

**Navigation is centred
on relative position...**

...and not absolute position

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How my talk is planned to go...



- Starts with a very quick relook at what navigation is all about
- Then goes through a 'mind-set' for using modern equipment
- **Hopefully, dispels the all-to-common myth that:**

“Safety is understood as the obtaining of your absolute location with high accuracy.”

[Taken from the main text on a GPS-centred website!]

My professional work on autonomous vessels has particularly impacted my thinking

Leisure marine navigation:

Is centred on **getting from 'A' to 'B' safely**, whilst attempting to meet all other criteria, including...

- Legal requirements
- Cost issues
- Time objectives
- Personal acceptance by those onboard and those affected by the navigational decisions; for leisure sailors an acceptable mixture of:
 - Pleasure
 - Comfort
 - 'Optimum' speeds
 - Nice views
 - Satisfaction and even pride in 'getting there'

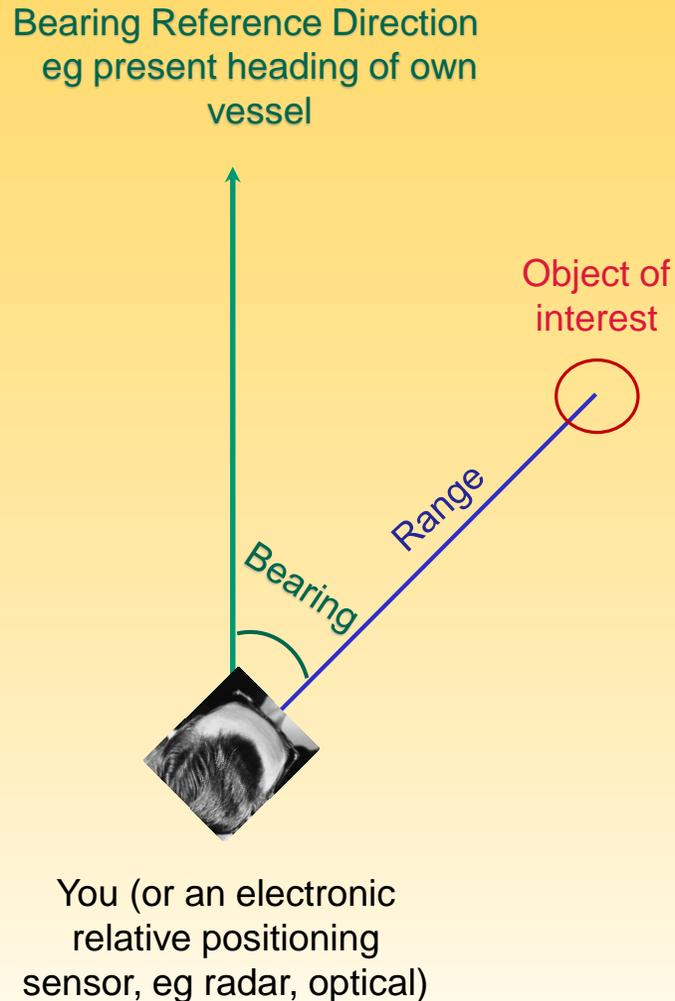
Knowing your position is essential

That is, your relative position to:

- All actual and potential hazards
- The next ‘positional objective’ (way-point) for the voyage, taking into account:
 - All known fixed hazards, especially from charted data
 - Predictable time varying features, such as tides, currents, dusk, dawn...
 - Predicted weather conditions, especially visibility, wind strength, and wave characteristics
 - Estimated effective ‘speed’ – time is an essential criterion for navigation

“We are going over there...and we should be safe”

The basics of 'direct' relative positioning



The time-evolving detail of the object:

- Helps us identify what it is, especially – is it:
 - A threat to our current intentions? or
 - A marker to help us on our way?
- Helps us determine its range, direction and motion relative to us
 - and therefore whether a change in our own speed and/or direction is necessary
- Gives the essential final check on any 'above water' hazard determined by absolute position techniques

Significance of direct relative positioning

Primary and (fortunately) 'obvious-to-all' – by eye:

- When berthing – need better than 10 cm relative accuracy...
 - Who uses GNSS/GPS then – but you may be looking at the echo sounder
- Similarly – within harbours, marinas and anchorages

Direct relative positioning remains important, at varying levels of dominance in other situations, as it:

- Provides the only collision avoidance 'data' available for all types of above-water hazards, in any waters – by, eg, optical and radar detection
- The direct visual scene helps the human brain assimilate the overall situation, especially when integrating information from multiple electronic sensors

Absolute positioning naturally becomes more dominant in areas with reduced or no 'observable' features – not least mid ocean...

Ironically, in situations where less accuracy is necessary!

Systems that help us determine our relative position

1. Directly – no reliance on ‘off-board systems’, eg:

- Human eyes
- Human ears
- Radar
- Depth (acoustic) sensors
- Speed-through-water (STW) log

Charted information highly useful

2. Indirectly – by the use of absolute positioning systems

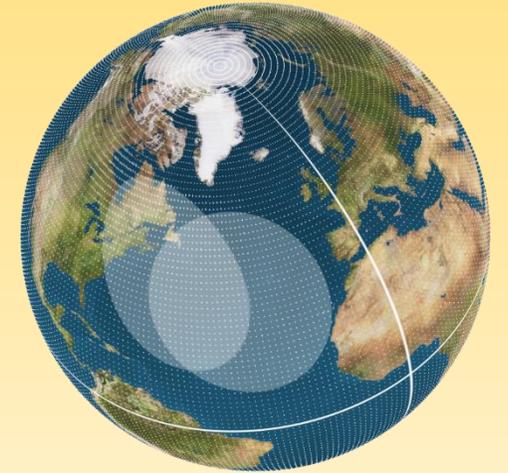
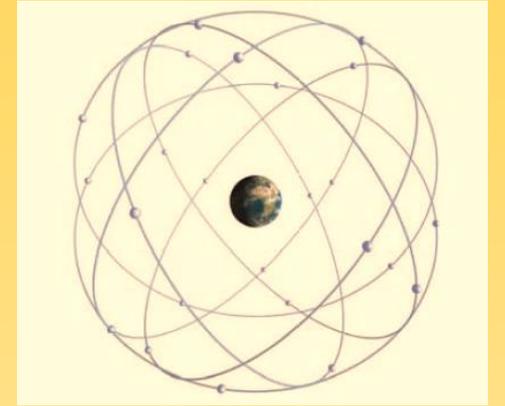
- GNSS and other radio-based positioning systems – such as eLoran
- AIS
- Celestial navigation

Charted and RF information essential

Charted information, ‘tables’ and good visibility essential

Of course – your absolute position is:

- Just your **relative position** to an agreed reference point
 - Typically, for Earth-based navigation, the Earth's centre
 - This point is inaccessible and invisible...
- Therefore, to establish our own absolute position we determine our relative position to objects with a known or calculable absolute position, eg:
 - Natural astronomical objects – stars, sun, planets, moon
 - Artificial satellites, eg GPS
 - 'In-view' objects on the Earth with known absolute position, eg from charts, using optical and radio methods

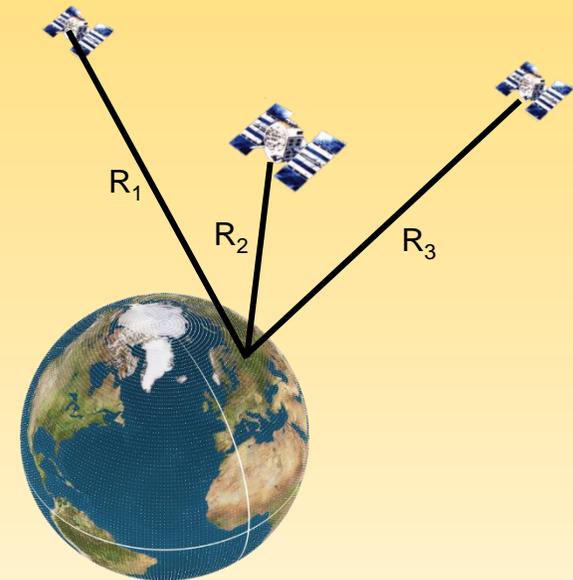


BUT the 'indirectness' of using absolute position to establish our relative position to potential dangers creates vulnerabilities

GNSS – a very useful aid: but vulnerable

Based on microwave frequency signals from distant satellites

- Random atmospheric/cosmic conditions affect accuracy and availability
 - Relatively weak signals :
 - Gives reception problems when there is no direct 'view' of satellites
 - less problems at sea but still can cause issues
 - Make jamming and spoofing easy – and difficult to prevent/detect
- (Apparently has yet to result in a major maritime accident)**
- Very expensive global systems owned by governments
 - They have the final say in their ongoing services...
 - Use of AIS adds further possibilities for error and deception



Total reliance on GNSS-derived position is dangerous

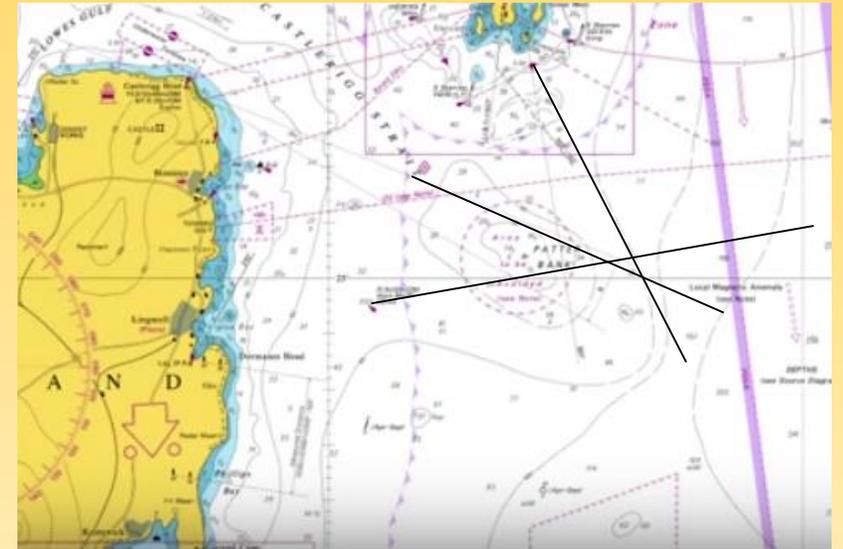
Charted information - essential for safe navigation

- Maps and charts originally started out as a major aid for relative position based navigation
- Hundreds of years ago charts became essential for absolute position based navigation...
- Weirdly(!) – some modern electronic chart systems are poor in helping users cope with degradations and/or non-availability of their own absolute position

Simply because of poor equipment design

- Charted Aids-to-Navigation (buoys, etc) are there to assist safe relative navigation
- Particularly as a visual aid to avoid underwater hazards

They also provide a useful check on your absolute positioning system



Courtesy UKHO

Determining the actual situation

Is through correlation of all available information

- The current optical scene
- The charted situation supplemented by Notices to Mariners
- Speed-through-water sensors
- Depth sensors
- Acoustic information
- Radar – essential for best safety in poor optical situations...
- Absolute position-based techniques
 - Especially AIS, when radar is not available
- Vessel-to-vessel communications

Highest confidence is achieved when all sources of data correlate

When there is no direct relative positioning info

and there are charted underwater dangers which are not 'AtoN marked'
(eg with a buoy)

Then:

- Major reliance on absolute positioning determination and good charts becomes essential
 - With some 'relative' assistance by checking for correlation of the actual depth soundings with charted data and estimated tidal height for the indicated absolute position
 - However, needs a greatly increased error margin in route planning

An unlikely situation in 'civilised' waters but it has caused problems in some remote areas around the world

Relative positioning determination...

- Needs intelligent human and/or machine collection and processing of data
- On 'pro' vessels, radar is typically the major source for relative position information
 - Primary advantage – not dependent on good optical visibility
 - But it has its own deficiencies...
- The need for human-collected optically based relative positioning is also recognised
 - BUT the skills and the perceived need for enhancing and plotting visual data have eroded
 - These were natural when paper charts were mainly in use
 - Has effectively put increased reliance on good radar and GNSS on professional vessels
- This has effectively happened for much of the leisure community, but...

**On most small craft radar is non-existent and, when fitted,
can be relatively poor in its capability**

But our obsession with absolute position

Has probably recently peaked...

- Primarily because of developments in the autonomous world
- Just a few years ago many involved with autonomy (apparently) naively assumed 'all you needed was GPS'
- The evolving work has led to a much increased emphasis on electronic systems that automatically and directly determine relative position information



Courtesy Rolls Royce

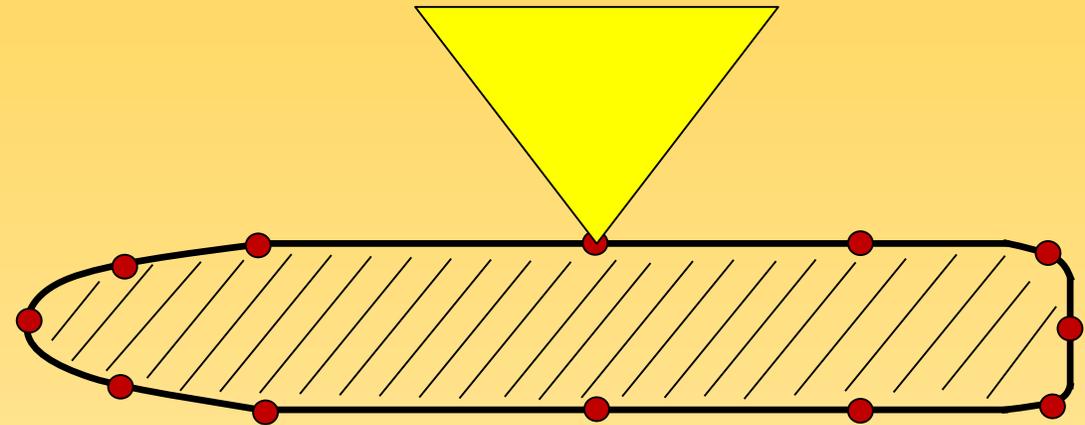
In the maritime world the Collision Regulations explicitly require actions to be taken on visual and aural data

Affordable optical sensors ease the process...



Optical sensor fitment on future vessels?

- Being driven by autonomous vessel considerations
- But also relevant to conventional commercial and leisure vessels
- Strategically mounted multiple sensors creating a total 360° view of the situation
- Accurate automatic bearings and approximate target range estimation are all possible
- Could readily add 'optical correlation' information to an 'integrated navigation' display – rather than just showing a conventional video-type view:



Alerting the user when a non-charted target is only detected optically and not by AIS or radar – and what direction to look...

Autonomy has also revived interest into:

Local detection of one's own relative movement from a previously known position

- By measuring the 'platform's' inertial changes (accelerations and rotation)
- Relatively well exploited by the military – and large aircraft – for some tens of years but, to-date, too expensive for most users
- BUT, domestic products, eg mobile phones, are increasingly using inertial sensors of steadily improving capability
- Potential, in the more distant future, to give useful position accuracy over many hours – and eventually days – in an affordable way, not least, checking on GNSS accuracy

Inertial navigation systems (INS) are basically jam and spoof proof provided they are kept 'off-line'

And so to end ...

Safe navigation at sea is all about:

- Good training and experience
- Reliable and sufficiently accurate knowledge of one's own **relative position** to all dangers by:
 - **Primary** use of direct relative positioning techniques
 - **Knowledgeable** use of absolute position techniques in assessing the relative positions of dangers, especially surveyed underwater hazards
- Best reaction to the emerging reality of the situation
- Realising that navigational aids and systems can fail and so must be knowingly used and sensibly backed-up

**Future technology will give ever-improving aid
from relative position based systems**

Thanks for listening...