 Voyage Data Recorder

Voyage Data Recorder (VDR), is a data recording system designed for all vessels required to comply with the IMO's International Convention SOLAS Requirements (IMO Res.A.861(20)) in order to collect data from various sensors on board the vessel. Then it digitizes, compresses and stores this information in an externally mounted protective storage unit. This unit is a tamper-proof unit designed to withstand the extreme shock, impact, pressure and heat, which could be associated with a marine incident such as fire, collision, sinking, etc. The unit may be in a retrievable fixed unit or free float unit or combined with EPIRB. The last 12 hours (48 Hours for the 2014 regulations MSC.333(90)) of stored data in the protected unit can be recovered and replayed by the authorities or ship owners in case of an incident investigation.

The primary purpose of the VDR is for accident investigation after the fact, there can be other uses of recorded data for preventive maintenance, performance efficiency monitoring, heavy weather damage analysis, accident avoidance and training purposes to improve safety onboard and reduce running costs.

Except from VDR there is also the Simplified Voyage Data Recorder (S-VDR), as defined by the requirements of IMO Performance Standard MSC.163(78), is a lower cost simplified version of VDR for small ships with only basic ship's data recorded.

The VDR consists of the following sections:

- Data Protection Cap
- Main Electronic Unit
- Alert Unit
- Microphone Socket
- Data Acquisition Unit
- Power Supply Unit.

The installation of a VDR or an S-VDR should be carried out by companies authorized for this purpose. The main units are installed on the ship’s bridge and connected via cables with various information transmitters, in engine room, in the spaces where the crew is present (accommodation) or passengers, as well as the ship's holds and tanks.

The unit or Black box, as it is called for ships, includes the information below:

- Position, date, time using Global Positioning System
- Speed through water (sow or speed over ground from the Speed log
- Heading using Gyro Compass
- *Data of the Radar
- *ECDIS (A screen capture every 15 seconds and a list of navigational charts in use every 10 minutes or when a chart change occurs)
- Audio from the bridge, including bridge wings
- VHF radio communications

- *Echo sounder (Under Keel Clearance-UKC)
- *All IMO mandatory alarms from main alarms
- *Hull openings (The status of hull doors as detected on the bridge)
- *Watertight & fire doors (The status as indicated on the bridge)
- *Hull stress (Accelerations and hull stresses)
- *Rudder (Order and feedback response)
- *Engine/Propeller (Order and feedback response)
- *Thrusters (Status, direction, amount of thrust % or RPM)
- *Anemometer and weather vane (Wind speed and direction)

Data marked with * may not be recorded in S-VDR, except Radar and Echo Sounder if data & standard interfaces available.

Push the "Save" button to save the recorded data at a marine accident case.

https://jrc.am/products/jcy-1900/features

3.17 Emergency Position-Indicating Radio Beacon

EPIRB is a distress tracking transmitter that is triggered during an accident, detected by satellites. The system is monitored by an international consortium of rescue services, COSPAS-SARSAT. The original purpose of this system is to help rescuers find survivors within the so-called "golden day" during which the majority of survivors can usually be saved.

The standard frequency of a modern EPIRB is 406-MHz. It is an internationally-regulated mobile radiocommunication service that aids search and rescue operations to detect and locate distressed signals from boats, aircrafts and people. It’s distinct from a Satellite emergency position-indicating radio beacon station.

https://www.marinesuperstore.com/safety-beacons/epirb/ocean-signal-rescueme-epirb-1

3.18 Electronic Chart Display and Information System

An Electronic Chart Display and Information System (ECDIS) is a geographic information system used for nautical navigation that complies with International Maritime Organization (IMO) regulations as an alternative to paper nautical charts. IMO refers to similar systems not meeting the regulations as Electronic Chart Systems (ECSs).

An ECDIS system displays the information from Electronic Navigational Charts (ENC) or Digital Nautical Charts (DNC) and integrates position information from position, heading and speed through water reference systems and optionally other navigational sensors. Other sensors which could interface with an ECDIS are radar, Navtex, Automatic Identification Systems (AIS), and depth sounders.

In recent years concerns from the industry have been raised as to the system's security especially with regards to cyber attacks and GPS spoofing attacks.(According to https://en.wikipedia.org/wiki/Electronic_Chart_Display_and_Information_System)

UTC 08 - 03 - 10 13 : 39 : 55

Prim DGPS 1 55° 22.724 N 011° 01.014 E

Sec: None

COG DGPS 1 142.0°

SOG 17.5 kn

HDG GYRO 1 141.7°

STW LOG 1 17.7 kn

Range: 6 NM

Rings: 1.0 NM

Transparency: 2

Accumulation: None

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