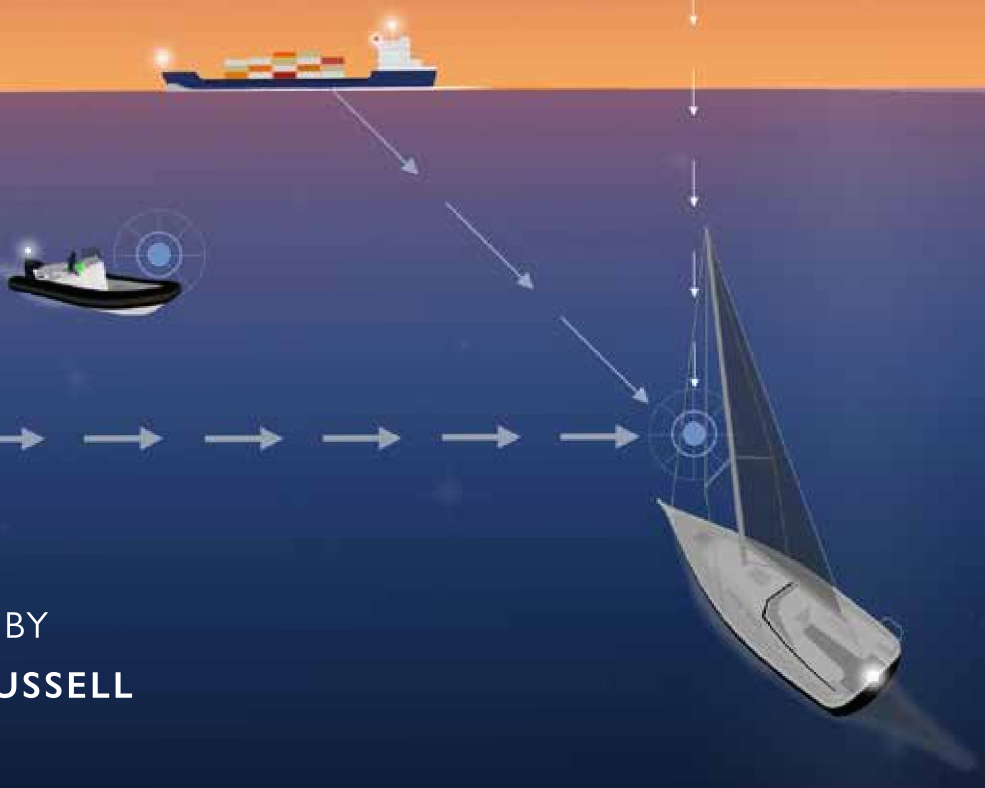
Electronic Navigation Systems

Guidance for safe use on leisure vessels v.2



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Published by
Royal Institute of Navigation
1, Kensington Gore
London
SW7 2AT
Tel: +44 (0) 20 7591 3135

Version 2, 2025

Cover graphic original by William Thomson, with sunset colouration and lights by Tina Rowe-Dunn.

Other graphics by William Thomson as credited, and by Tina Rowe-Dunn.

Produced by CGT Interactive Limited – cgt.uk.com

ISBN 978-1-8382360-2-1 (Print)

ISBN 978-1-8382360-3-8 (Digital)

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

In the past few years, the RIN, via the Pleasure Vessel Navigation Systems Working Group (PVNSWG), has been putting more pressure on all our leisure chart providers and equipment manufacturers and maritime authorities to agree to some minimum standards of display and function. The increased use of apps and software-controlled functionality on standard operating systems should make it much easier for suppliers to update their products, via software upgrades and firmware updates, to meet these proposed standards. Reports on this ongoing work of the PVNSWG are available on our website: ***https://rin.org.uk/page/SCG***

Contents

Acknowledgements

It would not have been possible to produce this document without the assistance of many people and institutions:

First, we must thank **Trinity House** who had the vision not only to actively support the idea for a booklet but also to provide key financial support. Secondly the contributors who wrote text for us or who edited and corrected the drafts, all of them unpaid. Your contributions form the backbone of content and expertise throughout this booklet. Out of necessity, many contributions were edited down or out as we altered the overall scope and size of the document.

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 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)*

The following people have been instrumental in providing text, information, images and feedback on the drafts:

Hugh Agnew
Jaime Alvarez
Roger Barker
Robin Baron
Richard Bell
Clive Blount
Bob Bradfield
Martin Bransby
Paul Bryans
Craig Burton
Nigel Calder
Nick Charman
Emma Clayton
Bob Crighton
Robert Dorey
Jim Duerden
Peter Eddis
Adam Egeland-Jensen
Timothy Evans
Richard Falk
Michael Gill
Alan Grant
David Hackett
John Hasselgren
Catherine Hohenkirk
Kathy Hossain
Darryl Hughes
David Irwin
Simon Jackson
Norman Kean
Matthew Keightley
Grant Kelly
Steve Lacey
Oliver Mallinson
Mungo Morris
Thomas Mellor
Andy Norris
Robert Orr
Rakesh Pandit
Tom Partridge
Susie Plume
John Pottle
Nigel Rennie
Mike Reynolds
Simon Rowell
Jane Russell
Peter Russell
James Stevens
William Thomson
Chris Tibbs
Antony Wells
Lucy Wilson
Regulations and Technical Services group (RATS) of the Cruising Association

and remembering the late
David Last
Roger Grimsdick
Richard Harris
Dag Pike

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. Thanks also to Tina Rowe-Dunn at CGT for all her help and expertise in the production of the booklet in both digital and print versions. 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 is a generic term applied to the variety of small recreational craft classified as 'Pleasure Vessel' or 'Watercraft' under UK legislation.

'Small' in this context means up to 24m Load Line Length. This document is aimed at all users of such 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. A 'Pleasure Vessel' under UK legislation is 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 various regulations; see MCA Small craft codes at https://www.gov.uk/government/collections/small-craft-codes-of-practice. 'Watercraft' were defined in the UK under The Merchant Shipping (Watercraft) Order 2023.

AIS	Automatic Identification System *(see page 47)*
ARPA	Automatic Radar Plotting Aid *(see page 46)*
AtoN	Aid(s) to Navigation *(see page 13)*
BMS	Battery Management System *(see page 57)*
COG	Course Over the Ground *(see page 43)*
CATZOC	Categories of Zones Of Confidence *(see page 33)*
ColRegs	International Regulations for Preventing Collisions at Sea, 1972, as amended
CPA	Closest Point of Approach *(see page 53)*
CSB	Crowd Sourced Bathymetry *(see page 29)*
DGNSS	Differential GNSS *(see page 14)*
ECS	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 84)*
ENC	Electronic Navigational Chart *(see page 21)*
EPFS	Electronic Position Fixing Systems *(see page 7)*
GBAS	Ground-Based Augmentation System *(see page 13)*
GFS	Global Forecast System *(see page 84)*
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 84)*

GT	Gross Tonnage (a volume calculation, not displacement)
HDoP	Horizontal Dilution of Precision (see page 11)
HMCG	His Majesty's Coastguard
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 28)
M	Nautical Mile
MCA	Maritime and Coastguard Agency
MFD	Multifunction Display (see page 20)
NavIC	Navigation with Indian Constellation (see page 11)
NOAA	National Ocean and Atmospheric Administration (see page 7)
POD	Print On Demand
PVNSWG	Pleasure Vessel Navigation Systems Working Group (see page 8)
QZSS	Quasi-Zenith Satellite System (see page 11)
Racons	Radar beacons (see page 42)
Radar	Radio Detection And Ranging (see page 41)
RNC	Raster Navigational Chart (see page 21)
SOLAS	International Convention for the Safety Of Life At Sea, 1974, as amended (see page 102)
SBAS	Space Based Augmentation Systems (see page 14)
SV-ECS	Small Vessel – Electronic chart system (UK MCA performance standard) (see page 20)
TCPA	Time to Closest Point of Approach (see page 53)
TSS	Traffic Separation Scheme
UKHO	United Kingdom Hydrographic Office
VDES	VHF Data Exchange System (see page 16)
WGS84	World Geodetic System 84 (see page 35)
ZOC	Zone Of Confidence (see page 33)

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. The ongoing development of Maritime Autonomous Surface Ships is one indicator of these changes. Many crewed 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 Electronic Position Fixing Systems (EPFS) in place on larger vessels are more robust than 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.

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 the United Kingdom Hydrographic Office (UKHO) and the National Ocean and Atmospheric Administration (NOAA), are moving away from the provision of paper charts towards being suppliers of digital, vector only, hydrographic information. Print On Demand (POD) currently offers continued provision of these official paper charts, but the probability is that the available coverage by such charts will be significantly reduced within a relatively short timeframe. Commercial suppliers may continue to supply the leisure market in selected areas while demand remains. However, whatever our preference, as leisure sailors we may be forced to rely on electronic charts. This reliance demands some key functionality and user knowledge.

There are many reasons why primary navigation 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 V regulations relevant to pleasure craft under 150GT. These include Voyage/Passage Planning requirements but do not extend to the carriage of charts. In essence, the navigation of leisure vessels is less regulated in UK waters. See: www.rya.org.uk/knowledge/regulations/pleasure-craft/solas-v-regulations

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 His 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. 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 was one of electronic versus paper. But in defaulting to that position we were perhaps distracted away from solving some key electronic navigation issues. In the past few years, the RIN has been putting more pressure on our leisure chart providers and equipment manufacturers and maritime authorities to agree to some minimum standards of display and function, for example to enable us to navigate safely on our e-nav systems with or without satellite signals. Reports on this ongoing work of the Pleasure Vessel Navigation Systems Working Group (PVNSWG) are available on our website: https://rin.org.uk/page/SCG

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.

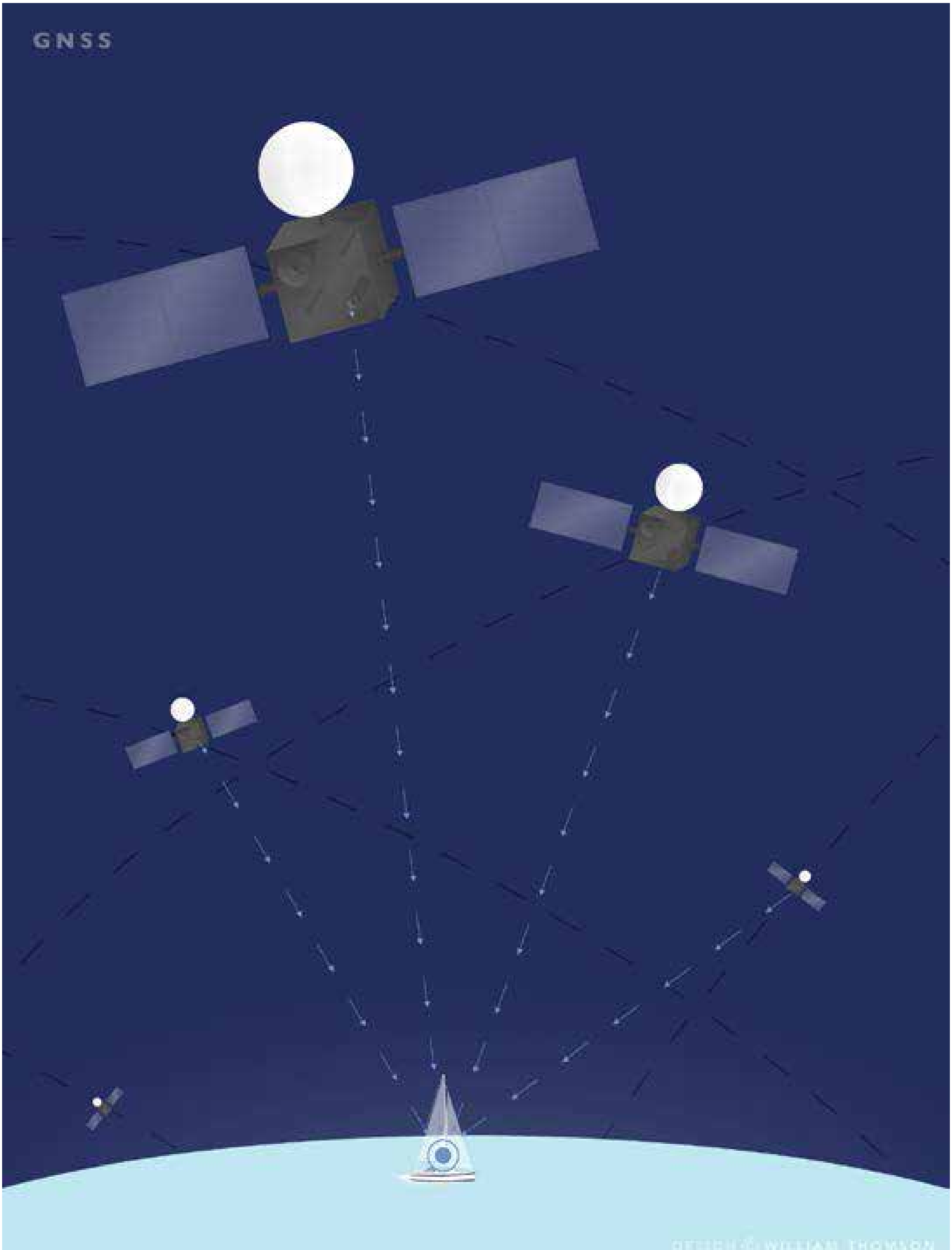
A note from the Chairman of the RYA/ MCA Yachtmaster Qualification Panel

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


GNSS

Chapter One

GNSS in marine navigation

Accuracy and vulnerability

Global Navigation Satellite Systems (GNSS)

Global Navigation Satellite Systems have become the mainstay of virtually all navigation systems. There are four global systems, each of which comprises 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. They effectively allow smaller, simpler, lower cost receivers to view all satellites across multiple constellations. Most newer receivers 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) – United States of America

Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) – Russian Federation

Galileo – European Union

BeiDou – People's Republic of China

There are also regional systems such as Navigation with Indian Constellation (NavIC) and the Japanese Quasi-Zenith Satellite System (QZSS)

GNSS positions are provided by a receiver when it 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 view of a wide 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.

Some equipment now enables visualisation of DoP quality using traffic light indicators.

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 can be 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 even kilometres have 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. The 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 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, were rare until relatively recently, but are now common in areas of geopolitical tension. 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. Simultaneous multiple spoofing events have occurred. Spoofing incidents are most often motivated by criminal activity or nation state actions which may increase during periods of geopolitical tension.

GNSS receivers do not always revert to 'normal' operation after spoofing attacks and may require a reset or, in extreme cases, a factory re-installation.

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 59). 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

A marine aid to Navigation (AtoN) is defined by the International Organization for Marine Aids to Navigation (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 GNSS (DGNSS)

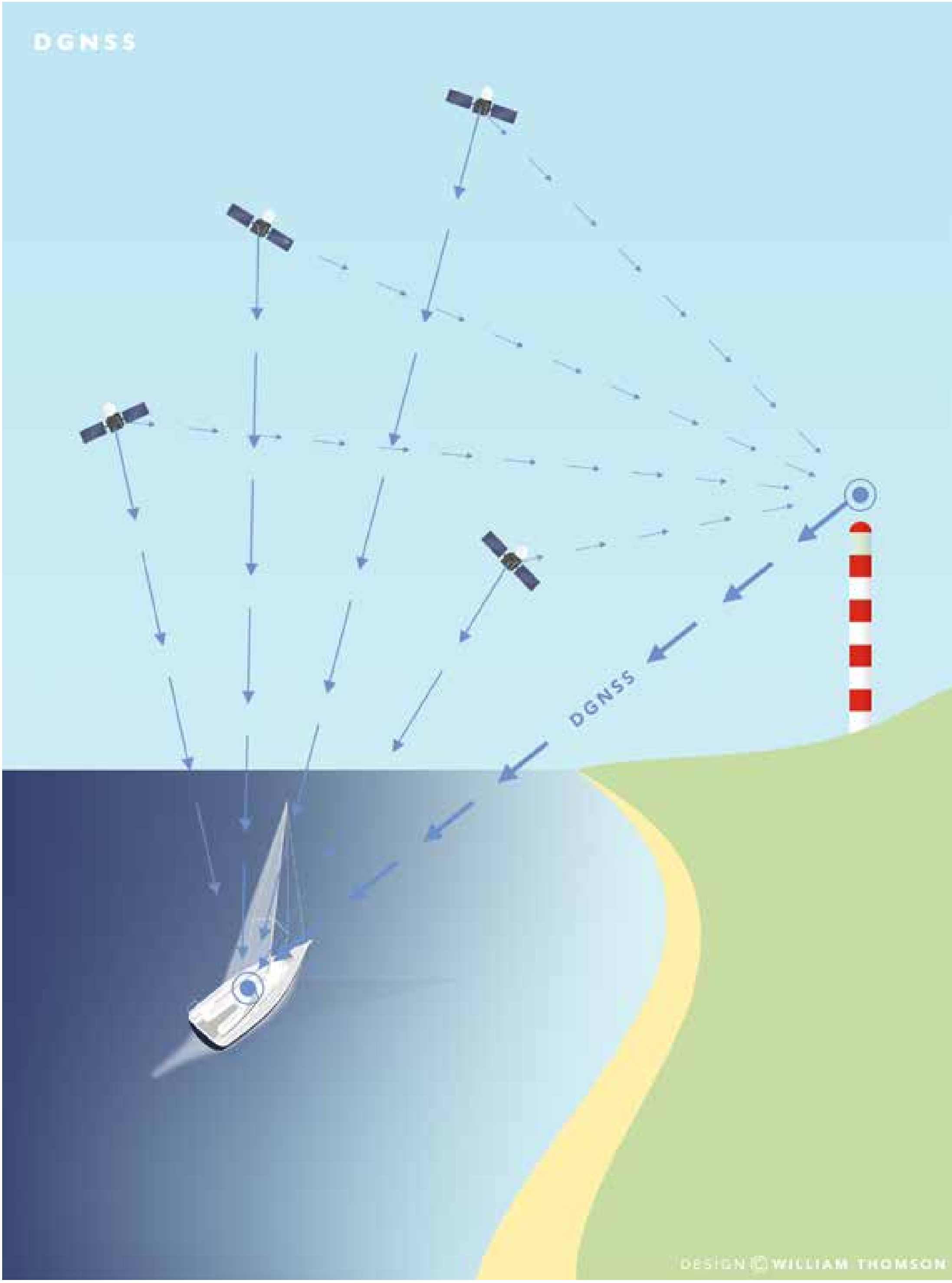
The IALA Beacon DGNSS service is provided variously around the globe. It is a good example of GNSS augmentation. DGNSS typically uses ground-based reference stations providing transmissions with coverage of at least 50M. The satellite fix is enhanced because the reference stations are able to compare their GNSS position to their known, surveyed, location and can therefore calculate the difference as a 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, DGNSS relies inherently on GNSS, the operation and characteristics of which are outside the control of DGNSS service providers and their respective governments, and both are still inherently susceptible to interference, whether natural, accidental or malicious. We should use all alternative means available to cross-check the information received. If we are reliant on the accuracy of DGNSS we should have a receiver which gives us sufficient warning of the complete loss of DGNSS signal and reversion to GNSS.

A number of national authorities have opted to close their DGNSS services. In these areas, DGNSS signals may still be received, but from other nearby authorities. As the signal used may be from a transmitter further away, the correction information may be less accurate.

Space Based Augmentation Systems (SBAS)

Many maritime receivers also include the ability to use Space Based Augmentation Systems (SBAS). These systems are similar to differential GNSS as they provide corrections for signal errors and check the validity (integrity) of the data. The main difference is that the correction information is transmitted from space, rather than via terrestrial signals. Another difference is the correction information remains valid over a very large area, often continental. SBAS systems are available over much of the northern hemisphere with new systems being implemented in the southern hemisphere.


DGNSS
DGNSS
DESIGN © WILLIAM THOMSON

AIS AtoN

Some AtoN are now fitted with AIS transmitters. The positional technology is GNSS reliant. AIS AtoN can currently be implemented in three ways, Physical (Real), Synthetic and Virtual:

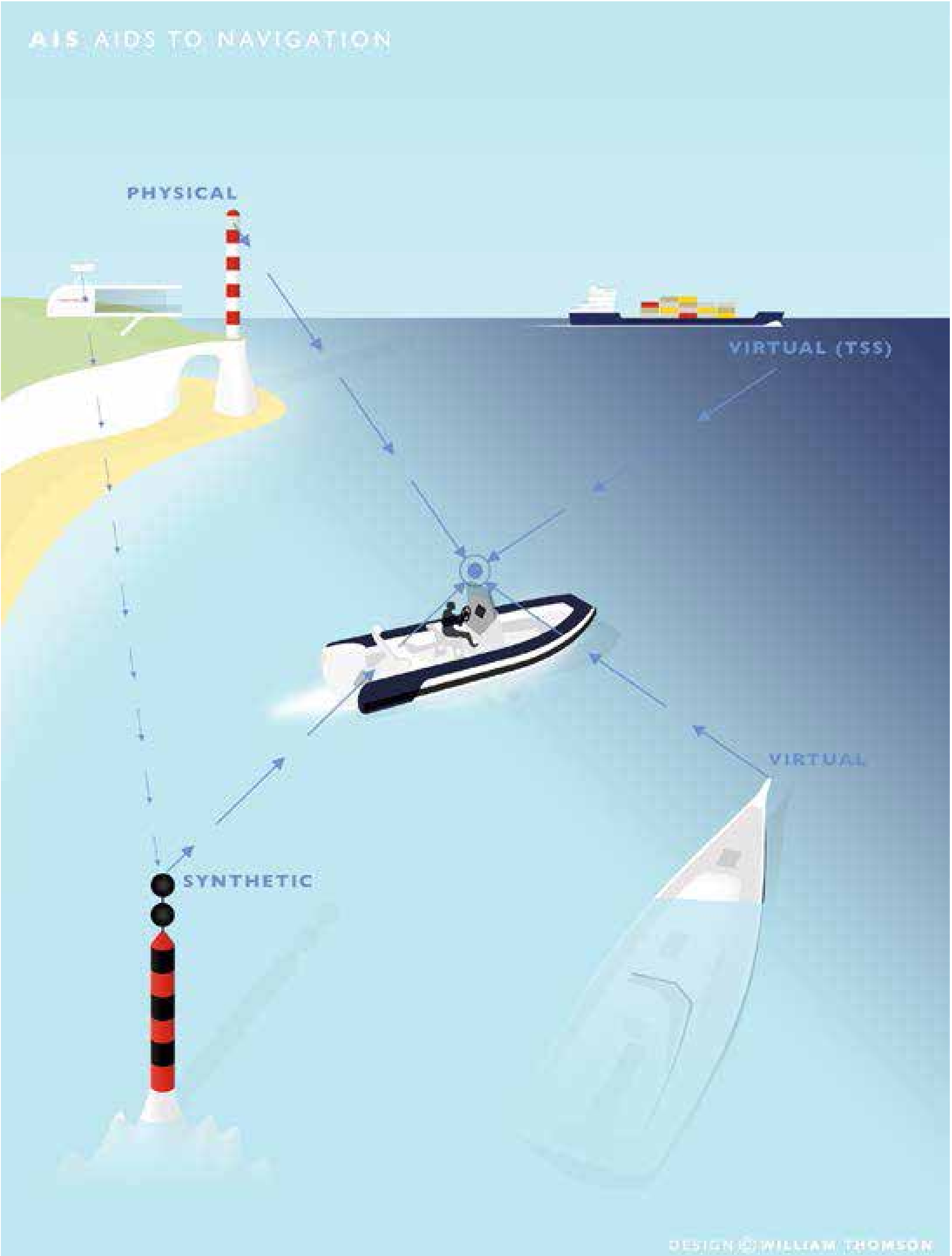
Physical (Real): An AIS AtoN is located on a physical AtoN. In other words, the AIS transmitter is housed on an actual buoy, lighthouse or other physical structure, helping to pinpoint its actual location. Physical (Real) AIS AtoN can broadcast dynamic position and AtoN status information.

Synthetic Predicted/Synthetic Monitored: An 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. A Synthetic Predicted AIS AtoN broadcasts a static position and no AtoN status information. So, even if the physical buoy has moved, the AIS AtoN will remain in the original location (see AtoN positioning page 35). A Synthetic Monitored AIS AtoN can provide some position and AtoN status.

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 iceberg 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).

Real (or Physical) AIS located at physical AtoN

Virtual AIS AtoN are shown on charts as V-AIS


AIS AIDS TO NAVIGATION
PHYSICAL
VIRTUAL (TSS)
VIRTUAL
SYNTHETIC
DESIGN © WILLIAM THOMSON

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 35).

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.

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. Any outages or failures of GNSS impact on the accuracy of AIS data. 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 35).

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 ENCs (see page 21) 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.

Small Vessel – Electronic Chart System (SV-ECS)

SV-ECS is a navigation system that conforms to new UK MCA standards published in January 2025. This new system effectively replaces the electronic chart system known as 'mini-ECDIS' that has been used mainly, but not exclusively, by UK fishing vessels under 24m in length. The system is similar to ECDIS but has some differing requirements with respect to display size and type, route planning and management, the provision of additional information and required back-up systems. A duplicate system may be installed as a back-up but other back-up options are available, including portable devices, provided these also display official ENCs. The new standard applies to fishing vessels and coded vessels (i.e. those in commercial use) up to 24m load line length.

Leisure vessel Electronic Chart System (ECS)

A leisure vessel ECS is an electronic chart system that does not meet the requirements of either ECDIS or SV-ECS. It does not have to be able to display official ENCs (see page 21) and can display raster charts (see page 25). There is currently no approval standard for leisure vessel ECSs.

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 and by SV-ECS. The current S-57 standard governs the data format, or 'language', for hydrographic data and also defines how an ENC is constructed. This standard is being replaced by S-101 (see page 100).

Leisure chart and information display systems

Electronic navigation systems are now the de facto main tool for primary navigation on small craft, especially leisure vessels. 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 SV-ECS. All of them are, therefore, currently unapproved for navigation use.

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). The functionality of MFDs is software controlled, and charts are displayed by chart-specific apps on newer equipment. There has, in general, been a convergence of technology between installed systems and mobile devices. This allows mobile devices to be linked to installed systems, usually through on-board Wi-Fi. However, there are some important considerations:

Multi-connected users: With interconnected systems it may be possible for crew members to override onboard settings. Skippers should exercise caution as to how many crew have access to the systems.

Touch screen controls: Many MFDs for leisure vessels now incorporate touch screen controls. Others retain a hybrid interface with both touch screen and button controls. Button controls can be more reliable to use in an exposed, wet, boat cockpit with wet or gloved fingers.

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 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 little standardisation. There are many different manufacturers, who pitch to different sectors of the market, especially yacht racing. There has been a convergence of technology and hardware functionality, though not software functionality, between the various manufacturers in recent years. However, it remains the case that 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.

Electronic Navigational Charts (ENCs)

Official, up to date, IHO-compliant ENCs are vector charts (see page 23) displayed in ECDIS and SV-ECS. They are now required on most larger commercial ships, and on coded vessels, when used for primary navigation. 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 or SV-ECS to malfunction and they also meet IHO standards for data authentication and the presentation of symbols, lines, colours and so on. HOs also produce Raster Navigational Charts (RNCs) (see page 25) but these are being phased out.

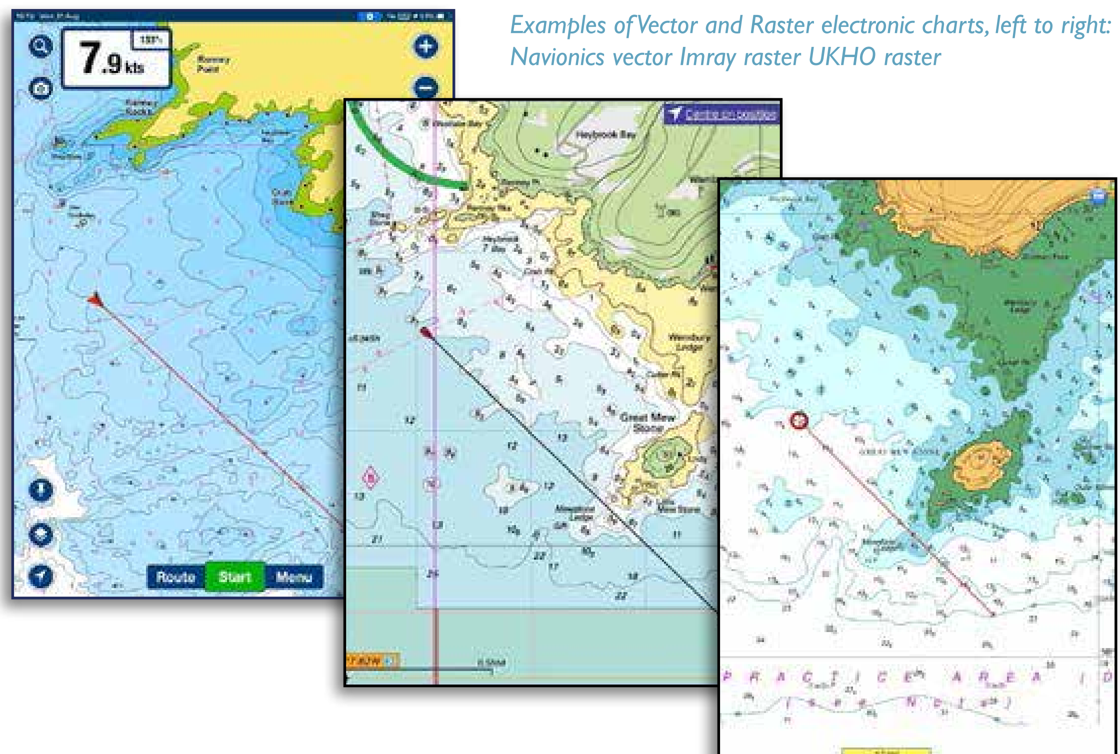
Shortfalls of ENCs for leisure use

Official ENCs, which are displayed on ECDIS and SV-ECS, were designed primarily for the shipping sector (>500GT). Features significant to smaller vessels used to be depicted on paper charts, including features that had been shown on older withdrawn charts, but many of these were omitted when ENCs were first created. With a focus on the needs of larger vessels, these omissions helped to reduce screen clutter. New surveys commissioned by HOs for ENCs also tend to focus primarily on commercial shipping routes, commercial ports and deeper waters. Few new surveys are commissioned for shallower inshore waters used only by leisure vessels. Consequently, ENCs currently do not display all the data needed by <24m vessels, which frequently navigate in areas inaccessible to vessels >500GT. Over the years, this gap has been filled by the leisure chart providers in one form or another. ENCs are purchased on subscription for individual chart cells and are very expensive as there is only one pricing plan for all vessels.

Electronic charts for leisure vessels

Electronic charts for leisure vessels first emerged in the early 1980s and pre-date official ENCs and the S-57 data standard (see page 20). There are many benefits to their use. They are affordable, convenient, and mostly intuitive to read and they can be regularly and automatically updated: The increased use of apps and software-controlled functionality makes it much easier for suppliers to update their products. Electronic charts for leisure vessels 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, electronic charts for leisure vessels often incorporate supplementary data from a variety of other, mostly unofficial, sources to provide helpful, sometimes essential, information to leisure vessels. This includes local surveys of harbour entrances, leisure marinas and small craft anchorages; indications of visitor moorings, seasonal pontoons and no anchoring zones; Marine Conservation Zones and Marine Protection Areas. They may also include data derived from Lidar and satellite images (see pages 28 and 36).

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. Together with their use of supplementary, unofficial, data sources, this is why they are considered unofficial and are marked 'not to be used for navigation' or similar such warning on startup. User acknowledgement of this warning is required by the agreements between chart publishers and the HOs.



Examples of Vector and Raster electronic charts, left to right: Navionics vector Imray raster UKHO raster

Vector or Raster electronic charts

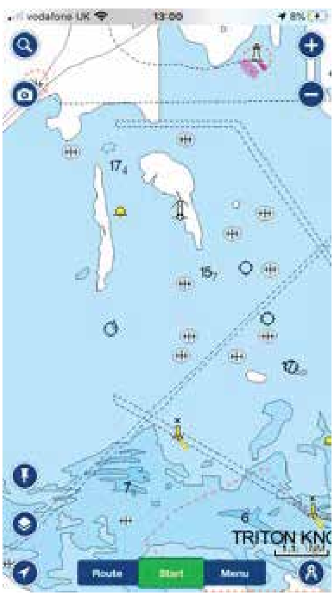
The data on electronic charts was originally extracted from paper charts. Now, it is primarily derived directly from survey data held in digital hydrographic databases. Within these databases, each charted feature or object is associated with a geographic location and with metadata or 'attributes'. Chart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

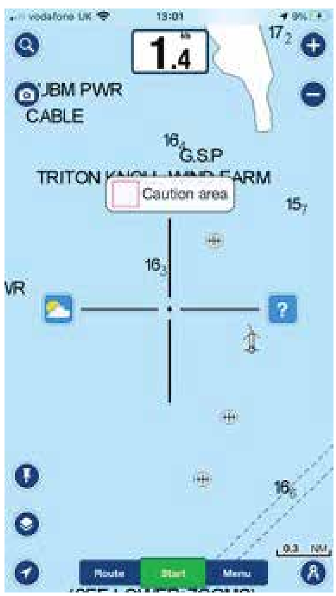
Vector leisure charts

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, 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, 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
- It is possible to zoom in (or over-scale) to a scale larger than that used in the compilation of the data. This may encourage a false confidence in the reliability of the charted information, particularly in regard to the actual size of hazards.
- 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 33)

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.

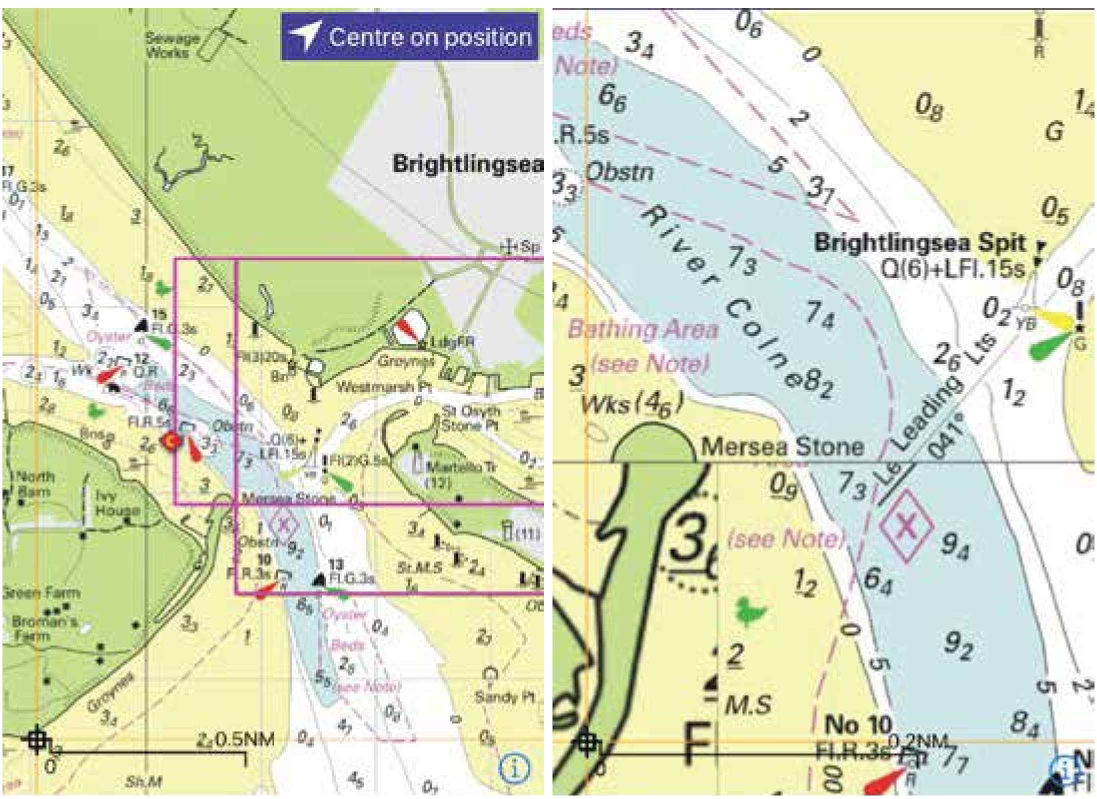
Note that as of 31st July 2026 only official ENCs will be officially recognised by the MCA for carriage on new coded vessels and fishing vessels under 24 m. Where there is limited or no official ENC coverage, Standard Nautical Charts, i.e. paper charts, must be carried. Interim arrangements apply to vessels fitted with mini-ECDIS prior to 31st July 2026. Currently, no leisure electronic charts are officially recognised by the MCA, whether raster or vector (even UKHO raster charts).

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 33)

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 33)
- 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 subsea 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 **Li**ght **D**etection **a**nd **R**anging. It uses pulsed laser light to measure depths.

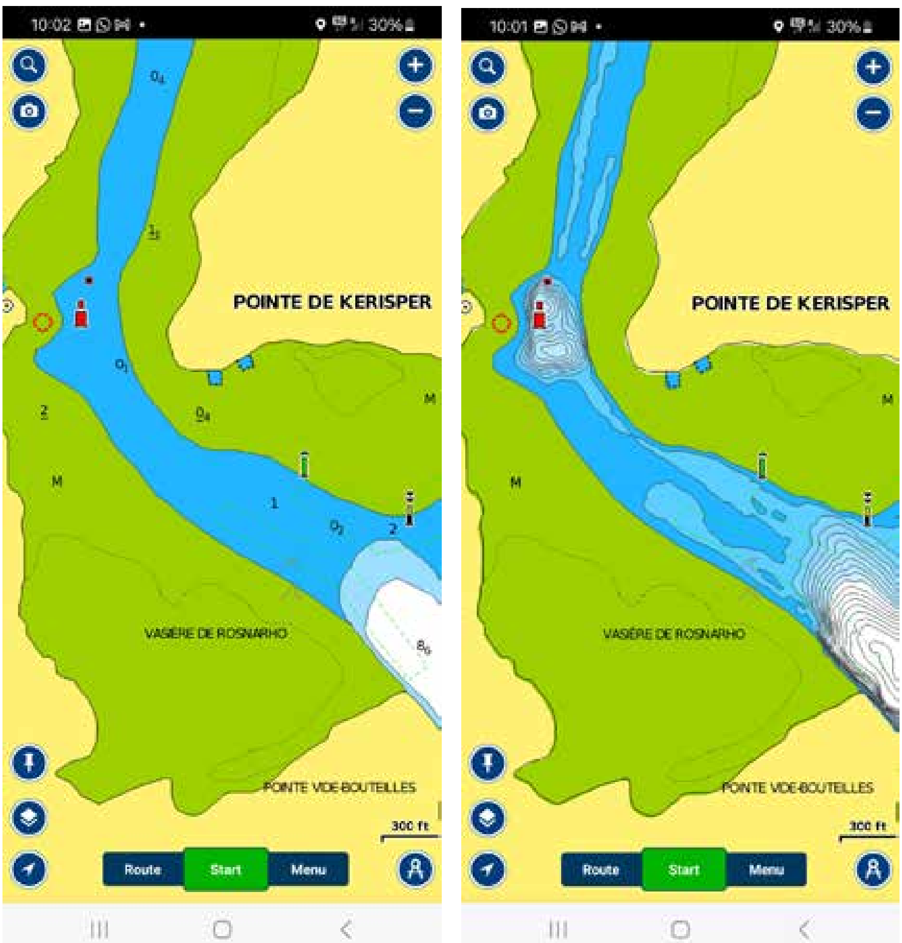
Ongoing limitations

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!

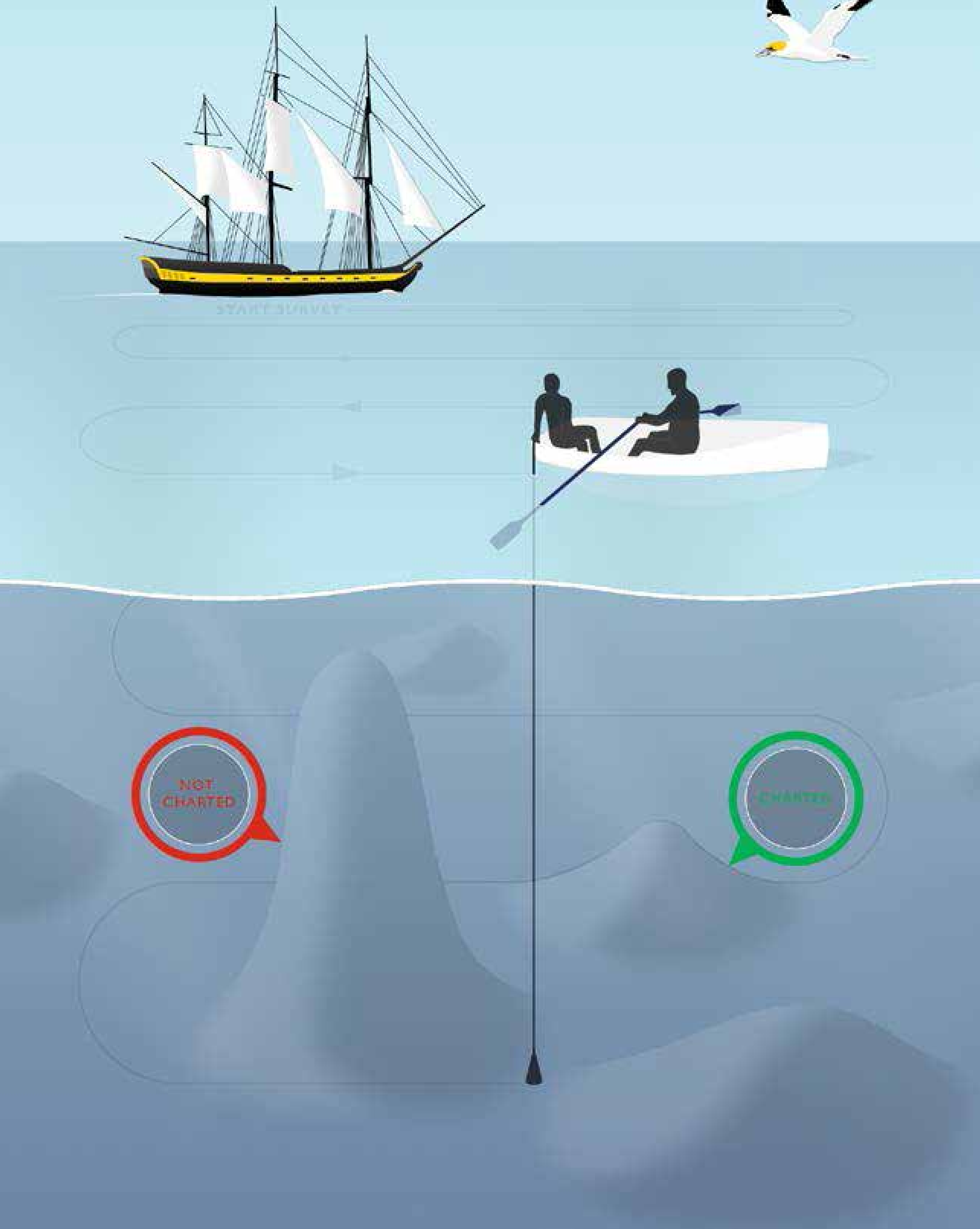
Crowd Sourced Bathymetry (CSB)

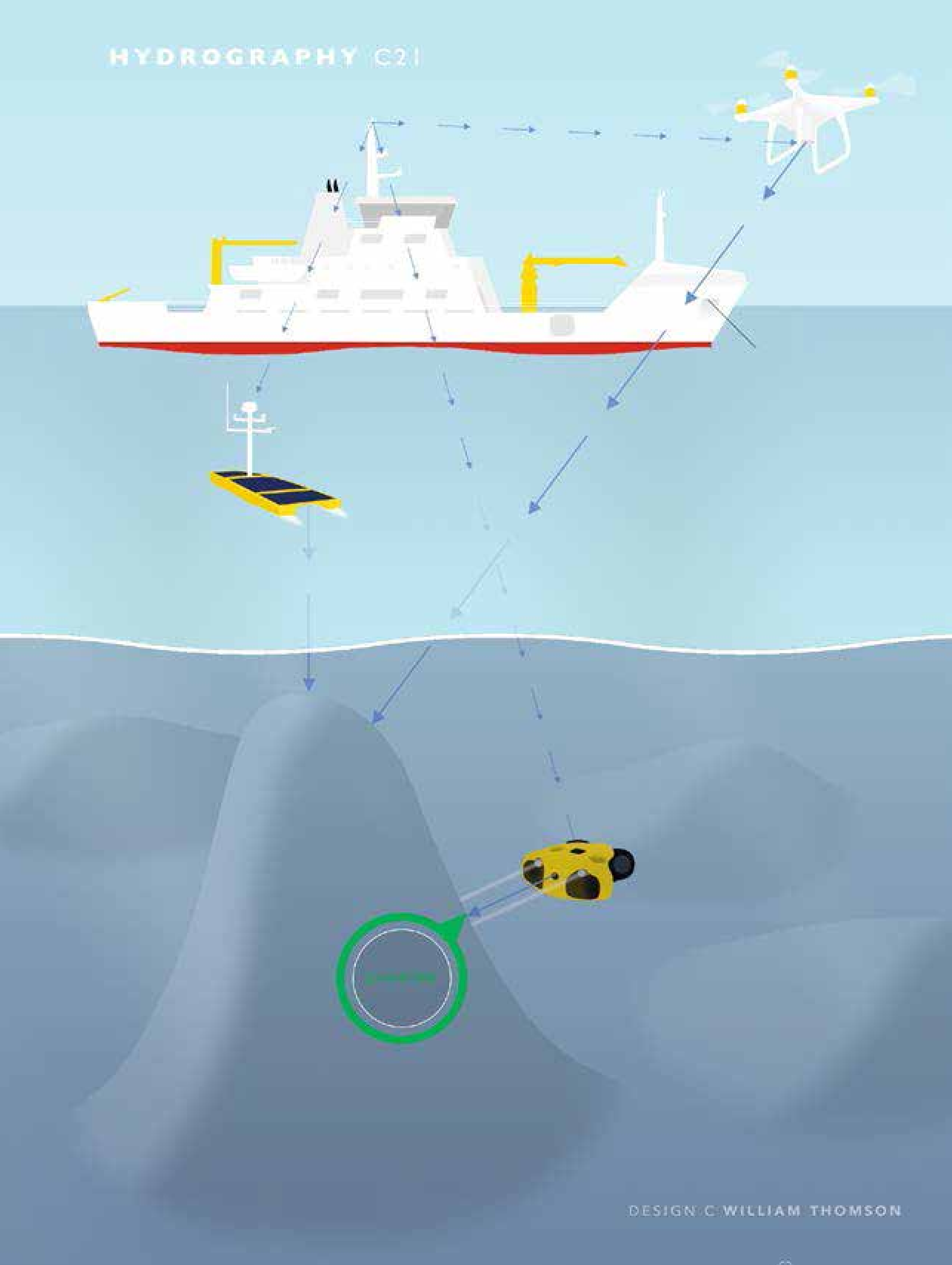
There is an ever-increasing body of CSB data available. Non-survey vessels, whether commercial, fishing or leisure craft, can automatically submit their depth and position data from their instruments for incorporation into electronic charts for leisure vessels. Having the option to switch to a CSB chart layer can be very helpful in areas where there is little or no alternative depth information, but should be used with caution because the displayed information may not be as accurate or complete as it appears: With crowdsourcing, data is processed algorithmically, with little control over the circumstances in which individual data points are gathered. Inputted data is 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. In areas where numerous vessels are engaged, any blips in the data tend to become ironed out over time. However, where inputs are few, the available data tends to be interpolated and may still display as apparently complete depth contours over areas that are, in fact, very sparsely reported.



In this positive example, at Le Bono on the Auray River in Brittany, local knowledge indicated a useful anchoring pool that was not shown on the leisure chart but was evident with the CSB overlay: (Left) Without overlay (Right) With CSB overlay

HYDROGRAPHY C18




HYDROGRAPHY C21
DESIGN C WILLIAM THOMSON

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. Such areas tend to be re-surveyed frequently, and to a high standard, but shifts can occur very quickly after a survey. It may take time for nautical charts of the area to be updated and even the most recent hydrographic data may already be out of date by the time it is published, whether on paper or digitally.

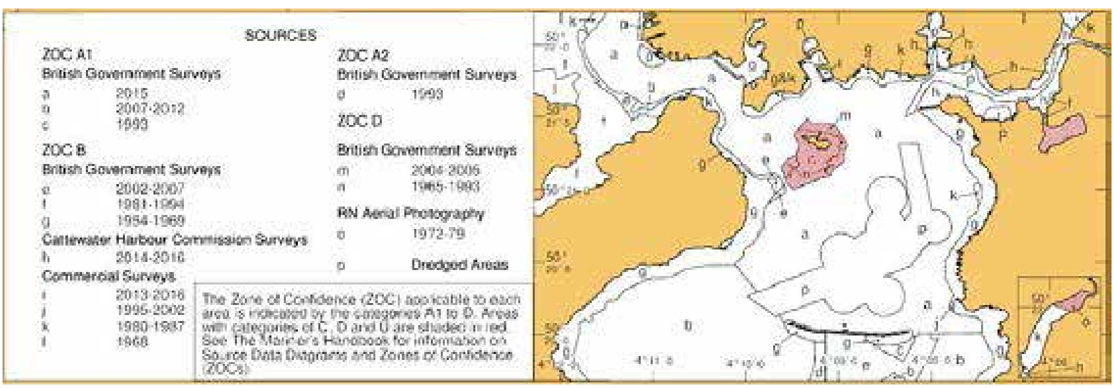
Cartography

Presentation of accuracy of data

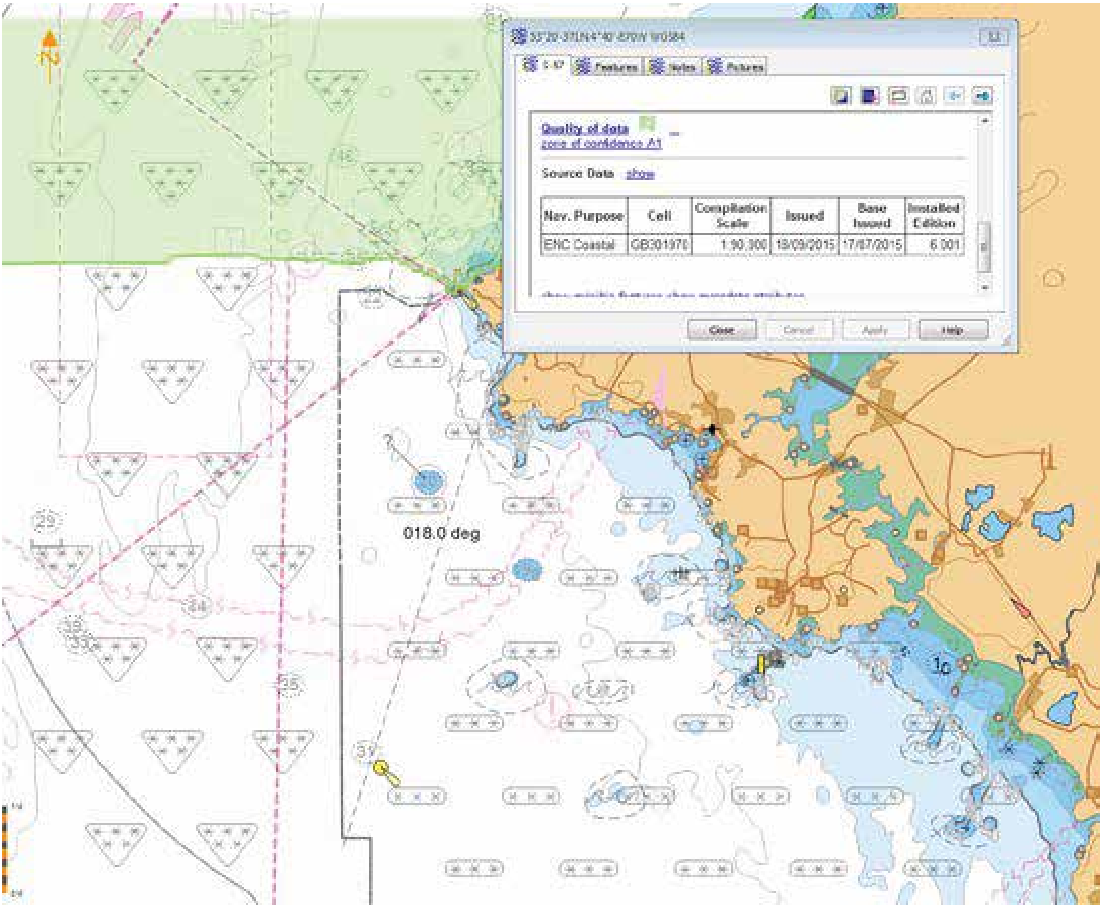
Most charts, whether paper or electronic, are compiled from a large number of surveys. These surveys will have been carried out at widely differing times, using different survey methods and to different levels of quality assurance. Each survey will have covered areas that are commercially relevant and 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)

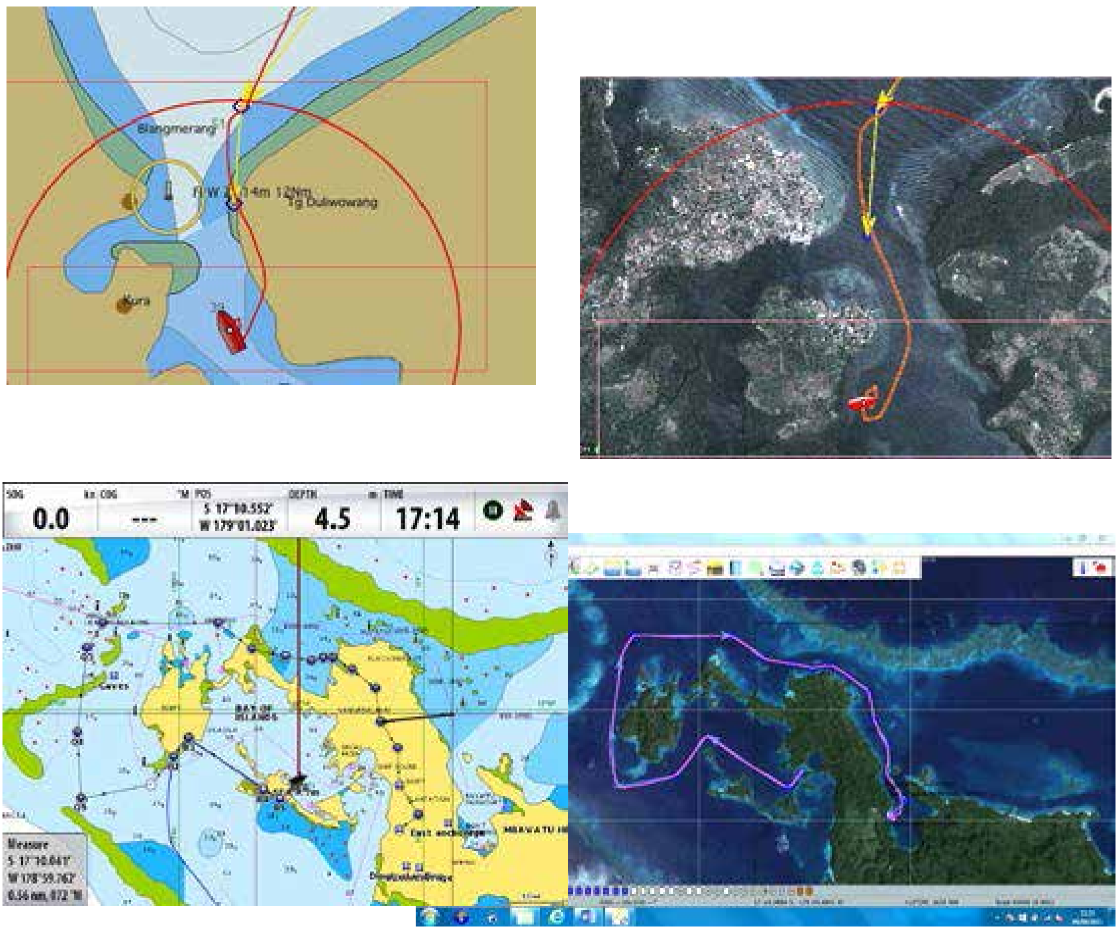
Even apparently WGS84 compatible charts can contain some charted areas with a wholesale datum shift (or chart offset). In these areas the positioning of hazards and features relative to each other may be very accurate, but the whole area may be misaligned with the satellite derived positioning. In some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

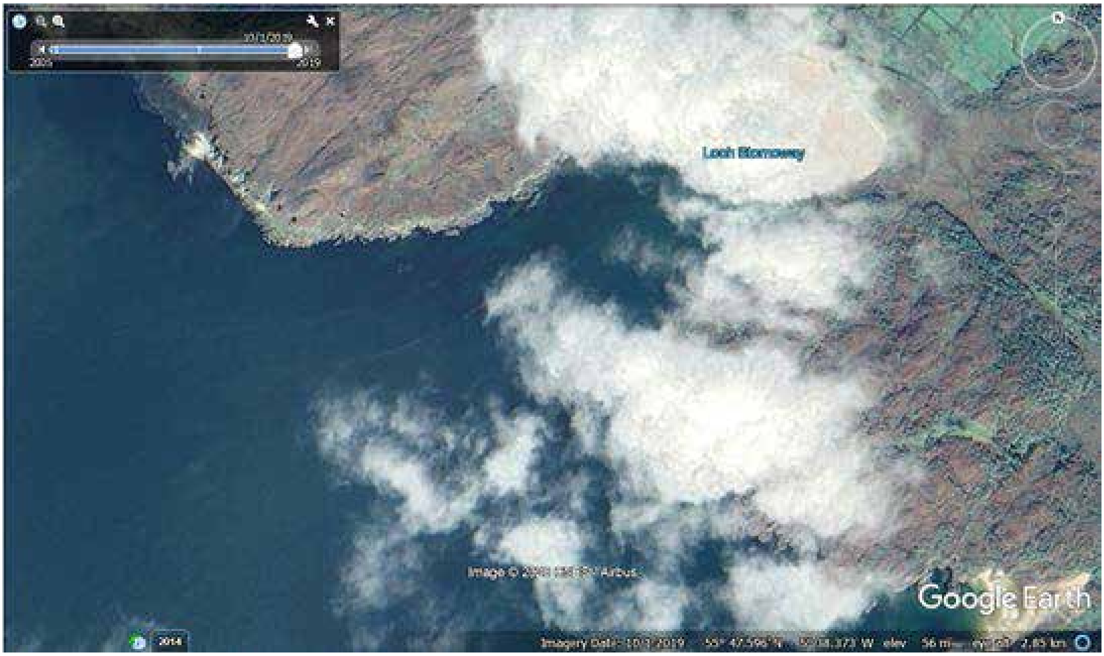
Satellite imagery is only another tool available to us. It has its limitations which include:

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.



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.

Chart overlays

Electronic charts for leisure vessels usually allow overlays of other information. This includes information from integrated systems such as radar (see Using radar on a leisure vessel on page 42 and Note on page 43) or AIS (see How often is AIS data transmitted? and Visibility of targets on screen, both on page 50). It also includes information that may be selected as a layer within the chart, such as satellite imagery (see Combining satellite images with marine charts on page 37), crowd sourced bathymetry (see page 29) or tidal predictions (see page 83). Whatever information we choose to overlay, it is important to understand the limitations of each, as discussed on the relevant pages referenced here.

Too much information

It is easy to become overwhelmed and confused by the sheer amount of overlay information on screen and, therefore, to miss key indicators. Do not get fixated with what you are seeing on the screen. See Keys to safety on pages 40 and 54.

Keys to safety

We should understand that:

Hazards positioned using old surveying techniques may not be shown in their correct, satellit-ederived 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 29) 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, using every means available, including satellite imagery (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 but both require familiarity and practice.

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 in the X-band (around 9GHz). Large vessels are usually also equipped with radar operating in the S-band (around 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 around 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. Older Racons may not show up well on newer digital radars fitted to many leisure vessels. Newer racons are being developed to address this issue.

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.

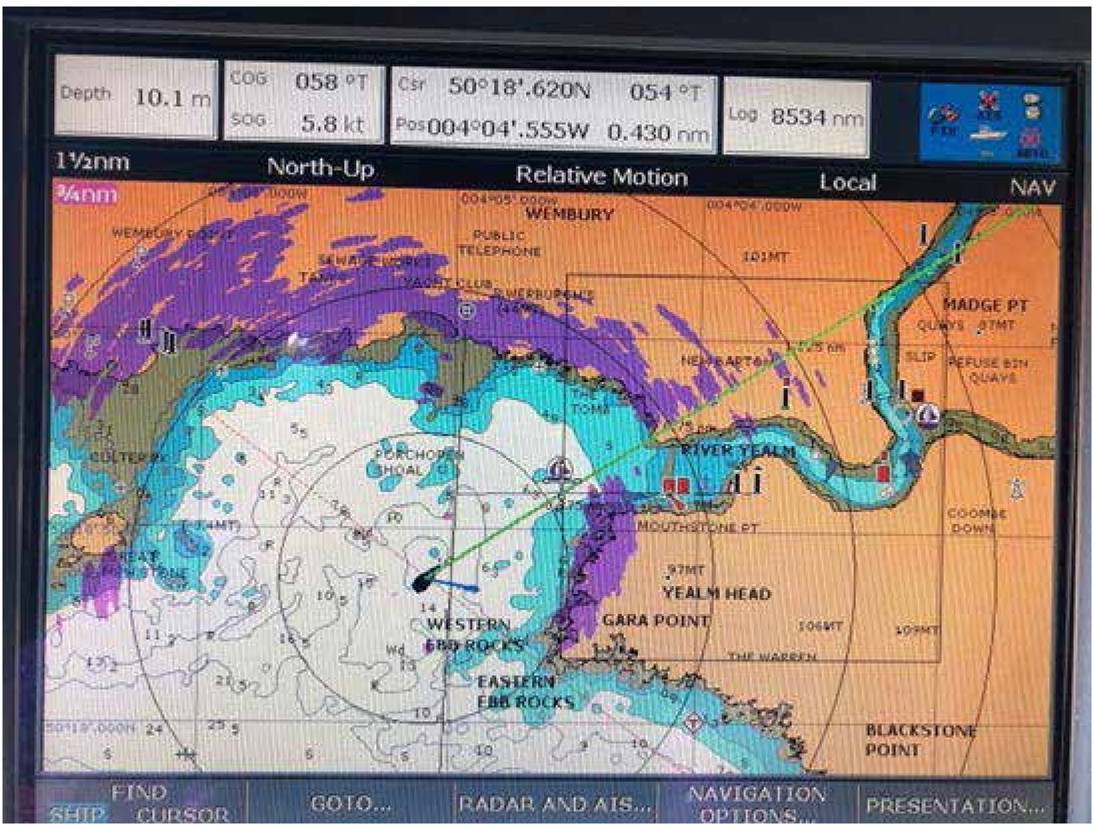
Radar overlay on a chartplotter can be very helpful in indicating chart offsets. If the radar positioning of a charted feature does not align with the chart it should alert us to be more cautious about our positioning assumptions.

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

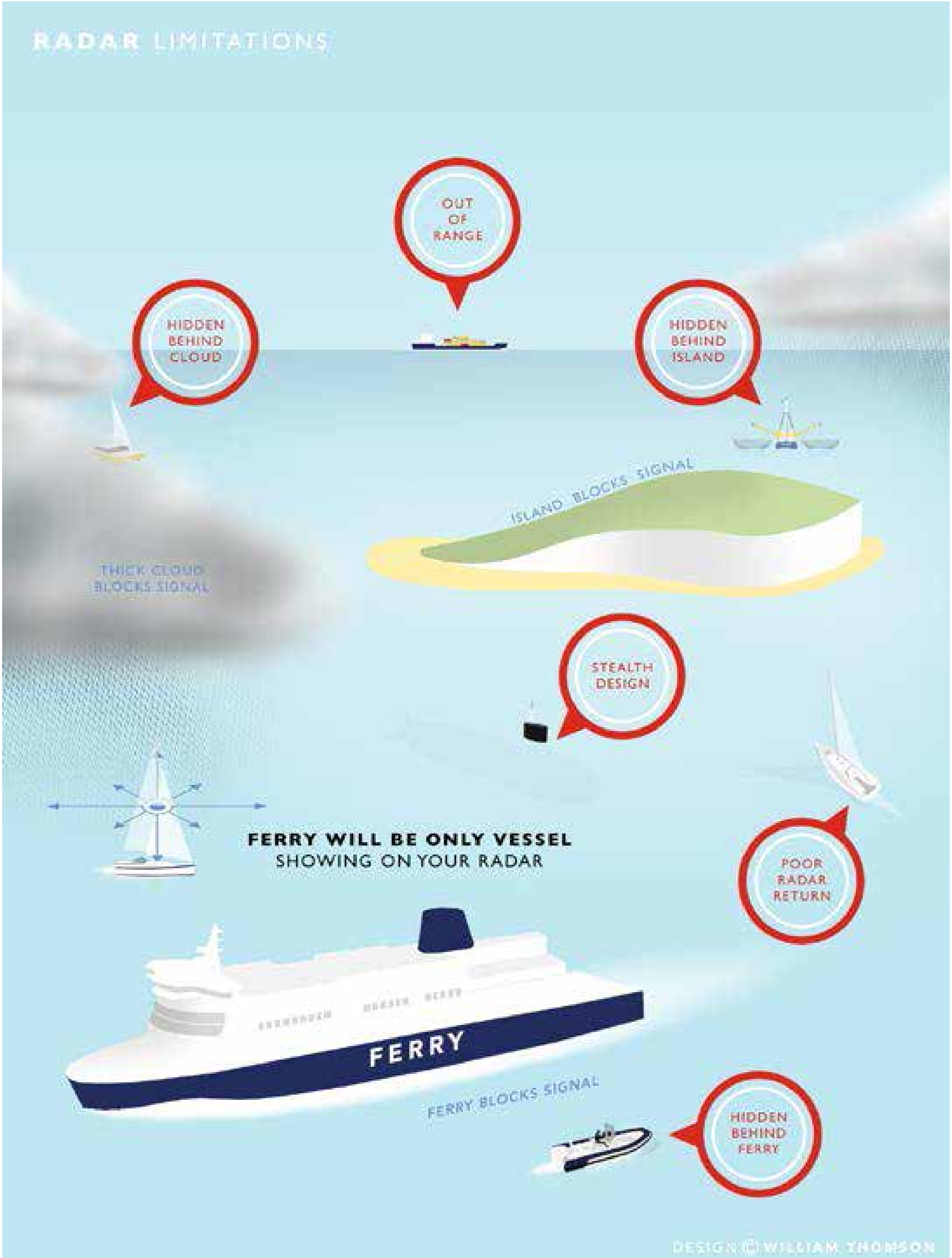
Note: Radar on a leisure vessel is now normally displayed on a chartplotter rather than on a stand-alone display. When radar is overlaid on a chart on a chartplotter the radar display will normally be north-up, giving direct positional orientation with the chart. To be truly north-up the radar will need 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

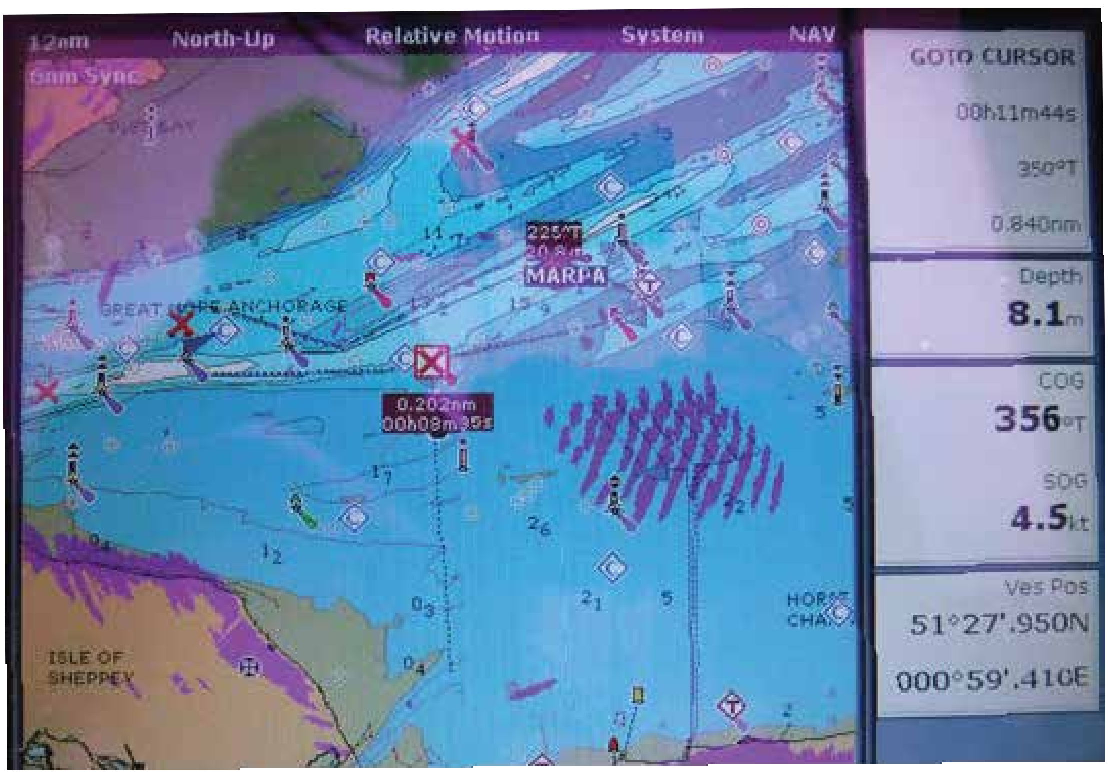
- **Power failure:** Radar is an electronic system and will stop working if its power source is lost or degraded, for example through corroded connections
- **Systems failure:** Radar can suffer from failures within its own electronic system
- **Poor set-up:** Optimal adjustments of settings, such as 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 practicable 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 or boom themselves, or even the sails, particularly when sails are wet. These types of 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
- **Vessel motion:** Rolling, heeling, pitching and yawing affect signal output and return, particularly with non-gimballed radar. The reduced effectiveness can be countered to some extent with self-levelling (gimballed) systems
- **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 UK, 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
OUT OF RANGE
HIDDEN BEHIND CLOUD
HIDDEN BEHIND ISLAND
ISLAND BLOCKS SIGNAL
THICK CLOUD BLOCKS SIGNAL
STEALTH DESIGN
FERRY WILL BE ONLY VESSEL
SHOWING ON YOUR RADAR
POOR RADAR RETURN
FERRY
FERRY BLOCKS SIGNAL
HIDDEN BEHIND FERRY
DESIGN © WILLIAM THOMSON

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 52)
- 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 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 from vessels 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 predetermining 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.

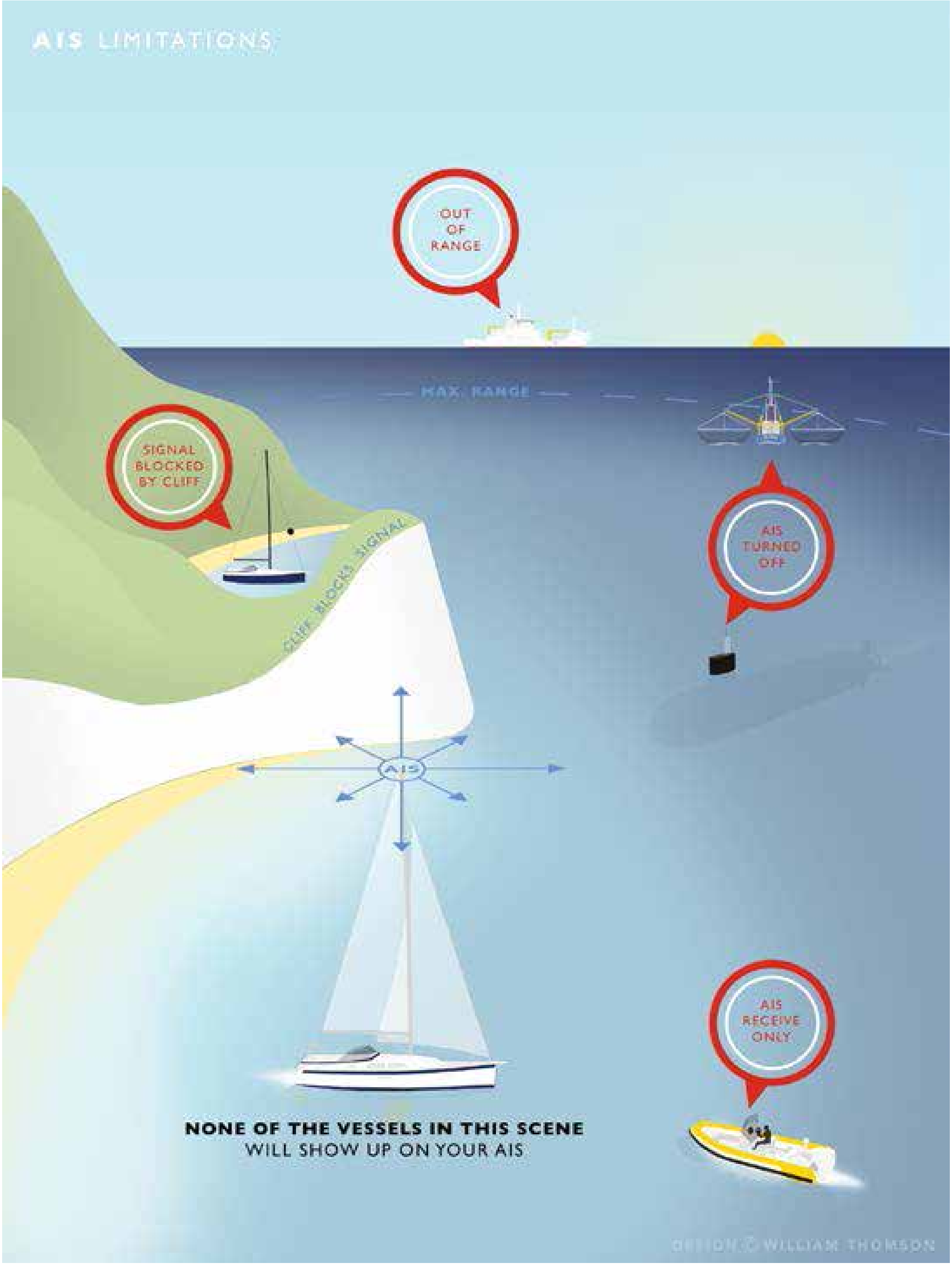
There can be quite a delay in AIS data transmission. Class A systems transmit Static and Voyage Related data only once every 3 minutes. Class B systems will wait longer than 3 minutes if there are no readily available slots.

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.

Note: The heading derived from AIS can depend upon whether the vessel is fitted with Class A or B systems. Class A provides a gyro compass heading input, whereas the vast majority of Class B fitted vessels will use GNSS COG, which is not always the same as the physical heading of the vessel. Therefore, the aspect of the vessel observed by eye may appear different to that indicated by AIS. This is particularly true of slow-moving vessels, including yachts, in tidal streams or when making significant leeway.


AIS LIMITATIONS
OUT OF RANGE
MAX. RANGE
SIGNAL BLOCKED BY CLIFF
CLIFF BLOCKS SIGNAL
AIS TURNED OFF
AIS
AIS RECEIVE ONLY
NONE OF THE VESSELS IN THIS SCENE
WILL SHOW UP ON YOUR AIS

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:** Power failure: AIS is an electronic system and will stop working if its power source is lost or degraded, for example through corroded connections
- **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 may be badly set-up, either on your own vessel or on another vessel from which you are receiving information
- **Height of AIS antenna:** Significant range improvement can be achieved by mounting as high as possible on the mast. Pushpit mounted antennas are also subject to wave masking, damage, or accidental masking by crew
- **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 jamming or '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 soundings.

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 gives 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.

Positioning of radar on a small vessel is often a compromise between safety, stability and effectiveness.

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 reports 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. Depending on our location, access to competent repair facilities may be hard to find. 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

- 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 DSC is the preferred means of distress calling, alongside EPIRBs and PLBs. 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. Carry a suitable high capacity powerbank as further backup.

Mobile devices and loss of GNSS

Most mobile devices now have built in GNSS receivers and most smartphones also use mobile phone base stations, Wi-Fi, Bluetooth and other technologies and sensors to generate a 'blended position'. If GNSS is lost or degraded, mobile devices on land will generally continue to report a position using these other technologies and sensors, even if the resulting position calculation is less accurate. At sea, in the likely absence of as many blended sources, mobile phone positioning is far more reliant on GNSS, and any outages or problems may result in large position errors - as much as several hundred metres or more. This 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 or on deck. This equipment includes wind speed and direction transducers, VHF aerials, AIS, SSB and GNSS antennas, satellite communications antennas, and radomes. These are vulnerable to accidental signal attenuation or damage during normal boat operations, 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 routeing 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 speed/distance 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 56)
- 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 lighting 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 onboard 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 separate backups to retain essential navigation and communication capability under partial or total failure of our primary, often integrated, 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/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 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 **S**afety **o**f **L**ife **a**t **S**ea **(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 routeing:** 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 retrieve relevant information in order to 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?

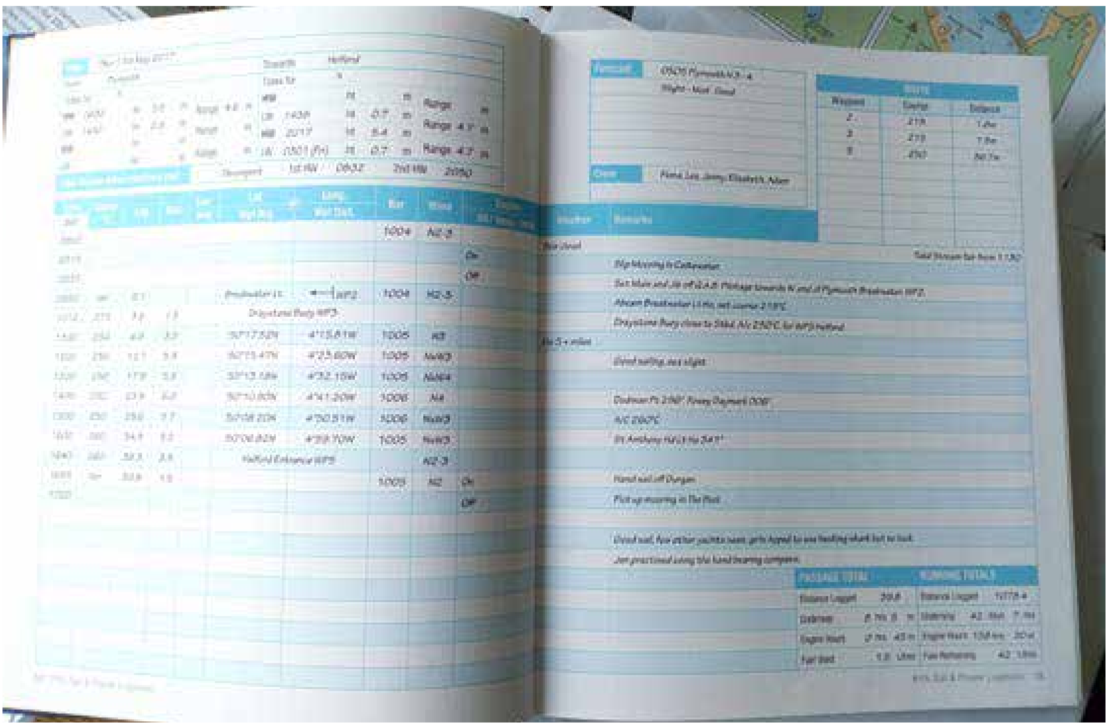
At regular and appropriate points of time we need to know the direction we are travelling, how fast we are going, how far we have gone and where we estimate we are. Our estimate is likely to have an area of uncertainty (see page 74).

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:



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.

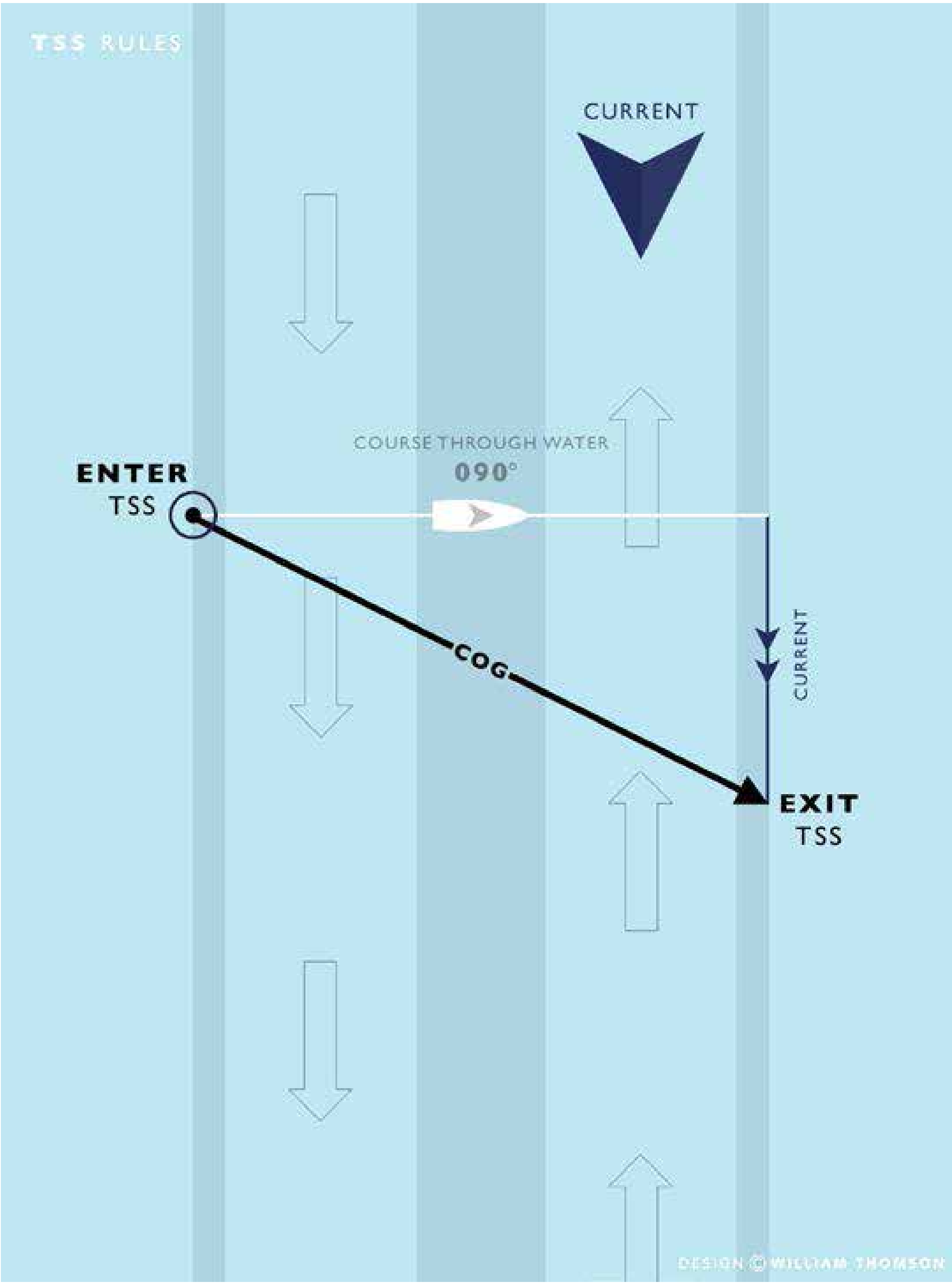
Ground-stabilised information helps us to navigate safely relative to fixed dangers. But if we want to navigate safely around other moving vessels we also need to remain aware of how we are moving relative to each other on the tidal travellator. This is key to collision avoidance.

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.


WATER STABILISED vs. GROUND STABILISED
CURRENT
2
KNOTS
10:00
SPEED THROUGH WATER
4 KNOTS
COG
SPEED OVER GROUND
6 KNOTS
CURRENT
2 KNOTS
11:00
COURSE THROUGH WATER
090°
ENTRANCE
10:00
COG
116°
180°
11:00
CURRENT
2 KNOTS
SPEED THROUGH WATER
4 KNOTS
11:00
COG
SPEED OVER GROUND
2 KNOTS
10:00
N
1 nm
DESIGN © WILLIAM THOMSON

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.


TSS RULES
CURRENT
COURSE THROUGH WATER
090°
ENTER
TSS
COG
CURRENT
EXIT
TSS
DESIGN © WILLIAM THOMSON

Dead reckoning (DR) and estimated position (EP)

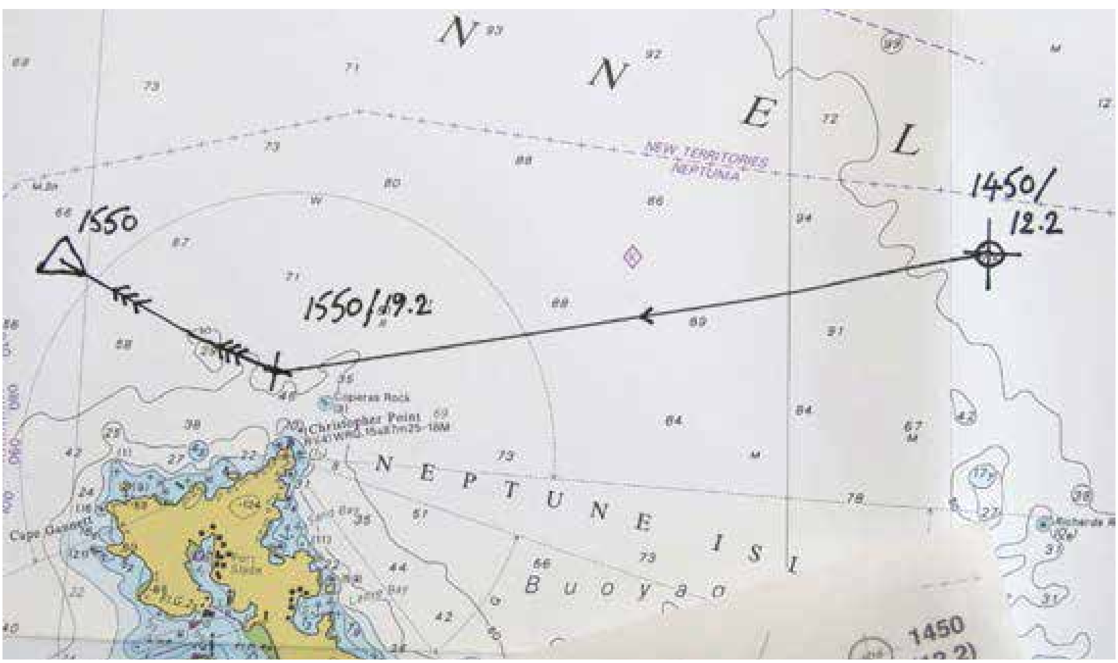
If GNSS positioning is lost and we also cannot plot a fix from landmarks or charted features,we should still be able to calculate our vessel's position from other information to hand. The DR position is calculated from the distance run on the course steered (this is water-stabilised data). The EP takes 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.

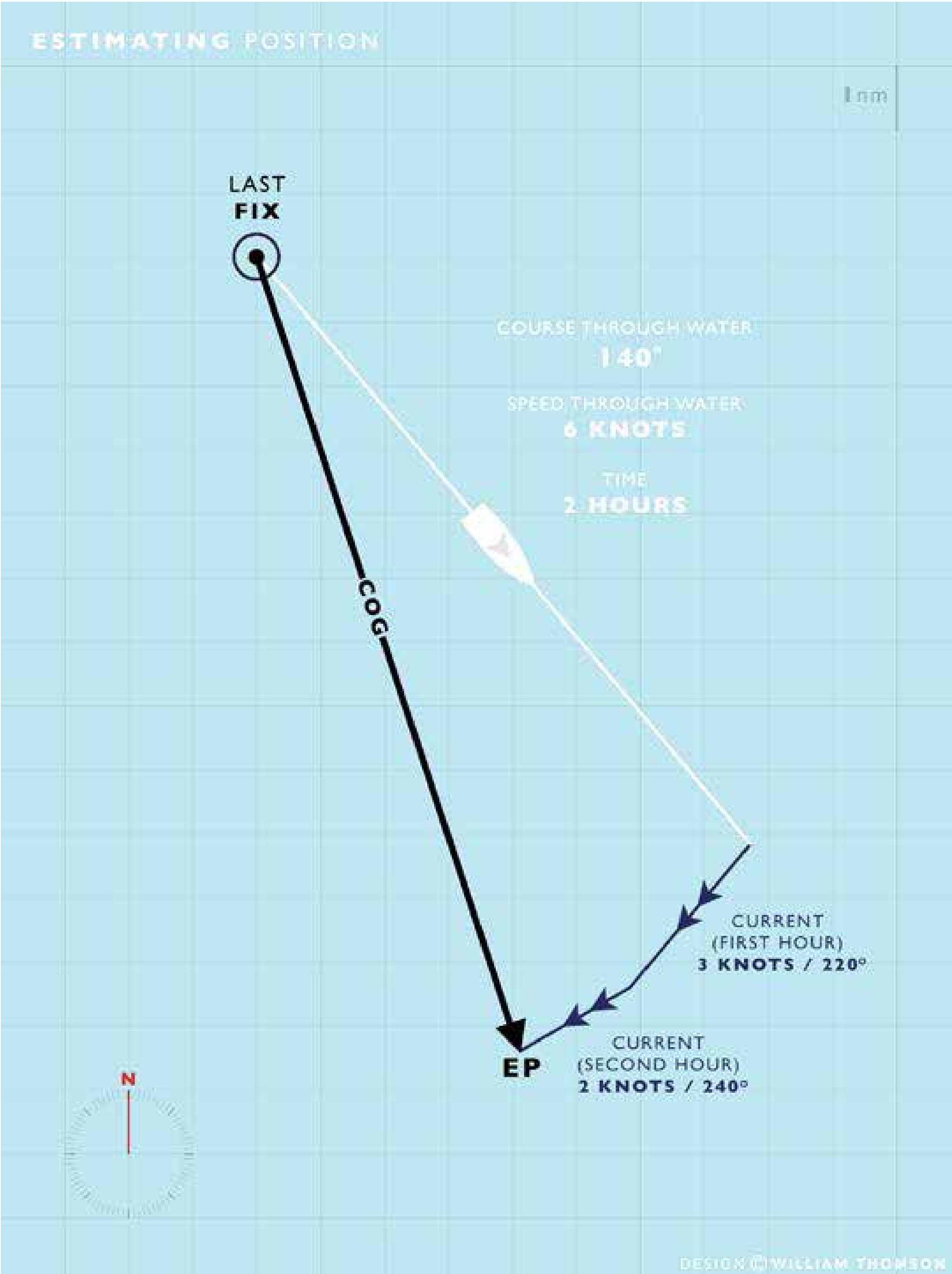
Estimating speed through the water (Log speed)

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 10m 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.




ESTIMATING POSITION
1nm
LAST FIX
COURSE THROUGH WATER
140°
SPEED THROUGH WATER
6 KNOTS
TIME
2 HOURS
COG
CURRENT
(FIRST HOUR)
3 KNOTS / 220°
EP
CURRENT
(SECOND HOUR)
2 KNOTS / 240°
N
DESIGN © WILLIAM THOMSON

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.

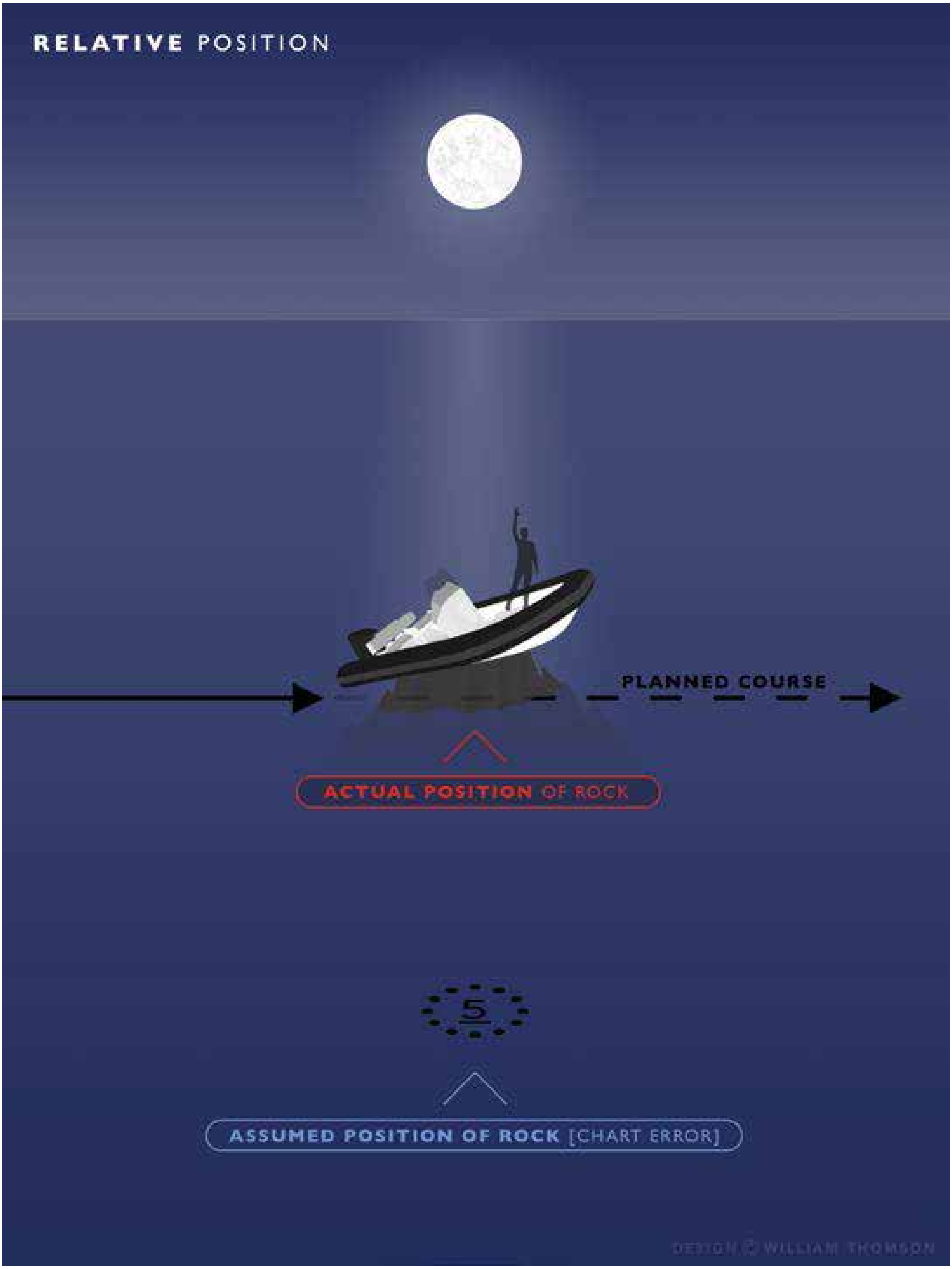
We should always use every available means to confirm reality:

- 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


RELATIVE POSITION
PLANNED COURSE
ACTUAL POSITION OF ROCK
5
ASSUMED POSITION OF ROCK [CHART ERROR]
DESIGN © WILLIAM THOMSON

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, tsunami, 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 means looking after any paper books and being very certain of all 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.

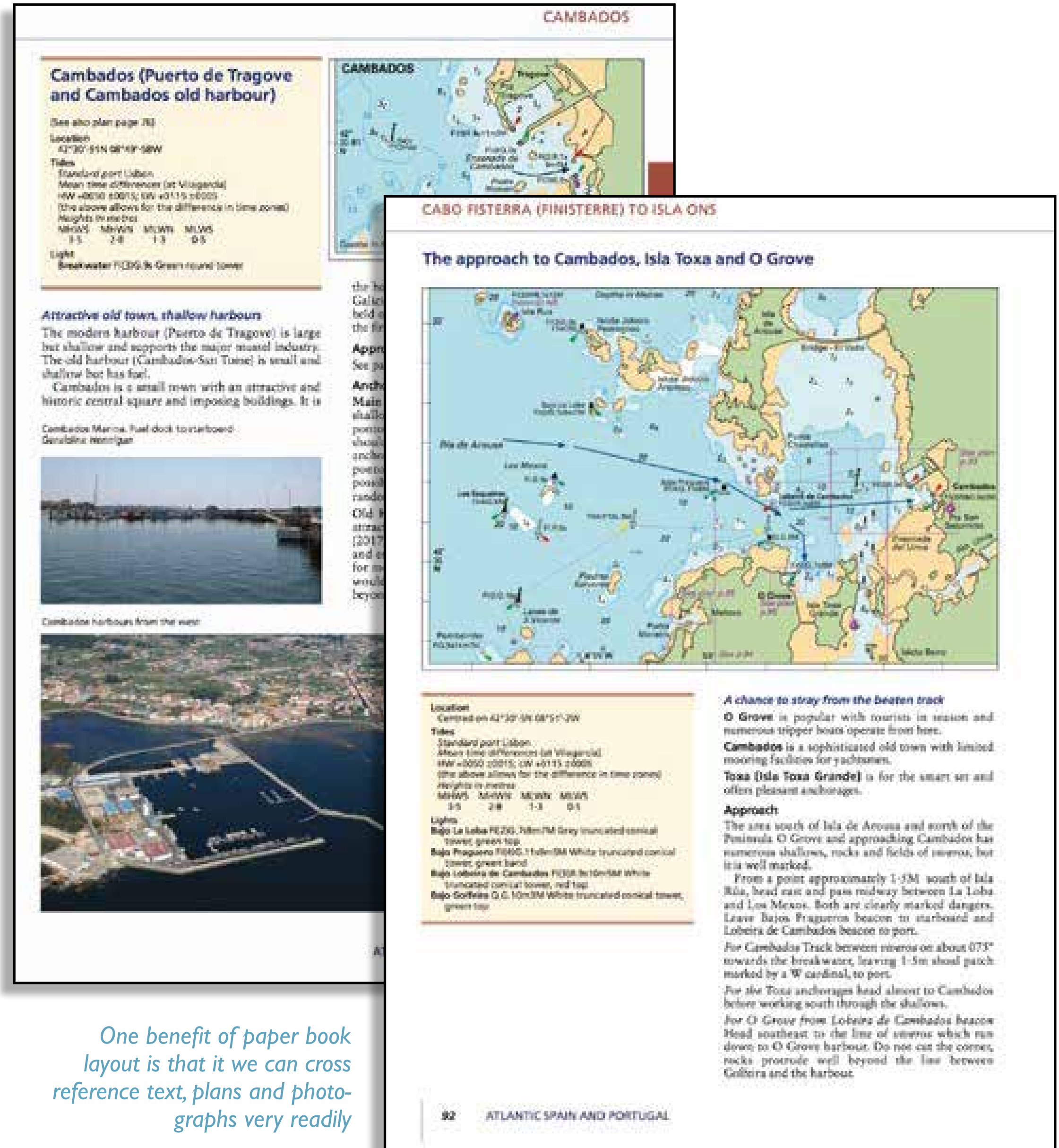
If we want to assess the reliability of pilotage information in any form, we should ask a few questions:

- 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.

Provenance

It is always worth finding out how and when pilotage information has been sourced. This might be by reading the preliminary sections of a pilot book or cruising guide - the Preface, Introduction, even the Acknowledgements. It is sometimes much harder to find the provenance of information within a website or an app. 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.


CAMBADOS

Cambados (Puerto de Tragove and Cambados old harbour)

(See also plan page 76)

Location
42°30'·91N 08°49'·58W

Tides
Standard port Lisbon
Mean time differences (at Vilagarcia)
(the above allows for the difference in time zones)
Heights in metres

MHWS	MHWN	MLWN	MLWS
3·5	2·8	1·3	0·5

Light
Breakwater Fl(2)G.8s Green round tower

Attractive old town, shallow harbours

The modern harbour (Puerto de Tragove) is large but shallow and supports the major mussel industry. The old harbour (Cambados-San Tomé) 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

CABO FISTERRA (FINISTERRE) TO ISLA ONS

The approach to Cambados, Isla Toxa and O Grove

Location
Centred on 42°30'·5N 08°51'·2W

Tides
Standard port Lisbon
Mean time differences (at Vilagarcia)
(the above allows for the difference in time zones)
Heights in metres

MHWS	MHWN	MLWN	MLWS
3·5	2·8	1·3	0·5

Lights
Bajo La Loba Fl(2)G Grey truncated conical tower, green top
Bajo Praguero White truncated conical tower, green band
Bajo Lobeira de Cambados White truncated conical tower, red top
Bajo Golfeira 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 Peninsula O Grove and approaching Cambados has numerous shallows, rocks and fields of viveros, but it is well marked.

From a point approximately 1·5M south of Isla Rúa, 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 viveros 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 viveros which run down to O Grove harbour. Do not cut the corner, rocks protrude well beyond the line between Golfeira and the harbour.

92 ATLANTIC SPAIN AND PORTUGAL

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

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.

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

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

Auto-routes: Even without any add-on routeing software, many of the more recent electronic leisure chart displays allow us to select our port of origin and our final destination to then create an auto-route. We can enter the draught of our boat, and the inbuilt software will suggest an optimised route for us. But unless we have a more sophisticated, integrated system this may simply be telling us the shortest route that allows for our draught. An auto-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. In some cases it may not be sensible or safe as weather factors, and the resulting sea state, may not be factored in fully. Even when we think that we have inputs such as tidal and current data, the interpolations of the source data may be more simplistic than the reality requires. This is particularly true in estuaries and other areas where the tidal curves are more complex. Use auto-routes with caution and check against all other information available. (Also see Autopilot settings page 88.)

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.

Rubber banding: The RYA recommends rubber banding as a useful way to create a route. Again, we select the start point and then add the end point, initially ignoring whether the route takes us over land or dangers. We then go back to the beginning of the route and work along it, zooming in and looking for hazards all along the route and close to it, adding waypoints as necessary. After each new waypoint is added, the remaining route will always give the shortest route to the final waypoint. As with auto-routeing, the route generated may need further adjustment to take account of wind, tide and sea state.

> Rubber banding is a useful way to check and modify an auto-route. If the system does not allow adjustment of auto-route waypoints, stick with rubber banding.

Some things to consider when creating waypoints:

- Only create a waypoint where a decision or action needs to take place
- Name the waypoint with a meaningful name. This could be a geographical reference or it could be a description of a necessary action at that point
- It is useful to select buoys or other physical markers to help to confirm our location at points along our route, but we must always set any such 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.

Whether we use an a auto-route or rubber band one ourselves, we should also be 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?

Tidal predictions

Comparison of various tide table publications and tidal apps has shown that predictions of tidal heights may vary between them by more than 20cm, and times of high or low tide may vary by nearly half an hour for secondary ports. Within apps or electronic chart systems, it is not always easy to find out how the tidal data has been sourced and processed. In some systems, relatively distant hourly data points may have been simply interpolated to display apparently accurate minute by minute tidal information for specific locations. However, tidal curves and current flow rates and directions are often quite complex, particularly in estuaries, narrows, over harbour bars and around some headlands. Tidal heights may also vary by 30-40cm or more with large changes in atmospheric pressure. Strong winds may also affect tides in constricted locations, either by driving in with the tide, accelerating it and elevating heights, or by blowing against the tide, delaying it and reducing the height.

It is important to understand that reality may differ considerably from the tidal predictions. We should always give ourselves some 'wiggle room' in our passage planning, particularly if the tidal predictions are being integrated into routeing.

Note: Where VTS is available in and around major ports, they will often report live tidal data against tide gauges and may report significant differences against prediction. Monitor the correct VHF channel for the port area.

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?

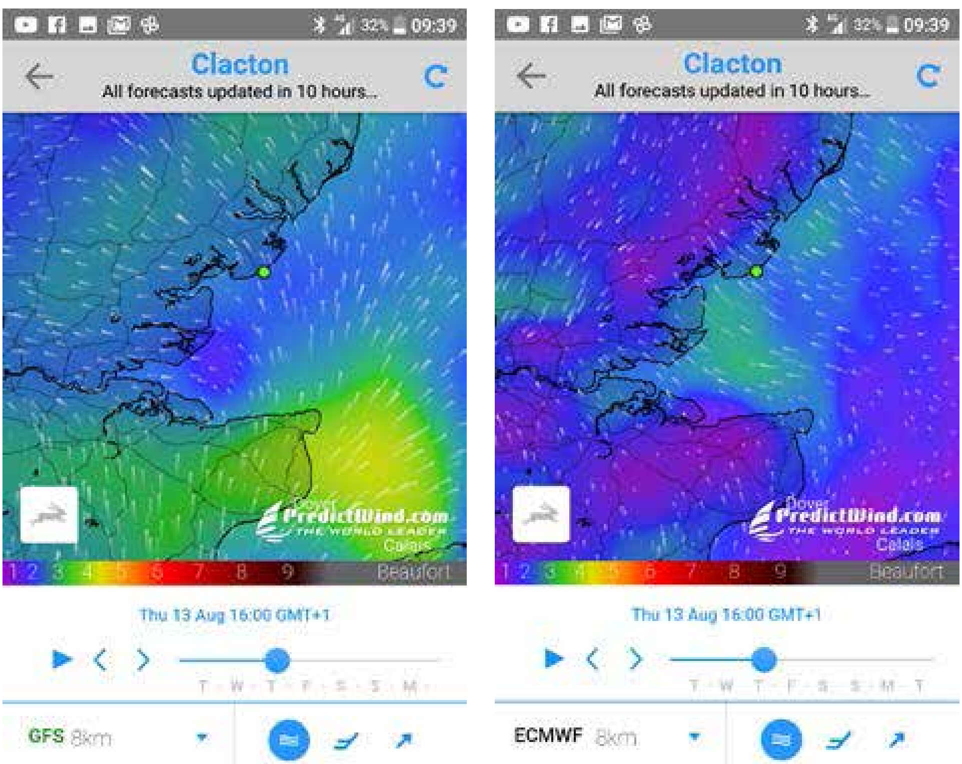
Audio forecasts are available via VHF, MW or HF radio in many coastal regions, sometimes by means of an automated electronic voice. We can also receive weather information via our mobile phones, but only if we are within range *(see Mobile phones as backups,* page 58*)*. We need a satellite phone or 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 routeing 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 routeing 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 routeing 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 X (formerly Twitter) every 20 minutes; each AtoN involved in the trial having its own X (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 routeing

A recent new addition to the routeing 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 routeing 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 routeing 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 routeing 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 a course linked to the autopilot's internal electronic compass then it will just keep correcting the heading onto that compass course. This does not take into account any tide or leeway and, if unmonitored, may result in the vessel heading into danger. Nor does it allow for any wind shifts which may result in an unexpected and potentially dangerous gybe, tack or broach of a sailing vessel.
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. Again, if unmonitored, this may result in the vessel sailing into danger.
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). This is probably not the most efficient way to cross a tide that is unlikely to be constant for the whole duration of the passage. It should mean that our track will stick to our planned route, but on a sailing vessel we will remain vulnerable to changes in wind direction (see 1. above)

If we are linking the autopilot to more integrated routeing (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. (See Routeing page 82.)

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. Inappropriately slow or exaggerated autopilot responses may result in an unexpected and potentially dangerous gybe, tack or broach of a sailing vessel.

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.

Even if our autopilot is integrated with our chart system and other instruments it will not be factoring in the actual real-time sea state, tidal sets, localised wind shifts, and so on, 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, including our autopilot settings, whenever necessary.

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

GNSS and routeing

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.

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 notebook) 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

Ocean navigation

Celestial navigation has been used for thousands of years in many forms, from simply sharing a spatial awareness of what the heavens look like over the passage of time, to building specialised instruments to measure angles and heights of celestial bodies to indicate a location on earth. Over the past few hundred years celestial navigation has been refined with improved instruments, astronomical almanacs and various sets of tables developed to help calculate a **line of position** (LOP) using spherical geometry. With increasing accuracy of sextants and especially timekeeping, the resulting position fixes (using LOPs from two or more sights) improved. Also, simplified **sight reduction** (SR) tables made the calculations much easier for the non-expert.

A celestial body is the sun or another star or a planet or the moon.

Many of us who head offshore to cross oceans would like to be confident in using a sextant to navigate but we may still be put off by the complex calculations using an astronomical almanac and SR tables. Fortunately, there are now a number of apps and programs to help us with all the calculations and also with star and planet identification. By automating the calculations, we can concentrate on practising use of the sextant and see our results quickly. This is a great way to improve confidence and makes sextant navigation much more familiar in the event that our primary electronic navigation systems fail. However, positioning by celestial navigation is not as accurate as GNSS and we should keep this in mind, particularly when nearing landfall – indeed an error of up to three miles would normally be considered a good celestial navigation fix. When several hundred miles from land or hazards such an error is, of course, minor.

A sextant is just an instrument which measures angles accurately – either the height of a celestial body (or a lighthouse) above the horizon or, if on its side, between two objects on earth at our position.

Observations can only be taken when both the celestial body and the true horizon can be seen, so for stars and planets that is usually during twilight. The moon can often be used in daylight and brighter planets before twilight but the bright reflection under a full moon at night often creates a misleading horizon.

Basic principles of celestial navigation

Terminology varies and the acronyms can appear daunting, but in simple terms celestial navigation is based on triangles and circles wrapped around planet Earth. For most of us, the biggest challenge is our ability to do the maths, working with base 60 for minutes of hours or degrees, base 24 for hours and base 360 for full circles.

How to visualise X

Normally, all the celestial bodies are considered to be on a **celestial sphere** concentric with and far outside the earth. Although this is not correct (since they are all at different distances) it is a useful way to simplify the calculations and is how the nautical almanac presents the positions of the bodies. So, X is where the line which connects the centre of the earth to the celestial body being observed passes the earth's surface i.e. every celestial body can have its position described as a point on earth. A helpful way to think about this is to imagine the celestial body is the lamp of a lighthouse many miles high with its base on the rocks at X.

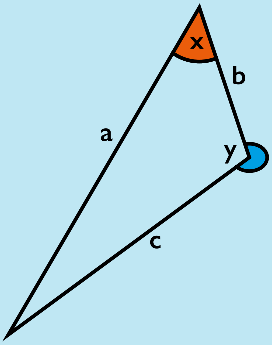
We can take a sextant reading of the height of the celestial body above the horizon at an exact time in UTC, this is called an **observation** (Hs). There are then some adjustments to correct this to the **Observed Altitude** (Ho).

Based on the time and date, using an astronomical almanac, we can deduce the exact position of the celestial body and our relationship to it. We will know our estimated position, but in order to use the **sight reduction** (SR) tables we may need to adjust this slightly to a **chosen position** (CP) nearby. Looking up the SR tables we can find what the sextant should read if we were at our CP, this is called the **Height Calculation** (Hc). Also, the SR tables will tell us the **True Bearing** or **Azimuth** to X.

The difference between Hc and Ho in minutes of a degree is called **the intercept** and is the distance in nautical miles towards or away from X along the azimuth. The **line of position** (LOP) is perpendicular to the azimuth and cuts it at the intercept point.

One LOP does not give us a fix; we need a second LOP for that. The second LOP can either be from a second observation on a different celestial body or a later observation the same celestial body (usually the sun: morning, local noon or afternoon) using a running fix.

PLANE TRIGONOMETRY

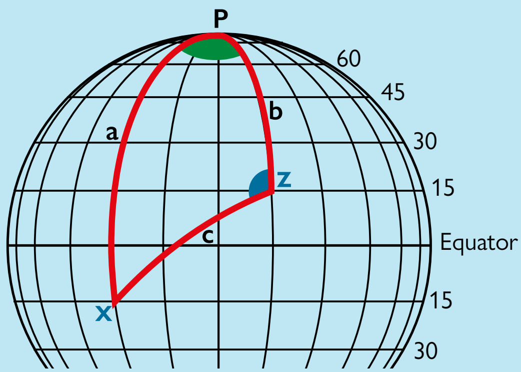


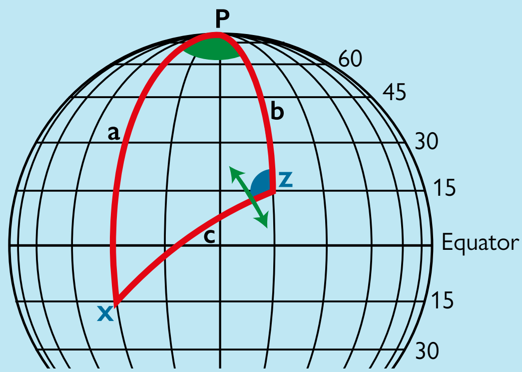
Given;
sides a & b, plus angle x

What is
side c and angle y ?

If we have a plane triangle and we know the lengths of two sides and the angle between them, by basic trigonometry we can work out the length of the third side and the other internal angles.

SPHERICAL TRIGONOMETRY





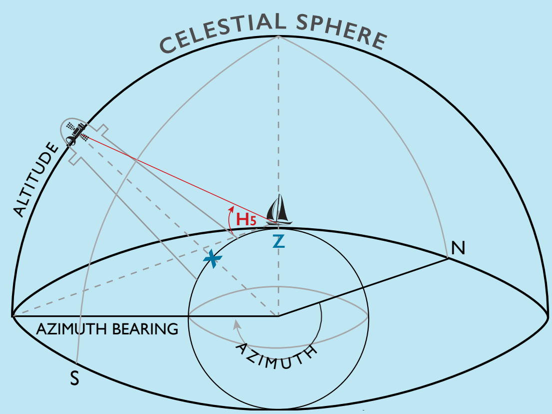
Now we must curve the triangle around the globe and use spherical trigonometry. This is called the P Z X triangle:

P (Pole) is the North or South Pole (depending on our hemisphere).

Z (Zenith) is our approximate position (EP or DR - see page 74).

X is the co-ordinates of the celestial body.

The lines a, b and c are all parts of Great Circles. To simplify the maths, Z, our EP, will generally need to be moved slightly in both Latitude and Longitude to a Chosen Position (CP) which will enable the SR tables to be used



Accurate position fixing by celestial navigation depends on at least two sights, often taken some time apart, and is affected by:

- Quality of the sextant, stability of the vessel and prevailing weather conditions
- Accuracy of the timepiece on UTC and our ability to correct to Time Zones
- Correct identification of the relevant celestial body(ies) being used
- Sight reduction calculations using tables
- Accuracy of course steered and distance run between sights
- Correct drawing and differentiation of working lines and plotting lines
- Spatial awareness of celestial bodies in order to judge relative accuracy

Electronic Computation of Celestial Sights

Celestial Navigation software

ADMIRALTY NavPac and Compact Data is used by many navies and commercial navigators who use it to provide independent and reliable verification to their onboard GNSS. It allows navigators to compute their position at sea using traditional celestial navigation techniques combined with modern technology with the aid of a PC running Windows.

Programable Calculators

Programable (scientific) calculators have long been available to use with computational spreadsheets, but they may require diligent manual input, including conversions from seconds to decimals of minutes. The calculations can be lengthy and take time, which may be especially problematic for seasickness sufferers.

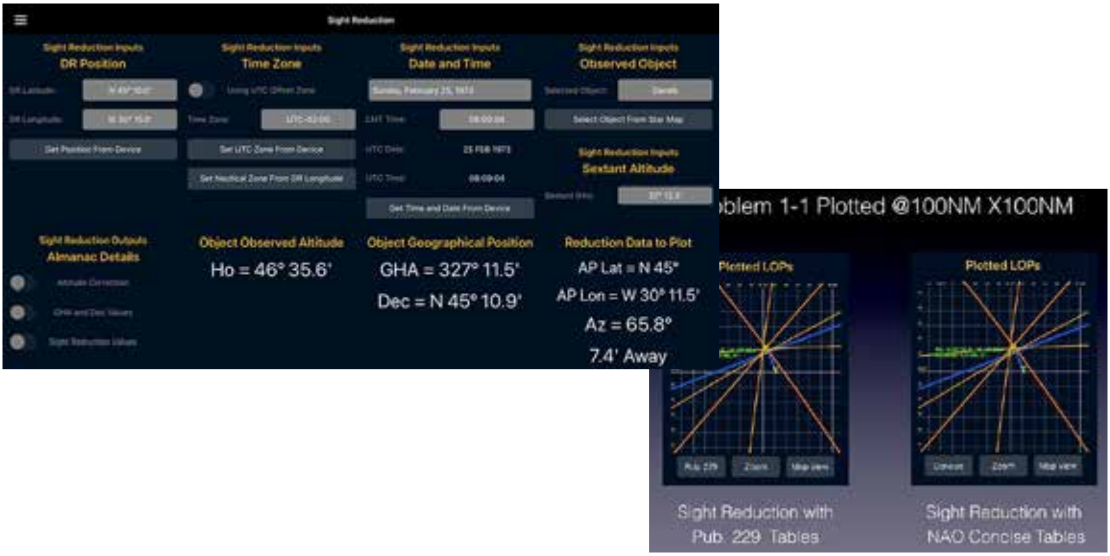
Mobile apps

There are now a number of mobile apps to help us compute or check our celestial navigation calculations. Ideally these should be able to identify which stars or planets to use, produce position lines, and not require internet access or GNSS to function. The functionalities of the various apps differ but may include:

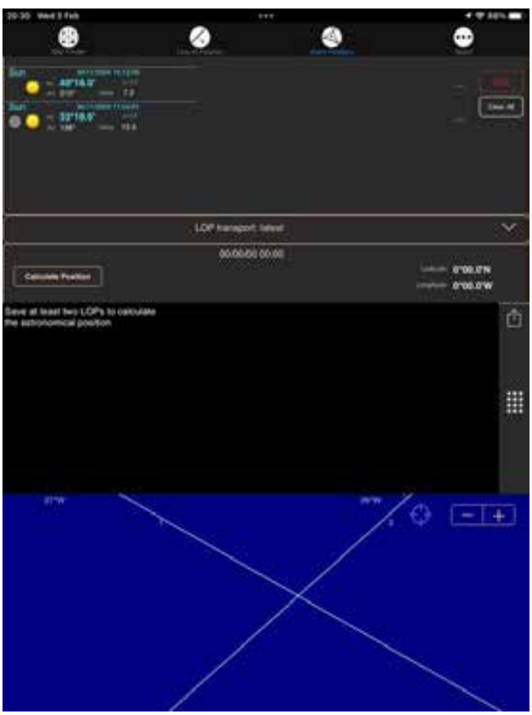
- Sight reduction, calculation and plotting of LOPs on the screen
- Identification of celestial bodies when held up to the sky (starfinding). They work in daylight as well, so are very useful for setting up an evening twilight sight
- Use of the level function of a smartphone to mimic a sextant. Although this will only give a crude angle and only be accurate in calm conditions, it may assist setting up a sextant before an observation.

Note: If part of the logic for using celestial navigation is as a backup in the event of loss of GNSS, it follows that offline celestial navigation programs or apps offer a more robust solution than those requiring connectivity. But we must also consider power sources in the event of total electronic failure (see Chapter 4).

EZ Celestial Navigation is a good example of a popular app with easy to input information and plotting data. No internet connection is required for it to function. It allows interrogation of stored data and has user-friendly displays



Navigator (tecepe.com.br) is another good example which works offline. It has a star finder function, built in almanac and will save several observations, calculate runs and plot the resulting fix



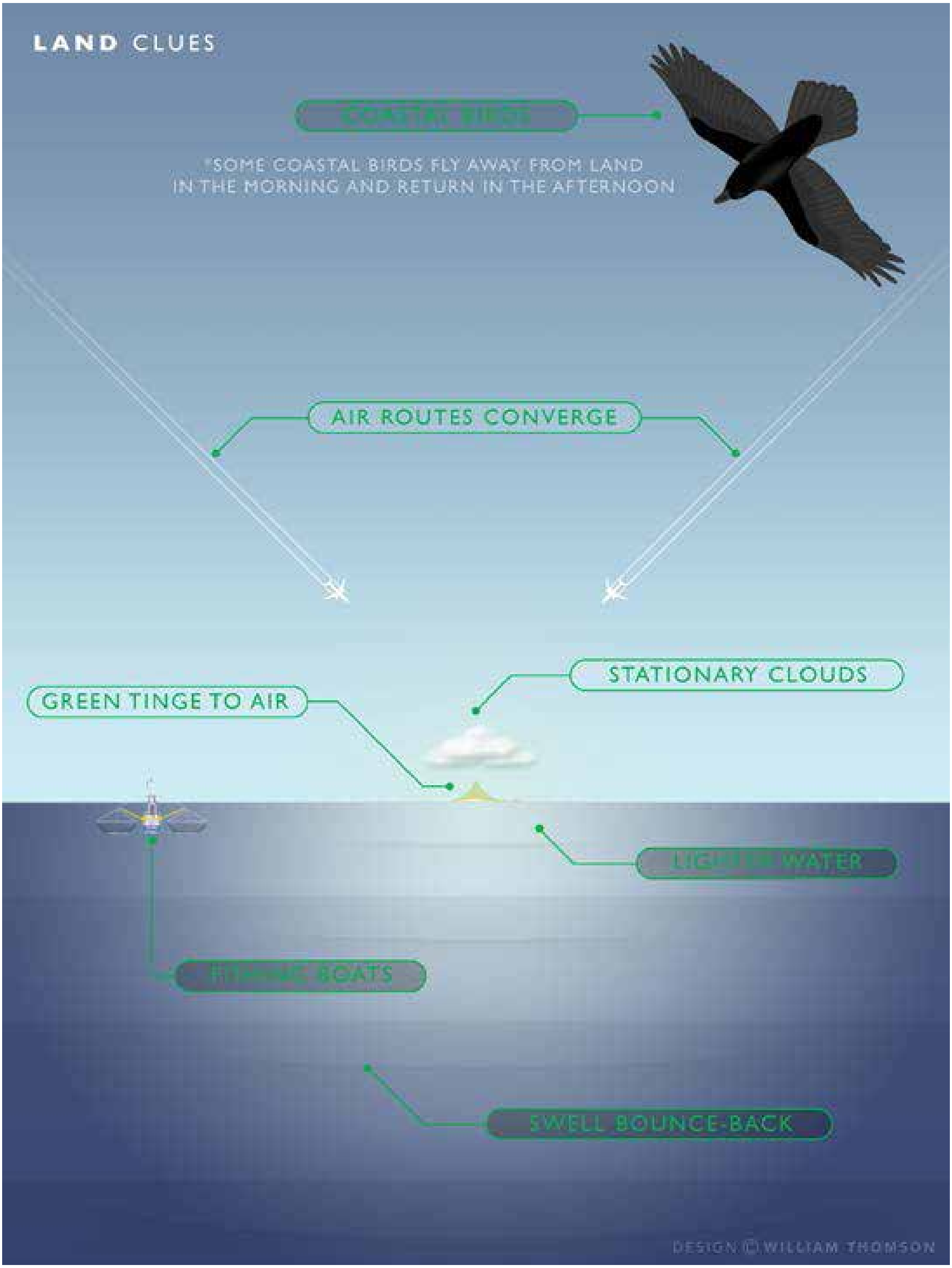
Photos courtesy of Navigator

Making landfall

If we are offshore and our electronic systems have been compromised in any way, our main concern will be making safe landfall. 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. Even if our electronics fail us completely mid-ocean the situation is far from disastrous. **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 74). 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.

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 or in reduced visibility. If there are signs of land and we are in an uncertain position it makes good sense to heave-to during darkness or poor visibility. Aim to close the shore in good visibility.


LAND CLUES
*SOME COASTAL BIRDS FLY AWAY FROM LAND
IN THE MORNING AND RETURN IN THE AFTERNOON
AIR ROUTES CONVERGE
STATIONARY CLOUDS
GREEN TINGE TO AIR
SWELL BOUNCE-BACK
DESIGN © WILLIAM THOMSON

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.

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. Practice makes us familiar with the routine, helps us improve how to estimate progress on passage, and means that we can continue to navigate if our electrics do fail us.

Positioning by celestial navigation is not as accurate as with GNSS. We should keep this in mind, particularly when nearing landfall.

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.

See: http://cilpublic.cil.ie/metocean/

ePelorus

It would also be beneficial if manufacturers and the GLAs could continue investigations into the use of an 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

S-100 is a new data framework that will underpin the next generation of navigation technologies. Within IHO's framework for S-100 data, the current S-57 chart standard, which was first adopted in 1992, is being replaced by S-101 and will start being fitted to S-100 ECDIS equipment from 2026. From 2029 all new ECDIS should conform to the new standard. One of the benefits under the new S-101 standard relates to buoyage symbology. This has been redesigned so that the colours of the buoy, as seen by eye, will be more closely resembled on the official ENCs.

See: ***https://iho.int/en/introduction-0***

Positioning, Navigation and Timing (PNT) developments

With recent increases in interference and spoofing, the vulnerabilities of satellite-derived positioning have been highlighted. At the same time, a range of alternative and complementary PNT approaches are in development at present. These range from low earth orbiting satellites to a range of terrestrial solutions including local transmitters and quantum technology for positioning. Some of these will no doubt enter service and become useful for pleasure vessel navigation over the next years and decades, something which we very much welcome.

AI

We expect that use of AI will soon enable very rapid comparison of multiple sources (marine charts, land charts, satellite imagery and LIDAR) to identify and correct chart information.

Recommendations for official bodies, developers and manufacturers

In the past few years, the RIN, via the Pleasure Vessel Navigation Systems Working Group (PVNSWG), has been putting more pressure on all our leisure chart providers and equipment manufacturers and maritime authorities to agree to some minimum standards of display and function. The increased use of apps and software-controlled functionality on standard operating systems should make it much easier for suppliers to update their products, via software upgrades and firmware updates, to meet these proposed standards. Reports on this ongoing work of the PVNSWG are available on our website: ***https://rin.org.uk/page/SCG***

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-o-nedlloyd-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

https://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)

https://keyassets.timeincuk.net/inspirewp/live/wp-content/uploads/sites/20/2015/04/Volvo-Ocean-Race-Team-Vestas-Wind-Report.pdf

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

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

Collision between ro-ro passenger ferry Red Falcon and moored yacht Greylag (MAIB 2020) - fixation upon information displayed on electronic chart - ignored other information - cognitive overload due to high stress

www.gov.uk/maib-reports/collision-between-ro-ro-passenger-ferry-red-falcon-and-moored-yacht-greylag

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 (SOLAS V):

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 priorplanning 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/regulations-for-pleasure-craft

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.

Circle vessel at least once.

Cross low, ahead a vessel rocking wings.

Overfly vessel and head in required direction.

Your assistance is no longer required.

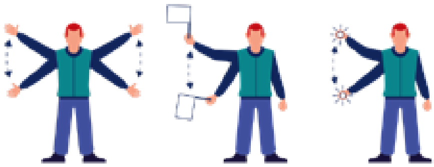
Cross low, astern of vessel rocking wings.

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

Life Saving Signals leaflet can be downloaded from: www.gov.uk/government/publications/live-saving-signals

Shore to ship signals

Safe to land here.



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

Morse code alternatives

Morse code signals by light or sound.

K −·−

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.

Morse code alternatives

Morse code signals by light or sound.

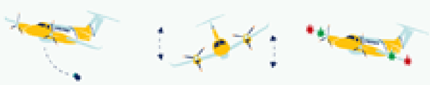
S ···

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.

Rocking wings.

Flashing landing or navigation lights on and off twice.

Morse code alternatives

Morse code signals by light.

T −

R ·−·

Message not understood – repeat.

Straight and level flight.

Circling.

Morse code alternatives

Morse code signals by light.

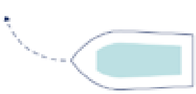
R ·−·

R ·−·

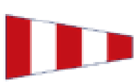
T −

Surface to air replies

Message understood – I will comply.



Change course to required direction.



Code and answering pendant "Close Up".

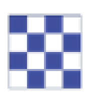
Morse code alternatives

Morse code signals by light.

T −

Note: Use the signal most appropriate to prevailing conditions.

I am unable to comply.



International flag "N".

Morse code alternatives

Morse code signals by light.

N −·

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Notes

Notes

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TRINITY HOUSE

RYA

Maritime & Coastguard Agency

Lifeboats

ROYAL CRUISING CLUB PILOTAGE FOUNDATION

Electronic Navigation Systems

Guidance for safe use on leisure vessels v.2

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.

ISBN 978-1-8382360-2-1

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