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Resilient PNT options and systems in maritime applications

Dr Alan Grant

(with support from GLA colleagues, ACCSEAS project partners and IALA ENAV Committee members)

RNN Seminar – Stockholm, October 2017

Use of GPS in the Maritime Sector

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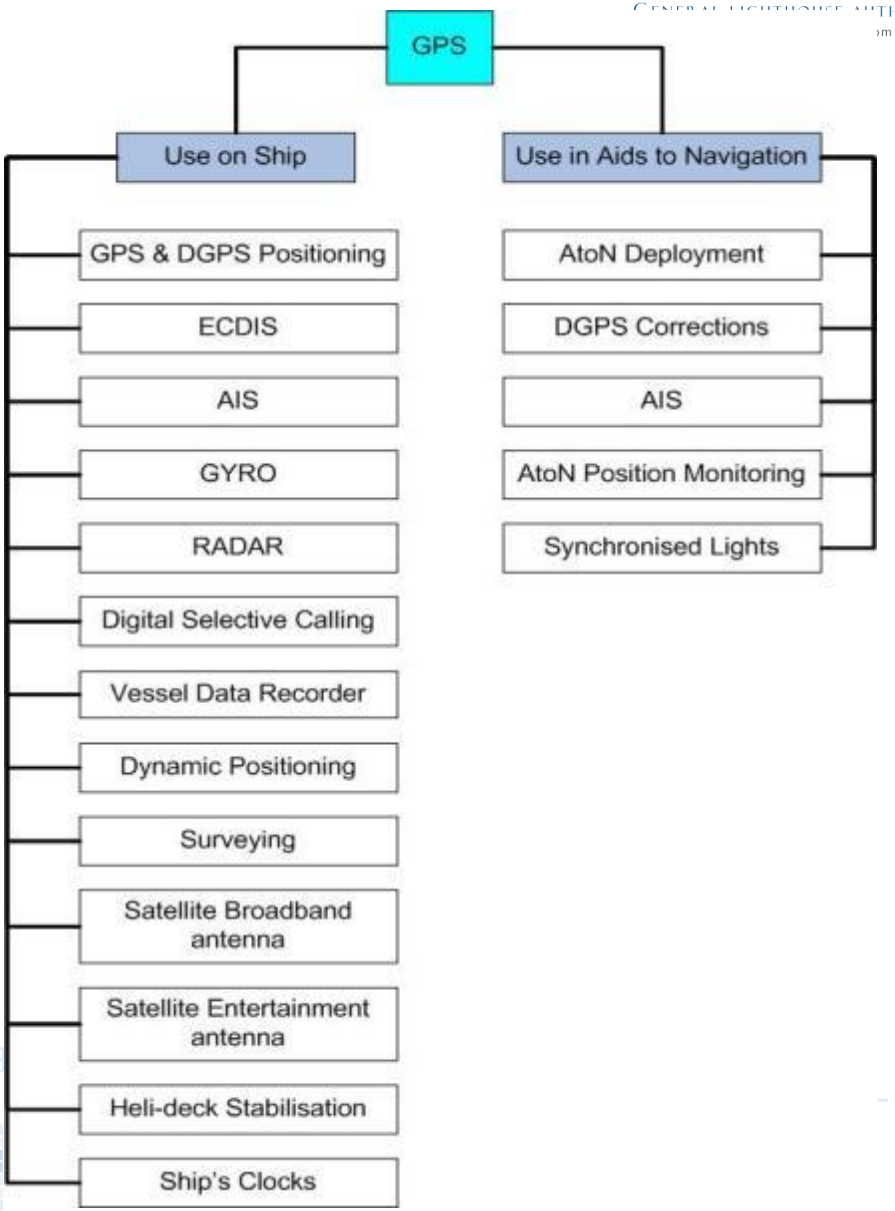
GPS has become the normal means for maritime positioning, navigation and timing.

IMO state:
“e-Navigation systems should be resilient …. robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems should be considered” (MSC 85/26, Annex 20).

Resilient PNT needed to support communications.



GNSS system errors

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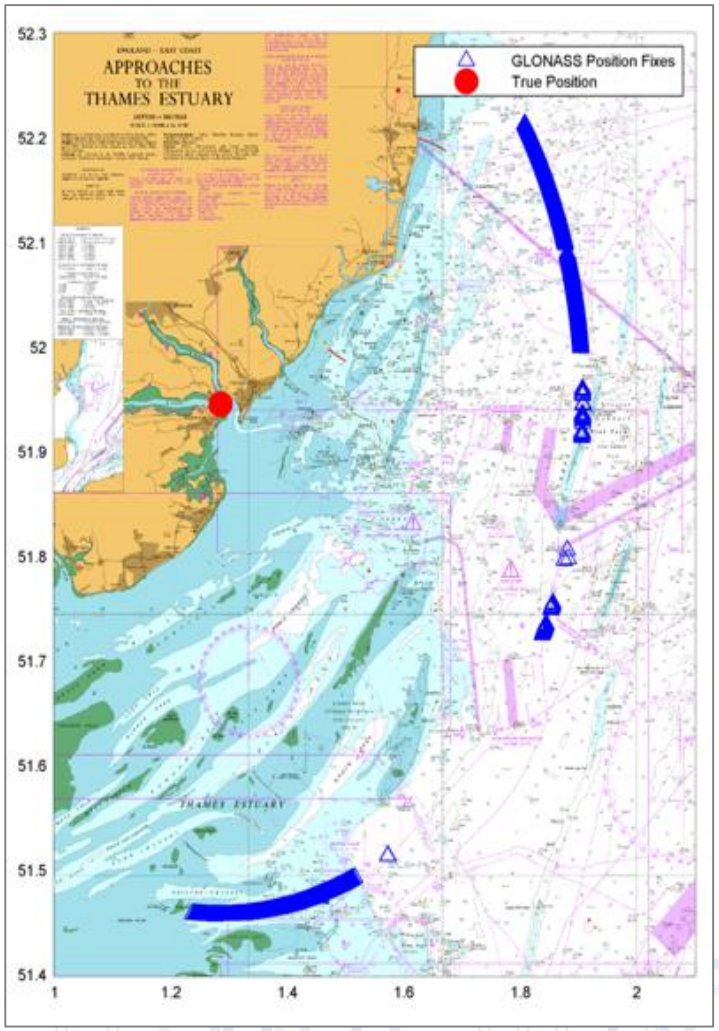
- GLONASS
  - April 2014 upload error, resulted in the constellation reporting significant position errors (~50km) before going off-air for 11 hours.
- GPS
  - SV clock error on 1st January 2004 resulted in significant position errors
  - 13 microsecond timing error in January 2016 affected most timing users and some position users.



GNSS signal interference

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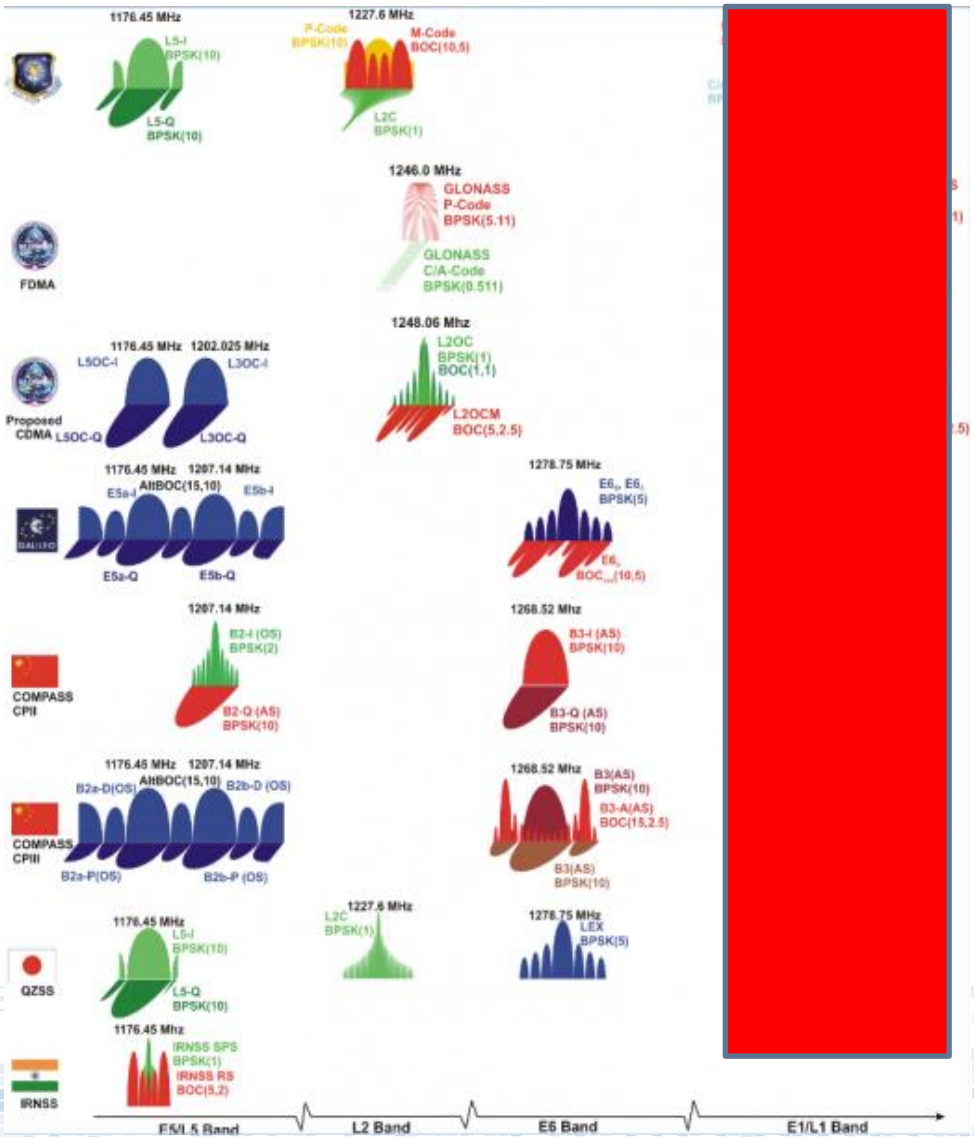
Access to different GNSS constellations does not mitigate the effect of signal interference.

Interference can be caused by natural and man-made sources.

- Space weather
- Accidental signal jamming
- Deliberate signal jamming
- Spoofing



Space weather

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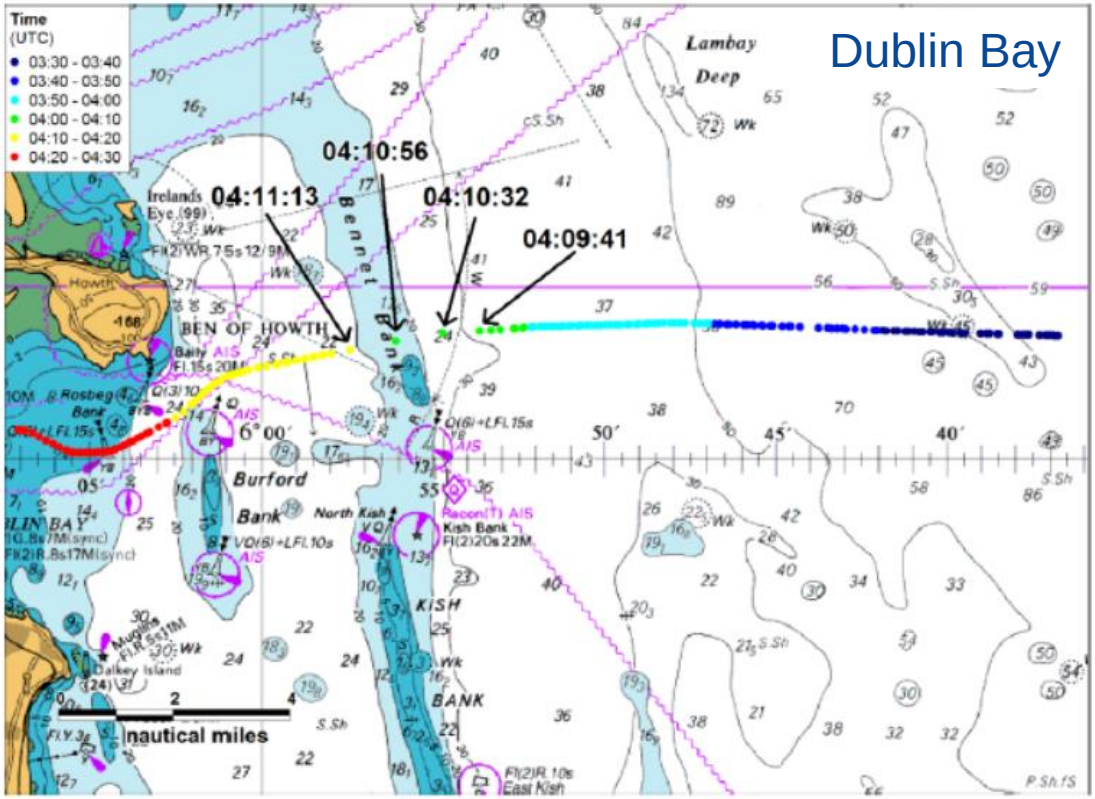
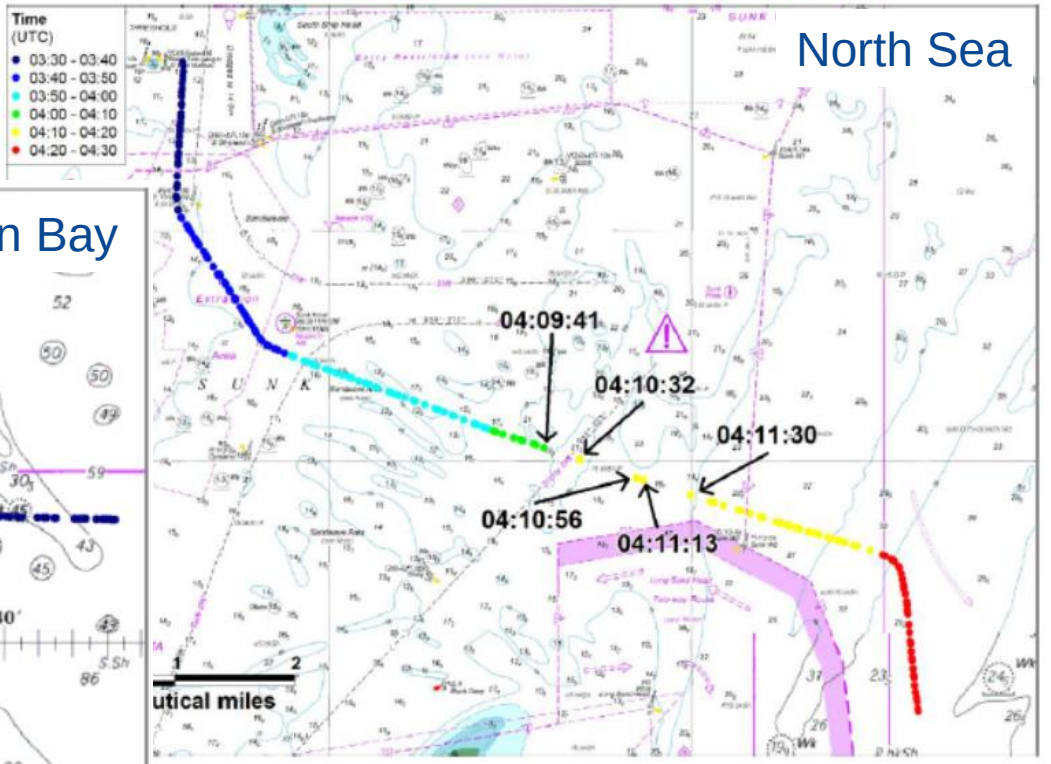
Reported AIS positions affected by Space Weather effects.






```
Space Weather Message Code: WARK07
Serial Number: 43
Issue Time: 2014 Sep 12 2307 UTC

WARNING: Geomagnetic K-index of 7 or greater expected
Valid From: 2014 Sep 12 2306 UTC
Valid To: 2014 Sep 13 0700 UTC
Warning Condition: Persistence
NOAA Scale: G3 or greater - Strong to Extreme

NOAA Space Weather Scale descriptions can be found at
www.swpc.noaa.gov/NOAAscales
```

Accidental jamming

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Faulty TV Aerial radiates on L1 preventing GPS signal reception over bay

THV Alert

Source: www.GPSworld.com/the-hunt-rfi

Deliberate jamming

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GPS jamming units available online.

Currently legal to own in the UK, but illegal to operate.

Multiple examples of use by criminals and road users to prevent tracking or charging systems.

Few examples to date of deliberate GPS jamming at sea. (Thankfully!)

Korean Peninsula GPS Jamming Notice

A continuing series of incidents have been reported in the general location of Incheon, Republic of Korea and the surrounding Gyeonggi and Gangwon provinces out to approximately 100 nautical miles beginning on or about 0000Z31March16.

The nature of the events appear to be Global Positioning System (GPS) jamming emanating from the Democratic People's Republic of Korea causing signal disruptions to airplanes, ships, and buoys in the area.

Exercise caution when transiting this area. If appropriate, further information may be forthcoming. Vessels experiencing disruptions in the area are urged to report them to the point of contact (POC) below.

State Department issues notice on North Korean jamming : GPS World
http://gpsworld.com/state-department-issues-notice-on-north-korean-jamming/

Spoofing (position)

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- Photo of a real radar screen from vessel in the Black Sea.
- Appears to be GPS spoofing on a large scale, certainly not subtle!
- Spoofing AIS data would look similar.
- Becoming more common occurring according to social media reports.

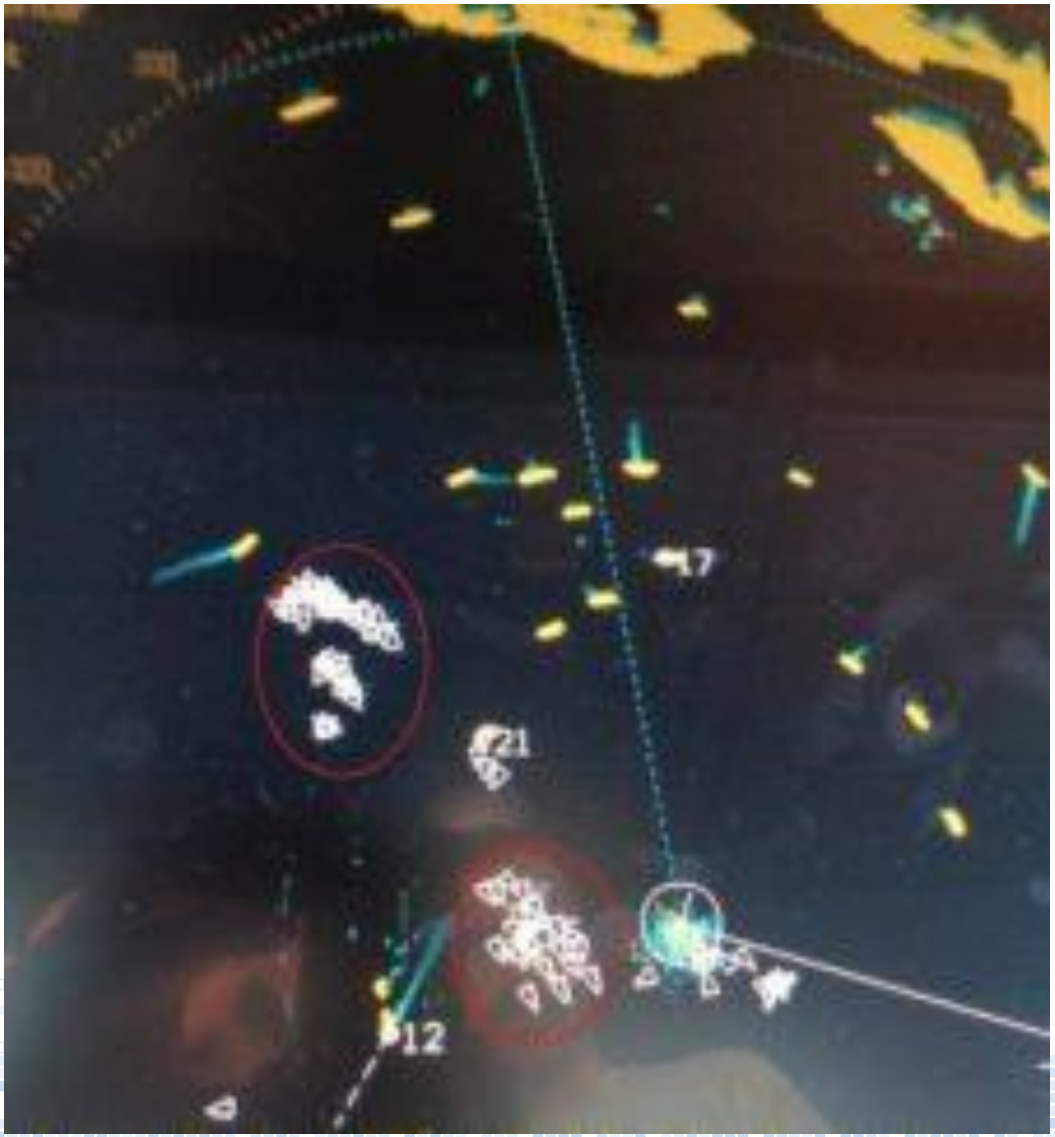

Image Credit: Resilient Navigation and Timing Foundation

Spoofing (data)

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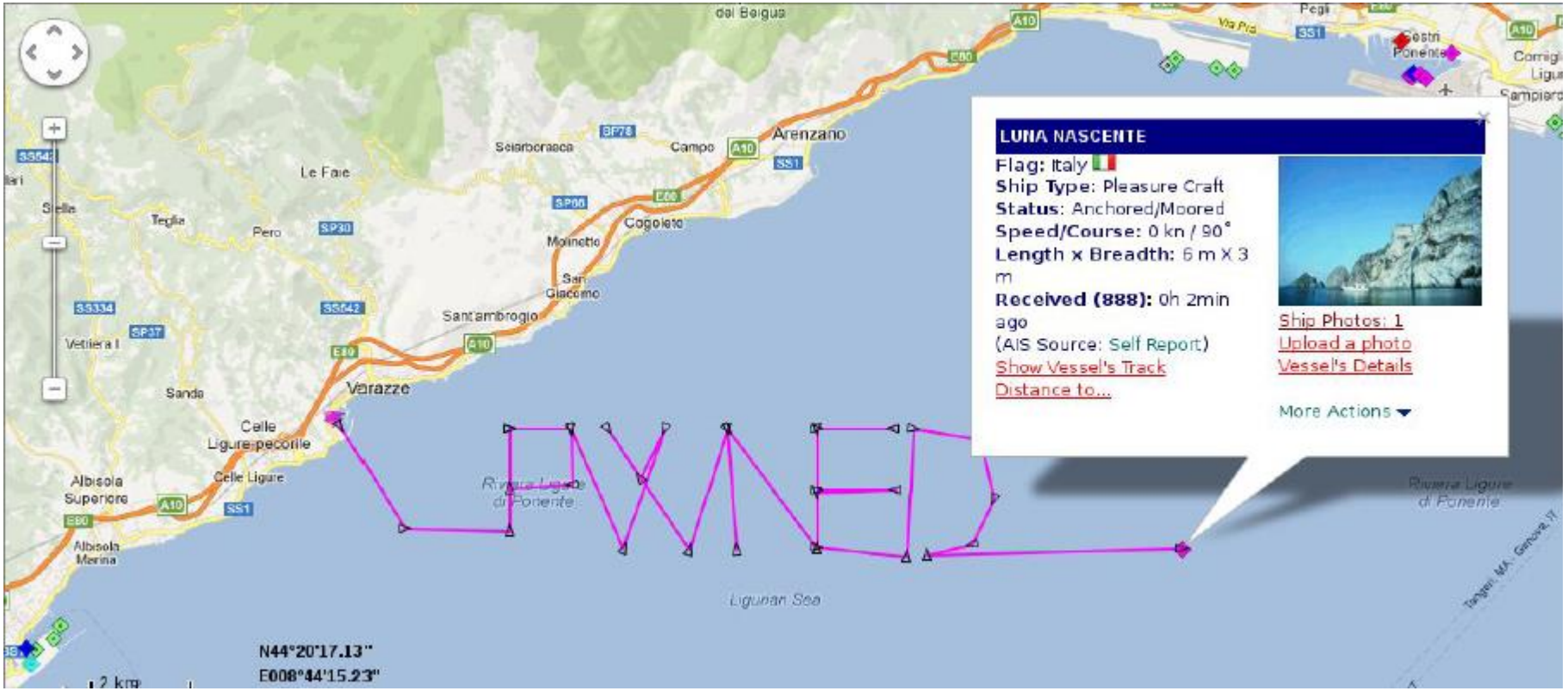

Image credit: *M. Balduzzi, K. Wilhoit and A. Pasta,*
"Hey Captain, Where's Your Ship? Attacking Vessel Tracking Systems for Fun and Profit"
Presentation given at 'Hack In The Box' Conference, October 2013

It’s a serious business

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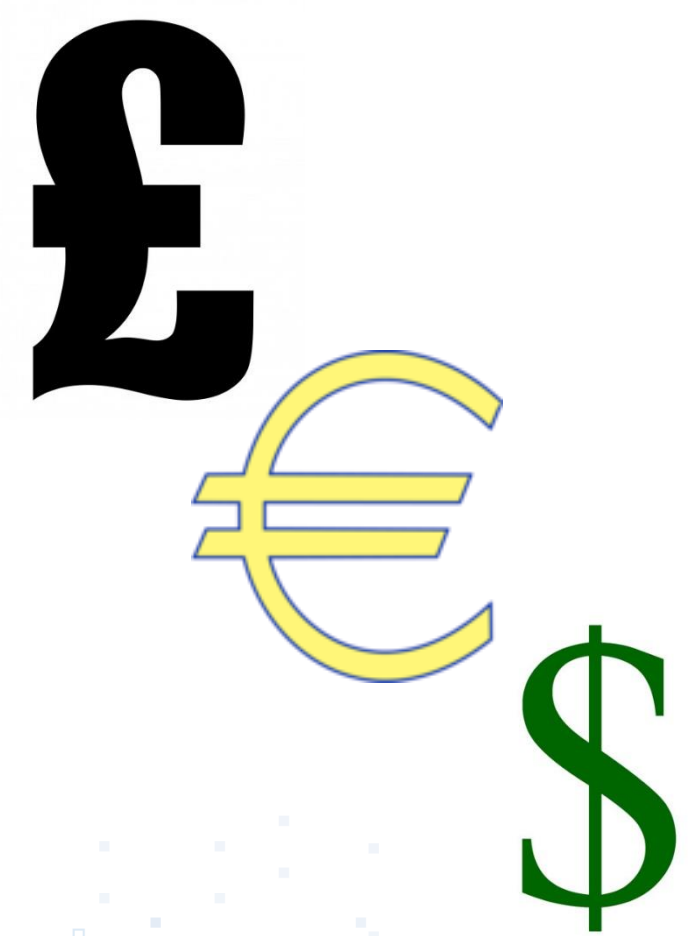
Maersk shipping affected by Petya virus in June, affecting operations across the world.

*“A five-day GNSS loss would impose significant disruption to maritime infrastructure and vessels. These direct and indirect impacts are estimated at **£1.1bn** or 21% of all estimated impacts”.*

- The economic impact on the UK of a disruption to GNSS



Lives are important too!

Resilient PNT – The Problem

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This video showed the impact of GPS denial on a GLA vessel, demonstrating how GNSS data is used across the bridge.

Video removed to reduce file size. The video shown was an extract of a larger video prepared for the ACCSEAS project, available via the link below.

https://www.youtube.com/watch?feature=player_detailpage&v=CNAr8eQQ_9E

GLA GPS Jamming trial (2008)

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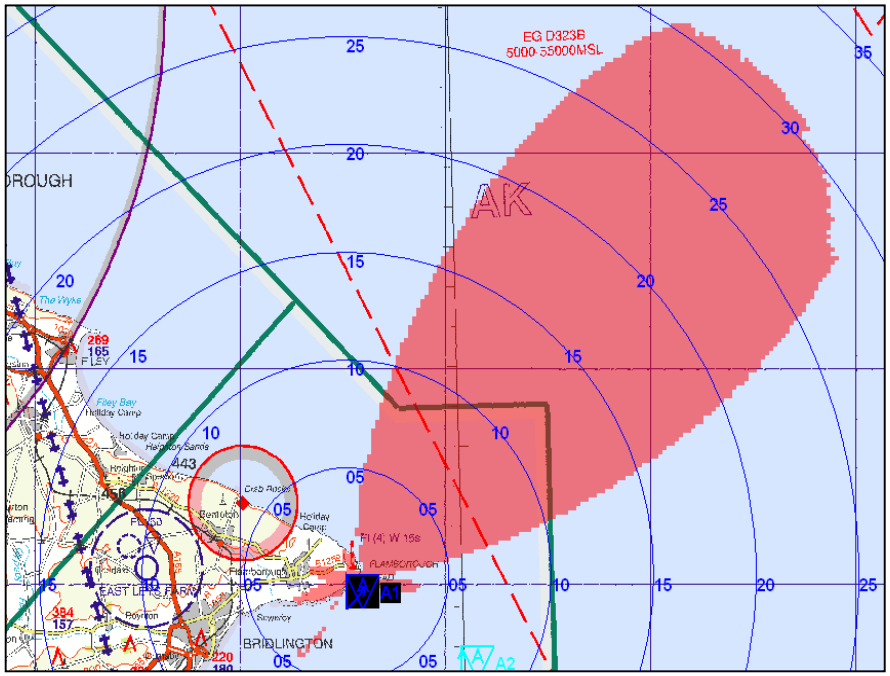
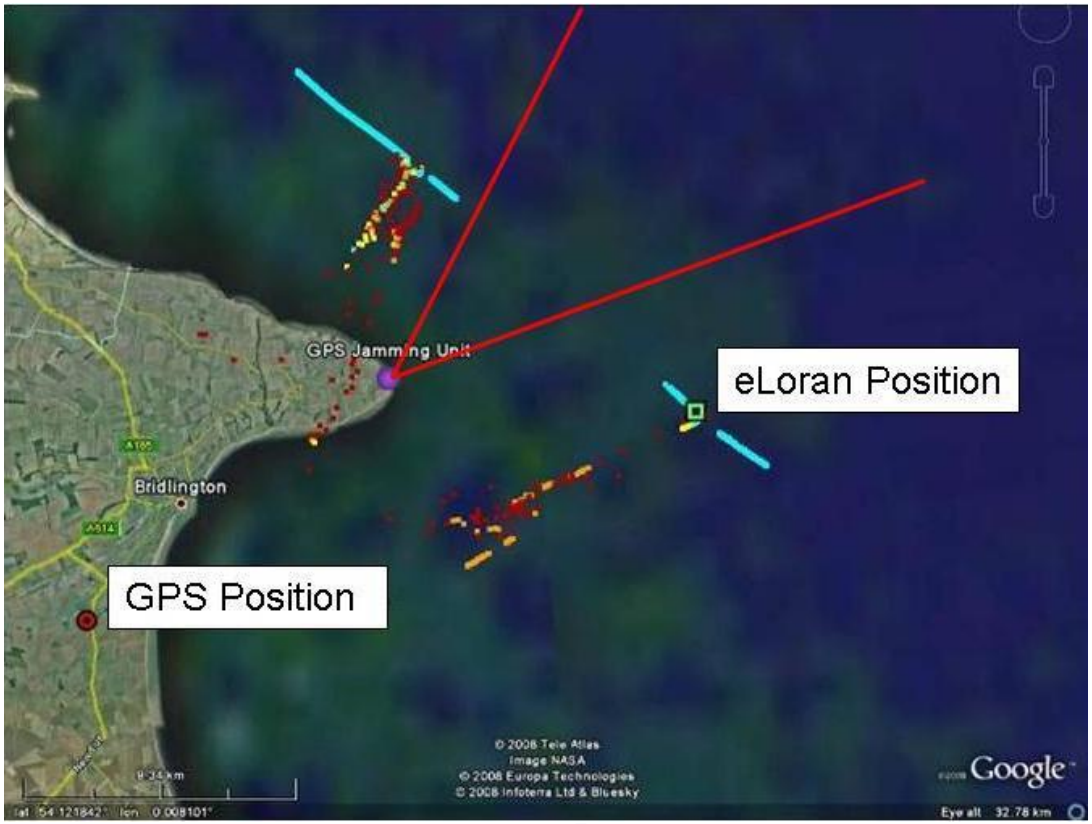


Coverage area of the GPS jamming unit at 25m above ground level on maximum power of 1.58W ERP.
(Image courtesy of DSTL)



GPS reported position is inland and 22km away from true position (eLoran).

Colours indicate reported speed: blue <15knts, yellow< 50knts, orange <100knots and red >100knts

Effect on Ship & Shore

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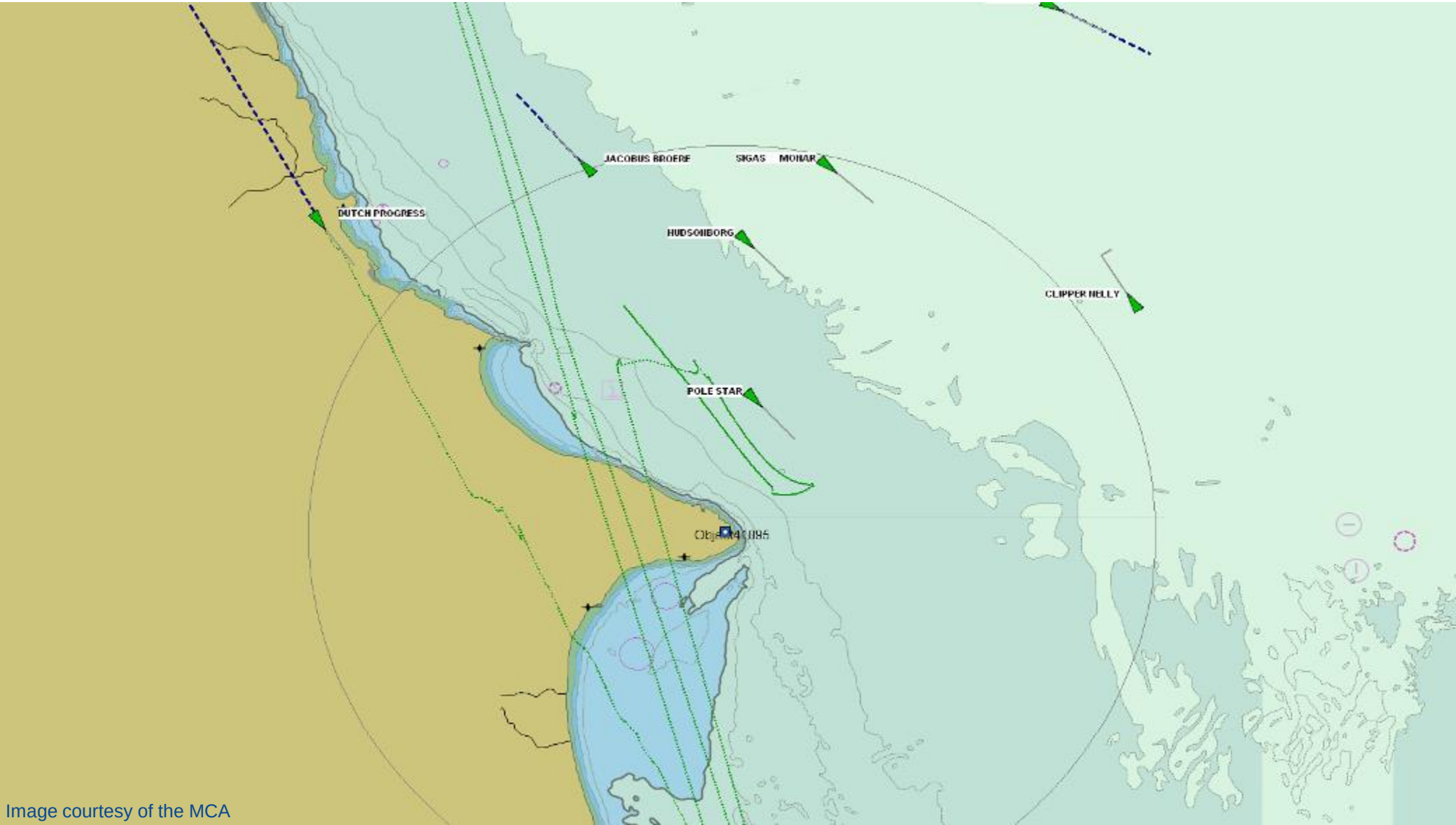

Image courtesy of the MCA

How do we achieve resilient PNT?

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- Raise awareness
  - General awareness
  - Identify when issues occur
- Harden GNSS receivers
  - Adaptive antennas
  - Internal management and monitoring processes
- Use dissimilar systems
  - Inertial Navigation Systems
  - eLoran
  - Radar absolute positioning
  - Ranging mode (R-mode)
  - BinoNav®

eLoran

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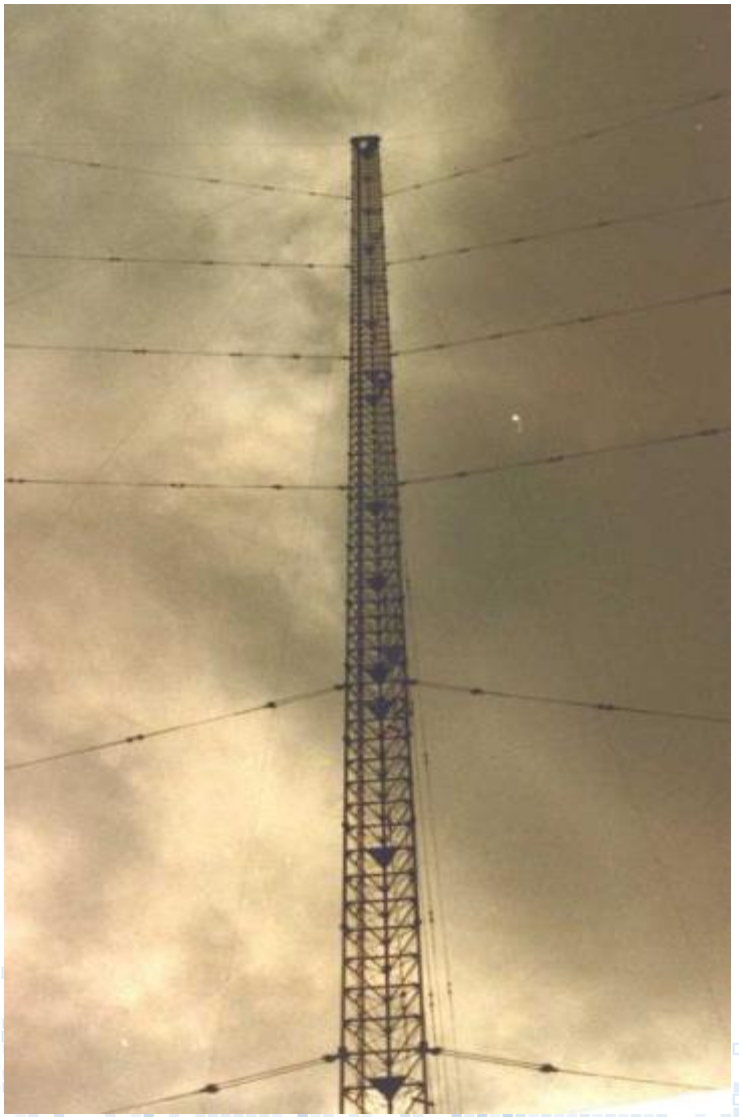
- Complementary to GNSS
- Low frequency/high power/terrestrial
- All in view, rather than hyperbolic
- Standardisation well advanced
- Independent Position and time source
- eLoran can meet the accuracy availability, integrity and continuity performance requirements of IMO



Northwest European Loran-C

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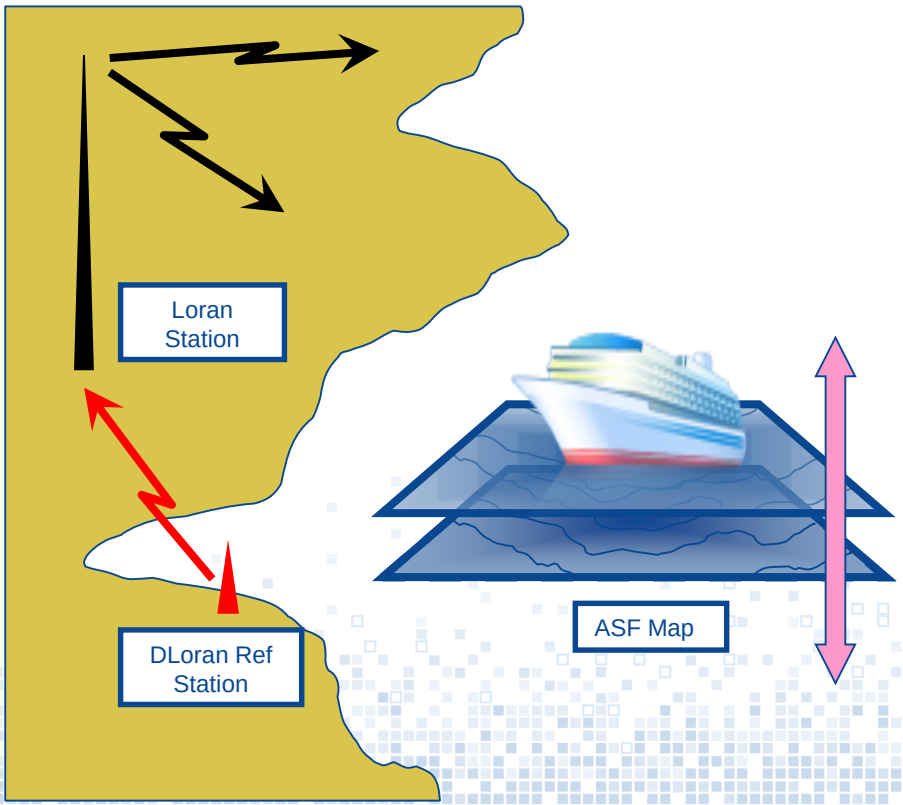
Loran-C Transmitter

Control station

- France
- UK
- Norway
- Denmark
- Germany



GLA eLoran Accuracy

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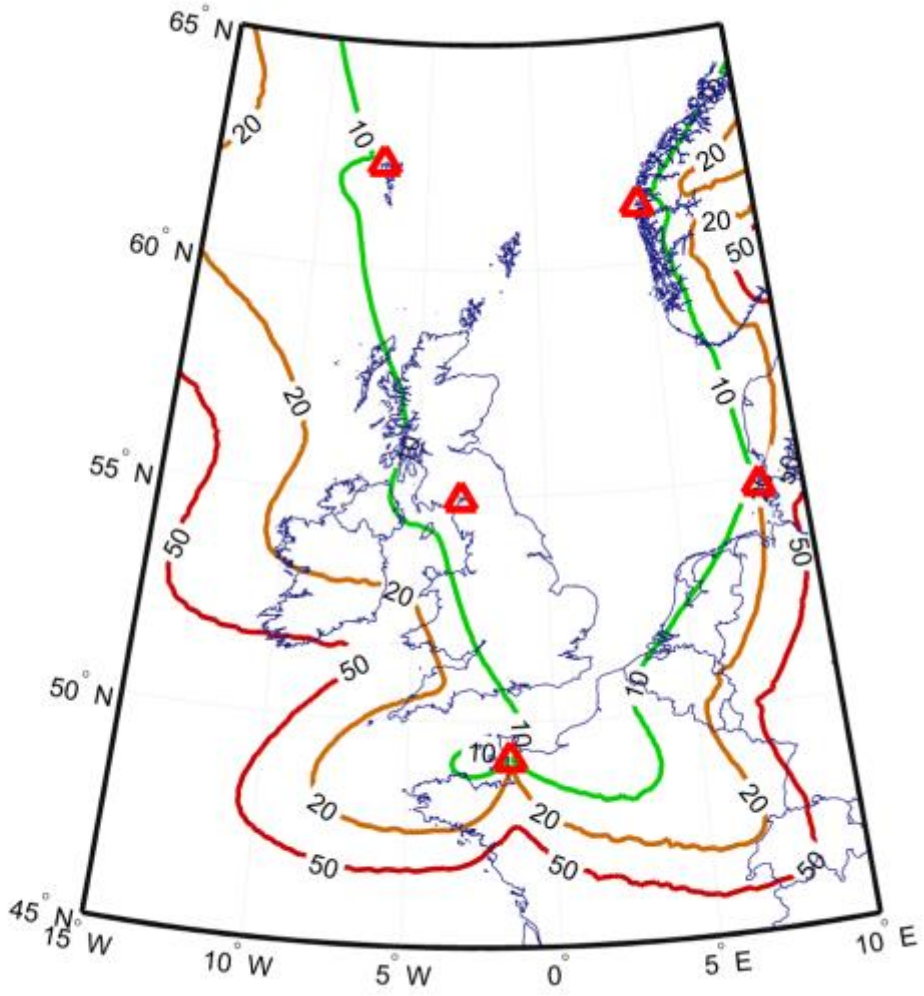

Green contour is 10m position accuracy (95%) achieving IMO requirement for **port and harbour approach**

GLAs' Maritime eLoran

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Initial Operational Capability reached October 31st 2014

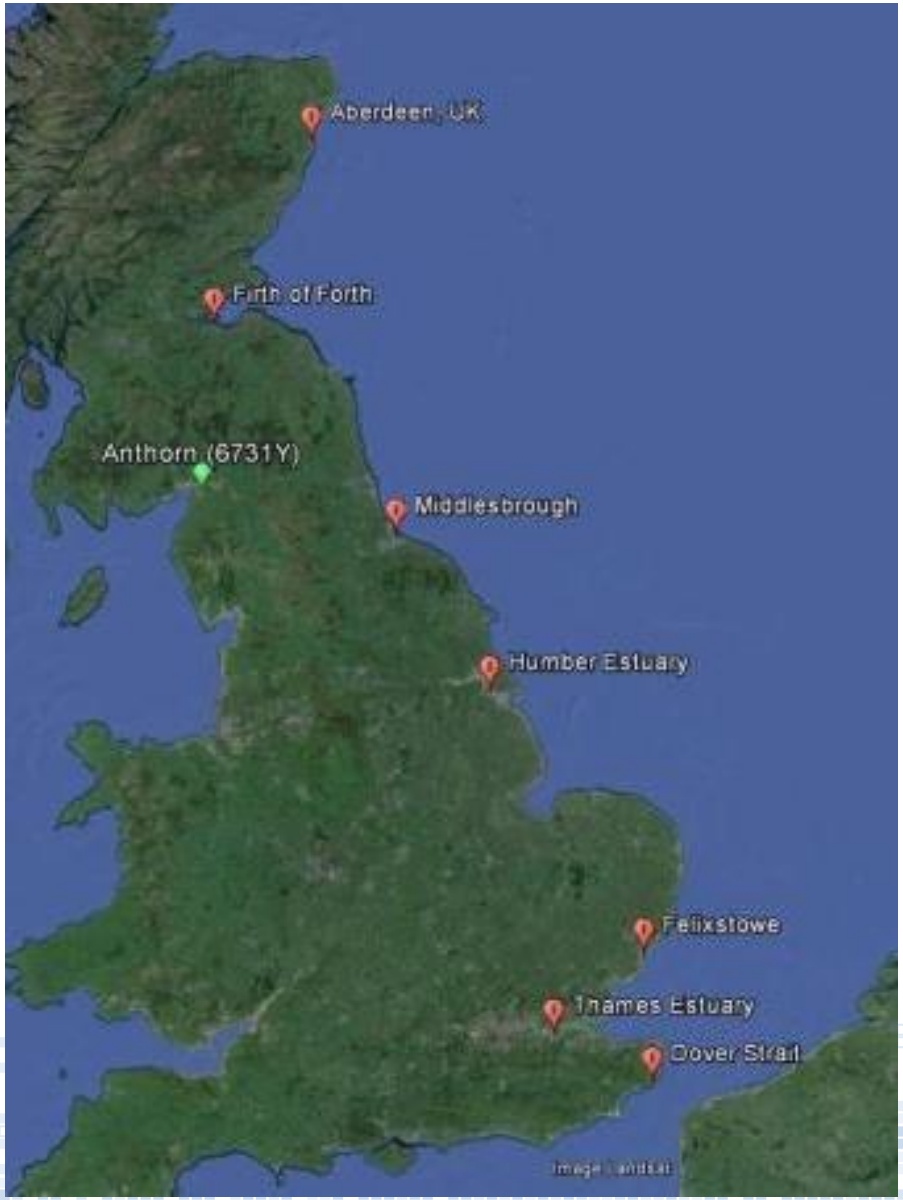
- 7 major ports on the east coast
- Port Approach Level, 10m (95%) accuracy eLoran

Encouraged users/stakeholders to take up use of the system

- Seeded vessels with receivers
- Multi-sector approach

Worked with international partners to develop standards

- RTCM
- IALA



European Loran-C – current status

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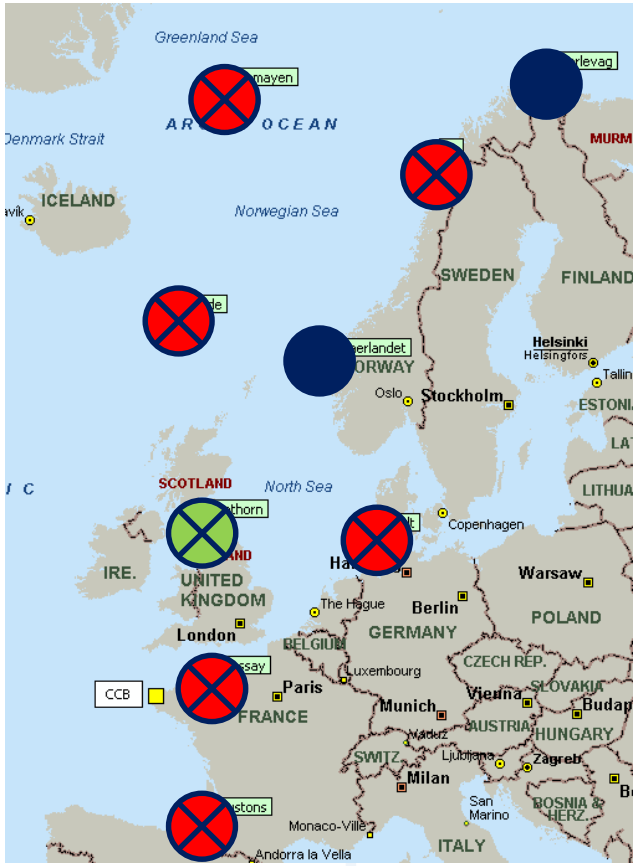
- Most nations closed their Loran-C stations at the end of 2016
- Understandable decision, given Loran-C is a legacy system, with limited user base.
- Key is whether infrastructure can be retained for future eLoran transmissions (some have been removed).



on air:
- Anthorn (UK)

not transmitting:
- Lessay & Soustons (France)
- Sylt (Germany)
- Ejde (Faeroes)
- Boe & Jan Mayen (Norway)

decommissioned:
- Berlevåg & Vaerlandet (Norway)

Radar absolute positioning - eRadar & eRACON

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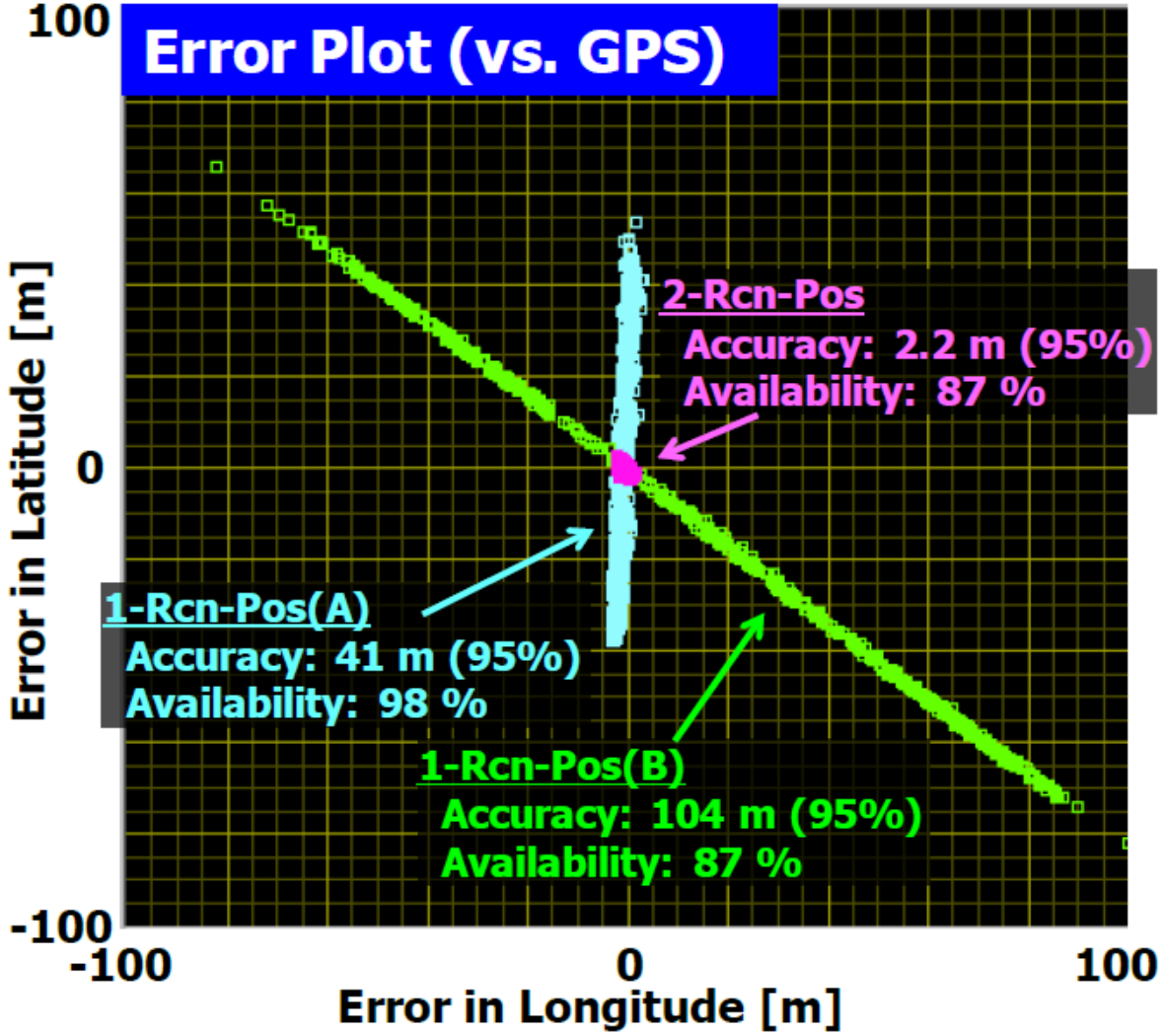

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Radar absolute positioning - map matching

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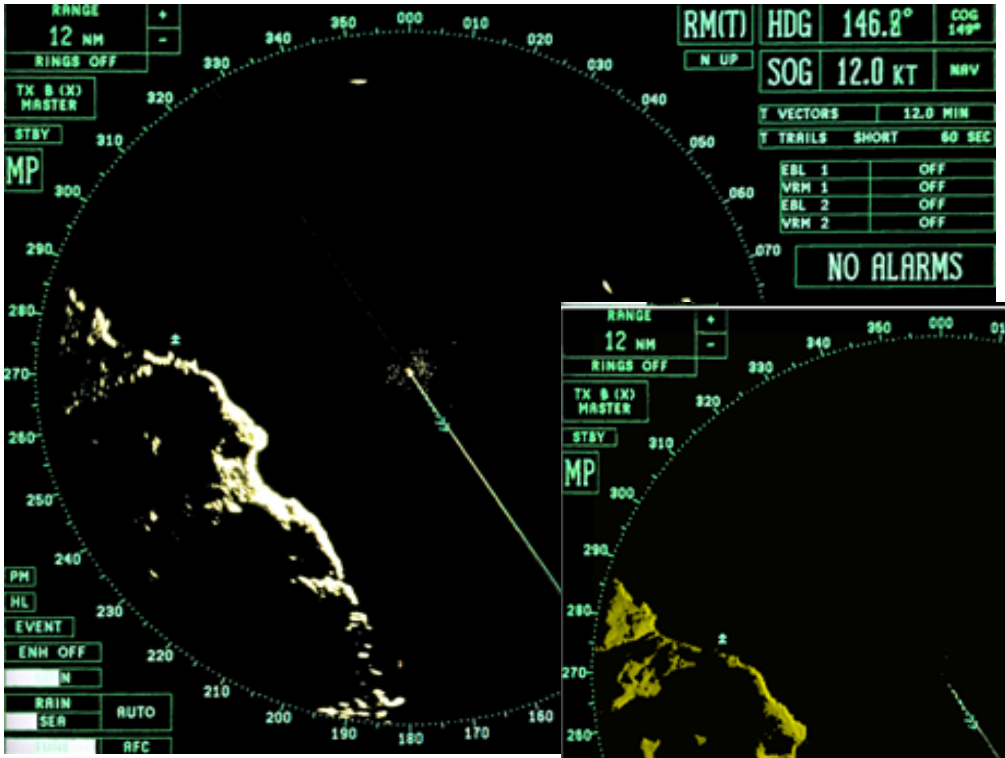
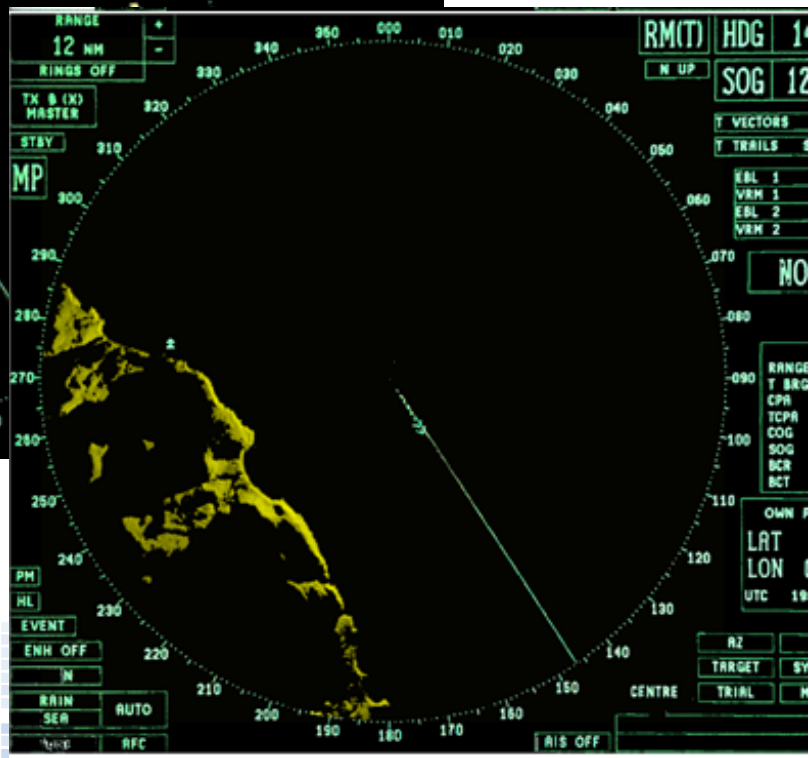
- Generate / obtain map
- Map match to the current radar image
- May need to add coastal features in some locations
- Accuracies in the order of 20-100m (95%) expected, depending on conditions



Actual response



Modelled response

R-Mode – Feasibility study

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The notion of broadcasting a ranging signal from existing maritime infrastructure (AIS and marine beacons) to provide an independent position solution.

The ACSEAS project funded a feasibility study which considered how R-Mode could be achieved and gave expected performance.

It also funded the development of a prototype R-Mode broadcast and receive equipment for MF transmissions.

Further details, including the feasibility report, are available on the ACCSEAS website (www.accseas.eu)

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ACCESSIBILITY FOR SHIPPING, EFFICIENCY ADVANTAGES AND SUSTAINABILITY

R-Mode MF

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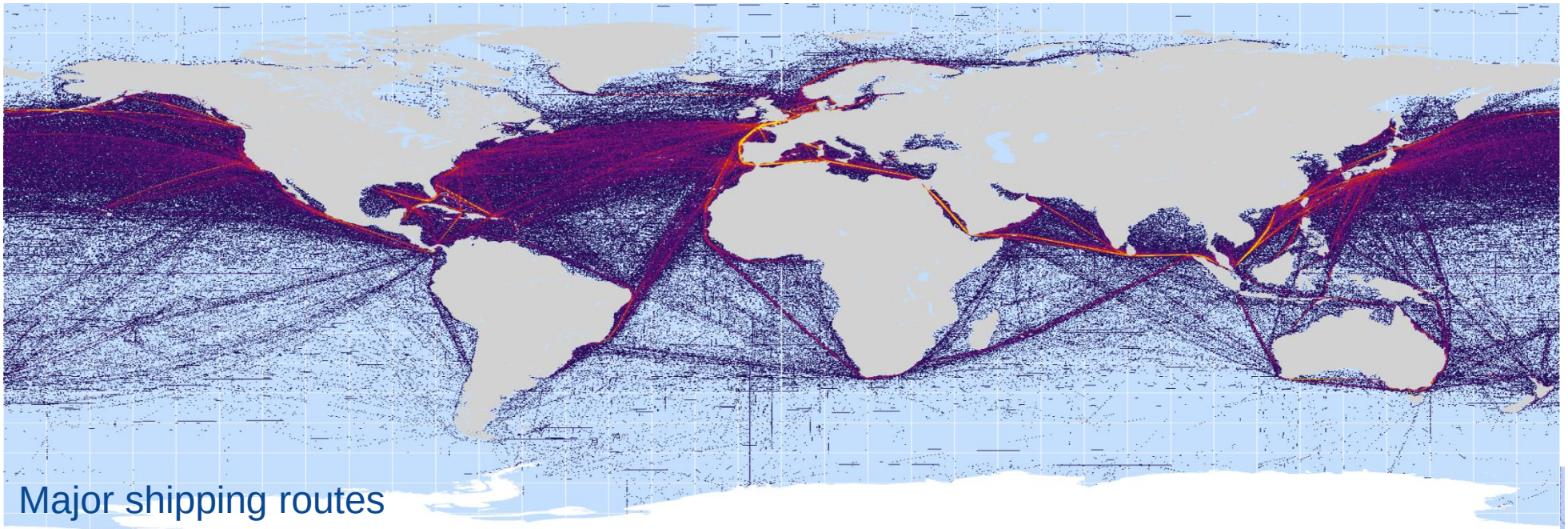

Major shipping routes

DGPS radio beacons

sources: forobs.jrc.ec.europa.eu, IALA

Predicted R-Mode accuracies (MF)

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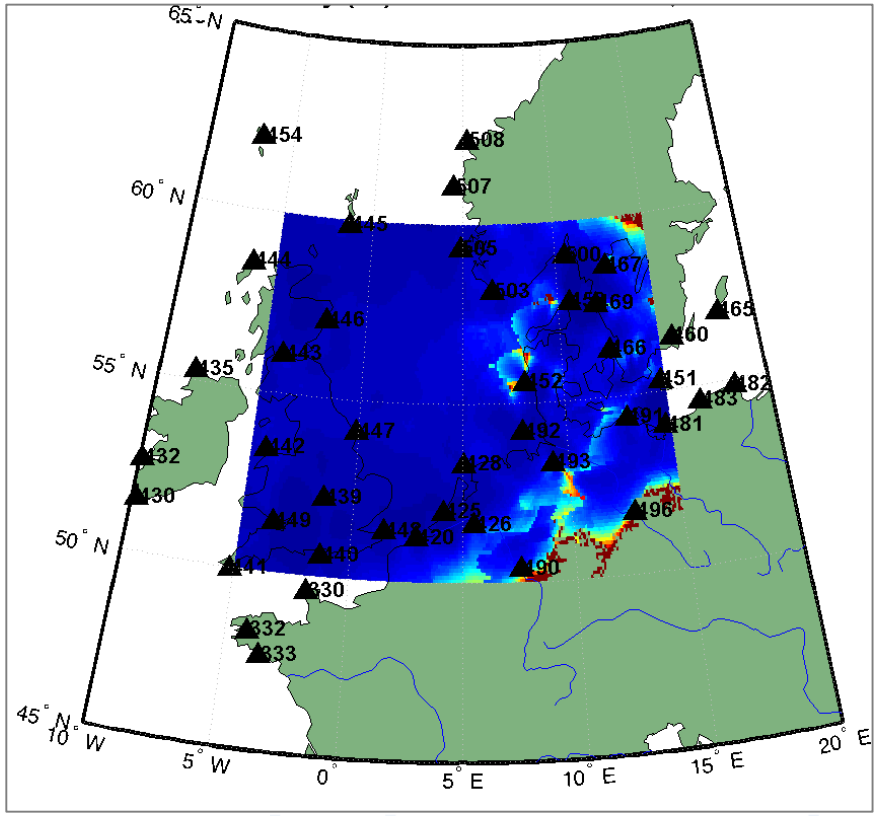
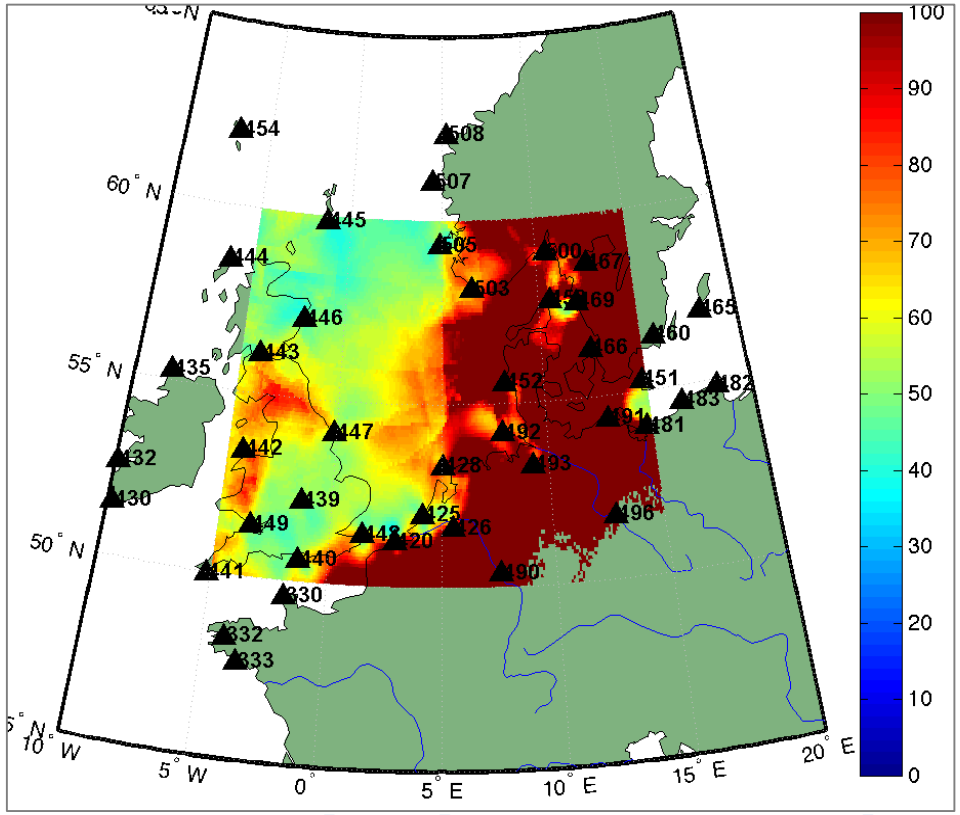
Day time (no sky wave)



Night time (sky wave)



Predicted positional accuracies (m) for R-Mode using MF transmissions over the North Sea region

ACCSEAS

source: ACCSEAS

R-Mode AIS

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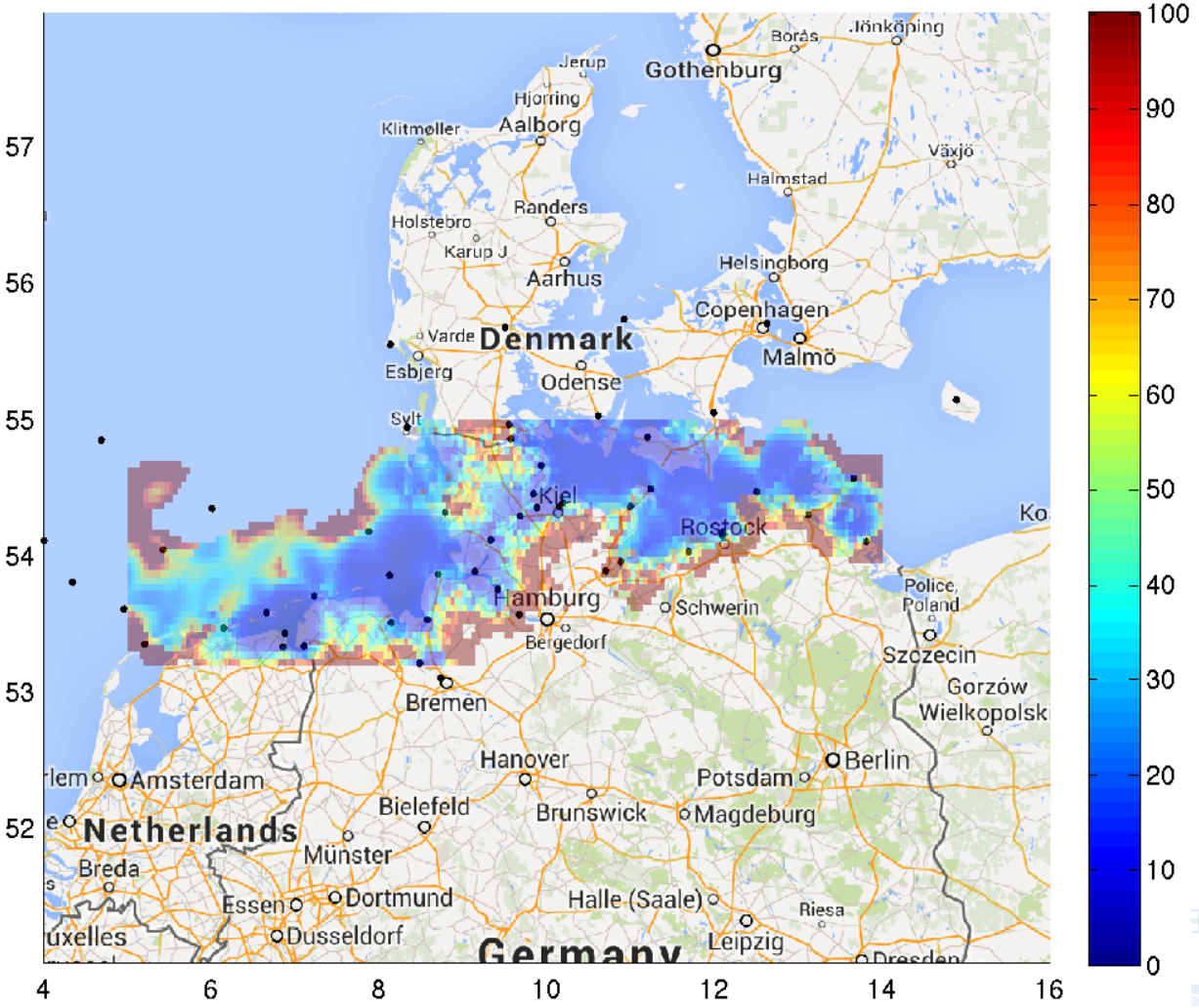
Predicted positional accuracies (m) for R-Mode using AIS transmissions across Northern Germany and through the Kiel canal.



ACCSEAS

source: ACCSEAS

R-Mode (combined)

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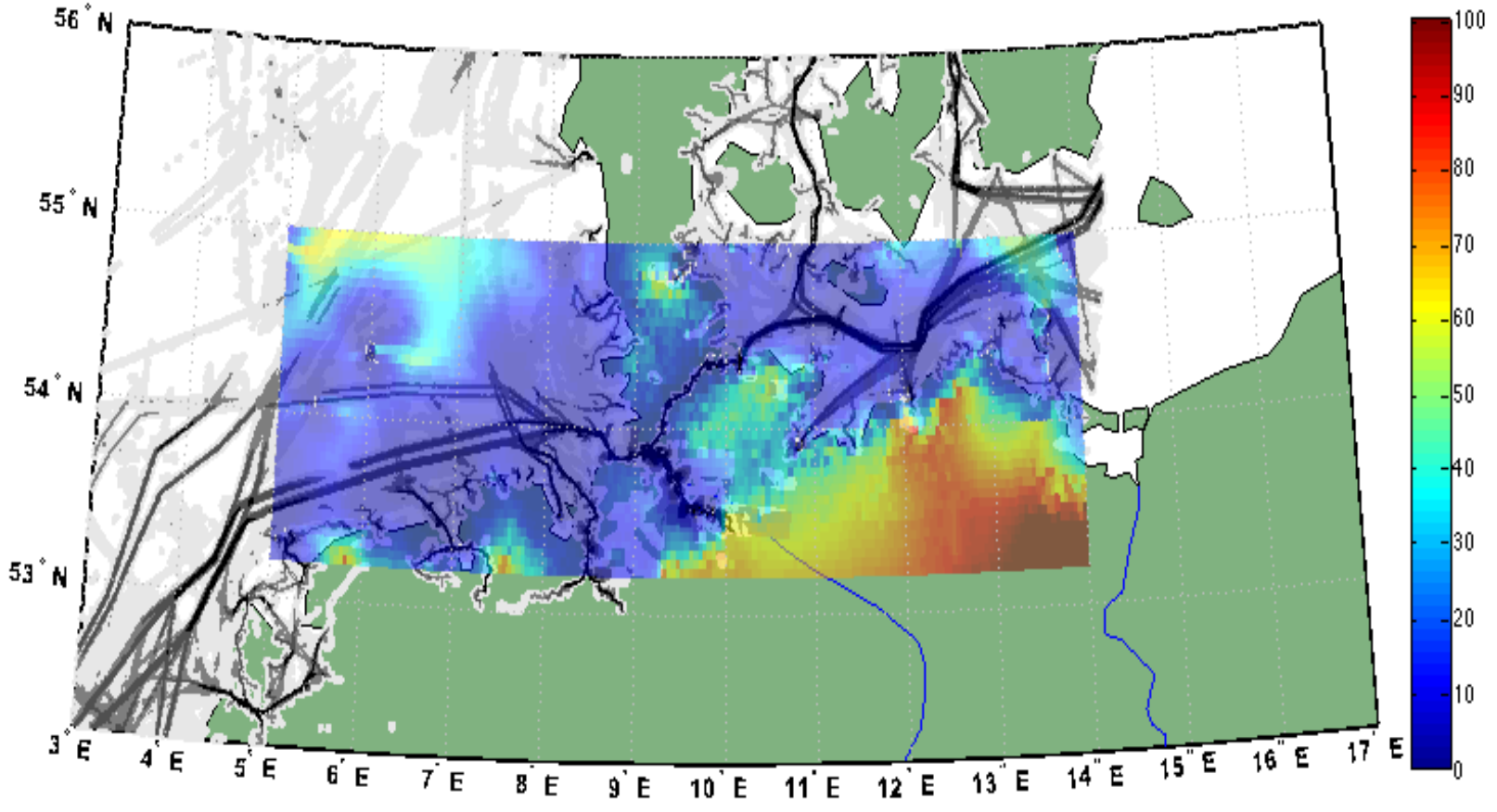

Predicted positional accuracies (m) for R-Mode using MF, AIS and eLoran transmissions over Northern Germany and the Kiel canal.

***) 1 eLoran site in Sylt**

ACCSEAS

source: ACCSEAS

BinoNav®

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Electronic Pelorus system

Navigator uses binoculars to identify targets shown on electronic chart and clicks a button to take bearing.

The bearing of the binocular position in relation to the centre of the vessel is calculated and a corresponding bearing line drawn on the chart.

After successive bearings, the vessel's position is calculated.

Trial systems being installed on all GLA vessels.

GLA BinoNav® fitted on THV Alert

Resilient PNT Architecture

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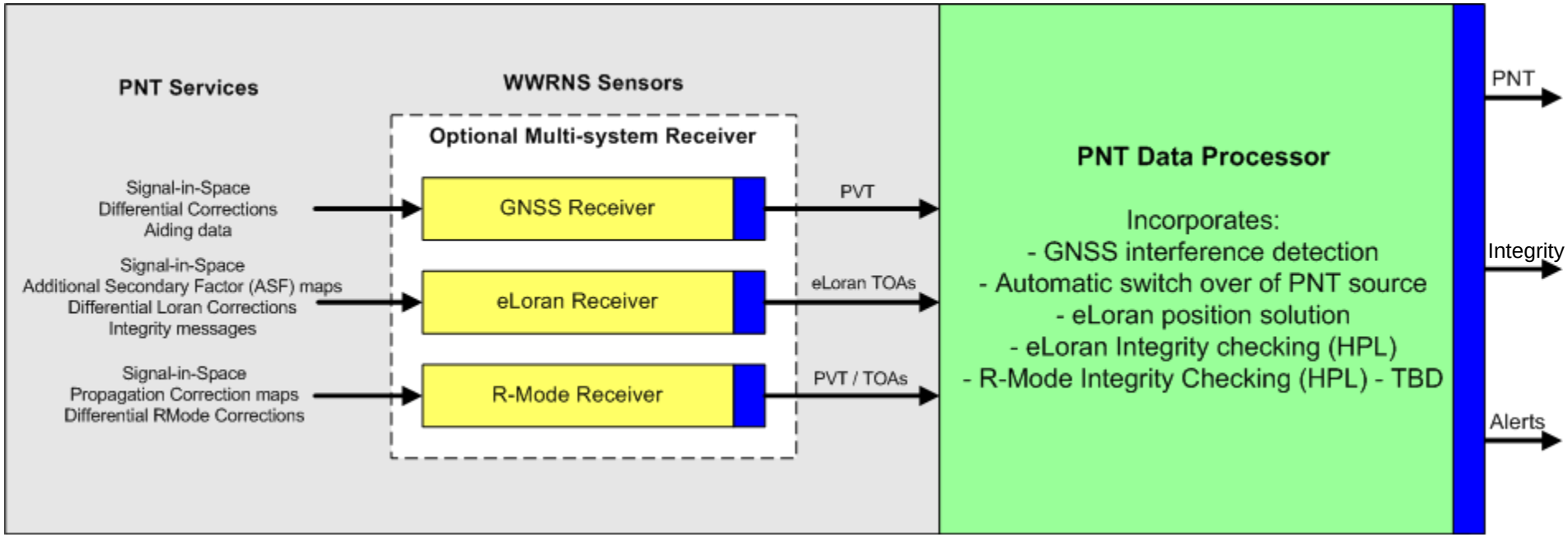

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Resilient PNT – A Solution

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This video showed how a resilient PNT receiver algorithm and test platform was able to identify GPS jamming and switch to a secondary PNT source, eLoran in this case.

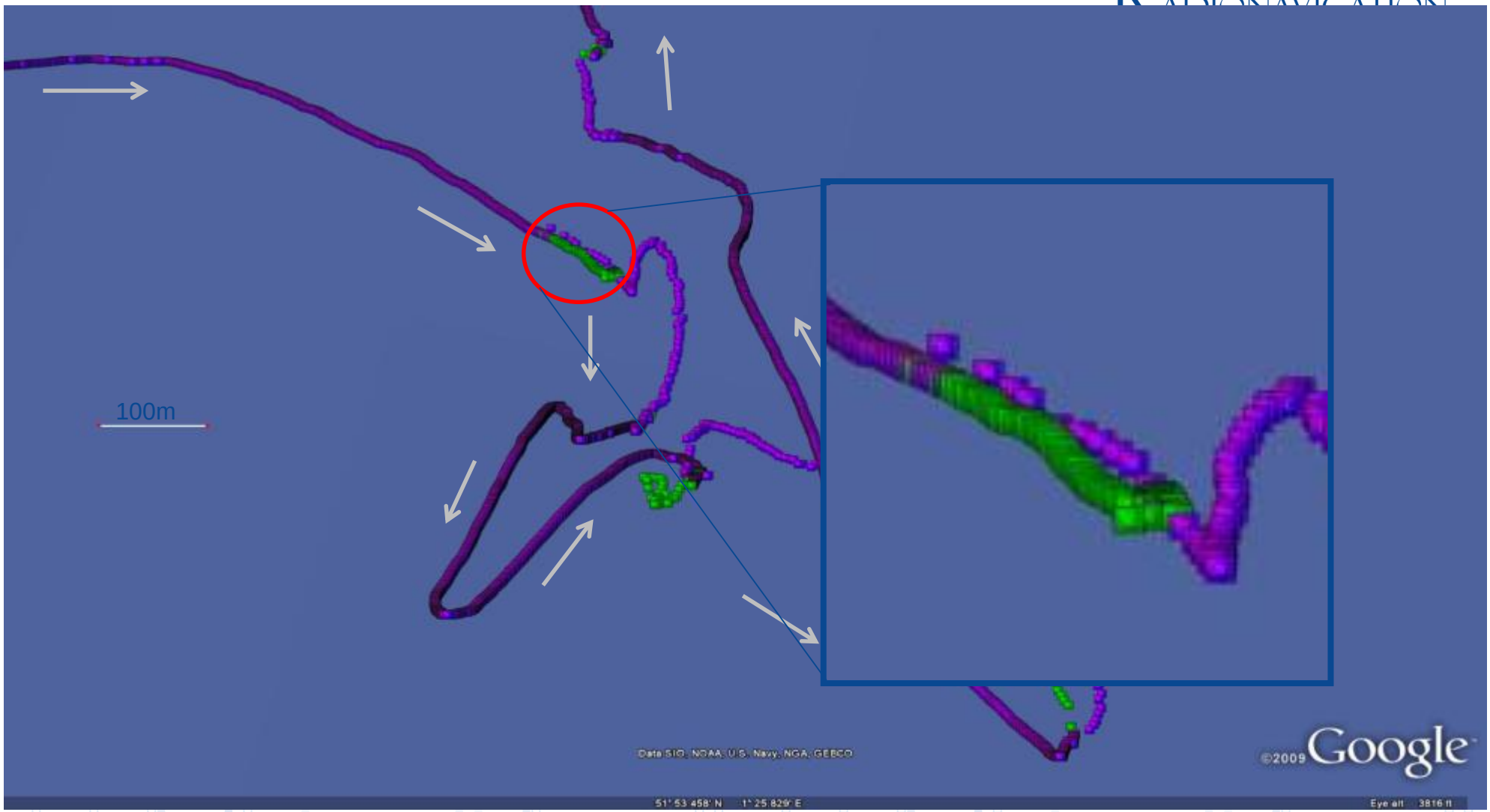
Video removed to reduce file size. The video shown was an extract of a larger video prepared for the ACCSEAS project, available via the link below.

https://www.youtube.com/watch?feature=player_detailpage&v=CNAr8eQQ_9E

2013 Jamming trial results

Green trace = GPS

Resilient PNT positions



Green trace = GPS, Purple trace = Resilient PNT

Multi-system receiver PS

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A multi-system receiver performance standard (MSC.401) has been developed to:

- Enable and support resilient PNT
- Define minimum performance requirements without defining systems to be used (a new approach)
- Enable further system development
- Future proof

Allows for use of:

- All GNSS (existing and future)
- All sources of augmentation (marine beacon and SBAS)
- All terrestrial signals (existing and future)

Refers to IMO PNT Guidelines on how different systems are used together. Adoption date of 31st December 2017

Now working on IEC Test specification

Conclusions

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GNSS has become the primary source of PNT information on most vessels.

While GNSS works perfectly most of the time, it is vulnerable to system errors and signal interference/corruption.

Mariners and vessel systems need to be resilient to any GNSS loss, so that situational awareness and mariner safety is not compromised.

Resilient PNT options are being developed and it's recognised that one solutions will not fit all requirements.

The IMO Multi-system receiver performance specification provides a platform for resilient PNT receivers to be built and used on all vessels.

It's been a long and enjoyable road so far and there's more to do!

Contact Information

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www.gla-rrnav.org