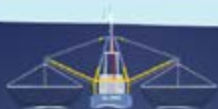




Electronic Navigation Systems

Guidance for safe use
on leisure vessels



EDITED BY
JANE RUSSELL



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Graphics by William Thomson

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Important Message

This document has been produced by the Royal Institute of Navigation (“RIN”) drawing on the expertise of a large number of people with skills in a range of areas which are relevant to the safe navigation of leisure vessels. It has been produced in good faith as an overview to the safe use of electronic navigation equipment and related systems on leisure vessels. As stated elsewhere it is not intended to be a comprehensive guide to their use but merely a summary of operational issues highlighting, where appropriate, the advantages and drawbacks of use. This document should not be taken as giving guidance for the use of electronic navigation or equipment on Commercial Vessels of any size.

The information and advice contained in this booklet is intended merely as general guidance to assist the navigator in the use of electronic navigational aids and, as always, the safety of the vessel and its crew is entirely the responsibility of the Master/skipper.

It is for the individual Master/skipper to decide whether it is prudent to act on this advice in the circumstances in which he/she finds him/herself and in no circumstances whatsoever will RIN, the authors, the editor or any of the organisations who have supported the production of this booklet accept any liability whatsoever for any damage, loss, costs or any penalty incurred by anyone acting upon the comments, suggestions or advice contained in this booklet.

Recommendations for official bodies, developers and manufacturers

The production of this document has highlighted a number of areas where improvements to electronic navigation systems could be made by manufacturers and official bodies to assist the safety of leisure vessels through better design or regulation. These recommendations do not sit comfortably in this document so are listed on the RIN website where they can be viewed at: <https://rin.org.uk/page/ENav>

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CONTENTS

Acknowledgements		2
Glossary of terms		4
Our Objective		6
Introduction		7
Chapter 1	GNSS in marine navigation	11
Chapter 2	Electronic charts and their display systems	19
Chapter 3	Using Radar and AIS	39
Chapter 4	Guarding against electronic failure on small craft	53
Chapter 5	Key navigational skills	65
Chapter 6	Future Developments	91
Appendix I	Extracts from accident reports	93
Appendix II	SOLAS regulations and small craft	94
Appendix III	Chart of emergency signals	97
Notes	For your personal use	98

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Jane Russell, of the Royal Cruising Club Pilotage Foundation, who has done a miraculous job as editor. That, however, understates her work. She took the text from all the contributors in as many styles and joined it together to form an almost seamless document. It is now very difficult to identify some of the contributions but most are there.

William Thomson, whose graphics have brought the book to life and we thank him for his attention to detail.

Finally, our other stakeholders: the **RYA, MCA and RNLI** who have all contributed comments and suggestions. It was always clear that we all shared the same objective of seeking to educate leisure vessel users in the safe use of new technology.

The overall purpose has been to provide, in a single short document, a comprehensive, accurate and authoritative summary of how electronic systems on leisure vessels function. In particular we hope it will provide an explanation of their benefits and also how to minimise the risks implicit in using them. By being available as a free download we hope to be able to update the document quickly when new technology appears, or if errors are spotted.

Although compiled by a UK navigation body, it is only the references to UK regulations in this booklet which are specific to the UK. All of the information about electronic systems applies worldwide (*except as noted*). However, the regulations applying to leisure/small vessels in other flag states will be different, even if apparently similar.

This booklet has been a joint effort by four charities, a government agency and the national governing body of boating in the UK, as well as all the individual contributors. Our thanks go to all of them.

Paul Bryans (*Chair of the Small Craft Committee, RIN*)

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Editor's note: *I am very grateful to all of the members of the RIN Small Craft Committee, in particular Paul Bryans and Kathy Hossain. I could not have brought this booklet together without their close collaboration and support. JAKR*

Glossary of terms

Note: For the purposes of this booklet our definition of electronic navigation systems includes onboard equipment and software, whether stand alone or integrated, as well as the satellite and land-based systems with which they link.

“Leisure Vessel” as used in this document means, in the UK, a small vessel classified as a “Pleasure Vessel” under UK legislation as set out in MGN 599. If a vessel is not a Pleasure Vessel then it is a Commercial Vessel. Vessels in commercial use (also called “Coded Vessels”) are subject to different regulations. See MCA Small craft codes at www.gov.uk/government/publications/small-craft-codes.

“Small” in this context means up to 24m Load Line Length.

This document is aimed at all users of leisure vessels, sail and power, and the terms “sailor” and “yacht” are used generically to encompass all. This document is intended to be non-specific to a particular type of leisure vessel except where the context dictates.

AIS	Automatic Identification System (see page 45)
ARPA	Automatic Radar Plotting Aid (see page 44)
AtoN	Aid(s) to Navigation (see page 13)
BMS	Battery Management System (see page 55)
CATZOC	Categories of Zones Of Confidence (see page 31)
ColRegs	International Regulations for Preventing Collisions at Sea, 1972, as amended
CPA	Closest Point of Approach (see page 51)
DGPS	Differential GPS (see page 14)
ECSC	Electronic Chart System (see page 20)
ECDIS	Electronic Chart Display and Information System (see page 19)
ECMWF	European Centre for Medium Range Weather Forecasting (see page 82)
ENC	Electronic Navigational Chart (see pag 21)
GBAS	Ground-Based Augmentation System (see page 13)
GFS	Global Forecast System (see page 82)
GLA	General Lighthouse Authorities)
GNSS	Global Navigation Satellite System (see page 11)
GPS	Global Positioning System, the US military operated GNSS (see page 11)
GRIB	Gridded Information in Binary (see page 82)
GT	Gross Tonnage (a volume calculation, not displacement)

HDoP	Horizontal Dilution of Precision (see page 11)
HO	Hydrographic Office
IALA	International Organization for Marine Aids to Navigation (originally called 'International Association of Lighthouse Authorities')
IHO	International Hydrographic Organization
Lidar	Light Detection and Ranging (see page 27)
M	Nautical Mile
MFD	Multifunction Display
POD	Print On Demand
Racons	Radar beacons (see page 40)
Radar	Radio Detection And Ranging (see page 39)
RNC	Raster Navigational Chart (see page 21)
SOLAS	International Convention for the Safety Of Life At Sea, 1974, as amended (see page 93)
SBAS	Satellite-based Augmentation System (see page 13)
TCPA	Time to Closest Point of Approach (see page 51)
TSS	Traffic Separation Scheme
VDES	VHF Data Exchange System (see page 16)
WGS84	World Geodetic System 84 (see page 33)
ZOC	Zone Of Confidence (see page 31)

Our Objective

The objective of this booklet is to provide guidance on the safe use of electronic navigation and associated systems on leisure vessels. Navigating a leisure vessel has always required the skipper/navigator to use all available information and that has never been more important than now, with the availability of ever increasing sources of information. Good navigational safety is still dependent on the continuous assessment by the skipper/navigator of all the navigation-related information available on the vessel – and not just over-concentrating on some, however beguiling they may be.

Introduction

In the past couple of decades marine navigation systems have changed beyond recognition. Many ships now navigate paperless and the leisure sector appears to be heading the same way. There is no doubt that the benefits of electronic systems have revolutionised our safety at sea. Satellite positioning, radar and AIS are especially helpful when the visibility is poor, but even in perfect conditions the combined systems can give us a much better assessment of what is happening beyond our line of sight, allowing us to respond to emerging situations in a much more informed way.

The systems in place on larger vessels are a step ahead of those used on smaller craft. For leisure sailors the technology is currently still in a transition phase and this creates some vulnerability. The aim of this booklet is to improve awareness of the current vulnerabilities and how to mitigate them, enabling all of us to make better and safer judgements, both when we are passage planning and when we are at sea.

In order to comply with regulations, ships that navigate entirely electronically are required to carry a backup navigation system which is completely independent of the main system and also has an independent power supply. These ships use approved charts on approved ECDIS (see *page 19*), and have navigation officers who have undergone both formal ECDIS training and onboard familiarisation specific to the system they are using. In contrast, electronic charts for the leisure sector are not approved by the relevant maritime authorities, they are displayed on a wide variety of systems, all equally unapproved, there is not much standardisation of functionality between systems, and there is currently limited training specific to electronic systems available in the leisure sector. As leisure sailors we tend to assume an accuracy that is neither provided by our onboard systems nor by how we use them. In the following pages we look at what our systems are and are not telling us and how we could be using them more effectively.

Global navigation satellite systems are now integral to so many aspects of our navigation, not just for positioning but for timing. Augmentations of these systems are giving us ever greater accuracy and reliability, but in Chapter 1 we consider some of the limitations and vulnerabilities that might affect our navigation systems.

With the transition from paper to electronic in the main commercial shipping market, the major providers of chart data (including UKHO in the UK and NOAA in the USA) are moving away from the provision of paper charts towards being suppliers of digital, vector only, hydrographic information. Print On Demand (POD) offers continued provision of these official paper charts, but the possibility is that the available coverage by such charts will be significantly reduced within a relatively short timeframe. Commercial suppliers should continue to supply the leisure market in selected areas while demand remains. However, whatever our preference, as leisure sailors we may sometimes be forced to rely on electronic charts. This reliance demands some key functionality and user knowledge.

There are many reasons why primary systems might fail on a small vessel, including several reasons why satellite signals might be lost. Small craft being used commercially (i.e. coded vessels in the UK) are required to carry approved charts and currently the usual way to comply with this is to carry approved paper charts. Non-commercial leisure sailors only need to comply with SOLAS regulations which require every vessel to have a backup means of navigation in case of failure of the primary system.

Many leisure sailors still choose to rely on paper as their backup, but an increasing number are relying entirely on electronics. Such reliance needs backup systems that are sufficiently robust. It is imperative that if we are using an electronic system as a backup it should allow us to continue to navigate if any or all of our primary systems fail. Can we, for example, plot a visual fix on our backup system? We consider some chart and display essentials in Chapter 2.

Avoidance of collisions with other vessels, particularly vessels much larger than us, is something we all take very seriously. Electronic systems, including radar and AIS, have given us some very useful extra tools to enhance situational awareness for collision avoidance. But, once again, many of us are placing too much faith in the systems without always fully understanding their different functionalities and this can occasionally get us into trouble. In Chapter 3 we will unwrap some of the key characteristics of radar and AIS to help us all to use these tools appropriately and effectively.

If it does all go wrong we have come to assume that rescue will always be on hand, and around the UK and Ireland we are particularly well looked after by our search and rescue services (SAR), especially the RNLI coordinated by the Her Majesty's Coastguard (HMCG). But if we assume rescue is available we tend to be less well prepared for a possible crisis, which makes us much more likely to need rescuing. And every time one of us needs rescuing at sea it puts the lives of our rescuers in danger. So it is infinitely better to be as well prepared as we sensibly can be so that we shouldn't need to be rescued. In Chapter 4 we look at some of the ways that onboard electronic systems can fail and what we can do to guard against such failure.

We have all come to depend on satellites for our positioning, and with this comes a tendency towards a complete trust in the accuracy of our location. But this mindset can be dangerous if the accuracy of our charts, whether they are electronic or paper, does not match the accuracy of our positioning. When using traditional navigation it was common to factor in a good margin of error – both for positioning and for expected passage timings. Nowadays we expect positional accuracy within metres rather than within a mile or more, so we tend to cut closer to dangers. We also tend to promise ourselves ever tighter arrival windows. In reality, it is our expectations that have changed, not our sailing ability. In Chapter 5 we illustrate the importance of having key navigation skills and of focussing on our relative position rather than our absolute position when avoiding dangers.

For a long time the debate on navigation has been one of electronic versus paper. But in defaulting to that position we have perhaps been distracted away from solving some key electronic navigation issues. Rather than insisting on paper *per se*, we should perhaps be putting more pressure on all of our leisure chart providers and equipment manufacturers and maritime authorities to agree to some minimum approved standards of display and function, for example to enable us to navigate safely on our e-nav systems with or without satellite signals. RIN has compiled a list of recommendations for manufacturers and authorities which is available on our website: <https://rin.org.uk/page/ENav>

Digital developments are ongoing and, over time, are likely to further increase and enhance the navigational tools available to us. In Chapter 6 we review some of the developments which are in the pipeline and may become available in the near future.

Finally, it is important that we learn from mistakes (both our own and those of others), so that we don't repeat them. We include an appendix of links to some of the available accident investigation reports which have important lessons for all of us. This is not an exhaustive list and there are many other reports available worldwide.

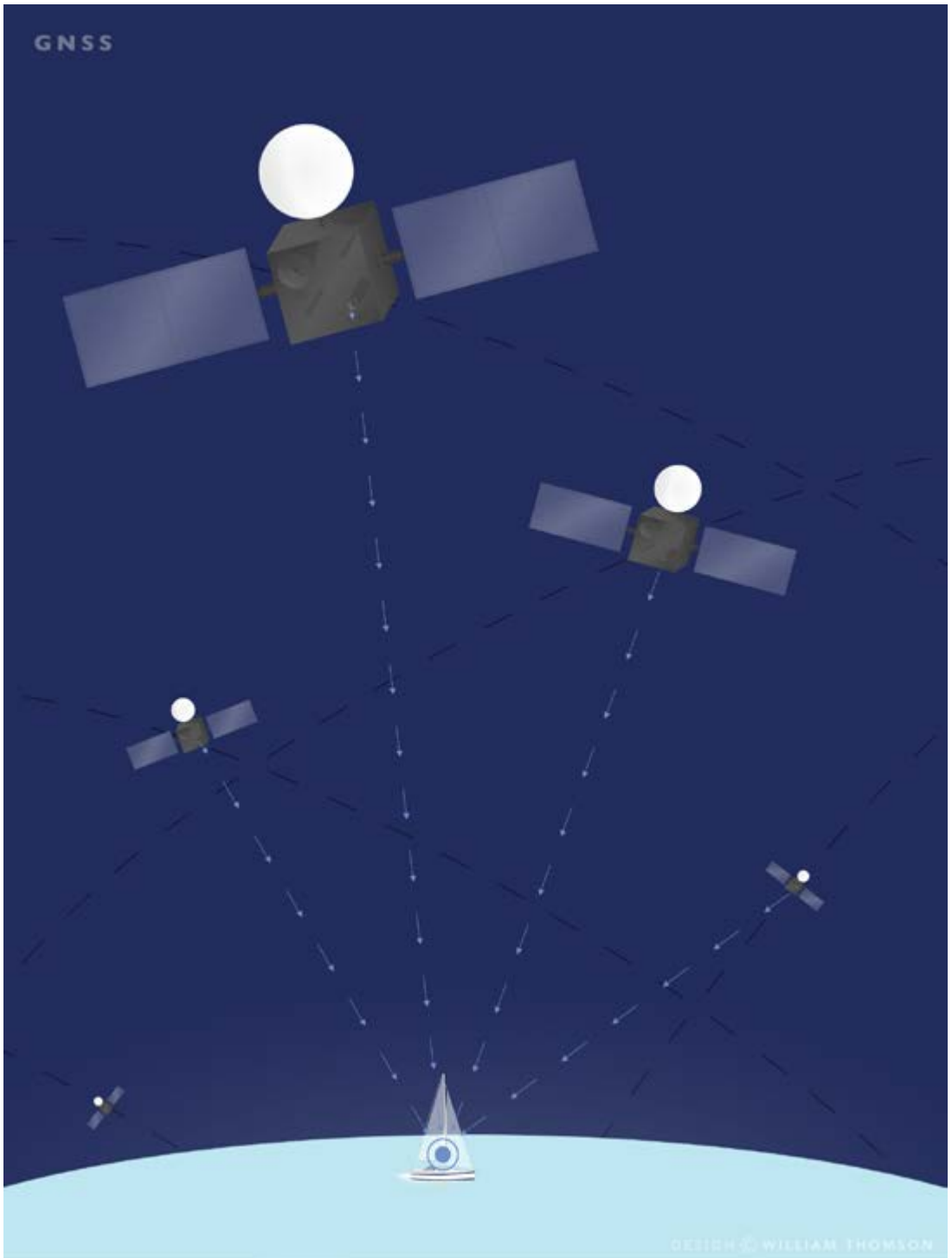
A note from the Chairman of the RYA/ MCA Yachtmaster Qualification Panel

Almost all skippers of small craft rely heavily on electronic navigation. There is no doubt that it has made recreational boating safer and navigation simpler. We no longer have to draw a circle of uncertainty around a fix and rarely have to draw triangles on a chart. Navigators can spend more time where they should be – on deck looking where they are going.

Good skippers are continually thinking ahead, the next course change, the approaching weather, the pilotage at the destination. They navigate ten minutes ahead rather than ten minutes behind. They are also thinking about the unexpected, hitting an object in the water, a rope around the prop and what they are going to do if the electronic systems fail. The UK has a large number of talented skippers who sail our coastline unnoticed because they sort out the usual and unusual difficulties of being at sea without recourse to the rescue services. These competent yachtsmen and women have usually taken training and have consolidated it with experience. They know that sailing is much more enjoyable if skipper and crew know the ropes and know how to interpret and use the electronic information on board.

Electronic navigation has taken much of the sweat out of position fixing, planning, collision avoidance, tidal calculations and much else. Used intelligently it adds greatly to the pleasure of sailing and gives time to simply enjoy being at sea.

James Stevens FRIN



Chapter One

GNSS in marine navigation

Accuracy and vulnerability

Global Navigation Satellite Systems (GNSS)

Global Navigation Satellite Systems have become the mainstay of all navigation systems. Each system is a constellation of about 30 orbiting satellites which provide us with information, mostly on common signal frequencies. These shared frequencies are intentional and allow interoperability. Receivers may operate on more than one system. The signals transmitted from each satellite give precise time and orbit information.

We tend to use GPS as a generic term but it is just one of the global systems:

Global Positioning System (GPS) – American

Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) – Russian

Galileo – European

BeiDou – Chinese

GNSS positions are acquired when a GNSS receiver obtains a fix by simultaneously locking onto the signals from at least four ‘in view’ satellites. If the satellites are spread quite well apart the accuracy of fix is better than if they are very close together. Accuracy degrades when only a small number of more clustered satellites are in view. We experience this when we are navigating in cities where tall buildings can block the signals from a wider spread of satellites. In confined coastal areas the same thing can happen and positioning may be less accurate than when we have a clear horizon. GNSS receivers that use multiple constellations to obtain a fix have access to more satellites, which should make the system more robust.

Dilution of Precision (DoP), in particular the Horizontal DoP (HDOP), is one indicator of the quality of a GNSS position. DoP takes into account the location and geometry of satellites relative to the GNSS receiver. A low HDOP value (less than 2.0, 1.0 being ideal) indicates a relatively high probability of accuracy.

System Outages

Although the possibility of complete system failure may be unlikely it remains a risk. GPS was developed as a US military system but has effectively become a utility that many vital civil systems, both in the US and worldwide, rely on, especially for timing. A failure would have a major impact and not just on navigation. Even if a total GNSS system failure is considered remote, localised failures (*outages*) causing position inaccuracy are not uncommon and we should be aware that they could affect us.

Interference to navigation satellite systems

Signals from GNSS satellites can suffer from interference and other vulnerabilities. On their journey to earth, the signals can be perturbed by natural events such as space weather and by passing through the Earth's atmosphere. All GNSS signals are extremely low power when they reach the earth, so they are susceptible to both intentional interference, or "jamming", as well as unintentional interference, for example from nearby communications masts. Signals can bounce off the sea or buildings, resulting in longer path lengths and "multipath" position jumps. Other effects tend to be rare but can cause large position errors when they happen. These include accidental signal errors which are often due to human error at satellite control centres, and also the intentional transmission of deceptive signals, known as "spoofing".

Sometimes these problems are obvious because the position display will show it lost or not available. However, it is more usual for these effects to result in an inaccurate position with no error flagged. Everything will seem fine despite the position accuracy being degraded, potentially by a large amount - as much as several hundred metres or more has been seen on numerous occasions. Systems connected to the GNSS receiver can also be impacted, particularly if GNSS is denied or lost for any more than a brief moment.

Natural GNSS interference

Space weather: The Earth's atmosphere always delays satellite signals, so all single-frequency GNSS receivers include models to compensate for this. Sometimes phenomena such as sunspots, solar flares and scintillation create changes in the ionosphere and/or troposphere which are too large or fast-changing for the models to compensate. The effects are position errors or, in extreme cases, the receiver losing its ability to report a position at all.

Accidental interference: Faulty equipment, poor set up or nearby transmitting antennas are common causes of interference. Onboard, the location of the GNSS antenna in relation to any other transmitting aerial/antenna, for example a VHF aerial, is the first thing to consider.

Intentional GNSS interference

Jamming: Jamming occurs when something is broadcast on GNSS signal frequencies. Thankfully, jamming events are most likely to be short lived and in a limited geographical area. There are many motivations, including prevention of tracking of an individual or nation state actions. Trinity House/General Lighthouse Authorities have conducted trials at sea, which show that the effects of jamming are more complex than we might think. But as a general rule, as jamming power increases, significant position and velocity errors become common. At medium jammer powers, errors are usually not flagged up at all. It is only at higher powers that we would see an obvious effect because the jamming simply overwhelms the GNSS receiver.

Spoofing: Spoofing incidents, fortunately, are rare. Spoofing of a single vessel relies on the perpetrator transmitting a false GNSS signal to a specific receiver or group of receivers, usually with the aim of being unnoticed, in other words without giving rise to a noticeable jump in position. Such a spoof results in a false position, time and speed which are then all used by interconnected systems, including AIS. Spoofing incidents are most often motivated by criminal activity or nation state actions.

AIS GNSS reliance

For further details about how the Automatic Identification System (AIS) works, see Chapter 3. All AIS units, with the exception of receive-only systems, are connected to a GNSS receiver. This is used to automatically determine:

- the **position** that will be transmitted by the AIS
- a **time** reference for each transmission to ensure that only one operating system in the same area ever transmits at the same time

In other words, AIS is totally dependent on the continuous availability and accuracy of GNSS. AIS suffers the same vulnerabilities as GNSS. **Any outages or failures of GNSS impact on the accuracy of AIS data.**

GNSS augmentation systems

A number of GNSS augmentation systems have been developed globally. These involve geostationary satellites (Satellite-Based Augmentation Systems (SBAS)) and/or a network of monitoring stations on the ground (Ground-Based Augmentation Systems (GBAS)) that provide checks on distance ranging and also on signal integrity. Amongst other applications this technology has enabled enhancements to Aids to Navigation. On or close to land some of our smartphone and tablet satellite navigation systems are similarly enhanced by a variety of other augmentation systems. Practically all modern mobile devices generate a blended position from a range of different sources that include Wi-Fi and mobile phone masts (*but see Mobile devices and loss of GNSS page 57*). Offshore much, if not all, of the positioning range information will come from GNSS alone – something to be aware of if we are heading off on longer passages.

Electronic Aids to Navigation (AtoN) and GNSS

An Aid to Navigation (AtoN) is defined by the International Organization for Marine Aids to Navigation and Lighthouse Authorities (IALA) as “a device, system or service, **external to vessels**, designed and operated to enhance safe and efficient navigation of individual vessels and/or vessel traffic.” In other words, AtoN are not on our boats. AtoN include all the familiar visual aids such as lighthouses, buoys and beacons that we have been navigating around, with gratitude, for hundreds of years. Many AtoN also incorporate radionavigation systems which include Racons, GNSS, DGNSS and Vessel Traffic Services. These are commonly referred to as electronic AtoN. Electronic AtoN are an important component of our navigation systems and many are GNSS reliant. Even the LED light synchronisation on some AtoN relies on GNSS timing.

Note: Audible signals, also referred to as sound/fog signals, are provided for hazard warning purposes only. They should not be used for navigation purposes for a number of reasons, which include the fact that propagation of sound varies in the atmosphere making the perception of distance and direction of the source of the sound signal difficult. Occasionally, the sound may be hardly audible close to the danger but can be heard clearly at a greater distance. For this reason, since 1985 IALA no longer refers to these signals as an aid to navigation.

Differential GPS (DGPS)

The IALA Marine Beacon DGPS system is provided variously around the globe and is especially prevalent in the Northern Hemisphere. It is a good example of GNSS augmentation. DGPS typically uses ground-based reference stations providing transmissions with coverage of at least 50M. The satellite fix is enhanced because one of the reference stations (which 'knows' exactly where it is) simultaneously receives the satellite signal and applies a differential correction. The correction is transmitted on Medium Frequency. The vessel's receiver receives signals direct from the satellites but also from the ground station. This correctional enhancement not only gives better accuracy, which is particularly important for large ships in tight channels, but also allows a check on the integrity of the GPS signal.

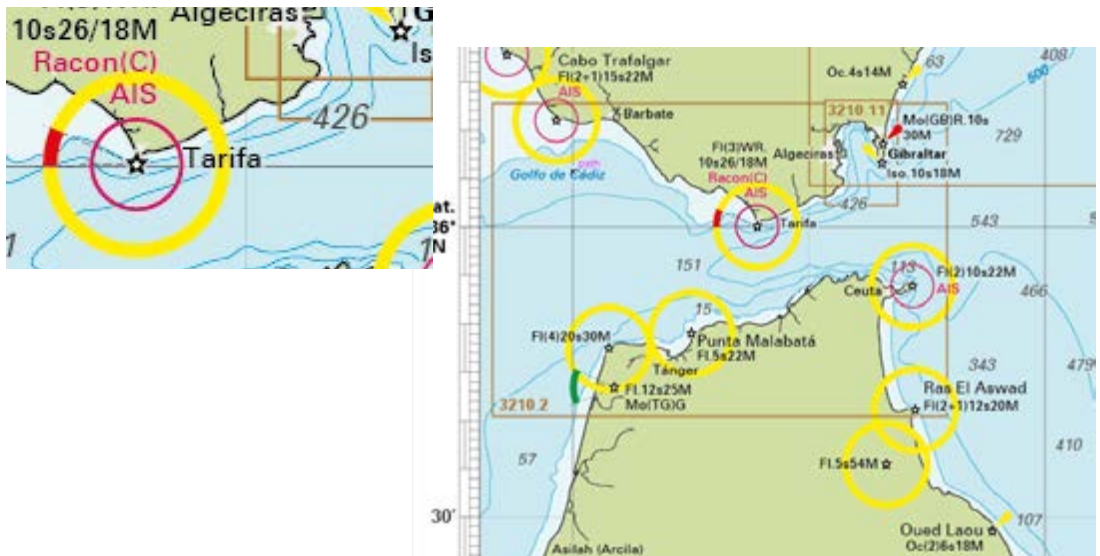
Of course, DGPS relies inherently on GPS, the operation and characteristics of which are outside the control of service providers and their respective governments and both are still inherently susceptible to interference, whether natural, accidental or malicious. The same is true of any other D/GNSS. We should use all alternative means available to cross-check the information received. If we are reliant on the accuracy of DGPS we should have a receiver which gives us sufficient warning of the complete loss of DGPS signal and reversion to GPS.

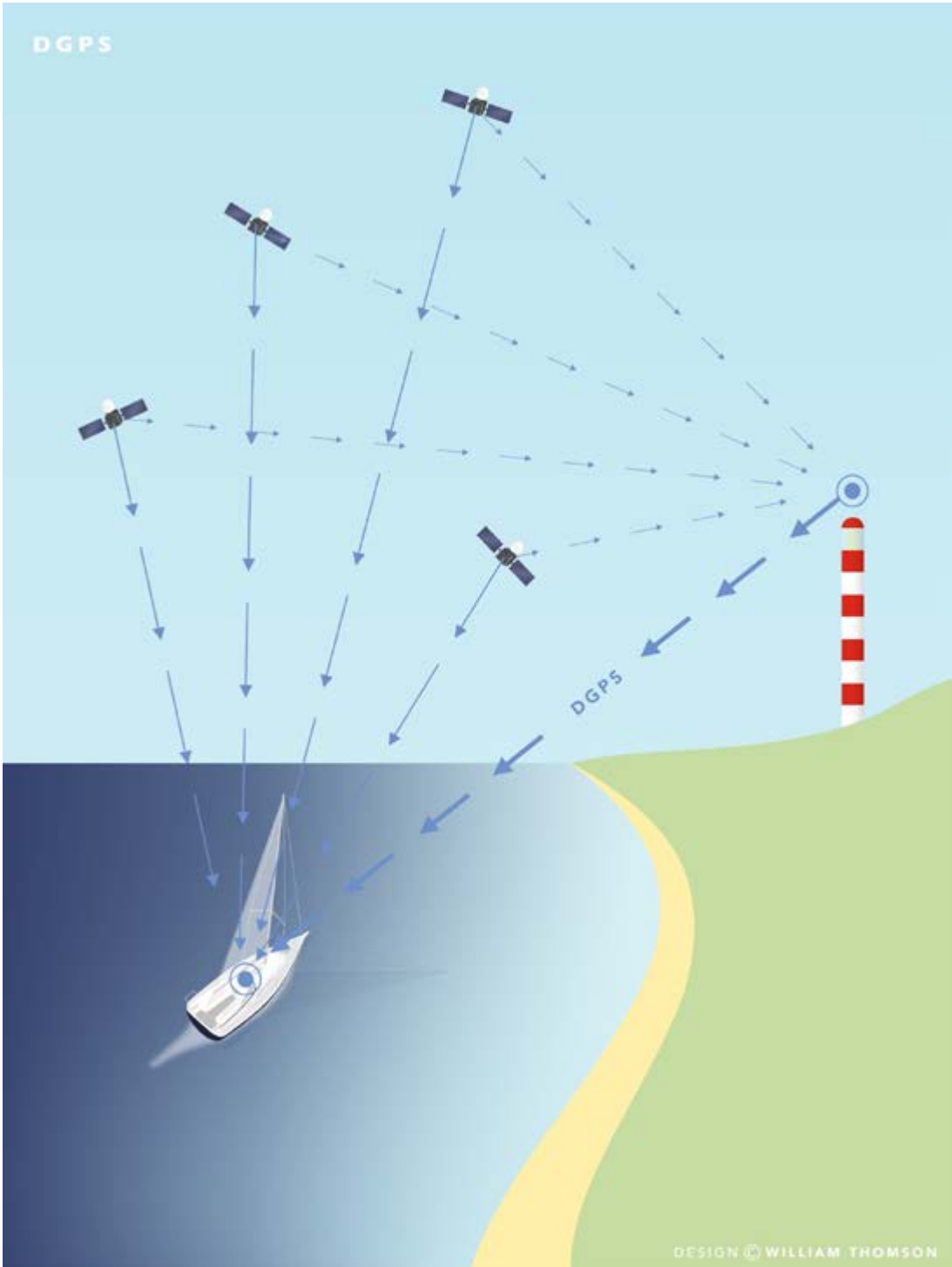
AIS AtoN

Some AtoN are now fitted with AIS transmitters. The positional technology is GNSS reliant. AIS AtoN fall into the following three general categories:

Real (or Physical): An AIS AtoN is located on a physical AtoN. In other words the AIS transmitter is housed on an actual buoy, lighthouse or other physical structure, helping to pinpoint its actual location.

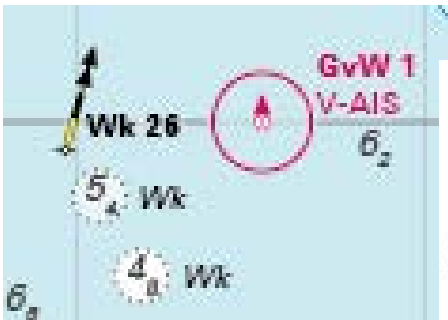
Synthetic: A virtual AIS AtoN is displayed over a physical AtoN but transmitted from another location. In other words there is an actual physical structure but the AIS transmitter for that structure is located elsewhere. The transmissions create an AIS target at the assigned position of the physical AtoN.





DESIGN © WILLIAM THOMSON

Virtual: AIS AtoN messages are transmitted but no physical AtoN exists in that location. In other words there is no actual buoy, lighthouse or other physical structure and the AIS transmitter is located elsewhere. The transmissions create an AIS target at the desired location. Virtual AtoN can be rapidly deployed by the authorities where it would otherwise take some time to deploy a physical AtoN. A particularly good use of virtual AIS is the creation of a series of virtual AIS targets to indicate the actual extent of an iced-up area as monitored by ice-surveys, or the position of a large ice-berg as tracked by satellite. Deep water TSS can also be marked this way. Another possible use is the virtual AIS marking of a *confirmed* wreck site before physical buoys can be put in place. However, virtual marking of areas of danger, such as obstructions and wrecks, is only likely to become more commonplace in conjunction with future developments in the VHF Data Exchange System (VDES).



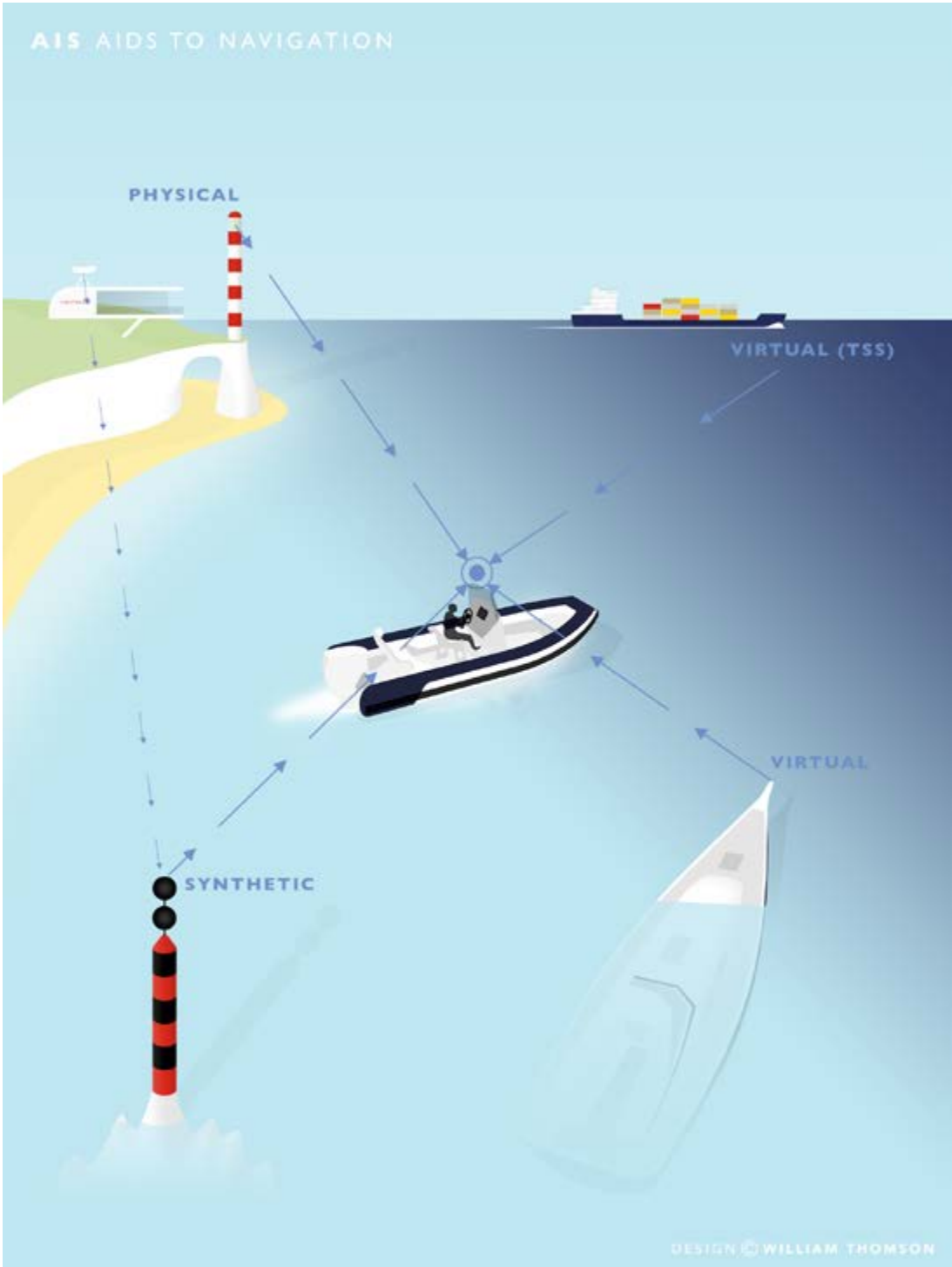
Virtual AIS AtoN are shown on charts as V-AIS



As long as we have an AIS receiver, the advantages of AIS AtoN are that we can positively identify buoys, lights and other navigation markers, whatever the weather. AIS also provides us with additional information about the characteristics of the physical AtoN and can act as an 'off station indicator' by showing when a floating AIS-AtoN has moved out of its charted 'guard ring' (or swinging circle) (see page 33).

It is important to understand that AIS positional information is derived from GNSS and is, therefore, subject to the same vulnerabilities.

Worldwide, there is some concern over proliferation of unauthorised or improperly risk-assessed use of AIS markers – fishing pot buoys are a good example. Our screens might become so cluttered that we stop seeing some of the important targets.



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Keys to safety

We must understand that **we might lose GNSS** because of obvious problems such as power failure on our own vessel (see Chapter 4).

We must also understand that **wider, usually temporary, GNSS failures or issues do happen and resultant position errors may not be apparent to us**. Some receivers provide error 'flags' or integrity indications, such as HDOP or GNSS signal loss indications. However, GNSS issues are not always clearly flagged. We should remain aware of the possibility of false GNSS position reporting.

We should further understand that **any GNSS failure impacts on onboard systems** using GNSS derived input, including GNSS compasses in autopilots. We should always factor this into our passage planning and take routine precautions as follows:

No single aid to navigation system should be used in isolation. Whenever appropriate we should use all alternative means available to cross-check our GNSS position against information from another source such as: a bearing, a charted object or a radar range. These navigational skills are as important as they ever were (see Chapter 5).

Visual AtoN, such as buoys and other markers, continue to give a good visual cross-check of position that is independent of any GNSS reliance of their electronic features. **A physical buoy will continue to be a physical buoy even if electronic systems fail.** It is a good idea to passage plan to pass close enough to visual markers such as buoys to enable position cross-checks along the route, even if that means deviating from the shortest and quickest course. But we must not pass so close that we run the risk of hitting them (see *AtoN positioning page 33*).

Chapter Two

Electronic charts and their display systems

Terminology around electronic charting can be very confusing. There are some important differences between various products:

Electronic Chart Display and Information System (ECDIS)

These electronic chart systems are used on commercial ships and are approved by national authorities under international standards, and conform to a formidable list of regulations when being used for paperless navigation. They involve costly hardware, software and licensing and their sheer size usually demands physical space requirements that put them well beyond the reach of the leisure user. They may be installed in duplicate if the vessel so chooses. Robust backup power systems are in place to guard against unexpected power failure. The information integrated by ECDIS includes ENC's (see below) and GNSS positioning as well as information from the ship's gyro compass and the ship's speed log. ECDIS can also display information such as radar, echosounder and AIS through an optional electronic overlay.



Electronic Chart System (ECS)

An ECS is any other electronic chart system that does not meet the requirements of ECDIS. It does not have to be able to display ENC data and can be solely a raster system. On some vessels, such as some types of commercial fishing boats and small commercial yachts, specific types of ECS may be certified to use official raster data in a way that does meet local requirements.

Leisure chart and information display systems

Electronic display systems for leisure sailors include purpose built chartplotters as well as PCs, laptops, tablets and smartphones. None of these leisure systems are required to meet the standards set for ECDIS or ECS authorisation.

Increasingly, many leisure display systems allow complex integration with other onboard systems such as wind instruments, log, radar, AIS, cameras and even engine information in a Multifunction Display (MFD). However, there are some important considerations:

Screen size: A major drawback of electronic charts on small vessels can be a limited screen size combined with a lack of detail when zoomed out at small scale. This makes it difficult to view a whole passage at a reasonable level of detail in order to absorb the relative positioning of any dangers and key points in the route. Without such an overview of the route it is very easy to become disorientated or oblivious to nearby dangers when zoomed in within one section of the route.

GNSS dependency: A number of leisure electronic chart display systems are particularly vulnerable to any loss of GNSS signal because there is no means of reverting to traditional methods of position fixing on their displays. For example, it is usually possible to drop a waypoint onto the screen but not to plot several bearing lines and a fix (see Chapter 5). It is important to know whether our system has this functionality. If it doesn't we need to have non-GNSS-dependent backups.

Standardisation: Leisure display systems are all designed to be intuitive but there is no standardisation. There are many different manufacturers, who pitch to different sectors of the market. All the manufactures use a variety of buttons and menu-driven settings in their systems, which not only differ between manufacturers but also between different models from the same manufacturer. Without product-specific training we are often unaware of how to use important functionality or to access key information. It takes time to gain familiarity with each system.

Marine resilience: There is a wide variation in the robustness of leisure chart display products in the marine environment, including their vulnerability to loss of power (see Chapter 4) or water damage.

IHO standards

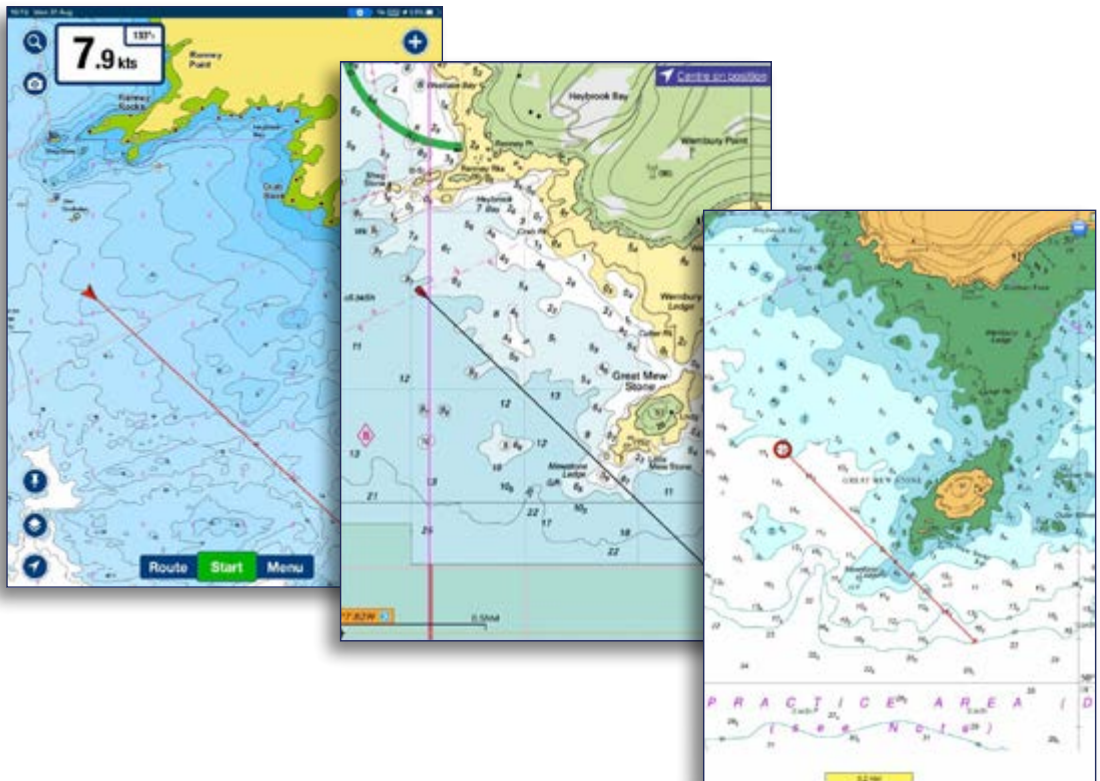
A number of ENC, RNC and ECDIS standards have been developed by the IHO to ensure that all ENCs are accurate, secure and can be interpreted correctly by type-approved ECDIS. The S-57 standard governs the data format, or 'language', for hydrographic data and also defines how an ENC is constructed.

Electronic Navigational Charts (ENCs)

Official, up to date, IHO-compliant ENCs are vector charts (see page 22) displayed in ECDIS and are now required on most commercial ships. ENCs can only be produced by the authorised Hydrographic Office (HO) of the relevant coastal state, unless that state authorises another HO to produce ENCs on their behalf. ENCs go through a process of IHO approved validation to make sure that none of the content could cause an ECDIS to malfunction and they also meet IHO standards for data authentication and the presentation of symbols, lines, colours and so on. HO's also produce Raster Navigational Charts (RNCs) (see page 24).

Electronic charts for leisure vessels

There are many benefits to electronic charts for leisure use. They are affordable, convenient, and mostly intuitive to read and they can be regularly and automatically updated. They can also provide information which is useful for leisure users but which would have no relevance for large ships. Although primarily based on the same HO data as official ENCs, the software and operating systems of most electronic chart products for leisure sailors are not validated to the same IHO standards as ENC displays for commercial vessels. Different manufacturers use different colours and chart symbols, which can be confusing when switching between systems. Specific functionalities and the processes for updating are usually unapproved by any official body. This is why they are considered unofficial and marked “not to be used for navigation”.



Vector or Raster electronic charts

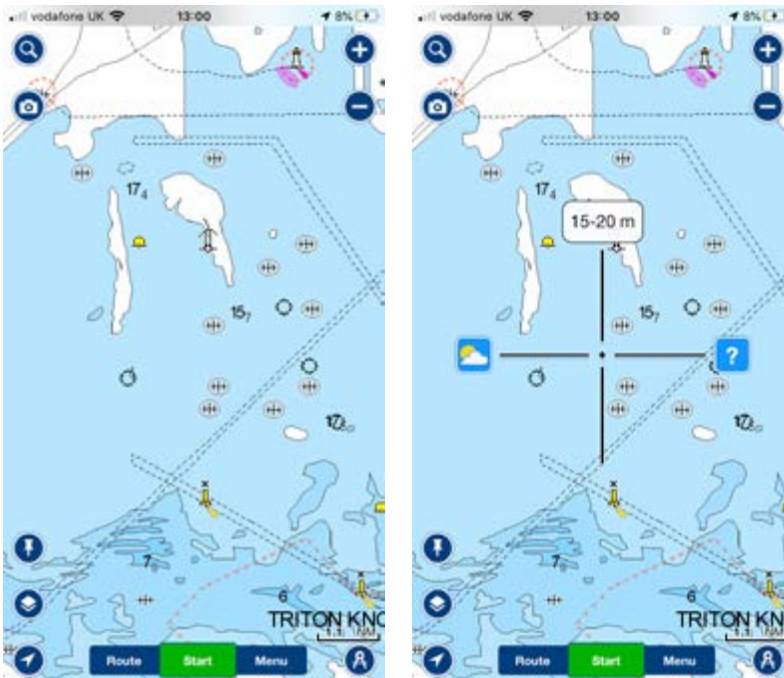
Until relatively recently, the data on electronic charts was extracted from paper charts. Now, it is more usually derived directly from survey data held in digital hydrographic databases. Within these databases, each charted feature or object is associated with a geographic location and with metadata or 'attributes'. Chart display software allows the data to be presented visually in one of two forms; vector or raster:

Vector leisure charts

The vast majority of electronic leisure charts are vector charts. A vector chart does not look like a chart until it has been run through a display system. It is really just lines of code with data embedded into it. It is the display system that allows us to see the data in the form of a chart. A vector chart is produced using a data management process which allows the selected chart to display quickly and without excessive clutter. To achieve this, the data is accessed in layers. The chart visible on the screen is a presentation of the stored data set for that particular level of zoom. This means that words and symbols on the screen stay the same size regardless of zoom. But it also means that important features can appear and disappear at different levels of zoom.

Again, in order to reduce clutter, the characteristics of various features are usually not shown. Instead we can 'interrogate' each feature to access further layers of information. For example, we would interrogate a light to find its description and characteristics.

The level of detail shown will have been customised by the manufacturer and can usually be modified by the user.



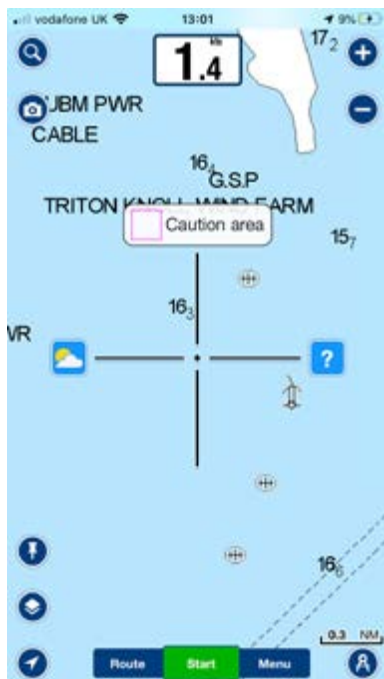
In these screenshots (left and page 23), the 'windfarm under construction' data is not fully visible until zoomed in and interrogated

Key features of vector leisure charts

- Information can be tailored to the leisure sailor
- The coverage appears seamless without ‘jumping’
- A similar level of clarity is retained at all levels of zoom
- The memory (RAM) requirements are typically a lot less than raster, which means faster loading, refresh and response times
- Each individual object within the chart is georeferenced and associated with ‘attributes’ or metadata. This chart data is ‘intelligent’ and can be interrogated, not only by the user but also by appropriate integrated software, to generate routes, warnings, alarms, and many other features
- Vector chart data is stored in a database which can be updated at any point in time and easily ‘pushed’ to the software or display system

Some things to be aware of with vector leisure charts

- To avoid cluttering, some data is only accessed when zoomed in to a large scale. This means that some vital information, such as small islands, TSS, and shallow areas, may not be visible when zoomed out at small scale
- If there isn’t enough data available at large scale (zoomed right in) whole areas may become blank
- Positioning of labels may be confusing at some levels of zoom
- Symbols may vary in shape, size and colour from those used on raster/paper charts and unfamiliarity can lead to misinterpretation
- On some systems metadata, such as information about source surveys, age of data, and horizontal and vertical datums, is omitted or hard to find, so it becomes much harder to make judgements about data quality (see page 31)



Raster leisure charts

A raster electronic chart was originally a scan of a paper chart. The way that raster charts are produced has now changed but the principle of equivalence remains the same and they still look like a paper chart and may be printable as a paper chart. Raster charts are now based on the same data as vector charts but they are displayed as an image, fixed at a specific scale, with coordinates attached to locate the geographic extent of the chart. It is a bit like taking a screenshot of a section of a vector chart at a specific level of zoom, but with the same attributes visible that are normally shown on a raster chart. In other words, a raster electronic chart is a series of pixels. There is no data embedded into it and so there is nothing to 'interrogate'. If we want chart display software to make any kind of calculation or command relating to a raster chart, it needs a database in the background (most likely holding the same kind of data that is embedded in a vector chart).

If you zoom in or out on an individual raster chart, nothing new appears and nothing existing disappears. Words and symbols on screen simply get bigger or smaller with the zoom. Zooming in on a raster chart is an equivalent process to looking at a paper chart through a magnifying glass.

Some 'quilted' or 'mosaiced' leisure raster chart products will automatically switch (or jump) to a larger- or smaller-scale raster chart (if there is one) at appropriate levels of zoom. They will also peg adjacent chart areas to one another to give a continual coverage area beyond the boundaries of an individual paper chart.

The information displayed on any raster chart is selected by skilled cartographers. If the chart has been tailored for leisure users it may have some deep-water information stripped out, such as deep water wrecks, and it may have shoal water information included. It may also have additional information such as small vessel marinas and anchorages, but the tailoring will always prioritise the display of hazards.

Note that while UKHO Small Craft Paper Chart Folios and Imray (Imray Laurie Norie & Wilson Ltd) leisure paper charts are officially recognised by the MCA for carriage on Coded Vessels, currently no leisure electronic charts are, whether raster or vector.

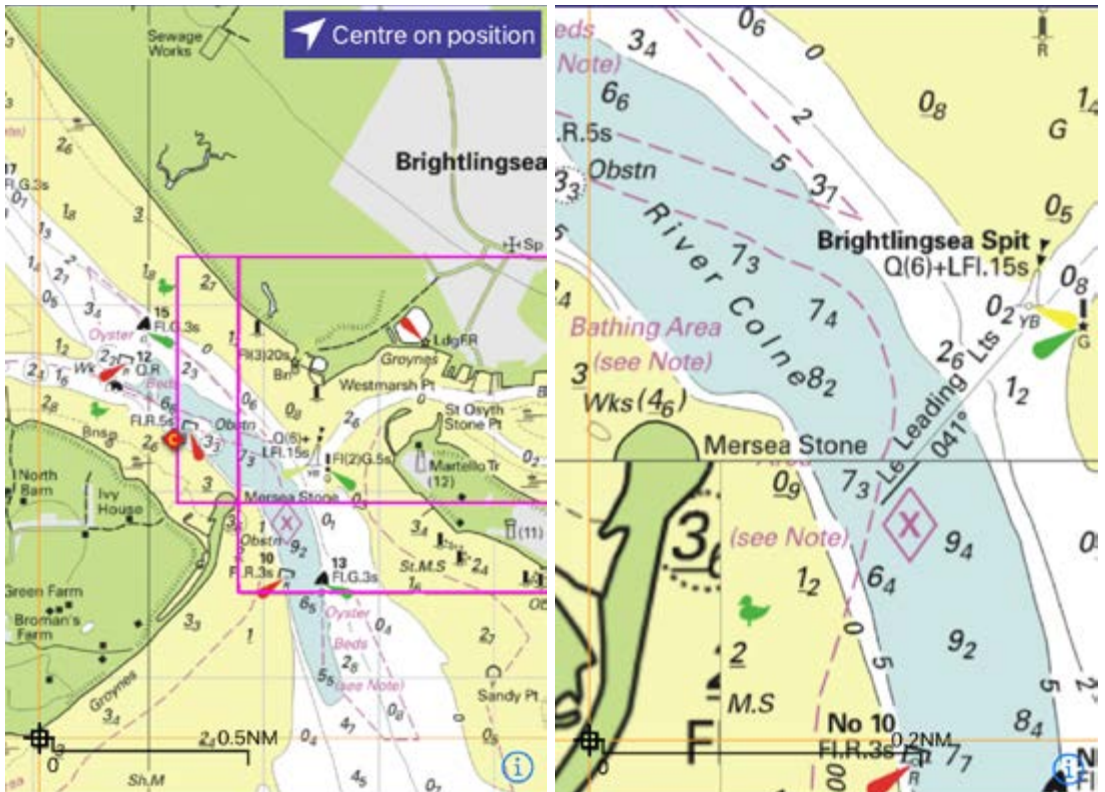
Key features of raster leisure charts

- Information can be tailored to the leisure sailor
- It conforms to the same standards as a paper chart
- Everything that appears on it has been considered for inclusion and verified by a human expert
- Details such as light characteristics are shown at the primary level (no need to go to a secondary level to see details)
- Metadata such as information about source surveys, age of data, and horizontal and vertical datums may be included, allowing a judgement on probable accuracy (see page 31)

Some things to be aware of with raster leisure charts

- On quilted raster products, at the joining boundaries of the individual raster chart images there can sometimes be problems in matching the scales of adjacent charts such that there is a visual 'step' in the chart detail. This can compromise clarity and, occasionally, compromise important detail
- On over zooming, if no larger scale chart is integral, details can become distorted by pixelation
- Selection of displayed information may be susceptible to human error
- Memory requirements are relatively high so loading can be slow

- Metadata is sometimes omitted or hard to find so it becomes much harder to make judgements about data quality (see page 31)
- The user cannot interrogate individual objects, characteristics or features within the chart itself. This means that features such as route planning, alarm and warning systems rely on a separate database rather than being embedded in the chart
- The production process is slower than for vector charts, meaning that updates are generally produced less frequently



In the screenshots above, we can see that at the joining boundaries of raster chart images any mismatch in scales can sometimes create a visual 'step' in the chart detail graphic

Chart accuracy

The fact that we can zoom in on electronic charts, whether they are official ENCs or leisure charts, tends to seduce us into feeling that we are navigating at a very high level of accuracy. But this may give us a false sense of security because the charts may not be as accurate as we think. The level of chart accuracy depends on both the hydrography and the cartography:

Hydrography is the gathering of hydrographic data from the sea floor by hydrographic surveys.

Cartography is the presentation of this data in the form of charts. Hydrographic data underlies all of our charts, whether paper, raster or vector.

These are two quite separate, highly skilled and focussed professions, each with its own very significant challenges. Commercial chart providers are not significantly involved in hydrographic surveying.

The creation of all charts is dependent on data from hydrographic surveys. The interface between hydrography and cartography is an important factor in the final quality of charts presented.

Hydrography

Despite the multitude of data that have been collected over the years, less than fifteen percent of the world's ocean depths have been measured and about half of all the world's coastal waters shallower than 200m remain unsurveyed to modern standards. These shallower coastal zones are mostly where we, as leisure sailors, choose to be, so this lack of survey data can be more of a problem than we realise. And it is predicted to get worse, not better. When small commercial vessels were plying our coasts for trade and nudging into the smallest of ports, sometimes anchoring in shoal bays to await the tide, sometimes heading up estuaries and rivers far inland, then there was sound commercial sense in surveying and charting all sorts of nooks and crannies that would appeal to the leisure sailor of today. But almost all of the commercial focus is now on big ships and deep channels. Shoal areas are not being re-surveyed and even historic large scale coastal data is sometimes simply being archived and is no longer available as it is not being digitised.

Historic depth survey techniques

Depths used to be obtained by lead line. In inshore waters this meant rowing or sailing a small boat along straight lines parallel to one another, at intervals casting a lead weight attached to a measured and marked line. The spacing between lines would depend to a large extent on what was expected to be found. In areas deemed to be more important, a metal bar or chain would be towed at a depth below the surface to ensure there that no isolated rocks had been missed that might be shallow enough to cause damage to shipping.

Inevitably a great deal of detail was missed, including important shoals and rocks. But over the years, reports of much of this missing detail were submitted, so that data accumulated and the quality of the charts became pretty good for normal navigational purposes. However, particularly in more remote places and in shallow coastal areas, there were still many hazards not adequately recorded on the charts.

Historic positioning of hazards

Horizontal positioning of identified hazards was generally done by triangulation. The accuracy would depend on the availability and accuracy-of-positioning of features ashore that could be used as reference points. The resulting positioning of the features would tend to be better inshore than offshore but still of unreliable accuracy when compared to the modern satellite-based positioning systems that are now available to us all. In other words, hazards positioned using old techniques may not be shown in their correct, satellite-derived position.

Modern surveys

Surveys commissioned by Hydrographic Offices (HOs) must now conform to International Hydrographic Organization (IHO) Survey Specifications. These require that both positioning and depth accuracy are strictly controlled. Modern hydrographic surveying has enabled much more accurate data collection with multibeam echosounders and GNSS positioning, specialised survey craft, including sub-sea drones, and optical (Lidar) depth measurements from aircraft, satellites and aerial drones.

Lidar

Originally a merging of **Li**-ght and **ra**-dar, Lidar is now commonly described as **L**ight **D**etection and **R**anging. It uses pulsed laser light to measure depths.

Ongoing limitations

Even with the latest technology there are still some limitations. Costs have to be justified, so shallower areas unlikely to be used commercially often still have incomplete survey data.

In some parts of the world, including the UK, huge effort has been put into correcting the historic horizontal positioning of known hazards as well as improving the depth data. But even with all of the latest equipment, there is a risk of detail being missed or wrongly recorded. False echoes can still occur – for example from weed that is colonised with barnacles, or contains air bubbles, or where fresh water mixes with salt water and causes unpredictable and erratic refraction errors. Information can be missed in the shadow of taller rocks. Computer algorithms are used to smooth out any spurious depth data, but algorithms don't always achieve the intended result. The physical characteristics of the underwater environment mean that it is still easier to survey the surface of the moon than the seabed!

Crowd Sourced Bathymetry (CSB)

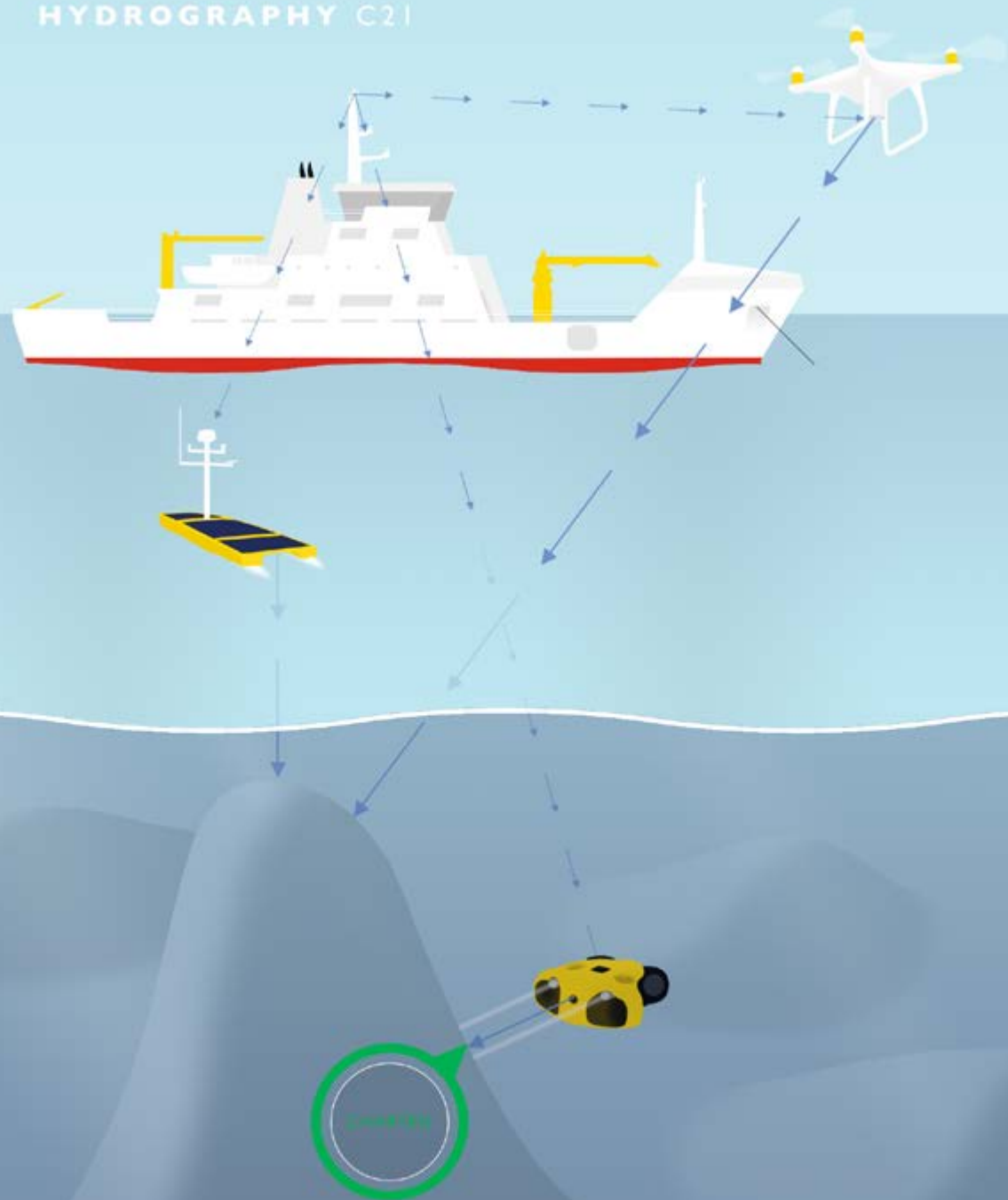
There is an ever-increasing body of CSB data available. Non-survey vessels, whether commercial, fishing or leisure craft, can automatically submit their depth and position data from their instruments for incorporation into electronic charts. With crowd sourcing, quality control has to be conducted algorithmically, with little knowledge of the circumstances in which individual data points were gathered. Reports from individual vessels have always been liable to a level of inaccuracy because so much depends on the localised circumstances at the moment that the data is recorded. For example, echo sounder readings can be less accurate over soft mud and any fouling of the transducer can also limit accuracy. However, in areas where numerous vessels are engaged, any blips in the data tend to become ironed out over time.

HYDROGRAPHY C18



START SURVEY





SANDBANK SHIFTING

Sediment shifts

In some coastal waters sand and gravel can move rapidly, sometimes to a significant extent during a single onshore gale. A good example is the Thames Estuary. These areas tend to be re-surveyed frequently, and to a high standard, but shifts can occur very quickly after a survey.



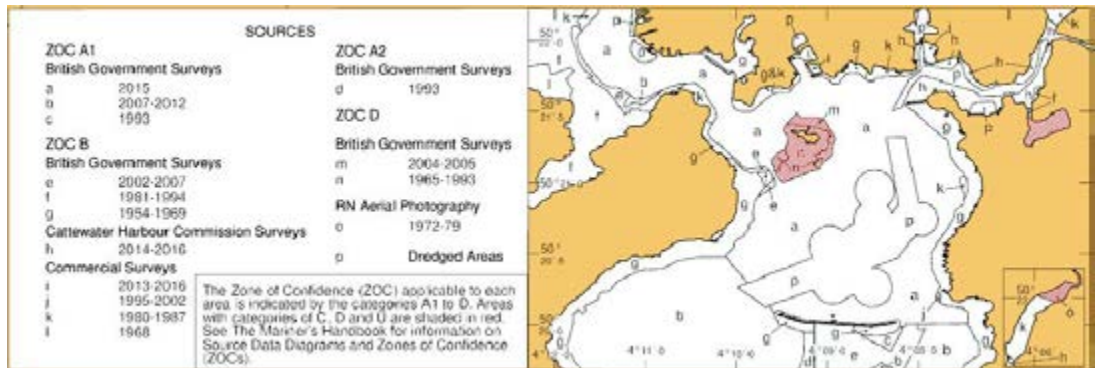
Cartography

Presentation of accuracy of data

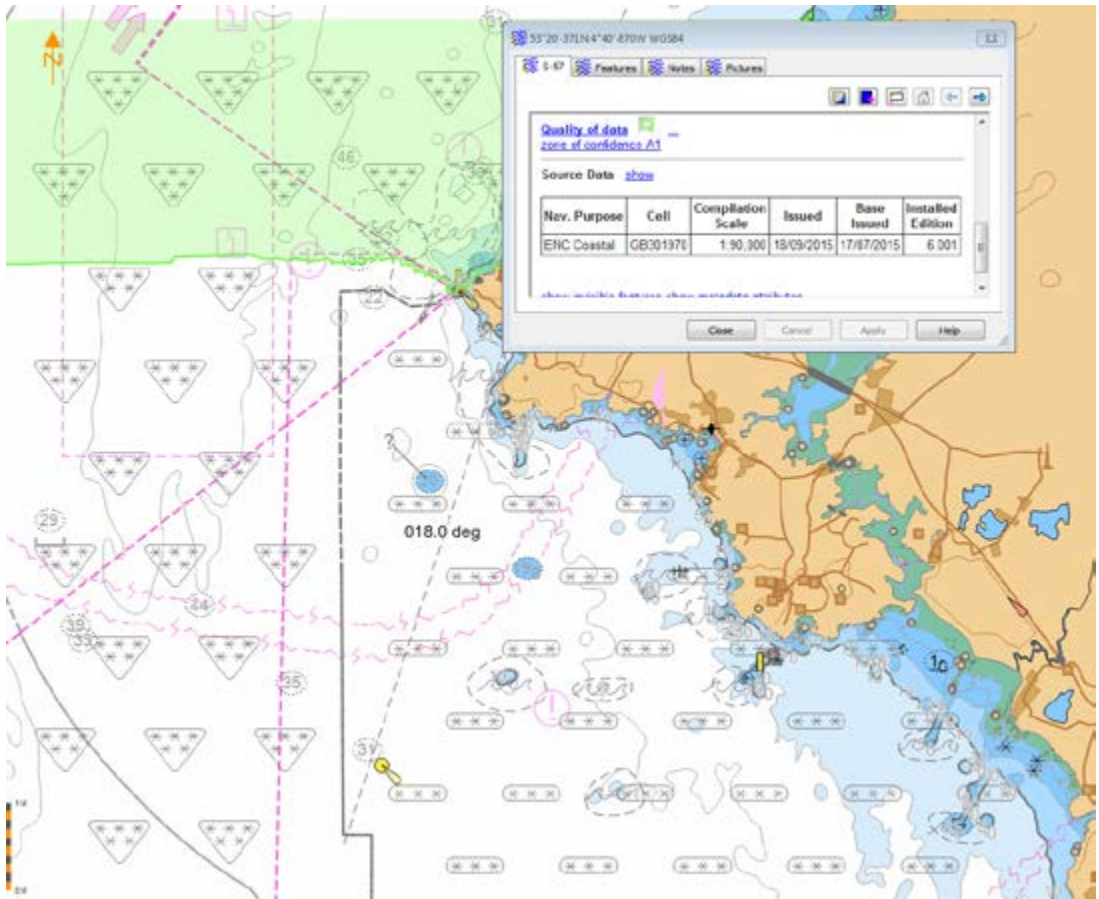
Most charts, whether paper or electronic, are compiled from a large number of surveys. These surveys will have been carried out at widely differing times, using different survey methods and to different levels of quality assurance. Each survey will have covered areas that are commercially relevant and accessible to the surveying equipment, rather than with the leisure sailor in mind. The shallowest waters, where we leisure sailors may choose to venture, might only be covered by older or much less reliable surveys. But we don't always realise this because the old and less reliable data may be presented seamlessly alongside the newer, more accurate data.

Understanding the limits of accuracy of the underlying data on our charts helps us to manage the level of risk when we are navigating in a particular area. Approved paper charts always give dates of surveys and an indication of accuracy, whereas electronic leisure charts usually do not. This is an important factor that ENCs on ECDIS systems have attempted to address.

ENCs display CATZOC values. These categories of zone of confidence figures are unfamiliar to most leisure chart users. They indicate the areas in which the underlying hydrographic data meets a minimum set of criteria for position, depth accuracy and seafloor coverage. In other words the ZOC indicates the position and depth accuracy of the data presented on different areas of the chart. A1 indicates the highest accuracy of survey, D the lowest, with U for unassessed.



EData quality on an RNC of Plymouth Sound compiled from a combination of accumulated surveys carried out between 1965 and 2016: The ZOC category D areas are shaded red to emphasise low confidence in the data.



Data Quality on an ENC: Geographic regions that were surveyed using the same methods and share the same accuracy characteristics are assigned a triangular symbol pattern with an equivalent number of stars. The number of stars contained within the symbol denotes the Category of zone of confidence. Six Stars equates to category A1, three stars is category C.

Chart production

The data presented on electronic charts is now mostly derived directly from survey data that has been processed and stored in digital hydrographic databases. Within the database, each charted feature or object is associated with a geographic location and with metadata or 'attributes'. Chart display software allows the data to be presented visually. The data can be readily updated, but the frequency of updates varies widely from area to area.

Some hydrographic offices have ceased raster nautical chart production altogether. Other HOs continue to produce raster chart versions. Individual raster charts may continue to be printed as paper charts. The key point to understand is that stored survey data is now used to build charts in all their

forms, rather than electronic data being extracted from the paper chart. This should mean a more precise equivalence between paper and electronic products. But the data accuracy will still depend on the source information.

AtoN positioning

Floating Aids to Navigation can break their moorings or be dragged “off station”. This is why they should not be used for position fixing. Even without any dragging, the **assigned** position of a buoy, which is its deployed sinker/anchor position, is not always precisely the same as its **charted** position due to charting constraints and anomalies. In addition, **its charted position is also unlikely to be its precise position at the water surface** - in tidal areas, such as around the UK, Ireland and the Channel Islands, where tidal streams can be in excess of 6 knots in some places, a buoy will rarely be found in precisely its charted position due to the scope of its mooring, unless it has some form of restricted mooring system, which is not currently common in UK waters. The actual extent and shape of a buoy’s so-called “swinging circle” depends on the charted depth, the height of tide and range, wind speed and direction, tidal stream direction and strength, the topography of the seabed, the length of chain or other mooring fitted, as well as other factors, such as if additional chain length is required to remain lying on the seabed to effectively add weight to the sinker. Rarely is it actually a circle. This may be particularly noticeable in narrow channels used by small craft in shoal tidal waters.

All Light Vessels and Light Floats in UK waters have their position monitored, and so do an increasing number of lighted buoys. Outside of major port/harbour areas, a good indication of whether a buoy is monitored is if it is fitted with AIS. In such cases, the authority concerned is provided with an automatic warning if a buoy drifts or is dragged outside of a pre-designated guard circle (which equates to the limits of the expected swinging circle).

Note: Notices to Mariners issued by the GLAs always refer to **assigned** position of floating AtoN.

Horizontal datum

A horizontal datum is the reference frame used to compute horizontal positions on Earth. GPS uses the World Geodetic System WGS84 as its coordinate reference system. The majority of modern charts are also georeferenced to a WGS84 compatible datum. However some charts, whether paper or electronic, are not georeferenced to WGS84. If this is the case it is necessary to input a datum correction.

Chart Offsets (Datum shifts)

Even apparently WGS84 compatible charts can contain some charted areas with a wholesale datum shift (or chart offset). In these areas the positioning of hazards and features relative to each other may be very accurate, but the whole area may be misaligned with the satellite derived positioning. In some remote places this offset can be very large (see Appendix I).

Satellite imagery as a navigational tool to mitigate chart offsets

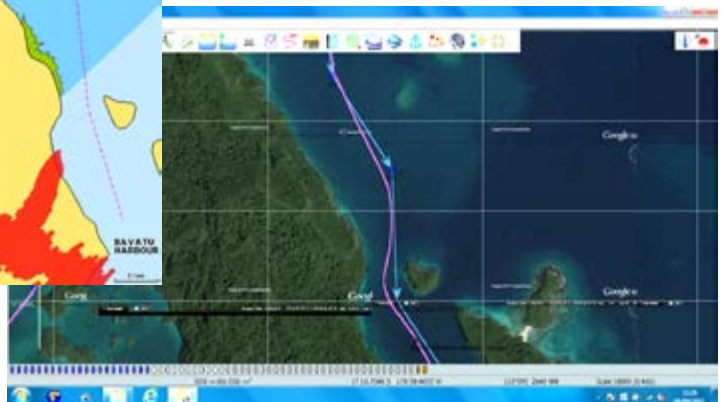
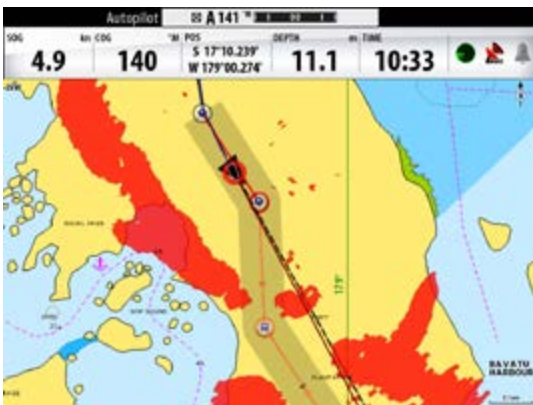
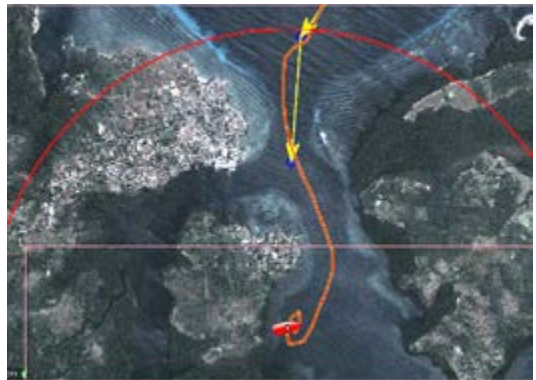
Although satellite images, such as Google Earth images, were never intended as a marine navigation tool, very helpfully such images are georeferenced using the WGS84 datum, which is the same datum used on the majority of modern marine charts. This means that in the less well charted regions of

Electronic Navigation

the world satellite imagery is a useful additional navigational tool, particularly at the passage planning phase with easy internet accessibility. It is perfectly feasible to zoom in on a specific location, such as a harbour or an anchoring spot, and in some cases, particularly for shoal water anchorages, you may find more surface detail than you do on a chart. You can often see shoals and reefs, sometimes with startling clarity.

The charted yacht track below appears to show the vessel deviating from the channel and onto the shore. The same track projected onto the satellite image indicates that it stays in the middle of the channel. There is a clear offset between chart and satellite positioning.

Satellite yacht track graphics to illustrate chart offsets



Combining satellite images with marine charts

Assessed by the human eye, the one key thing a satellite image cannot offer is accuracy of depths, nor does it show detail of buoys or other Aids to Navigation. But software is now available that allows the overlay of satellite images onto an electronic chart. This process helps to reveal how much the charted position varies from the satellite derived position – in other words it indicates the chart offset (or datum shift). It also helps to mitigate such an offset by allowing a repositioning of the layers to achieve the correct positioning.

Some things to be aware of

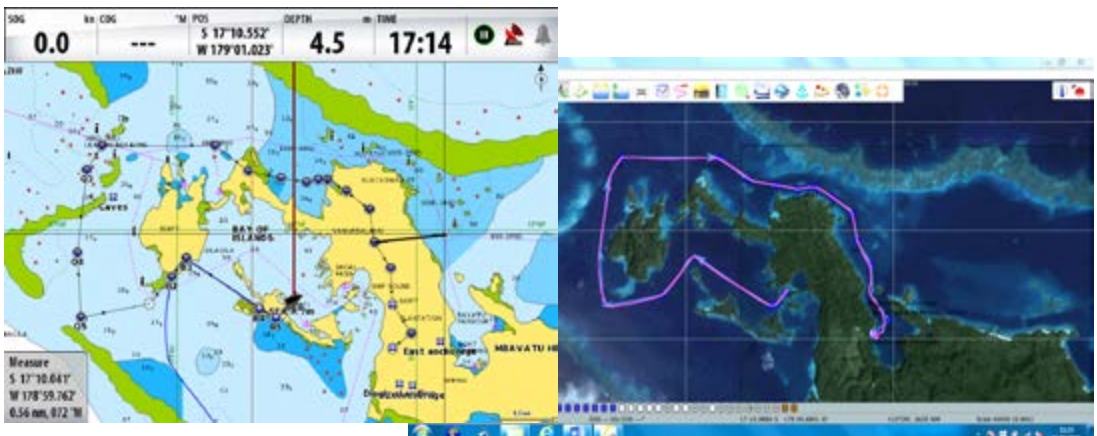
Satellite imagery is only another tool available to us. It has its limitations which include:

Missing data: Satellite imagery suppliers focus on providing images for populated regions and areas of interest to the general public, and the number of updates made to the images are based on commercial objectives. While most landmasses and their coastal areas are well represented, there are still small islands, shallow reefs and dangerous rocks that are yet to be covered in remote areas. Sea areas without satellite imagery are usually coloured a hazy blue. This can be misleading and it is important not to assume it is safe deep water; check your charts - there may be areas that have not yet been detailed.

Image Clarity: One of the biggest issues in relying on satellite images for navigation lies in the clarity of the images. Blurred images or images with cloud cover are not uncommon, making them of little or no use for navigational purposes. One potential source of help to overcome this is that Google Earth retains historical images and using a slide bar you can view older images which may provide better clarity. There are also several alternative providers of satellite imagery, such as Bing and others.

Location accuracy: While Google Earth uses WGS84 data for georeferencing the process is not fool proof as image capture is subject to vagaries such as the bending of light through the atmosphere. Google states that satellite images are not simply snapshots but a composite of multiple distinct frames which are then digitally combined. Errors do occur. Remember that these images are not intended for marine navigation.

Depth and other data: In areas of rapidly changing depths, such as sandbanks, satellite imagery should not be relied upon. The single date given for the image may cover multiple frames from different dates and may be misleading; the image being viewed could be much older than stated.



Electronic Navigation



An anchorage on the west coast of Scotland.

In 2019 the imagery was poor, but in 2014 it was much better, clearly showing the reefs.



Awareness of chart updates

All the evidence from Hydrographic Office and RIN surveys would suggest that, in general, we leisure sailors do not routinely correct our own charts from Notices to Mariners. Even our paper charts go steadily out of date without any corrections being made. It is one of the huge benefits of electronic charts that corrections can be achieved through automatic updates.

But there is a danger to automatic updates, particularly in familiar, home waters. The evidence for this comes from the world of commercial shipping where mariners routinely listened to or read Navigation Warnings and then actually put a pencil to a paper chart to make all the necessary changes. The process of that meant that they were tuned in to any updates. Automated updates that are silent and unflagged are much more likely to go unnoticed. In unfamiliar waters we all tend to look more carefully at everything and we will absorb key information from the updated electronic chart we are working on. But in home waters we can become complacent and we might not notice that a sandbank has shifted and a buoy has been moved. If we set our track using a waypoint we have regularly used, we may end up on that sandbank.

Mariners are still encouraged to plot and process all Navigation Warnings such that the skipper/ navigator is aware of the danger such a change may present. We should all be aware of the importance of giving Navigation Warnings the attention they deserve. This means a fresh and careful passage plan, or at least a review of it, each time we sail, even in home waters.

Keys to safety

We should understand that:

Hazards positioned using old surveying techniques may not be shown in their correct, satellite-derived position. This is true for every chart, whether paper or electronic, however recent an edition.

Hydrographic data is likely to be less accurate in shallow areas of low commercial interest.

On a vector chart, at a particular level of zoom, we are only seeing partial information. Some critical hazards may not be displayed at every level of zoom.

Crowd sourced data (see *page 27*) can be really useful in poorly charted areas, but it also carries a risk of inaccuracies. Use with caution.

In areas where the seabed is frequently shifting, even recently charted hydrographic data cannot be entirely relied upon.

Floating AtoN are often found not precisely in their assigned or charted position because of their swinging circle.

Floating AtoN can occasionally be dragged off station or break their moorings as a result of adverse weather conditions.

Automated chart updates can go unnoticed, particularly in familiar waters.

We should passage plan with all of these factors in mind, leave some margins for error and routinely cross-check the accuracy of our position and charts, whether electronic or paper (see *Chapter 5*).

Chapter Three

Using Radar and AIS

Radar and AIS are particularly useful to us at night or when visibility is poor, but even in perfect conditions they may allow us to ‘see’ beyond our visual horizon as well as providing additional information. This means that we have more time to assess any developing risks and respond safely. Each gives us extra tools in our navigational toolbox.

Radar (Radio detection and ranging)

Radar works by transmitting a beam of radio frequency energy from a radar antenna (on leisure vessels this is usually housed in a protective “radome” rather than being a rotating “open array” scanner). The transmitted energy is reflected back from any objects in the path of the beam. Usually, the same antenna then receives the reflected signal. A radar processor then amplifies and optimises the received information to allow a clean display of radar targets. Radar displays on small craft might be stand-alone or might be an overlay on an electronic chart screen integrating data such as direction, speed, and so on.

The majority of marine radars operate on X-band (at a frequency of 9GHz). Large vessels are usually also equipped with radar operating on S-band (at a frequency of 3GHz) which has benefits in fog and rain but requires a much bigger antenna – too big for most leisure vessels.

Radar does not rely on ‘cooperating’ targets. It can detect passive, non-transmitting, land masses and large floating objects such as vessels, buoys or icebergs. Radar operates independently of satellite-based navigation systems (GNSS) and is less vulnerable to natural or accidental signal interference, though not completely immune to malicious disruption.

Understanding Radar

The transmitted energy diverges from the antenna. Only a small fraction of the transmitted energy will hit a target. Some of the energy is absorbed by the target; most of it is reflected back. But again the reflected energy diverges. The return energy that arrives back at the transmitter is much less than what was transmitted and the energy levels in both directions diminish rapidly over increasing distance. The range of radar is therefore very dependent on the power at which it operates. In clear conditions, under SOLAS regulations, a large commercial vessel is expected to have a minimum detection range for other large vessels of 11M. **In similarly good conditions, the minimum range for a large vessel detecting a 10m leisure vessel is only about 3M.**

Radar reflectors

Small craft usually return a very weak reflected radar signal and are therefore poorly visible or invisible except at very close range. Radar reflectors improve the reflectivity of the vessel. Broadly speaking, radar reflectors are either passive or active:

Passive reflectors work by providing reflective (metallic) surfaces in several different planes (or angles). Commonly these used to be simple octahedral designs made of aluminium. More popular nowadays are reflectors housed within polyethylene cylinders.

Active radar reflectors or Radar Target Enhancers (RTE) help to enhance, or boost, the return signal. Nevertheless, the relatively small size and low power of these reflectors mean that the vessel may remain only weakly visible on radar, particularly in rain and/or big seas. RTE are frequency specific. Dual band versions are preferable to single frequency versions because other vessels may not be on the same single frequency.

Whether passive or active, the effectiveness of radar reflectors can be diminished depending on the angle of heel of the vessel.

SOLAS Regulation V/19 requires all small craft (less than 150GT) to fit a radar reflector or other means, to enable detection by ships navigating by radar at both 9 and 3 GHz 'if practicable'

Radar beacons (Racons) on AtoN

Racons are receiver/transmitter devices used on fixed or floating AtoN to help improve their identification. They are particularly useful to radar equipped vessels when visibility is poor. Since their initial introduction, advances in technology have extended their application and use to include:

- Range and identification of positions on inconspicuous coastlines
- Landfall identification
- Leading lines
- Centre and turning point identification in precautionary areas or in Traffic Separation Schemes
- To mark new and uncharted hazards (Morse D)
- To indicate navigable spans under bridges

Most Racons deployed worldwide are now dual frequency X and S band. They operate independently of satellite-based navigation systems and are particularly useful to radar equipped vessels when visibility is poor. Their operation, like radar itself, is independent of satellite-based navigation systems.

Using Radar on a leisure vessel

Radar is naturally vessel-relative which helps interpretation of what is on screen; our vessel is shown as a fixed position on the screen, typically the centre, and everything else is positioned around us and appears to move around us in a relative motion. But in other ways radar settings and adjustments are not always intuitive to use and if we are unfamiliar with the relative motion presentation it can leave us disorientated. We might miss radar targets completely or we may misinterpret what our screen is telling us. It is particularly easy to become disorientated if we are manoeuvring at slow speed and/or in poor visibility when there is no visual horizon to help make sense of what we are seeing on screen.

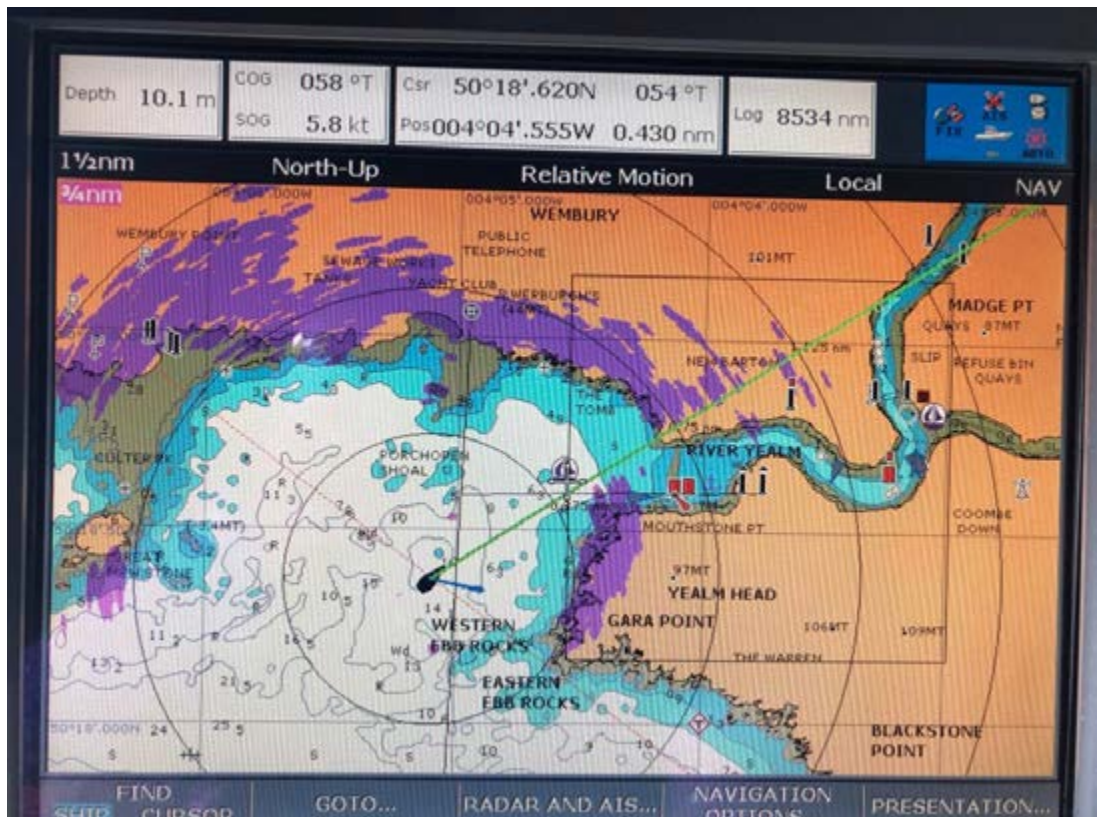
Radar overlay on a chartplotter can be very helpful in indicating chart offsets. If the radar positioning of a charted feature does not align with the chart it should alert us to be more cautious about our positioning assumptions.

The two main radar displays modes are:

- **Head-up:** the heading of the vessel is always towards the top of the screen. Targets will appear to move as the heading changes, which can be confusing for inexperienced operators
- **North-up:** the system orientates the display so that north is always at the top. Targets may appear to be more stable but the vessels heading will move as the vessel yaws

Note: Radar on a leisure vessel is now normally displayed on a chartplotter rather than on a stand-alone display. When radar is overlaid on a chart on a chartplotter the radar display will normally be north-up, giving direct positional orientation with the chart. To be truly north-up the radar will need an input from an electronic compass. Without this input most systems will estimate north based on the COG calculated by a GNSS receiver. Depending on the relative speed and direction of the vessel, and any tidal stream or leeway, this may be significantly different from actual north and would impact on the accuracy of the radar overlay and any calculations relying on north. If reliant on GNSS, the radar display or overlay will not usually be able to be displayed north-up without the vessel moving to create a COG.

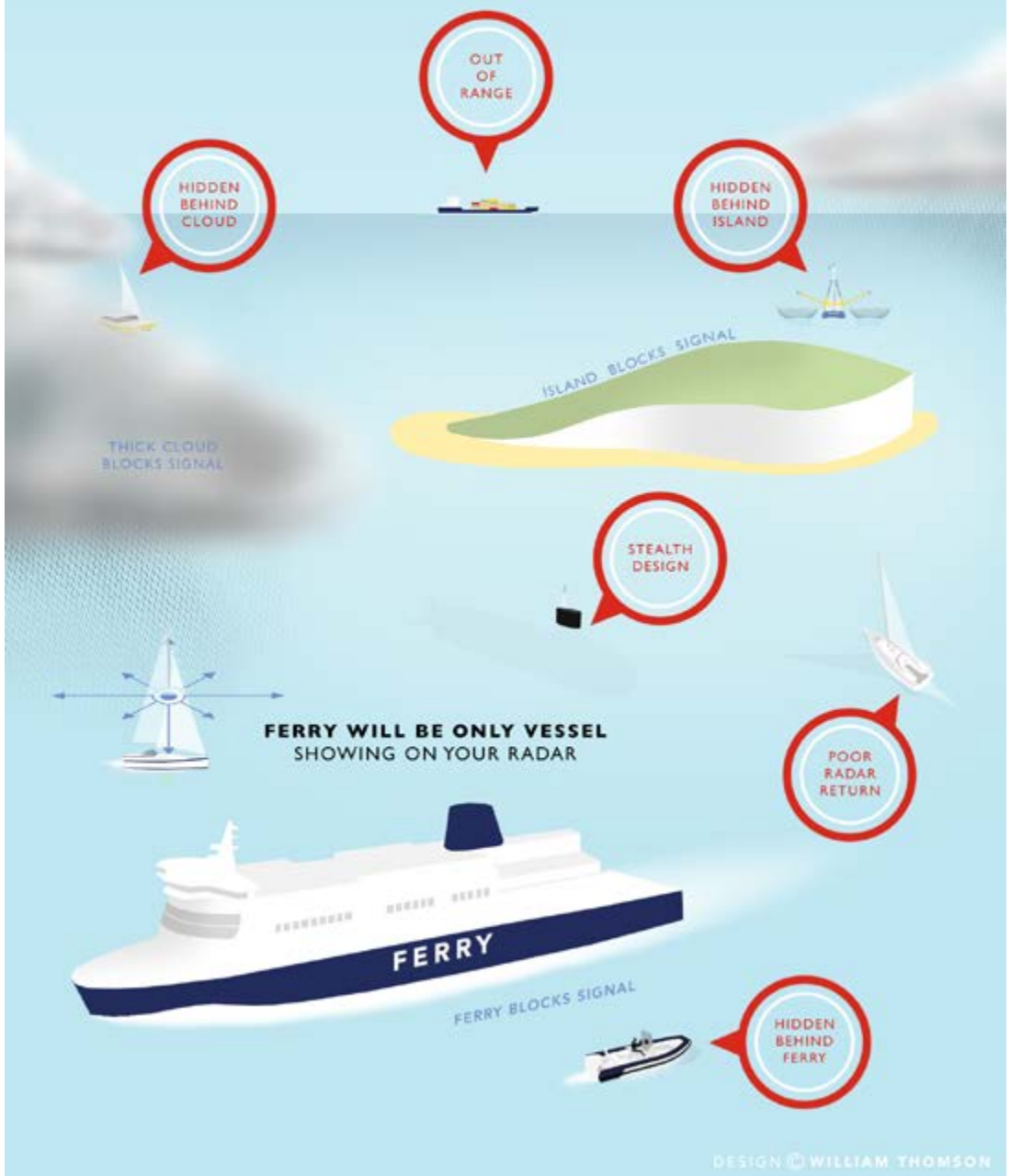
Here the fluxgate compass has about 15°E deviation, so this shows the issue with an overlay if not set up correctly. The chart is north-up but the radar is twisted anti-clockwise by the deviation.



Some things to be aware of

- **Power failure:** Radar is an electronic system and will stop working if its power source is lost
- **Systems failure:** Radar can suffer from failures within its own electronic system
- **Poor set-up:** Optimal adjustments of settings, such as gain control, require some understanding of the equipment. For example, if threshold is set too high or too low, targets will not be visible
- **Multi-path effects:** False targets can appear if radar has been reflected off the side of a large ship or building. In calm conditions, when radar can steadily be reflected off the sea, the direct path and the reflected path can either combine (which makes the target appear much bigger than reality) or they can cancel each other out (which makes the target disappear)
- **Shielding:** When a transmitted radar signal encounters a large 'shielding' obstacle, such as a nearby ship or a headland, the signal will be reflected and there will be a hidden area, or 'blind spot', behind that object. In other words, the radar cannot 'see' what lies behind the obstruction. A radar antenna should be fixed as high as possible on a vessel to help to reduce these shielding effects
- **Other blockages:** Even a mast-mounted radar on a yacht may be susceptible to reflection of the radar signal from objects nearby, including the mast itself or even the sails, particularly when sails are wet. These types of blockage can sometimes be permanent and can cause complex reflections that result in targets being displayed in false positions on the radar display. They can also reduce the target detection range in certain directions – even to zero in extreme circumstances
- **Clutter:** Rain and sea may 'clutter' the screen and thereby obscure important targets
- **Delay:** A radar image can take quite a few seconds to react to a rapid change in the direction or speed of a target
- **Operator experience:** Target heading, on which collision avoidance rules are based, is not always easy to interpret. Operator experience is needed
- **High powered radar:** Long range high power search radars on warships, when operating, can 'swamp' reception in low power small craft receivers by pushing so much energy into the receiving aerial that it makes it impossible to extract the returns from its own low power transmission. Regulations are in place to suspend such high power transmissions when in coastal waters, however, where Naval exercises are routinely conducted around the coast, especially off Plymouth, there will be high power radars in use for some of the time
- **Jamming:** Radar can be heavily disrupted by malicious jamming, though this is rare
- **Radar invisibility:** Naval (stealth) vessels are designed and built to minimise their radar visibility
- **Leisure vessel Radar systems:** May not comply fully with the requirements of the ColRegs for collision avoidance by Radar (especially Rule 7(b))

RADAR LIMITATIONS



Practise using radar

If we have radar we should practise using it in a variety of ways so that we feel comfortable in using it as a tool when we need it:

- Use the ranging function to give a navigational fix
- Use the electronic bearing line to take bearings (But note: Exercise care: Radar bearings are prone to inaccuracy on small vessel systems because of compass errors, scanning alignment and heading offsets)
- Use parallel indexing to set safe corridors of navigation (requires north-up display)
- Use relative bearing for collision avoidance (see page 50)
- Use the ARPA function to track vessels which may present a danger. Note that ARPA systems employ 'smoothing periods' so may be slow to react to small, frequent course alterations that can occur, for example, when using autopilot
- Use the CPA function to display the closest point of approach of a target



AIS

AIS (Automatic Identification System)

Vessels fitted with a transmitting AIS automatically send their position, heading, speed and some vessel details to other vessels in the vicinity. AIS transmissions use specific channels within the Maritime Mobile frequency band and require a VHF licensed operator. But access to AIS channels is fully automatic and so there is no tuning required by the user, even when installing the equipment. All AIS information is sent as simple digital data, with no voice or video capability. Transmitted information is automatically received by AIS equipment onboard other vessels. On small craft it is typically displayed as an overlay symbol on a chartplotter.

AIS Range

As with all VHF transmissions a number of factors limit the range at which AIS signals can be received by other vessels:

Even though AIS (VHF) range is much better than the range of human sight it is commonly described as being 'line of sight' because it is limited by:

- The curvature of the earth – though it usually transmits a little way beyond the visual horizon
- The height of the transmitting and receiving antennae
- Physical barriers to transmission such as a headland, mountain, high buildings, large vessels - though in reality an advantage of AIS is it often 'sees' round corners in a way that neither radar nor sight are able to

Other factors which affect AIS range are related to the weather conditions. Typically, transmissions from ships are directly receivable by other vessels out to 15-25M. However, for systems used on smaller vessels, the receivable range is usually more like 5-7M. A masthead antenna increases range and reduces any masking by swell and waves.

AIS SIGNAL DOES NOT BEND WITH CURVATURE OF EARTH



AIS Class A

According to national and international legislation, all of the biggest ships (vessels 500 GT and above) must be fitted with AIS. Vessels 300 GT and above must also be fitted if they trade internationally. These large vessels have to comply with extensive 'Class A' requirements for their AIS equipment. Class A systems broadcast their position-related data at much higher rates and at a greater power. They also send more detailed information about themselves.

Caution: Warships are not required to fully comply with all IMO regulations where those regulations may make it difficult for them to function as a warship. However, the Royal Navy uses tailored AIS that is configured to transmit selected identifiers, such as 'Warship' or 'NATO Warship' and 'Military Ops'. However, when deemed appropriate they may switch off transmissions and use a receive-only mode. Similarly, Border Force cutters do not always transmit on AIS. The same will be the case in most other countries for naval and other official patrol vessels.

AIS Class B

Any other vessels, including small leisure vessels, can voluntarily fit AIS, but normally only to the Class B standard. Fitted equipment must meet the requirements of national and international legislation for Class B systems.

Class B filtering on ships

Class A ships can choose to filter out AIS Class B targets. This is to avoid displays becoming cluttered in areas where there are numerous Class B vessels. Ships' masters/navigators can adjust their settings so that they will automatically display any Class B targets that become a potential collision risk, but this depends on appropriate settings adjustment. When ships have filtered out Class B targets a warning is permanently displayed on their screens.

In European Union waters, fishing vessels over 15m are required to have operational AIS onboard but rarely transmit.

Receive only

Many leisure vessels are fitted with receive-only AIS. This consumes less power than a transceiver system and does not need a radio licence to use. Receive-only allows an improved awareness of AIS transmitting vessels in the vicinity but means your own vessel is definitely not visible on AIS.

What types of data are transmitted on AIS?

Three types of data are transmitted: Static, Voyage Related and Dynamic.

Static data

- MMSI (Maritime Mobile Services Identity) identifying code
- Vessel name
- Registered Call Sign
- The type of vessel/cargo (Type 37 is 'pleasure craft')
- The length, beam and 'reference point for reported position' (not usual on Class B)

Voyage Related Data

- Draught (not on Class B)
- Destination (optional on Class B)
- Estimated time of arrival (optional on Class B)
- Hazardous cargo type (not on Class B)
- Number of persons onboard (only on some Class A systems)

Note: Voyage related data can be subject to human error. For example, Destination may not have been changed since the previous voyage.

Dynamic data

- latitude/longitude, using the WGS 84 datum (**GNSS reliant**)
- Time (in UTC) of the position fix (**GNSS reliant**)
- COG (Course Over Ground) derived from 'immediate past' GNSS positions (**GNSS reliant**)
- SOG (Speed Over Ground) (**GNSS reliant**)
- Heading (optional on Class B)
- Rate of turn (not on Class B)
- Navigational status (not on Class B) e.g. "At anchor", "Not under command", etc.

Much of the dynamic data is totally dependent on the continuous availability and accuracy of GNSS on all vessels using AIS within your vicinity, including your own. Any vessel could be suffering from very localised GNSS failure or interference which would skew the dynamic AIS data.

How often is AIS data transmitted?

Class A systems transmit their Dynamic data very frequently, enabled by built-in intelligence that continuously 'pre-books' desired transmission slots. The Class A reporting intervals for dynamic information range between every 3 minutes for a moored vessel and every 2 seconds for a vessel travelling at more than 23 knots or more than 14 knots and changing course.

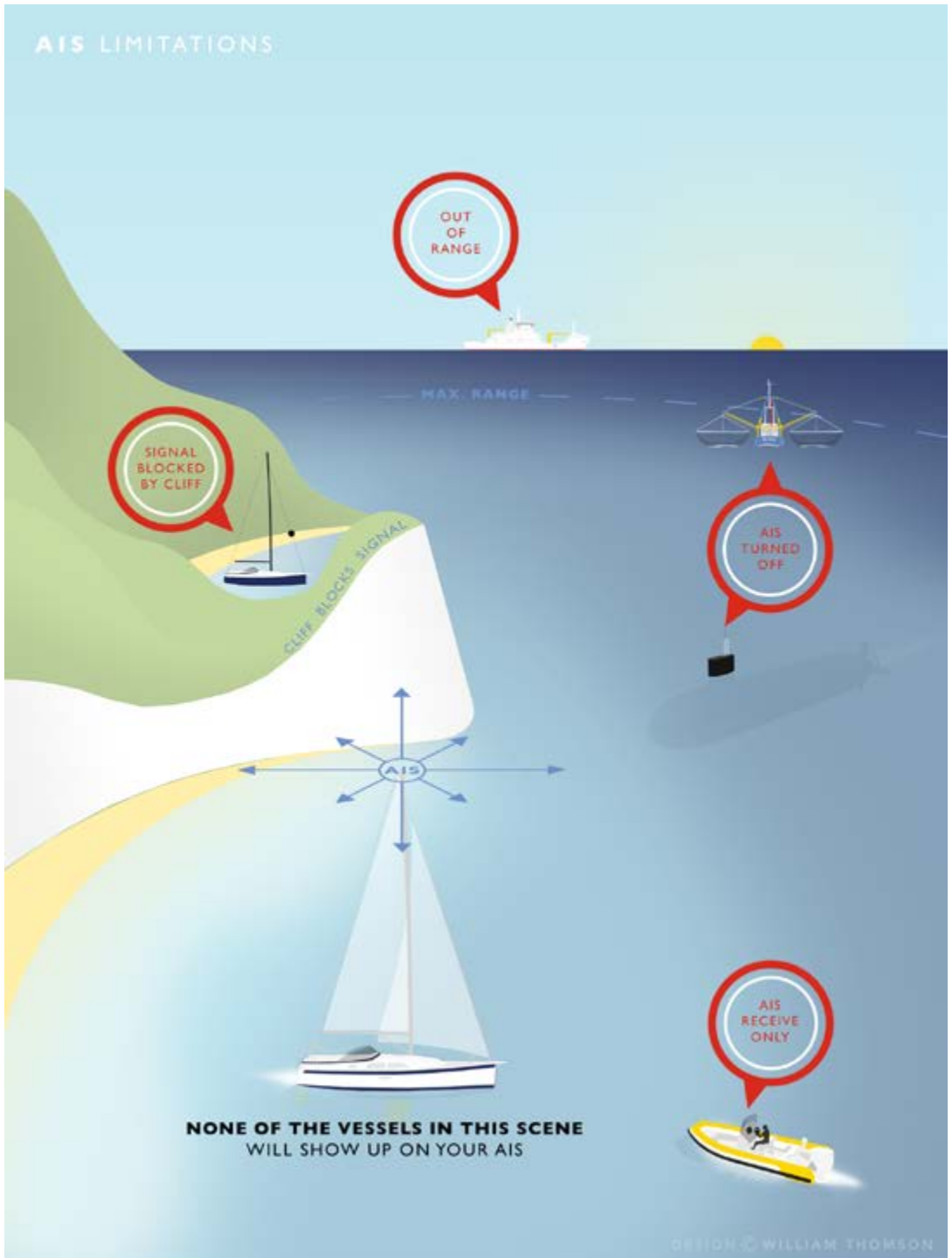
Older Class B systems just wait 'unintelligently' for an obviously free time slot in which to transmit and attempt to send their dynamic data every 30 seconds when travelling at a SOG of 2 knots or more. However, if travelling at less than this speed the attempts for transmission go down to once every three minutes. Newer Class B systems attempt to transmit their data more frequently by intelligently pre-determining useable time slots, and because they are more efficient in their use of the available channels they are also allowed to transmit at higher power, both of which gives other vessels greater awareness of their presence, both in frequency of transmissions and their detectable range. Fast leisure vessels and any leisure vessels heading offshore are advised to fit one of the new B+ systems.

There can be quite a delay in AIS data transmission. Class A systems transmit Static and Voyage Related data only once every 3 minutes. Class B systems will wait longer than 3 minutes if there are no readily available slots.

Visibility of targets on screen

We should never assume that displayed AIS information shows all vessels in our vicinity. There may be naval vessels, fishing vessels or other leisure vessels not transmitting, or not having AIS at all. Equally, we should never assume that our transmitted data is showing up on the screens of other vessels. If we are transmitting on Class B our data may have been filtered out.

The range of AIS can also impact on its overlay on our chart display. If the chart display is ranged out to 12 nautical miles, AIS targets will not necessarily show up from the edges of the screen but might suddenly appear at about 7 nautical miles when they come into range. Appropriate range settings are very situation dependent. We need to range in and out as necessary.



Things to be aware of

- **Not all vessels will have or use AIS:** The screen display of targets is not always the whole picture of vessels around us
- **Power failure:** AIS is an electronic system and will stop working if its power source is lost
- **Systems failure:** AIS can suffer from failures within the integrated systems it relies on: It uses both GNSS and VHF transmissions
- **Poor set-up: AIS** can be being badly set-up, either on your own vessel or on another vessel from which you are receiving information
- **Clutter:** The number of AIS transmissions in busy areas can make it difficult to identify which targets are of most concern. Vessels that continue to transmit when unattended in marinas, or even when laid-up ashore, add to the clutter
- **Malignant attacks:** AIS signals are susceptible to malignant ‘spoofing’ which may result in an apparent translocation of a vessel to a fictional position (see Chapter 1)
- **Accidental jamming:** GNSS-targeted jamming also affects the performance of AIS: For example, the AIS signal from car ferries has been known to be disrupted if they are transporting an onboard vehicle with a low-power GNSS jammer in operation. Such illegal systems are not uncommon (see Chapter 1)
- **Cyber Security:** AIS was designed in an era when cyber security was not an issue. The signals are, at present, not protected. Although a license is needed to transmit AIS signals, there have been incidents when non-authorised transmissions have occurred

Where a vessel is fitted with AIS, the reported position, whether true or false, or no position at all, is reported to other vessels and shore stations within range. So if a vessel is being jammed it may be transmitting periodically false information which would affect the apparent relative positioning between all nearby vessels. In other words, the vessel might be invisible on AIS or it might not be where you think it is.

Using radar and AIS in collision avoidance

Radar and relative bearing

If radar is integrated with other instruments and we are using it for collision avoidance it is really important to differentiate the water-stabilised scenario from any ground-stabilised information (see an explanation of this in Chapter 5). **For collision avoidance, our position, speed and direction relative to other vessels on the water is the information we need to focus on.** Do not confuse GNSS-reliant (ground-stabilised) information such as Speed Over Ground (SOG) and Course Over Ground (COG), with relative log speeds and relative headings on the water. Note: A head-up only radar display shows relative motion, but a north-up radar overlay on a chart is always ground-stabilised.

In the simplest terms, if we place an electronic bearing line on a contact on our radar screen and that contact remains on that same bearing line, we are on a collision course and avoiding action will be needed by whichever is the give way vessel.

Note that in the ColRegs in restricted visibility there is no such thing as a stand-on vessel. Rule 19(d) states “A vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time, ...”

AIS The ColRegs (1972) predate use of AIS. Nevertheless, Rule 5 of the ColRegs states that: “Every vessel shall at all times maintain a proper lookout by sight and hearing **as well as by all available means appropriate in the prevailing circumstances and conditions** so as to make a full appraisal of the situation.” (See MGN 324) That being so, if we do have AIS, we should certainly be using it to help our understanding of what is going on around us. But we should not rely on AIS primarily or alone for collision avoidance. The inherent time delays and GNSS vulnerabilities mean that we cannot be certain that displayed AIS information is an accurate enough presentation of what’s happening in real-time. AIS is just one of our tools and we need to cross-check it against all the other information available to us, including radar bearings and ranges, visual bearings and sound.

Radar and AIS combined

No navigation sensor, including our own eyesight and hearing, is completely reliable. The same is true for radar and for AIS, but using them in combination, and together with our own eyes and ears, does improve our chances of spotting hazards and avoiding collisions.

On a chartplotter it is usually possible to overlay Radar and AIS information. If we can correlate received radar information and received AIS information it will significantly improve the overall picture of what is going on around us on the water. Each of them give us an ability to ‘see’ beyond our visual horizon in different ways, which gives us a clearer picture over a wider area and thereby gives us time to absorb and react to developing scenarios. For example, what appears as a single radar target might be revealed on AIS as two vessels in close proximity.

Large vessels generally return big radar echoes. If we have overlaid radar and AIS this gives an immediate indication of which targets are likely to be more of a concern. This can help us to prioritise which AIS data to interrogate. This is helpful in busy areas such as the Solent.

CPA and TCPA

AIS and radar sets for leisure vessels now usually incorporate automatic systems that warn us when targets are detected that are on a course and speed that will result in a close encounter with us. Two fundamental aspects are automatically calculated. The first is the **Closest Point of Approach (CPA)** that will arise if both vessels maintain their present courses and speeds. The second is the estimated **Time to the Closest Point of Approach (TCPA)**. As long as we set appropriate alert levels for CPA/TCPA, it enables the system to give us advance warnings of detected targets that could become a danger to us. On the open ocean a coarse setting for CPA/TCPA alerts might be appropriate, but in a busy harbour approach the setting needs to be adjusted to avoid the confusion of multiple warnings.

Whatever the CPA/TCPA alert setting, the combined dynamic data may not always be sufficiently accurate for CPA/TCPA to be relied upon. It is always important to check the true situation by all possible means.

If it seems that the CPA/TCPA does not tie in with other data, including what we can see around us, we need to check the true situation. A mismatch of information might just be due to poor electronic data being received, but it might be indicating that the real-time scenario is not quite what we thought.

Keys to safety

We should understand that:

Navigating a leisure vessel has always required us to use all the navigation-related information available to us on our vessel. We must not focus our attention too narrowly on one or other source or system, however beguiling they may be.

Radar reflectors fitted to small craft, whether active or passive, do not guarantee that the vessel will be seen. We must keep visual watch for other vessels and alert them to our presence if necessary.

We should practise using radar in good conditions so that it is familiar when we really need it.

We cannot assume that our vessel is visible on AIS as our transmissions may have been filtered out, may be weak or may be transmitted infrequently.

Targets, whether radar or AIS, may not always be visible on our screens. What we see on screen is not necessarily the full picture of what is happening around us.

We must factor in likely delays between real-time scenarios and what we see on screen and know that there will be delays on the screens of other vessels as well.

We should routinely range in and out to pick up AIS targets farther away.

GNSS outage or performance issues cause inaccurate AIS data to be transmitted.

An apparent AIS 'target' may not always have a visible, physical manifestation - for example an AIS target may be a virtual AtoN. Equally, the nature of some physical targets may be unusual and unexpected – for example pot buoys or similar.

We should always maintain a visual watch to confirm the real situation to the extent possible in the prevailing conditions and visibility.

Chapter Four

Guarding against electronic failure on small craft

Adopting the mind-set of being prepared

In any occupation, keeping ourselves safe is about having the right mind-set of assessing the risks and then planning and acting to mitigate them. Making the right judgements on risks requires an understanding of what might go wrong, which boils down to training and experience. Going to sea on a small boat is exactly the same; we need to think about all of the potential hazards long before we slip our lines.



Marine accident enquiries show, time after time, that the people most likely to come through are those who have had some preparation as to how to respond in a particular crisis. This is why, no matter how much effort has gone into maintaining our equipment, it is still important for us all to be prepared for electrical and electronic failure. If we have a better understanding of the sorts of things that could go wrong, and if we have thought through the ways we can prevent them happening in the first place, how we might fix them when they do happen and what sort of backups we have in place – then we will be prepared.

Modern electronic systems are both easy to use and relatively reliable. Many are robust and waterproof. It is easy to assume that they will always continue to function when needed, even in challenging marine environments. However, power problems and equipment failures are common on small craft and we must be ready for them.

Causes of electronic failure

Battery/charging system failures

Most small craft at some stage experience completely flat batteries. Lead/acid batteries slowly self-discharge, and if left completely or partly discharged for long, can suffer a permanent loss of capacity. A pattern of use in which long periods are spent idle is not conducive to good battery life. Many small craft depend entirely on the engine's alternator for charging, and in the event of alternator failure or engine breakdown, all power will soon be lost.

There should be separate domestic and engine batteries so that we can always start the engine even if the domestic batteries are flat.

Battery capacity

A full suite of navigational electronics, especially if it is tied into an autopilot and radar, can create a significant drain on a boat's batteries. We need to work out the maximum likely drain between recharge opportunities. We should take into account any other loads that will be powered from the same batteries. This should be reviewed every time new electronic or electrical equipment is added to the vessel. We need to have some means of monitoring the state of charge of our batteries.

Whatever is taken out of a battery needs to be put back, with an added margin for inefficiencies in the battery charging process. We need to budget our power and routinely test our batteries. On longer passages, inadequate charging capabilities can lead to an electrical systems crash within one to three weeks of departure.

The capacity of a lead-acid battery bank should be at least three times the total energy drain between recharge intervals (or the capacity of a lithium-ion battery at least one and a half times). Before heading offshore on any extended passage, the electrical system should be reviewed by a competent person to ensure it is set up for the intended use, with the discharge and recharge sides in balance.

High draw devices and electronic shut-down

Modern boats frequently have an array of devices which draw high currents (amps). Examples of these are engine starter motors, windlasses, bow and stern thrusters, and electrically-powered winches. Most boats are still using some variant of lead-acid batteries. High-draw devices are capable of pulling down battery voltages, even if the device is only used for a second or two. If electronic navigating equipment is powered from the same batteries, the voltage can be pulled below the shut-down threshold ('brown out' voltage) for that equipment. This will happen even if the low voltage occurs only momentarily. Once shut down, it will take the electronics some time to reboot, especially PC-based charting systems. The more discharged a battery, the greater the likelihood of the voltage crashing under high loads.

Navigation systems should be wired to batteries that will not experience any intermittent voltage drops. Ideally, they should be powered by batteries which are not also powering high-load devices.

Old batteries

As batteries age and lose capacity, the voltage is more likely to crash under high loads. An electronic navigation system that performs flawlessly with new batteries may begin to experience intermittent crashes as the batteries age. This is particularly likely if the electronics are wired to an engine cranking battery. It is good practice to have a separate engine start battery.

Periodically monitor the health of the batteries powering any electronics, particularly before setting sail on an extended voyage.

Lithium-ion batteries and Battery Management Systems (BMS)

Lithium-ion batteries are becoming increasingly commonplace. These invariably include a battery management system (BMS) which is designed to protect the battery against potentially unsafe conditions. If the BMS detects a condition that threatens the battery, the standard protection mechanism is to disconnect the battery from the boat's electrical system. At this point, if this battery is powering the navigational electronics without a backup battery, the electronics will crash. BMS-initiated battery disconnects are not uncommon on small craft. It is a good idea to set the system such that the BMS will provide some kind of an alarm or warning before initiating a disconnect.

If electronics are powered from a lithium-ion battery, it is important to review the battery disconnect thresholds, and to ensure that the battery is never likely to disconnect at a critical moment.

Internal batteries

Smartphones, tablets and other handheld devices have internal batteries. Extended use for navigation purposes may discharge the battery relatively rapidly. Some means of either continuously plugging in the device, or of periodically recharging it, will be needed. This can be a 12-volt USB-style source, a 12-volt automotive cigarette-lighter style of outlet, or an AC outlet powered by a DC-to-AC inverter or an AC generator.

One way or another, there needs to be a means to keep the devices charged **at the location at which it is intended to use them.**

Faulty wiring

On any boat large enough to have a significant electrical system, the electrical system is commonly the primary source of onboard problems! Many of these problems originate in wiring harnesses, especially at connections and in fuse holders. The keys to a successful installation are:

- Use stranded copper cables throughout (not the solid core cables commonly found in houses), preferably tinned for corrosion resistance, with quality insulation
- Ensure all connections, fuses and other wiring harness components are protected from moisture. Cable terminals, busbars, fuse holders and any other conducting components should also be made from tin-plated copper or a more corrosion-resistant metal (e.g. silver or gold plated)
- Fuses should be readily accessible and labelled

Electronic Navigation

- For corrosion resistance, and in order to maintain the quality of radio signals over time, coax cables should also have a tinned copper core and tinned braid
- Cables should be appropriately sized

Crimping

Normally cable terminals are crimped onto their cables. A well-made crimp creates an excellent connection, whereas poorly made crimps are the weak link in many electrical systems. When crimping terminals, quality tools are essential.

- Test crimps for strength before completing a connection by tugging on the crimped terminal with a pair of pliers.
- Connections should always be made in accessible locations (NOT behind permanently-installed panelling).

Conduits or supports

If not in a conduit of some sort, cables should be supported at least every 500 mm and installed such that there is no strain at any connection point, regardless of how extreme the boat motion may be at sea.

Product malfunction or failure

The marine environment is harsh. Marine products usually go through a rigorous process of testing in extreme conditions in order to ensure that they are robust enough. The same cannot necessarily be said for mobile phones, tablets and personal computers (unless marinised), though drop-proof and waterproof casings go some way to improving protection. Nevertheless, product failure can occur. The only guard against this is to carry some sort of replacement.

Mobile phones as backups

In many coastal waters our mobile smartphones can continue to be a useful aid to us – not only for navigation and pilotage information, including tide, weather and routeing apps, but also for calling the emergency services should the need arise. In worst case scenarios the mobile phone can be transferred into a liferaft.

However, there is a serious limitation on mobile coverage, particularly when we are more than a few miles offshore. More than 10 miles offshore and we are unlikely to get any signal at all.

Note: VHF is the preferred means of distress calling. It is a broadcast medium, transmitted from one to many, and will, therefore, be heard by vessels nearby who may be able to render assistance rapidly.

Carry a backup mobile phone or tablet, with charting software installed, for use in emergencies. Any backups must be regularly switched on to check their functionality. Keep them fully charged.

Mobile devices and loss of GNSS

Increasingly, mobile devices have built in GNSS receivers. In addition, many use a combination of GNSS with mobile phone base stations, Wi-Fi, Bluetooth and other sensors to generate a 'blended position'. Such devices are programmed to prioritise continuous position availability over accuracy. If GNSS is lost or degraded, the position calculation is derived from the other, less accurate, sensors. At sea, mobile phone positioning uncertainty will typically be several hundred metres or more, which may be enough to put us into danger.

RYA SafeTrx

All of these limitations apply to the RYA SafeTrx mobile app. The RYA SafeTrx app requires a mobile data connection to transmit location data in real time, and to start/stop Sail Plan and Track Only trips. To avoid triggering an unnecessary search for us, we must be certain that we will have sufficient mobile coverage and a functioning phone during our passage and when we arrive at our destination.

All boat owners are strongly encouraged to at least register details of their vessel and its equipment at safetrx.rya.org.uk. Registration means that, if we are involved in an incident on the water, the SAR authorities will have easy access to details of our vessel. It is worth registering even if we plan to sail exclusively outside UK waters. This is because if an EPIRB or PLB is triggered, the Maritime and Coastguard Agency (MCA) in the UK would be alerted to the beacon going off, anywhere in the world, and will then assist local Search and Rescue (SAR) authorities with the registered vessel details, as appropriate.

RNLI advice

In their current guidance on the use of mobile phones in Search and Rescue (SAR), the RNLI state that, although a mobile phone may be used as a means of notifying others of an emergency situation, it should only ever be considered as a secondary device because of certain vulnerabilities:

- The lack of universal coverage - we just cannot be certain that we will have signal when we most need it. In many areas we may struggle to get any signal at all
- Phone battery life is limited **so re-charging capability onboard is a key requirement**
- Phones only allow closed one-to-one communications, so other vessels in our area won't be listening in and therefore won't be aware of a threat and/or a developing situation
- Waterproofing and physical robustness are issues

High frequency switching and radio interference

High frequency switching takes place in many LED lights and this can cause interference with radio signals, especially VHF radios. If you have a masthead VHF aerial and use LED lights for the masthead navigation lights and the anchor light, it is essential that these lights come from a recognized manufacturer with appropriately 'suppressed' LED fixtures. Similarly, if installing LED lighting in the navigation station, or close to any electronic equipment, make sure the lights come from an experienced marine manufacturer. Similarly, stray radio frequency currents, for example from MF/HF SSB transceivers or engine alternators, can cause interference with other equipment. **Autopilots are especially susceptible.**

Something else to be aware of is that speakers, including mobile blue tooth speakers, contain relatively strong internal magnets which can cause significant errors if placed near to a compass.

Vulnerability of externally mounted equipment

Most modern, electronically-loaded, boats have a significant number of essential navigational components mounted to masts, rigging, poles, stern pulpit railings, and various other rails. This equipment includes wind speed and direction transducers, VHF aerials, AIS, SSB and GNSS antennas, satellite communications antennas, and radomes. These are vulnerable to damage from both normal boat operations, such as berthing, or a sheet wrap during sail handling, but also in heavy weather when waves may break over them. If they are mast mounted they become disabled if the rig is lost.

Protect the equipment in so far as this is practicable. Have hand-held and other backups in case of damage to or loss of the equipment.

Antenna separation: If installing new antennas in the vicinity of existing antennas, check with an electronics expert to ensure minimum antenna separation requirements (both horizontal and vertical) are met.

Cable insulation: Any cables running to externally-mounted equipment need to have appropriate, robust, weatherproof and UV resistant insulation. Cables should be well supported and protected from damage. There must be no possibility of chafing damage, particularly for cables that are in contact with aluminium. If chafing should occur, it can result in rapid stray current corrosion. In the case of an aluminium mast this can lead to catastrophic rig failure.

Integrated Systems

Many boats are now fitted with fully-integrated, linked systems which are becoming ever more sophisticated, allowing chartplotter, autopilot, wind instruments, depth sounder, log, radar, AIS and more, all to be overlaid in one Multi-Function Display (MFD) hub to 'talk' to each other and to routing software. At its simplest this means a single display, either in the cockpit or down below. Repeat displays can be positioned where needed. The MFD can also 'talk' to phones or tablets via onboard wi-fi systems. More developed integrated systems enable an autonomous vessel to navigate itself with little human interference. Integrated systems are clearly a powerful tool.

A major drawback of this integration is if the failure of a single component affects the functionality of the whole system. For example, should an electronic wind direction indicator fail it is unlikely to be more than an inconvenience. But if that failure led to the loss of other instrumentation, the situation might be more serious.

If we do have an integrated system it is a good idea to keep separate a basic log, GPS and autopilot that are independent of other instruments and can be used as backup.

Network cabling

Integrated systems rely on the transmission of data over a single network cable or set of interconnected cables. In the navigational world NMEA 0183 has been the predominant network but has now largely been supplanted by NMEA 2000. NMEA 2000 is designed to be a 'plug and play' network, which means that in principle it should be possible to connect any compatible device from any manufacturer and have it function on the network with minimal user set-up and interaction.

The role of the NMEA 2000 network has been greatly expanded over the years until now it has the capability to control not only navigational data but also such things as entertainment systems, air conditioning, digital switching systems, and so on. As more and more equipment is connected to the 'backbone', with ever expanding amounts of data flowing on the network, there is an increasing likelihood of changes being made to the network that are unrelated to navigational functions but yet could impact these functions.

Assuming a proper installation, these networks have proven to be extremely robust and reliable. However, undue faith in the 'plug and play' concept can lead to entire networks being taken down, with a loss of core navigational functions. If adding equipment to an existing network, or modifying it in any way, the following should be taken into account:

- Ensure the equipment is 'NMEA 2000 certified' and not just 'NMEA 2000 compatible'. The certification label means it has been rigorously tested
- Integrated systems are considerably more power hungry than more simple, stand-alone electronics. As well as transmitting and receiving data, some of the equipment may draw its power from the NMEA 2000 network cable. Depending on a number of factors, it is possible to create an excessive voltage drop within the network cable. Voltage drop calculations can be complex. If adding equipment to an existing network, and if in doubt, consult an expert electronics technician. (see *High draw devices and electronic shut-down page 54*)
- Correct grounding of electronic networks at a single point is essential. If in doubt consult an expert
- Power is supplied to a network via a 'power insertion point' (PIP). This needs to be connected to a battery that will not experience momentary voltage drops. If there is any question about the quality of the power supply, consider supplying power to the PIP from more than one independent battery

Do not take the 'plug and play' concept too literally. Think about the implications of making any changes to the multiplicity of equipment tied to the network. If in doubt, consult an expert.

Lightning strike

Many small craft, particularly sailing vessels, are struck by lightning every year, and the effects can be catastrophic. As electronic equipment onboard becomes more sophisticated and integrated, the consequences of a strike are more likely to be totally disabling.

At a critical trigger voltage between the clouds and the sea a fork of lightning will arc downwards and will be met by a return strike from the sea up to the cloud base. If our boat is struck it is most likely that the charge path will come up through the hull from the water and exit at the top of the mast, exploding the VHF aerial on the way.

Methods of protection differ depending on the materials of hull and rig, but the aim is to make the path to earth as low a resistance as possible. It is possible that this can be done by connecting the chain plates to a keel bolt with large diameter wire (similar to battery cable). This protection is improved if a lightning rod is connected at the top of the mast. But even this may not do the trick.

Avoidance is not always possible, but try to steer clear of thunderstorms. Use radar, if equipped, to track likely squalls, particularly at night. If it looks as if a thunderstorm is coming our way, we can try to protect some of our electronic instruments, particularly hand-held ones, by putting them into the oven if we have one onboard. This may act as a Faraday Cage.

Lightning is a notoriously quirky phenomenon, and even a near strike can blow sensitive electronics. If we are struck the ramifications will be unique to our vessel. On any yacht it is likely that anything wired up through the mast, including lights, VHF, radar and wind instruments will be damaged or destroyed. Beyond that the damage will depend on the route of discharge through rig and hull but electrical and electronic systems will be the most vulnerable. It is likely that other equipment will be affected, including the main engine and auxiliary generators. This would result in an inability to charge any surviving electronics.



Be prepared; a lightning strike or near strike is not as rare as we think. All of our main electronics could go down simultaneously and any surviving hand-held devices could lose their source of re-charge.

A near strike can damage a yacht in ways which may not be easily visible. You may think you have escaped but find that some wiring has melted in a conduit. Electronic systems may subsequently fail or electrical systems (e.g autopilot) or mechanical systems (eg engine) suffer random failures in their control units. The consequences may not become apparent until much later.

Be aware that damage may have been done if there has been lightning nearby or the vessel has been left unattended while there has been lightning in the vicinity. Inspect the vessel carefully, especially the wiring runs and check the functionality of all the electronic, electrical and electrically controlled mechanical equipment.

Alternative power generation

Additional demands on the electrical system and improvements in alternative technologies mean many small craft now have at least one alternative energy source - which might replace or supplement a conventional auxiliary generator. There are advantages and disadvantages to each source, which should be weighed against where and when the extra power will be needed. For example, a hydro generator will be great on passage but useless at anchor. Solar panels won't be doing anything at all overnight. So, we must consider when we will most need extra power. Whichever solution we choose we will need a regulator to prevent over-charging. It will work hard so it is worth investing in a good one.

Solar panels

Solar panel technology has improved markedly in recent years and modern panels are considerably more efficient than older ones. Theoretical output is significantly reduced if any part of a panel is in shadow. Ideally the panel should be on a pivoting mount such that it can be positioned at right angles to the sun and adjusted at intervals throughout the day or according to how the boat is lying. Many leisure vessels do not achieve this and output is correspondingly compromised. Wiring should be maintained in good condition. Even with optimal mounting and under tropical skies, solar panels will produce no power at all during the hours of darkness, but they are a useful contributor to the on-board power bank.





Hydro generators

There are now two main types of hydro generators: the fixed, transom-mounted type and the towed type. The fixed hydro generators are more efficient in terms of both power generated and reduced drag and are now commonly used on offshore racing boats. They are also easier to deploy. Some types are on a fixed leg. The disadvantage of this is that the impeller is constantly changing depth and sometimes coming clear out of the water, reducing its efficiency. One model uses a 'dive plane' to control the operating depth of the impeller and to automatically adjust to sea state. The traditional towed generators tend to be cheaper and some will convert to wind generators for use when at anchor. But towed generators are not as efficient, particularly at lower speeds, they do create some drag and they can be quite a handful to get back onboard. It is usually necessary to slow or stop the boat to do so. It is often said that towed generators are attractive to predatory fish, but it would have to be a very big fish. Nevertheless, they are vulnerable to damage from any debris in the water. The stern-mounted generators are more protected by their proximity to the hull, which will tend to deflect any debris.

Wind generators

There are several wind generators on the market specifically designed for leisure vessels. They vary from small trickle chargers to machines capable of producing up to 250 watts in a fresh to strong breeze. Older models struggled to generate charge in light winds but some of the latest models have become more efficient at low wind speeds. In most types, an alternator is driven by a propeller with three to six blades, and the unit is mounted aft on a pillar or on the mizzen mast above head height and clear of all rigging. Some have the blade tips protected by a guard, but even with this they can inflict serious injuries. To a greater or lesser extent, all wind generators make a noise. This can be detrimental to the crew as well as to any neighbours and should be taken into account before committing to purchase. Noise levels may be influenced by the type of mounting as well as by the hull resonance.

Wind-up devices

A wind-up torch is a basic backup in case of total electronic failure. It is a good idea to have a few onboard and in the emergency grab bag. A wind-up MW radio can also be very useful. Tuned to a local frequency it should start picking up a signal from around 30 to 40 miles during daylight hours.

Other battery charged backups

Even navigation lights become a concern after complete electronic failure. It's a good idea to have battery powered ones of each, red, green and white.

Portable chargers

Portable battery packs are a good backup for charging mobile phones and tablets, but only if they still have some charge in them when they are most needed.

Keys to safety

We should have a mindset that is prepared for any electronic failure.

We should set up our boat systems to limit failures and build redundancies and resilience into our systems.

We should identify likely points of failure and know how to work round them.

We should have sufficient spares and backups to retain essential navigation capability under partial or total failure of our primary electronic systems.



Chapter Five

Key navigational skills

with and without electronics

It is not the purpose of this booklet to provide the guidance and training which is already provided by RYA shorebased theory courses: Essential Navigation & Seamanship, Day Skipper, Coastal Skipper/Yachtmaster Offshore and Yachtmaster Ocean. If you have any doubt as to your navigational understanding it would be advisable to enrol on whichever course matches your level of boating. www.rya.org.uk/courses-training

Electronic navigation systems are a wonderful aid and have brought us a positional accuracy we would not previously have even dreamed of. And we only need to be fog bound at sea for a few minutes to be reminded how important modern electronic navigational systems are to improving the safety of all vessels. The ability to know our satellite derived position and to receive radar and AIS targets off other vessels and navigational marks has made poor visibility at sea considerably less hazardous and less frightening (see Chapter 3). Even in good visibility electronic systems allow us an enhanced, composite picture of where we are and what is going on around us which helps us to make better informed decisions. However, electronic systems are themselves only a part of the full picture. Safe navigation always entails using every available source of navigational information to confirm the reality of any situation.

The basics of navigation

Whether or not we are using electronic systems in our navigation, it is important to retain the bigger picture, an overview of where we are, what is around us and where we are heading. If we just keep staring at our screens without an eye on our horizon it can sometimes leave us disorientated when we 'resurface' because our brain has become too narrowly focussed and hasn't absorbed other unfolding information from the world around us. This mismatch between the real world and what we think we're seeing on screen can lead to unsafe decision making. Without a firm understanding of basic navigation it is possible to misinterpret the displays on electronic navigation systems, which can put us into danger.

We also need to guard against a false sense of security that electronic systems can give. Most fundamentally, electronic systems on small craft can and do fail (see Chapter 4) and it is essential that we have a backup plan, including the confidence to go back to the basics, to continue to navigate in a safe manner.

When we embark on any passage we should be confident that we have the sufficient navigational skills and equipment to enable us to reach a safe haven, **without outside assistance**, in the event of partial or total electronic failure of our primary systems.

Note: Parts of Chapter V of the International Convention for the **Safety of Life at Sea (SOLAS)** apply to small, privately owned pleasure craft (see Appendix II)

A reasonable level of understanding of the following topics is assumed:

- **Charts and chart features:** Types of charts, differences and advantages of each; chart features and symbols including seabed information, survey data, magnetic variation, tidal stream information. Plotting a position in latitude and longitude as well as measuring distance on the latitude scale.
- **Fixing a position:** Getting bearings from features shown on the chart and plotting the resulting “lines of position” to provide a “fix”.
- **Compass variation and deviation:** Understanding that the steering compass will not point to true north but in a direction which is affected by variation (which is shown on the local chart) and by deviation (errors caused by the boat and its equipment, which will also depend on the course steered and angle of heel).
- **Tidal heights:** Understanding about tides (especially springs and neaps) and how to calculate the predicted depth of water for any location and time. Knowing how to calculate clearing heights under bridges and cables.
- **Tidal streams:** Tidal streams and ocean currents, even if fairly slow, can have a profound effect on a small vessel over several hours. An essential skill is being able to calculate the predicted stream strength and direction from the available information.
- **Working out a course to steer:** Calculating the course to steer to reach a waypoint, using the expected speed of the vessel and the predicted tidal streams or currents during that time, plus an allowance for leeway, especially if sailing to windward.
- **Plotting a route using waypoints:** Laying out a safe route for navigation, taking into account any dangers and factoring in a safe distance off them.
- **Weather forecasts and the effect of wind and sea state on the vessel:** Knowing never to go to sea without checking the weather forecast for the period of the proposed passage; not just the wind in the immediate area but also the wider wind patterns and the likely sea state, particularly in areas of strong tides and currents where wind against flow can create very rough conditions.
- **Weather routing:** Choosing a route to make best advantage of the wind, currents and tidal streams. In light airs, for a sailing vessel, this might mean seeking the most consistent wind flows, but in stronger winds it would probably mean choosing a route that minimises windward work and rough seas.

Keeping a log book

We should all keep an adequate written log onboard. This is so that we can calculate our position and navigate to a safe harbour without external assistance **even if our electronics let us down**. It also means that there is written evidence in the event of any sort of incident such as a collision with another vessel. So, given that this is information that will keep us safe, what should we be recording in our logbooks?

At regular and appropriate points of time we need to know the direction we are travelling, how fast we are going, how far we have gone and where we estimate we are.

When to record?

The closer the danger the more frequently we should record in the logbook. At regular intervals; probably every hour in coastal waters, every two hours further offshore but less frequently on an ocean passage, we should record the vessel's position (Lat. and Long.). We should also record every time the course is changed or when passing any clearly identifiable feature, for example a fixed navigation mark, conspicuous landmark or headland.

Other relevant information to record includes wind, weather, and sea state. Sails set and if reefed. If motoring, we need engine hours and fuel usage. Interesting facts like dolphin or whale sightings make the log an interesting record of a passage.

If we are working on paper, we need to have calculated tidal effects and we need to know some key information:

The image shows an open logbook with two pages. The left page is a detailed log page with columns for Time, Speed, Wind, Sea, and Position. The right page is a summary page with a table for 'Passage Totals' and 'Working Totals'.

Time	Speed	Wind	Sea	Position
0800				5004 A2-3
0815				On
0830				On
0845	0.1			Breakwater 11, WPT 1004 A2-5
0900	2.1	8.0	1.0	Displacement Buoy WPT
1100	2.5	4.0	3.0	50°17.50N 4°15.61W 1005 A3
1200	2.5	12.1	5.0	50°15.47N 4°23.60W 1005 NA63
1300	2.5	17.0	5.0	50°13.58N 4°32.15W 1005 NA64
1400	2.0	23.0	5.0	50°10.80N 4°41.20W 1005 A4
1500	2.0	25.0	5.0	50°08.25N 4°50.91W 1005 NA63
1600	2.0	34.0	5.0	50°05.82N 4°59.70W 1005 NA63
1640	2.0	35.0	5.0	Headland Entrance WPT A2-3
1655	0.1	35.0	1.0	1005 A2 On
1700				On

Distance	0000 Plymouth to 3 - 4	0000	0000
Waypoint	2	215	1.0hr
	3	215	1.0hr
	5	250	1.0hr

Passage Totals	Working Totals
Distance Logged	20.0
Distance	42.0
Engine Hours	1.0
Fuel Used	1.0

What to record?

Satellite linked electronic systems give us a plethora of information allowing us to record heading, 'bearing to waypoint' (BRG), 'cross track error' (XTE) 'velocity made good' (VMG) and 'distance to waypoint' (DTW). From these we can get a rapid picture of leeway, currents, and so on. Similarly we could record 'course over the ground' (COG) and 'speed over the ground' (SOG) to allow us to monitor deviation from our heading and our log speed. If we don't come from a racing background some of us can get confused with what all of this information is telling us. It can help to think of it as either 'ground-stabilised' or 'water-stabilised'.

Ground-stabilised vs water-stabilised data

These are not necessarily familiar terms but they may help us to understand the relevance of the information we are monitoring: Our GNSS position or a position from a traditional fix, any waypoints, bearings or distances to those waypoints, COG and SOG - this is all 'ground-stabilised' information. This information tells us where we are, where we are heading and how fast we are going relative to the solid, fixed, surface of the earth. Our position on a chartplotter is ground-stabilised, as is a traditional fix on a paper chart.

Our log speed and distance, our heading and leeway - these are all 'water-stabilised'. They are how we are moving relative to the water surface. The water itself is usually moving as well, which is why we need to factor in the tides and currents to know our ground-stabilised positioning.

The RYA recommend visualising this as if we are sailing on a 'travellator'; you might be moving at 5 knots in the same direction as the travellator (i.e. with the water) but if the travellator itself is moving at 2 knots you will be covering the ground underneath at 7 knots.

In simplistic terms, if we adopt the same mindset that we have in our cars, switch on an electronic chart system on our boat, set a destination waypoint and set off on the bearing it gives us, we may get into some sort of trouble. The GNSS linked data is all ground-stabilised so it is not taking into account any tide or current. So, for example, the bearing to waypoint (BRG or BTW) is usually not the same as the course we should be steering - because we're on that tidal travellator and the water is moving us forwards or backwards and sideways from that BRG. If we understand the basics of sea navigation this is obvious, but if our navigation is screen and menu led it may not always make sense. At the very least our journey will take us much longer or be much quicker than we expected.

Ground-stabilised information helps us to navigate safely relative to fixed dangers. But if we want to navigate safely around other moving vessels we also need to remain aware of how we are moving relative to each other on the tidal travellator. This is key to collision avoidance.

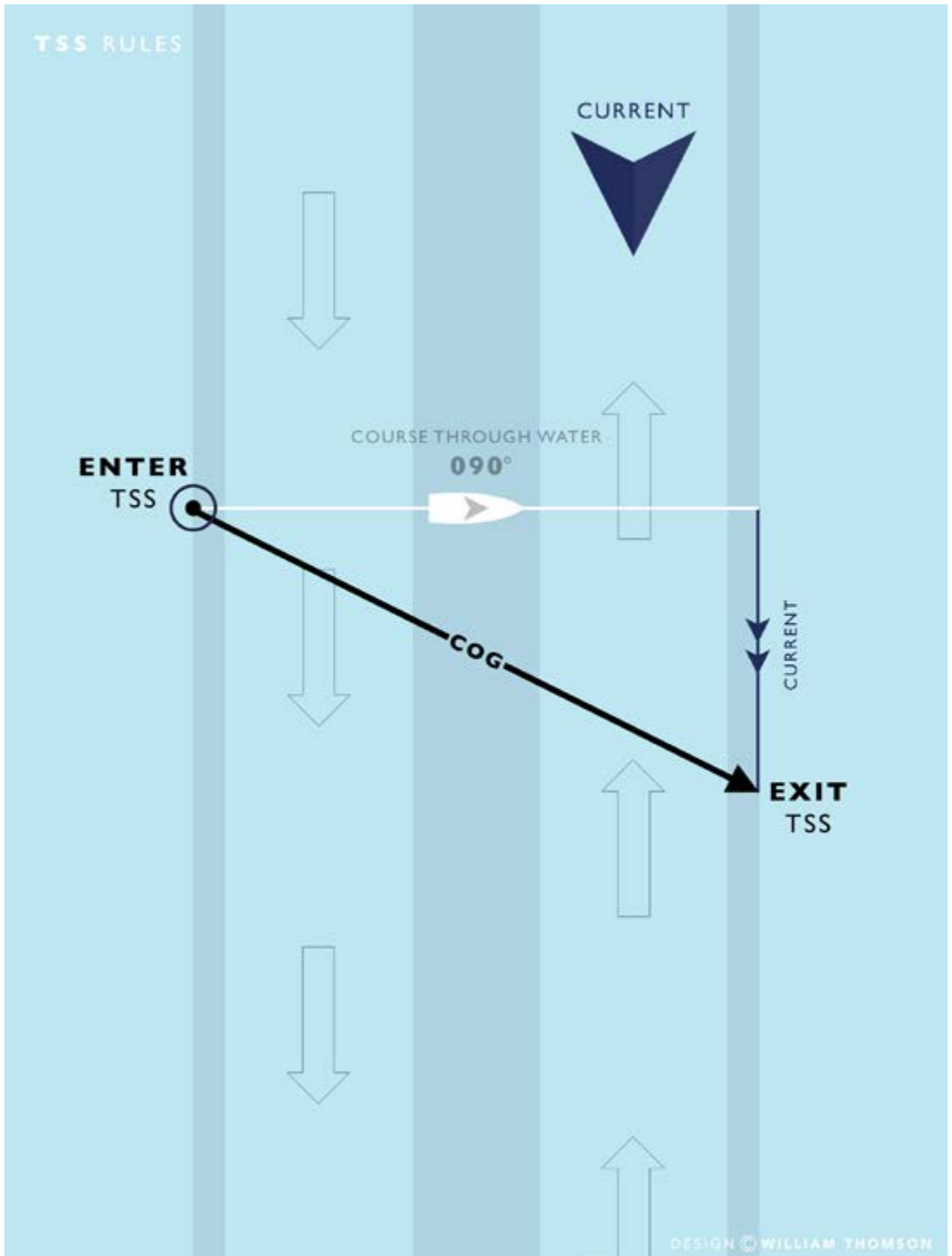
For navigators brought up with paper charts, water-stabilised is what is understood and ground-stabilised is the new concept. For more recent navigators the reverse position is probably the case.



Traffic Separation Schemes

It is our heading that is important i.e. our course through the water, not our COG. A TSS should always be crossed at right angles through the water, this complies with the ColRegs and also minimises our time in danger.





Dead reckoning (DR) and estimated position (EP)

If GNSS positioning is lost and we also cannot plot a fix from landmarks or charted features, we should still be able to calculate our vessel's position from other information to hand. The DR position is calculated from the distance run on the course steered (this is water-stabilised data). The EP takes into account the effects of the tidal stream and leeway (and approximates a ground-stabilised position). Any estimate of position will involve uncertainty, so an EP should be the centre of a "circle of uncertainty" the radius of which will depend on the accuracy of the estimates used; 10% of the distance travelled is the usual assumption. The information we need to plot an EP should be in our log book.

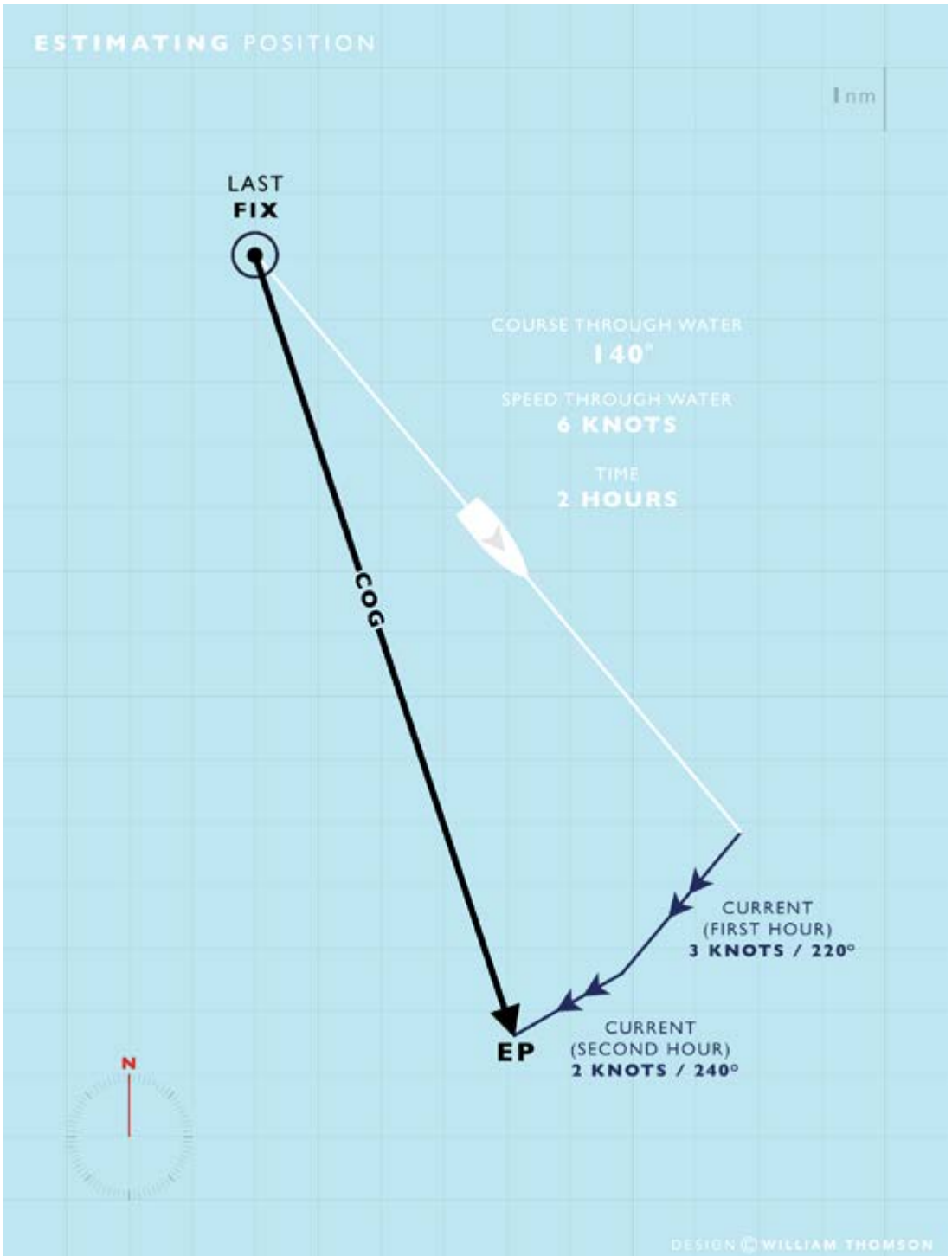
Estimating speed through the water (Log speed)

If our boat speed indicator (log) is only readable electronically, we need a backup. We could carry an old fashioned towed log, but any small floating object can be used to check the speed of the boat through the water. Mark off 10m back from the bow. Record the time (in seconds) it takes for the object to travel these 10 m back along the hull. Use the table below, or halve the speeds over a 5m length.

Distance (metres)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Time (seconds)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Speed (knots)	19.4	9.7	6.5	4.9	3.9	3.2	2.8	2.4	2.2	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1

If we can estimate our speed like this, and we know how long we've been travelling, we can also estimate our distance travelled through the water (DR). Add in any predicted tides and currents and we've got an EP.





Absolute vs Relative positioning

An **absolute position** is an exact location defined by latitude and longitude.

We know from Chapter 1 that it is possible for satellite positioning to be compromised, even if only temporarily.

We know from Chapter 2 that our charts can also let us down. Electronic leisure charts would benefit from a standardised system similar to CATZOC to enable us to judge the accuracy of charted information, but at the moment the best we can do is to be aware that there might be some differences in accuracy across our charts. Areas of commercial shipping are likely to be more accurate but shoal areas 'off the beaten track' may still be based on old and inaccurate data. In shallow coastal waters everywhere we can never be completely certain that our charts are as accurate as we might think.

If our satellite positioning does not precisely correlate with our charts, we may not be in the position relative to danger that we think we are - we might be closer to danger than we assume.

The only way to mitigate this is to cross-check our positioning in relation to identifiable charted features/hazards. Knowing our **relative position** in relation to features we can see around us helps us to keep a safe distance relative to danger.

In areas where satellite images or radar overlays and charts do not align, or where we know there to be an offset or inaccurate data, we need to be even more tuned in to the danger of relying on absolute positioning.

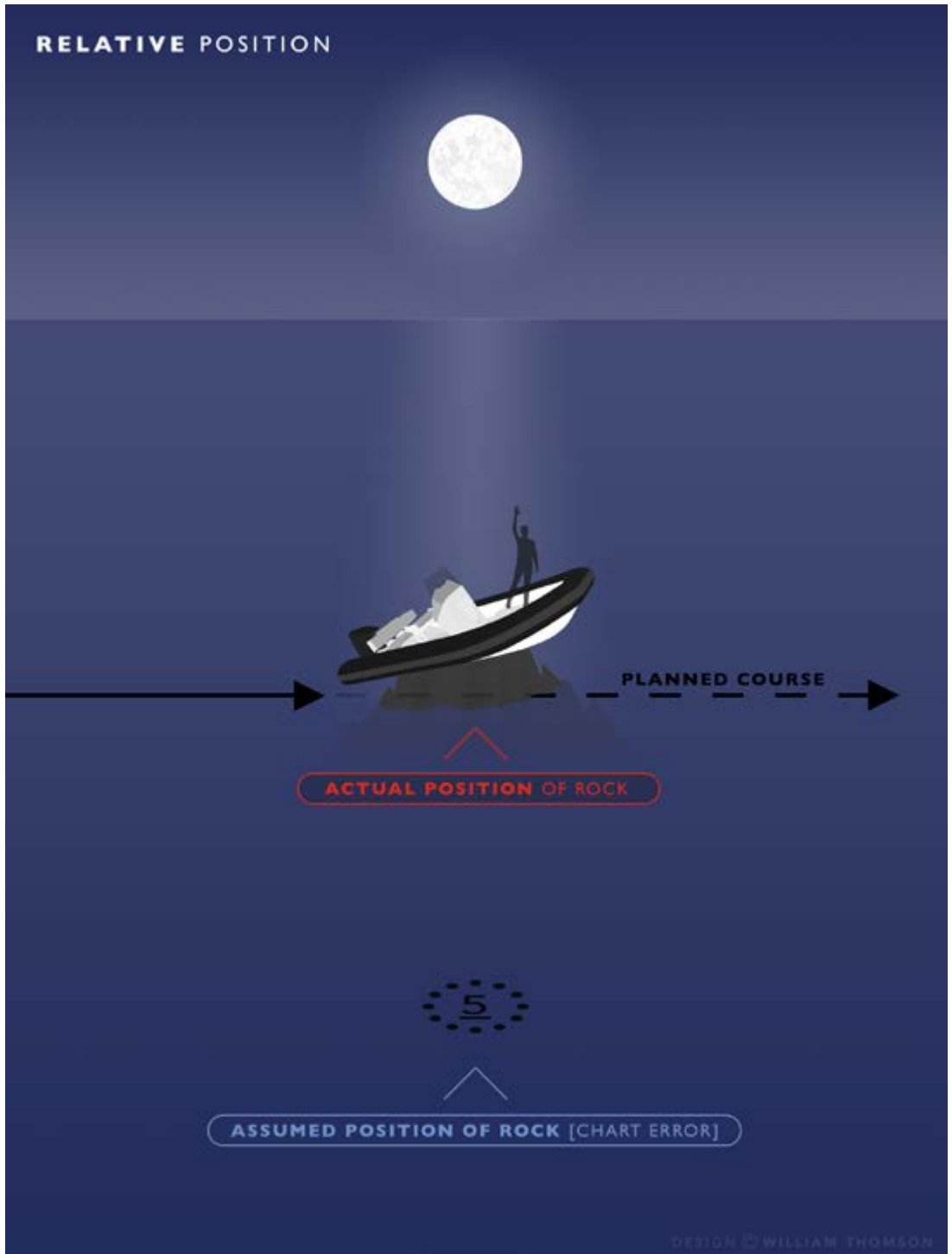
We should always use every available means to confirm reality:

- Visual bearings
- Sighting a navigation buoy or marker (Visual AtoN)
- Depth soundings
- Radar ranges
- Our own (or a lookout's) eyes, in good light, preferably with the sun overhead or slightly behind us, to look at the colour and behaviour of the water ahead

Visual, physical AtoN, whether fixed or floating, play a very important role in confirming our relative position and they also help with our more general situational awareness. Even if they are AIS enhanced, visual AtoN are less compromised by electronic failure because they are physically present, so we can continue to use them as an aid even if we, or they, are suffering electronic failure.

Whenever possible we should take other factors into account. Further useful cross-checks of our charts include:

- Other relevant nautical publications such as up to date pilot books or cruising guides
- Caution Notes such as Navarea messages, Navtex warnings, etc.
- Bottom quality / nature of the sea bed (is it likely to be shifting? – If it is, keep a sharp lookout for signs of shoaling and closely monitor depth soundings)
- Information published by Local Authorities such as the Harbourmaster regarding recent works or dredging or seasonal changes to a channel



Pilotage information

Pilotage information, in parallel with charts, has a continuous history at least as long as the printing press - among the first to be printed was a so-called “rutter” (from “*routier*”) for the west coast of France, published in 1483. And use of a ‘*periplus*’ - a written guide to coastal navigation - goes back to the ancients. Pilotage information helps us to passage plan appropriate to our specific vessel. It helps us to navigate, drawing our attention to any dangers that might otherwise be overlooked, particularly in coastal waters where safe channels are sometimes quite intricate, and to find our way into and out of harbours and anchorages in a safe and seamanlike manner. It gives us information on berthing and anchoring and informs us about port facilities and any places or sights of usefulness or interest.

These written descriptions, now usually combined with illustrative plans and aerial and sea-level photographs, help to give us a deeper understanding of what is shown on the charts. For example, a written and illustrated description of specific tidal overfalls from the perspective of a small leisure vessel can really help to interpret their significance to us when we are planning a voyage. An overhead bridge clearance marked on the chart is often difficult to visualise, but a photograph of the bridge helps with identification and with approximation of height and scale. Recent photographs of transit lines are also very useful for recognising key features from the water.

If the combination of plans with text and photographs is laid out in a clear and logical sequence, and using well defined terms, it helps us to absorb what is sometimes quite a complex real-life situation.

A good source of pilotage information contains:

- a description of the coast, its attractions and its dangers
- details of seasonal and longer term weather patterns, including any localised effects such as wind acceleration zones
- details of any likely extremes such as cyclones/hurricanes, ice, tsunamis, and advice on strategies to avoid or mitigate for these
- details of landmarks, lights and marks
- current, tide and tidal stream data
- swell (prevalence, predictability, forecasting of)
- advice on relevant chart coverage, both paper and electronic, with some indication of the local chart accuracy
- courses, offings, bearings and transits for safe navigation in a range of possible/likely conditions
- where appropriate, information on specific local dangers or risks and any possible mitigations
- plans or chartlets and photographs to illustrate the text
- details of any regulations/requirements relevant to the country or region
- advice on dealing with authorities and official procedures
- descriptions of harbours and anchorages with directions for access from seaward
- details of locally available facilities
- an indication of local accessibility to communications, including sources of weather and maritime safety information
- details of any local search and rescue facilities
- where appropriate, a language glossary

On screen pilotage

A growing number of websites and apps provide pilotage information and many established paper pilot books, cruising guides and almanacs are now available electronically. Advantages over paper books are that they are instantly available, often for free, they can be updated frequently, and they may be interfaced (or layered) with other onboard electronics. Information contained within them may include links to real-time information such as weather data tweeted from buoys or even webcams trained from landward onto hazardous river mouth bars (such links require data access, so may not be available when you decide you need them).

Logs, blogs, vlogs and posts

These can all provide an excellent source of information, especially at the planning stage, and are another basis for decisions on where and when to cruise.

Disadvantages

- Usually a one person account
- Often a single visit or voyage
- May be commercially driven

When it comes to gleaning any pilotage information from individuals' storylines we should always look at more than one source to reach a more balanced, less personal view.

Backup pilotage information

As with all systems onboard, relying on electronics for our pilotage information leaves us vulnerable to power failure or drop out of signal and to a more general lack of resilience of our phones, tablets or PCs in the marine environment. A paper book doesn't need a power source and cannot break down. On the other hand it can be soaked to a pulp or it may get sufficiently damp that its pages stick together irretrievably. Either way, just like our charts, we need to know that our pilotage information will be available to us on passage when we need it. That might mean looking after our paper books or it might mean being very certain of all of our electronic backup systems.

A strong argument in favour of paper books is that their layout helps us to look across and between pages to absorb all of the relevant information quickly. On screen that can sometimes be more time consuming and involve a lot of scrolling up and down or clicking/zooming in and out. A disadvantage of paper books is the time it takes to publish. Content will have been gathered some time before publication, so even a brand new pilot or cruising guide will contain information that is out of date. We need to factor in this probability and regularly check the publisher's website for any updates.

How to know what pilotage information to trust

There is a vast amount of pilotage information available, both in paper and electronic form, but the quality of the information varies very widely. A growing number of websites and apps are home to crowdsourced pilotage information. These are accumulations of reports, usually from single visits. They are often posted on open forums, or hosted by club websites. In the case of club-based sites the information may not be accessible to non-members. Both club and open-forum websites may attract thousands of contributions. If reports are not kept under review they may accumulate contradictions and inconsistencies which become confusing over time.

It is sometimes difficult for pilotage moderators to make the right judgement about incoming information. Even reports written by experts with local knowledge, such as harbourmasters, can suffer from subjective bias; one writer's "challenging" may be another's "dangerous", "bustling and vibrant" may translate as "overcrowded and stressful", and so on. A common problem is that one boat will visit a place when it is completely protected and tranquil whereas another boat will be there in a gale with swell diffracting round the headland and making life an uncomfortable misery. The two experiences will be completely different and it can be difficult to unpick any comments made unless background information such as wind direction and strength or direction of prevailing swell is known.

If we want to assess the reliability of pilotage information in any form, we should ask a few questions:

- Is the information accurately geolocated to the correct place?
- Has it come from a known and trusted individual or organisation?
- When was the information published? Is this made clear?
- Are more recent corrections and updates (supplements) available?
- Is the content driven by advertising or other promoting commercial pressures?
- Is it a one season account, or has the information accumulated over a longer period, perhaps with multiple editions?
- Is the coverage balanced and relatively free of the subjective opinions of one person?
- Is it appropriately comprehensive in its detail? If not, is this made clear?
- Are units, datums and other technical information used consistently?
- Does the information seem to correspond with what we know from other sources?
- Does the information appear to have been edited, reviewed or quality checked in any way?
- How complete is the information?

In terms of content, some of the information available from websites or in apps may be short on the broader cruising advice and sailing directions that are usually contained in more established books and guides.

CAMBADOS

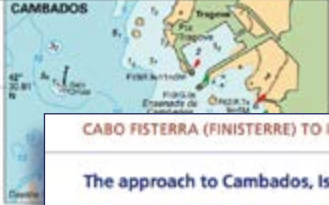
Cambados (Puerto de Tragoso and Cambados old harbour)

(See also plan page 76)

Location
42°30' 51N 08°49' 58W


Tides
Standard port Lisbon
Mean time differences (at Vilagarcía)
HW +0830 1007L; LW +0115 2600S
(The above allows for the difference in time zones)
Night's in metres
MHWS MHWN MLWN MLWS
3.5 2.8 1.3 0.5

Light
Breakwater F(2G) 6 Green round tower



CABO FISTERRA (FINISTERRE) TO ISLA ONS

The approach to Cambados, Isla Toxa and O Grove




Attractive old town, shallow harbours


The modern harbour (Puerto de Tragoso) is large but shallow and supports the major trawler industry. The old harbour (Cambados-San Toxas) is small and shallow but has fuel.

Cambados is a small town with an attractive and historic central square and imposing buildings. It is

Cambados Marina. Fuel dock to starboard.
Geraldine Hennigan



Cambados harbours from the west



Location
Centred on 42°30' 51N 08°51' 2W

Tides
Standard port Lisbon
Mean time differences (at Vilagarcía)
HW +0950 2007L; LW +0115 2000S
(The above allows for the difference in time zones)
Night's in metres
MHWS MHWN MLWN MLWS
3.5 2.8 1.3 0.5

Lights
Baño La Loba F(2G) 7.0m 7M Gray truncated conical tower, green top
Baño Pragaero F(4G) 11.0m 5M White truncated conical tower, green band
Baño Lobeira de Cambados F(2R) 6.10m 5M White truncated conical tower, red top
Baño Gólfera Q. G. 10m 3M White truncated conical tower, green top

A chance to stray from the beaten track

O Grove is popular with tourists in season and numerous tripper boats operate from here.

Cambados is a sophisticated old town with limited mooring facilities for yachtsmen.

Toxa (Isla Toxa Grande) is for the smart set and offers pleasant anchorages.

Approach

The area south of Isla de Arousa and north of the Península O Grove and approaching Cambados has numerous shallows, rocks and fields of seaweed, but it is well marked.

From a point approximately 1-1.5M south of Isla Ria, head east and pass midway between La Loba and Los Mexos. Both are clearly marked dangers. Leave Bajos Pragueros beacon to starboard and Lobeira de Cambados beacon to port.

For Cambados Track between riveros on about 075° towards the breakwater, leaving 1-5m shoal patch marked by a W cardinal, to port.

For the Toxa anchorages head almost to Cambados before working south through the shallows.

For O Grove from Lobeira de Cambados beacon Head southeast to the line of riveros which run down to O Grove harbour. Do not cut the corner, rocks protrude well beyond the line between Gólfera and the harbour.

92 ATLANTIC SPAIN AND PORTUGAL

BOOK SUPPLEMENTS WITH UPDATES AND CORRECTIONS

The quality of Imray and Royal Cruising Club Pilotage Foundation publications is enhanced by contributions from sailors visiting the area. We welcome all feedback for updates and new editions. If you notice any updates, errors or omissions, please let us know via info@rccpf.org.uk or www.rccpf.org.uk/Provide-Feedback. Reports are posted on the Cruising Notes page of the Pilotage Foundation website and incorporated into an annual supplement available free of charge from www.imray.com or www.rccpf.org.uk.

Printed copies are available on request from Imray.

One benefit of paper book layout is that it we can cross reference text, plans and photographs very readily

Good sources of pilotage information are corrected and updated on a regular basis

79

Provenance

It is always worth reading the preliminary sections of a pilot book or cruising guide - the Preface, Introduction, even the Acknowledgements. Is it a one off or the latest update of knowledge accumulated over many years? How well do the authors know the area and how well-connected are they with other cruisers, harbourmasters, and so on. The preliminaries give a good feel for the provenance, or pedigree, of the information; by how many people, and for how long has it been collected, studied and revised, and to what extent has it been moderated, validated and kept up to date. One advantage of books – either hard copy or electronic - is that this background information is normally presented as part of the publication. It is sometimes much harder to know the provenance of information with a website or an app.

Cross checking pilotage information

At the planning stage it is sometimes difficult to assess reliability, but once we are out on the water we should compare any pilotage information with the reality we are facing. The amount of information contained within some of the most long-standing pilot books is enormous and, taking into account the likely time delay before information is published, it is reasonable to expect some errors. However, if there are a lot of errors and inconsistencies, the reliability of the source should be questioned.

Routeing

Routeing on electronic leisure charts

Even without any add-on routeing software, many of the more recent electronic leisure chart displays allow us to create a line between our port of origin and our final destination to then pull up an optimised route. We can enter the draft of our boat, and the inbuilt software will suggest a route for us. But unless we have a more sophisticated, integrated system this will simply be telling us the shortest route that allows for our draught. A chartplotter route like this may not be the best route for us once boat performance, wind, tides, currents and sea state, or other unknowns such as visibility, have been taken into account. Use such routes with extreme caution and check against all other information available.

Whether we use an automated route plot or plot one ourselves, if we are using vector charts, we need to zoom out to view as much of the area of the route as possible, but then progressively zoom in to high zoom, looking for hazards all along the route and close to it, making adjustments to the route as necessary, and also thinking about a backup plan if conditions should change. For example, if we take longer than expected to reach the next headland will we be at the mercy of a dangerous tidal race? Has our route taken the race into account with our expected timings?

It is useful to select buoys or other physical markers to help to confirm our location at points along our route, but we must set any waypoints off to the safe water side of the buoys, and with a margin to allow for swinging circle, so that we don't accidentally run into them.

For our favourite routes it is very common to use a previous passage plan already plugged into our chart display systems in a track library. But things do change, sandbanks shift, windfarms are built, ships are wrecked. Our electronic chart may well have been updated to take all of these into account but we need to check our route to make sure that we have spotted any changes where our old route might now put us onto danger.

Weather routeing

Although usually not in a formal way, we all weather route when we make a passage plan. Knowing the performance of our own boat, we look at the tide and the forecast wind to work out what the fastest or most comfortable route will be. We make a best guess at our likely speed and use that to time our arrival at tidal gates or other key points along our route. As departure approaches we look at the actual wind and adjust the plan as necessary.

The latest explosion in technology has revolutionised both the amount and accuracy of weather forecasts and the way in which we can receive them. Now, GRIB files and algorithms give routeing results at the touch of a computer key. A clear route can be presented to us on our chart and, in theory, all we have to do is to sail along that route to get there the fastest or the most comfortable way.

Increasingly common on weather routeing programs is the ability to add in ocean currents and tidal stream information, which can be integrated into the routeing solution as they are also available in GRIB file format. This takes out some of the guess work when sailing in tidal areas. Sea state, a combination of ocean swell and wind waves, can also be taken into account, allowing the route to be adjusted to avoid rough areas if required.

WEATHER INFORMATION

How do we access weather information?

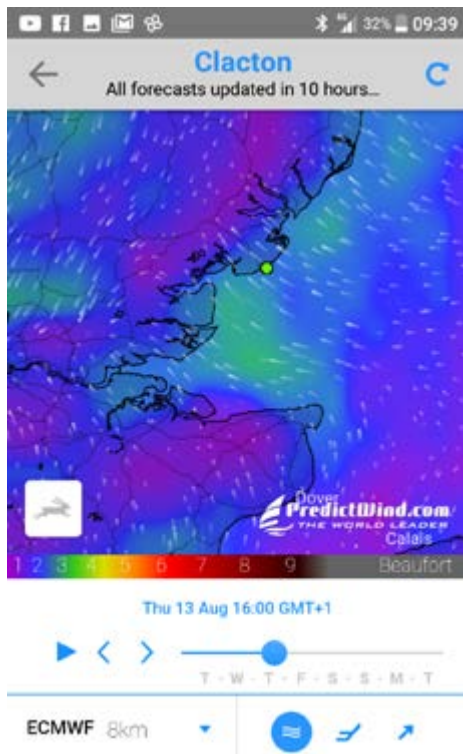
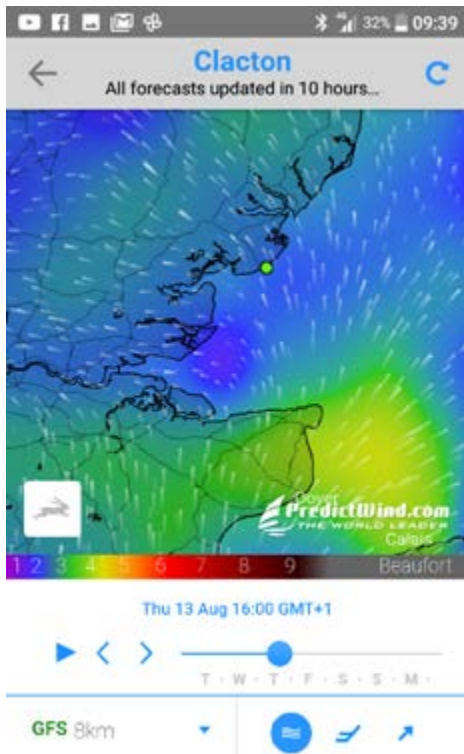
Audio forecasts are available via VHF, MW or HF radio in many coastal regions, sometimes by means of an automated electronic voice. We can also receive weather information via our mobile phones, but only if we are within range (see *Mobile phones as backups*, page 56). We need a satellite phone or HF radio if we are heading further offshore, and on longer offshore passages the amount of data we can download becomes an important consideration.

GRIB

GRidded Information in Binary (GRIB) is a data format that allows large amounts of historic and forecast weather data to be stored and transferred in relatively small files. It is used by most meteorological centres worldwide to generate their weather prediction models.

Weather prediction models

Global forecast data models include the Global Forecast System (GFS) model, produced by the US National Oceanic and Atmospheric Administration (NOAA), and the European Centre for Medium-Range Weather Forecasting (ECMWF) model. There are other global models as well as many regional models. Data points in the global models are relatively spread apart, typically 9km or more between data points. Regional models reprocess the global data on a much finer grid of closer to 1km between data points, factoring in a more detailed representation of land features.



As a rule of thumb, when the models differ there is less certainty in the forecast.

Weather apps

Weather forecasts and weather routing capabilities may now be packaged together in a single app. The variety of such apps has markedly improved the access to, and use of, digital weather information. All of the various weather apps source their data from one or more of the data models.

Some things to be aware of

- A relatively low resolution model, with data points spread 9km or more apart, is usually adequate offshore, away from the effects of land
- Regional interpolations are better for coastal sailing, but meaningful data can still only be produced for land features that are bigger than the data grid. So, even at the much higher regional resolution any localised coastal effects, such as acceleration zones off high peaks, around headlands or up and down river valleys, are unlikely to be factored in with any accuracy
- Forecast timing is important. Some apps do not use the most recent data set and, depending on the frequency at which source data is published, there may be up to a twelve hour time lag in what we see in an app
- High resolution interpolations tend to give unstable results after about 36-48 hours, so using them as the weather input for a routing app passage plan for longer passages is usually counterproductive.

The best apps use recent, original data, at the best available resolution, from a reputable source. It is easy to get sucked into the comfort of professional displays and easy-to-use routing programs without understanding the data behind them, but it is still just as important as ever to understand and monitor basic weather patterns in order to judge how accurately the screen predictions match reality. We should monitor a variety of forecasts for several days before a passage and then continue to monitor them, as much as possible, during the passage itself

When weather systems are more settled the forecasts will tend to align. When systems are more chaotic the different models tend to interpolate differently and there may be diverse presentations of forecast weather. In itself this is a good indicator of how trustworthy, or not, any of the predictions might be.

AtoN - Value added services

Modern AtoN now often have spare power available, due to sophisticated solar panels and LED lights. This spare capacity can be put to use for value added services to support safer navigation. For example, in Irish Lights jurisdiction this spare power is used to run weather measuring sensors and to transmit the trial data gathered via AIS. Much of this data is relayed to Met Eireann for use in their forecasts. However, it is also transmitted back to the Irish Lights HQ where, after some formatting, the values are automatically posted on Twitter every 20 minutes; each AtoN involved in the trial having its own twitter account. In addition, the data is stored, analysed and graphed via the Irish Lights MetOcean website pages, where it can be viewed or downloaded in different formats to assist in passage planning.

The expectation is for an increase in these sorts of remote sensing techniques, but there are still some challenges to be resolved during the trials phase.

Professional weather forecasting and routeing

The last few years have seen a significant jump in both the accuracy of forecasts and also the availability of the information. For a weather forecaster it has opened up new markets, as it is now possible to obtain almost as much information as the state-run meteorological offices.

With access to multiple high resolution models, satellite imagery, and observations, as long as broadband is available it is now possible to make accurate forecasts for anywhere in the world. In many cases it is not the shortage of information that is an issue, but the filtering of what is relevant and accurate from the rest.

The immediacy of so much information has created a number of weather routeing “experts” who are not themselves forecasters and whose main skill is in putting a GRIB weather file into a routeing program and interpreting the results. This is alright as far as it goes, but the true experts are both forecaster and router and offer a very different level of information. It is important to understand the differences in services available.

Forecasters can look at an array of information to get a general picture of what is actually happening. Satellite pictures of a decade ago were often 6 hourly, however now they come through every 10 minutes (US satellites) or hourly (European) for multiple bands. Although only twice a day, satellite derived wind information from polar orbiting satellites is available for large areas of the oceans.

The forecaster will take all the information available and then look at possible routes. Routeing programs will be used for this, matching the expected wind speed and direction with a boat’s individual sailing characteristics and with tides, currents and sea state. By projecting the expected position of the boat forward in time with the next time step of the forecast algorithms, an optimum route can be generated.

Once an optimum route has been computed a truly expert forecaster will also make a risk analysis of the route in terms of what would happen if there were small changes in the weather or boat speed; would this make a large difference in the route? What is driving a particular solution? If it is the conditions at the end of a long range forecast, how realistic are those conditions likely to be? Different routes can be given risk factors, and a slightly slower route may well carry a lower risk.

There is also the requirement of the client; weather routeing for shipping grew out of damage avoidance and not, as is sometimes quoted, to save fuel. Leisure vessels may also have an objective other than pure speed. In theory, on all but light displacement boats, the stronger the wind the faster the boat, so routeing will tend to steer towards the strongest wind. However, away from the most serious racers, the requirement is often for a comfortable and safe route. If the wind drops below a certain level, leisure sailors will often be happy to motor and this is seen as preferable to the discomfort of high winds and seas.

GRIB file forecasts are an average and there will be significantly higher gusts; squalls or thunderstorms will not be represented. This is another area where a proper forecaster can add value. The best example of this is an active cold front where so much more is going on than just the slow veer shown on GRIB files. An unstable atmosphere may well give gale force squalls within a front whilst the files are indicating much less.

There are a lot of variables to take into consideration when weather routeing. Commissioning a professional to prepare a forecast and route will tend to give more accurate results the longer the time that is given to it. But such a shore based forecaster and router is not always available, and of course there is a cost implication.

Automatic, off the boat, weather routing

A recent new addition to the routing market is the possibility of sending our position and destination to a computer ashore which will then send us back a route. We need to set up and register our boat polars on the system, adjusted as necessary, and, depending on subscription level, opt into any other preferences, such as inclusion of tides and ocean currents, or comfort vs speed. Once registered it is then fully automatic and not only will we be able to display the route on our chart screen, but the information will also be presented in tabular format.

Some services run the route through up to four models, rather than basing everything on a single model. This gives a confidence level, depending how close the different routes are. If the routes are similar, then the level of confidence is high but dissimilar routes indicate low confidence.

The main advantage of this type of service is that having the routing done ashore and just the solutions sent to the boat is a huge saving in data. The main disadvantage is that we then only have a solution but not the workings, which can leave us working from nothing if the forecast proves to be wrong or if our electronics fail. Without any of the forecast we would be blindly following a route without understanding why. For this reason it is a good idea to also download separate GRIB files for part, if not all, of the route. For a long passage we would want to keep updating the route, day by day.

Calibration

With integrated systems it is essential that the various components are correctly calibrated. An offset wind instrument or an offset log will have a big impact on the apparent information on each tack. Likewise, a fouled log will have a big impact on speed calculations. All of these will impact on polars. With any weather routing programs, it is true to say that “Rubbish in gives rubbish out”. Incorrect polars or an inaccurate forecast will give results that are misleading. It is also important to keep updating forecasts and routes to reflect the changing conditions, as any changes in the forecast on successive model runs may have a significant impact on the route.

Polars

We can take the design *polars* (the boat's potential speed on each point of sailing) and integrate them with weather predictions and tidal information to optimise our passage planning. When it is available, this off-the-shelf performance data usually needs some modification to take cruising into account. Polars are usually for light boats in flat water and sailed by a full crew, not loaded with cruising gear. The reality on longer passages or races is that the boat is loaded with food and equipment and is heavy, the crew is more likely to be short-handed and tired, and the sea state is never flat. It is perfectly possible to test and refine the polars for a specific boat, but it is really only the top end race boats that have accurate boat performance data. Without this accuracy, the fine tuning of weather routing is not possible, although it will give a reasonably good indication.

Autopilot settings

An autopilot will simply steer a course to maintain a given setting:

1. If that setting is simply a course linked to the autopilot's internal electronic compass then it will just keep correcting the heading onto that compass course.
2. If set to an apparent wind angle linked to the wind instruments then it will adjust the course steered as the wind changes direction.
3. If set to "Go To" a waypoint the autopilot will try to keep as close to the rhumb line as possible and the deviation will be displayed as XTE (cross track error).

If we are linking the autopilot to more integrated routing (a series of waypoints), we must make sure that any waypoints are set to seaward of any AtoN, taking into account their probable swinging circle. We should also ensure that an appropriate XTE alarm is set to keep clear of any hazards close to the route.

Autopilot settings allow adjustment of the speed/angle of rudder response to changes. These may not be able to cope with holding a course in all weather conditions. Depending on wind strength and sea state, autopilots may be a major drain on power and this increases at higher response settings and in more extreme conditions.

The autopilot is not making any calculations about tidal sets or sea state. Even if our autopilot is integrated with our chart system and other instruments it is still 'blind' in many respects and we need to monitor it constantly. Not only is there a possibility of it heading us into danger but it may not be able to cope with the conditions, especially under sail. Again, we must continue to use all available sources of navigational information to confirm our situation and adjust our route plan when necessary

The ColRegs require a that *"Every vessel shall at all times maintain a proper look-out by sight and hearing..."*

GNSS and routing

Any loss of GNSS accuracy or availability will impact on all of the onboard instruments that use GNSS derived input, whether for positioning or timing, including GNSS compasses in autopilots.

Ocean navigation

Many of us who head offshore to cross oceans would like to be confident in using a sextant to navigate but we may be put off by the complex “sight reduction” calculations using astronomical almanac and tables. There are now a number of apps and programs to help us with all the calculations and with star and planet identification. This is a great way to improve confidence and makes sextant navigation much more familiar in the event that our electronic navigation systems fail.

It is worth remembering that people successfully navigated across oceans for hundreds of years without even mechanical logs or sextants, let alone modern electronic systems. If our electronics fail us mid-ocean the situation is far from disastrous. For example, any vessel on a trade wind route is likely to arrive at its approximate destination sooner or later. This is proved every time an abandoned yacht turns up on the windward shore of a Caribbean island several weeks or months after being left at sea. As long as we have access to a copy of our passage log and a passage chart, we should have some idea of our position and likely track. We can use a compass to maintain and record our direction and navigate by dead reckoning (DR) and we can estimate and record our log speed and any effect of current to give us an estimated position (EP) (see page 72). Then we should aim to make landfall a couple of miles to one side of our intended destination so that we know which way to turn to find it.

Wherever we are sailing, the normal availability of GNSS makes it easy for us to practise emergency navigation, whether by DR and EP or by sextant, and then check the accuracy of our results. Practise makes us familiar with the routine, helps to mark the progress of the passage, and means that we can continue to navigate if our electronics do fail us.

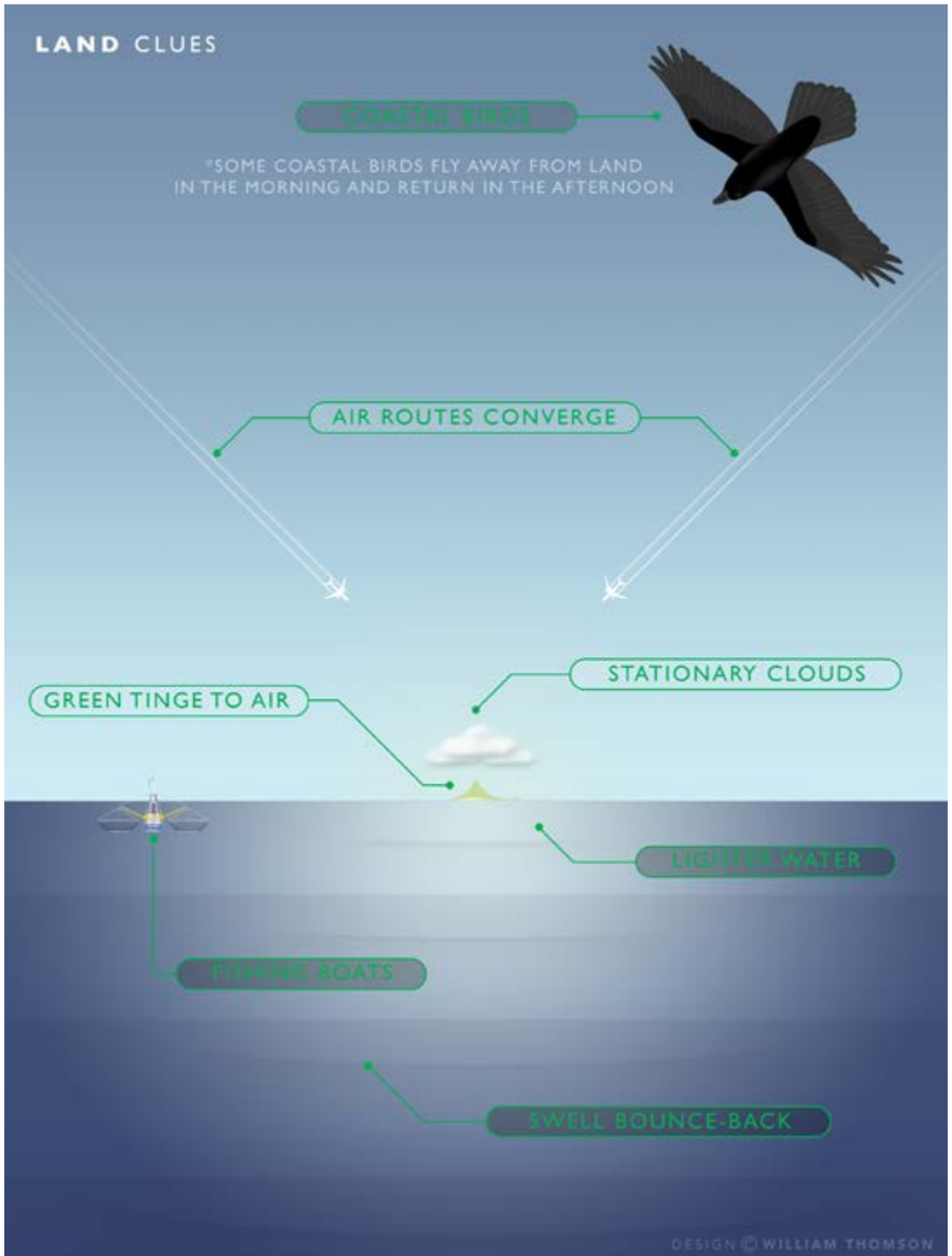
Making landfall

If we are offshore and our electronic systems have been compromised in any way, our main concern will be making safe landfall. We should have some idea of our position, but it is a good idea to assume that we are one or more days closer, depending on how long we have been estimating everything. Inhabited coasts tend to be well lit and it is likely that we will see the loom of lights from at least 40 miles in good visibility. Clouds tend to form over land and can be a good indicator during the daytime, particularly over mountainous islands. We are likely to see an increase in bird activity and may notice varieties of coastal birds. We may notice a change in sea colour and we would usually expect to see fishing boats and in increasing numbers. Commercial flight paths and the frequency and direction of shipping traffic can be another guide. The availability of commercial radio stations is also a sign that we are closing in on land. The language spoken can help to confirm which country we are approaching. Closer in we may start to smell the land or, closer still, hear breakers on the shore. In other words even if we are very lost we should have plenty of indicators that we are approaching land, whether by day or night.

Navigation essentials to keep onboard

The level of backup we need depends on the passage we are planning and the risks likely from any system failure. We might choose secondary, stand alone, electronic systems such as a smartphone or GNSS enabled tablet equipped with suitable charts, tidal and pilotage information, or we might prefer to have enough paper charts, navigation instruments, navigation records and pilotage information to enable us to complete the voyage without relying on electronic systems. Either way, a robust and resilient ability to navigate requires some backup essentials:

- Up to date chart(s) of a suitable scale, covering the expected route for our voyage and including any ports of refuge which we might need to go into if the passage plan has to change
- In the case of an electronic device these must be installed on the device and must not rely on a data transfer;
- A logbook (which can be a simple note book) with an ongoing record of key information at specific times
- A corrected compass fitted to the vessel
- A hand-bearing compass
- A pair of binoculars
- An echo sounder or 20m plumb line marked every 1m
- The functionality to plot a position, whether or not GNSS is available: Pencils, dividers and a plotter or parallel rulers to plot positions and courses onto paper charts OR menu tools that allow us to plot bearings and positions on our electronic system
- A current almanac or tide tables for the planned ports (or other written details of the tides sufficient to enable any necessary calculations of heights and streams to be made;
- Details of forecasted weather, sea state and swell direction
- Pilotage information for unfamiliar sea areas and ports



Keys to safety

All sources of navigational information, whether electronic or not, are tools to help us to navigate safely, but each have their limitations. We should never rely on only one source of information. We should always cross-check all the information available. If something doesn't seem to fit we should ask questions and make further cross-checks.

We must remember that buoys and other floating AtoN usually have a swinging circle and can break their moorings or be dragged off-station, particularly after adverse weather. We should always allow for passing a safe distance off a buoy's charted position.

Aids to routeing, whether onboard, shore-based, human or automated are also only aids. We must always retain sufficient information to cross-check our routeing and to resume safe routeing decisions ourselves in the event of system failures or if the situation changes.

Autopilots and autopilot settings need constant monitoring and cross-checking. In particular, it is essential that we keep a good lookout at all times and monitor where the autopilot is taking our vessel, it is not unknown for them to alter course unexpectedly due to an error in the setup.

When using vector charts we must always remember, as a matter of regular routine, both during passage planning and when on passage, to zoom in and out along our intended route to ensure that all possible hazards are accounted for.

Chapter Six

Future Developments

Value added services

MetOcean data

It would be beneficial to leisure sailors if the trials with MetOcean data, currently restricted to Irish waters, could be extended to UK waters, and for these trials to include other remote sensing techniques, such as the transmission of ocean current/tidal stream data, salinity, ice etc. However, there are still some challenges to be resolved with the trial MetOcean data, which should be used with caution.

ePelorus

It would also be beneficial if manufacturers and the GLAs could progress investigations into the use of ePelorus with electronic leisure charts. There is future potential for use on leisure vessels, embedding resilience in case of GNSS failure:

The GLAs have been working on resilient positioning, navigation and timing (PNT) for many years. This work has included a comprehensive review of different potential solutions and their availability. One option proposed is the development of a ship-based positioning system, independent of GNSS, that makes use of a modernised and enhanced Pelorus to provide a position estimation on the navigation chart. This enhanced Pelorus (ePelorus) system has been developed and installed on all GLA vessels for trials. It enables the navigator to take visual bearings to known targets, using a handheld device. In effect a pair of binoculars fitted with an electronic compass. When used to take a bearing this can be transmitted to the ECDIS or electronic chart system, appearing as a line on the chart at the correct angle. Its position can then be moved using the mouse until it coincides with the object from which the bearing was taken. Another bearing from another prominent object can then cross the first line, giving a fix. Better still, a third bearing can be used to give the traditional “cocked hat”:

Advantages

- It is independent of satellite-based navigation systems
- The device is moveable to where it is needed
- Measured bearings are automatically registered and drawn on an electronic chart
- Multiple bearings can be made with ease
- The information can then be used to feed other systems and confirm the vessel’s position

Disadvantages

- Still in the early development stage and not yet commercially available

S-100 Chart Data

The new S-100 system is set to replace the S57 chart data standard. This is a change akin to the move from 4G to 5G on mobile phones as it will enable a much greater range of value-added service, not all of which are relevant to leisure vessels or small craft generally. The S-100 Standard is a framework document that is intended for the development of digital products and services for hydrographic, maritime and GIS communities. It comprises multiple parts that are based on the geospatial standards developed by the International Organization for Standardization, Technical Committee 211 (ISO/TC211).

See: <http://s100.iho.int/S100/home/s100-introduction>

Recommendations for official bodies, developers and manufacturers

The production of this document has highlighted a number of areas where improvements to electronic navigation systems could be made by manufacturers and official bodies to assist the safety of leisure vessels through better design or regulation. These recommendations do not sit comfortably in this document so are listed on the RIN website where they can be viewed at: <https://rin.org.uk/page/ENav>

Appendix I

The following accident reports, amongst others, are available on the internet as PDF documents and provide useful lessons:

Wahkuna (MAIB 2004) – errors in interpreting the radar (yacht run down by Vespucci in fog)

www.gov.uk/maib-reports/collision-between-container-vessel-p-onedlloyd-vespucci-and-sailing-yacht-wahkuna-in-the-english-channel-off-the-south-coast-of-england-resulting-in-wahkuna-sinking

Ouzo (MAIB 2007) – yacht did not show up on radar and was run down by Pride of Bilbao

www.gov.uk/maib-reports/sinking-of-sailing-yacht-ouzo-after-encounter-with-ro-ro-passenger-ferry-pride-of-bilbao-off-isle-of-wight-england-with-loss-of-3-lives

Gas Monarch and Whispa (MAIB 2007) – collision in fog between LPG carrier and yacht

www.gov.uk/maib-reports/collision-between-liquid-gas-carrier-gas-monarch-and-sailing-yacht-whispa-off-lowestoft-england

Cork Clipper (CV4) (Maritime Claims & Services 2010) – Major horizontal datum error (yacht ran aground on Pacific Island)

www.gov.je/Government/Pages/StatesReports.aspx?ReportID=362

Price Waterhouse Coopers / Flinders Islet (CYCA 2010)

– Service outage (positional error – yacht hit rocks)

<https://s3-ap-southeast-2.amazonaws.com/piano.revolutionise.com.au/site/vqhmeqp8zgzkrjp0.pdf>

Team Vestas Wind (Volvo Ocean Race 2015) – errors in using a vector chart and plotter (yacht hit reef only visible at higher zoom level)

www.volvoceanrace.com/static/assets/content_v2/medialfiles/m36616_team-vestas-wind-inquiry-report-released-on-9-march-2015.pdf

Grounding and loss of commercially operated yacht CV24 (MAIB 2018) - loss of yacht off Cape Town - need for proper passage planning

www.gov.uk/maib-reports/grounding-and-loss-of-commercially-operated-yacht-cv24

Appendix II

Maritime and Coastguard Agency SOLAS V for Pleasure Craft

Chapter V of the International Convention for the Safety of Life at Sea, 1974 (SOLASV):

Parts of Chapter V apply to small, privately owned pleasure craft and are reproduced here:

Voyage Planning

Regulation V/34 'Safe Navigation and avoidance of dangerous situations', is a new regulation. It concerns prior-planning for your boating trip, more commonly known as voyage or passage planning. Voyage planning is basically common sense. As a pleasure boat user, you should particularly take into account the following points when planning a boating trip:

- **weather:** before you go boating, check the weather forecast and get regular updates if you are planning to be out for any length of time.
- **tides:** check the tidal predictions for your trip and ensure that they fit with what you are planning to do.
- **limitations of the vessel:** consider whether your boat is up to the proposed trip and that you have sufficient safety equipment and stores with you.
- **crew:** take into account the experience and physical ability of your crew. Crew members suffering from cold, tiredness and seasickness won't be able to do their job properly and could even result in an overburdened skipper
- **navigational dangers:** make sure you are familiar with any navigational dangers you may encounter during your boating trip. This generally means checking an up to date chart and a current pilot book or almanac carried onboard
- **contingency plan:** always have a contingency plan in case something goes wrong. Before you go, consider places where you can take refuge should conditions deteriorate or if you suffer an incident or injury. Bear in mind that your GPS set is vulnerable and could fail at the most inconvenient time. This might be due to problems with electrical systems, jamming or interference with the signals or meteorological activity. It is sensible and good practice to make sure you are not over-reliant on your GPS set and that you have sufficient skills and information (charts, almanac and pilot book) to navigate yourself to safety without it should it fail.
- **information ashore:** make sure that someone ashore knows your plans and knows what to do should they become concerned for your wellbeing. The MCA now approves and recommends the use of the RYA App SafeTrx which has replaced the CG66 system

Radar Reflectors

Many large ships rely on radar for navigation and for spotting other vessels in their vicinity. So, whatever size your boat is, it is important to make sure that you can be seen by radar. SOLAS Regulation V/19 requires all small craft (less than 150GT) to fit a radar reflector or other means, to enable detection by ships navigating by radar at both

9 and 3 GHz 'if practicable'. This means if it is possible to use a radar reflector on your boat then you should use one. You should fit the largest radar reflector in terms of Radar Cross Section (RCS) that you can. Whatever length your boat is, the radar reflector should be fitted according to the manufacturer's instructions, and as high as possible to maximise its effectiveness.

Assistance to other Craft

Regulations V/31, V/32 and V/33 require you:

- to let the Coastguard and any other vessels in the vicinity know if you encounter anything that could cause a serious hazard to navigation, if it has not already been reported. You can do this by calling the Coastguard on VHF, if you have it onboard, or by telephoning them at the earliest opportunity. The Coastguard will then warn other vessels in the area.
- to respond to any distress signal that you see or hear and help anyone or any boat in distress as best you can. Misuse of Distress Signals Regulation V/35 prohibits misuse of any distress signals. These are critical to safety at sea and by misusing them you could put your or someone else's life at risk.

To download a copy of Solas V for pleasure craft visit:

www.gov.uk/government/publications/solas-regulations-for-pleasure-boat-users

LIFE SAVING SIGNALS

To be used by Ships, Aircraft or Persons in Distress, when communicating with life-saving stations, maritime rescue units and aircraft engaged in search and rescue operations.

Search and Rescue Unit Replies

You have been seen, assistance will be given as soon as possible.



Orange smoke flare.



Three white star signals or three light and sound rockets fired at approximately 1 minute intervals.

Surface to Air Signals

Message	ICAO/IMO Visual Signals
Require assistance	V
Require medical assistance	X
No or negative	N
Yes or affirmative	Y
Proceeding in this direction	☒

Note: Use International Code of Signals by means of lights or flags or by laying out the symbol on the deck or ground with items which have a high contrast to the background.

Air to Surface Direction Signals

Sequence of 3 manoeuvres meaning proceed to this direction.

1



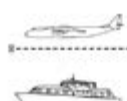
Circle vessel at least once.

2



Cross low, ahead a vessel rocking wings.

3



Overfly vessel and head in required direction.

Your assistance is no longer required.



Cross low, astern of vessel rocking wings.

Note: As a non preferred alternative to rocking wings, varying engine tone or volume may be used.

This diagram is internationally agreed and is contained within the official MCA leaflet on Life Saving Signals that the MCA advise should be kept on board, or if this is not practicable, at least to study the above diagram before going boating.

Appendix III

Shore to Ship Signals

Safe to land here.



Vertical waving of both arms, white flag, light or flare.

Landing here is dangerous. Additional signals mean safer landing in direction indicated.



Horizontal waving of white flag, light or flare. Putting one flag, light or flare on ground and moving off with a second indicates direction of safer landing.

OR



Morse code signal by light or sound.

OR

S: ...

Morse code signals by light or sound.

R: - - -

Land to the right of your current heading.

L: - - - -

Land to the left of your current heading.

Air to Surface Replies

Message Understood.



Drop a message.

OR



Rocking wings.

OR



Flashing landing or navigation lights on and off twice.

OR



OR

R

Morse code signal by light.

Message Not Understood – Repeat.



Straight and level flight.

OR



Circling.

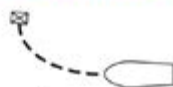
OR



Morse code signal by light.

Surface to Air Replies

Message Understood – I will comply.



Change course to required direction.

OR



Morse code signal by light.

OR



Code & answering pendant "Close Up".

I am unable to comply.

Note: Use the signal most appropriate to prevailing conditions.



Morse code signal by light.

OR



International flag "N".

A copy of this leaflet can be downloaded from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/856119/04_Life_Saving_Signals_small-August_2018.pdf

Notes



Electronic Navigation Systems

Guidance for the safe use on leisure vessels

The objective of this booklet is to provide guidance on the safe use of electronic navigation and associated systems on leisure vessels. Navigating a leisure vessel has always required the skipper/navigator to use all available information and that has never been more important than now, with the availability of ever increasing sources of information. Good navigational safety is still dependent on the continuous assessment by the skipper/navigator of all the navigation-related information available on the vessel – and not just over-concentrating on some, however beguiling they may be.



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