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eLoran and Resilient PNT Update

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eLoran IOC Accuracy Coverage

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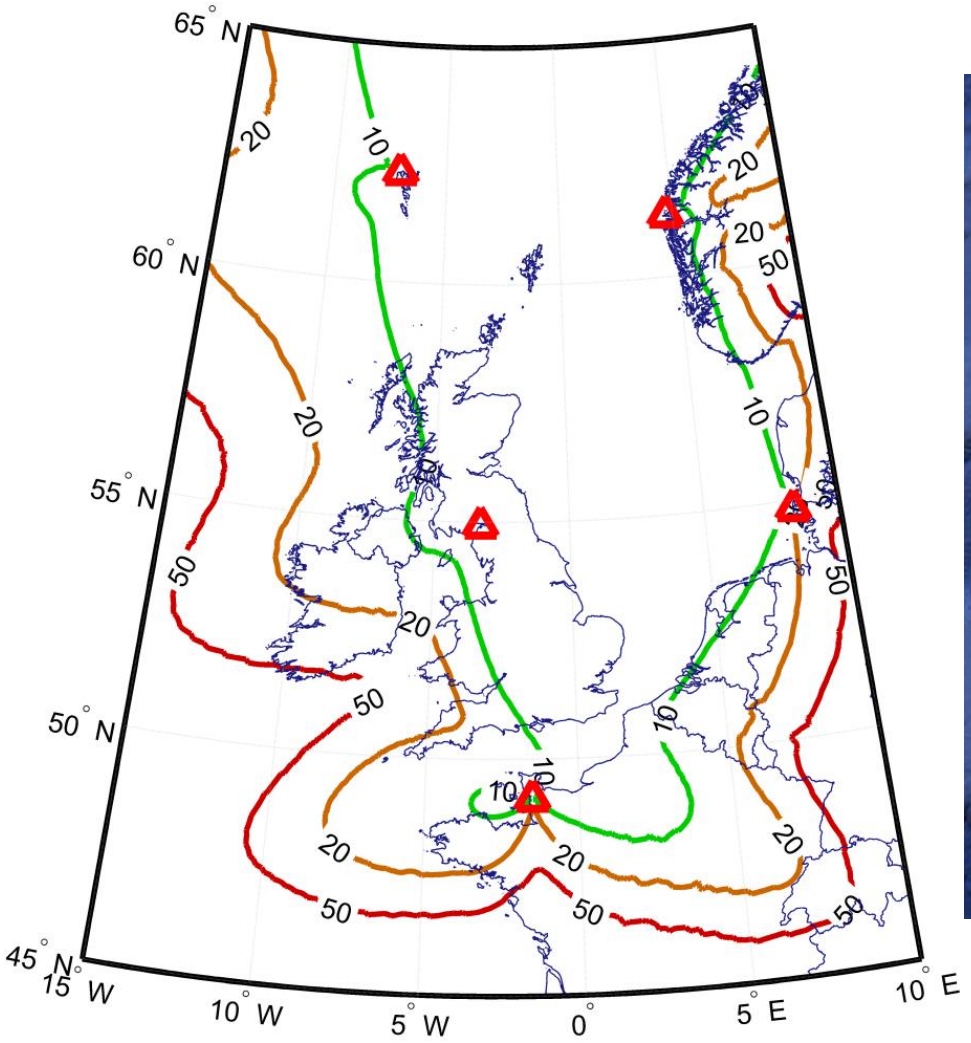

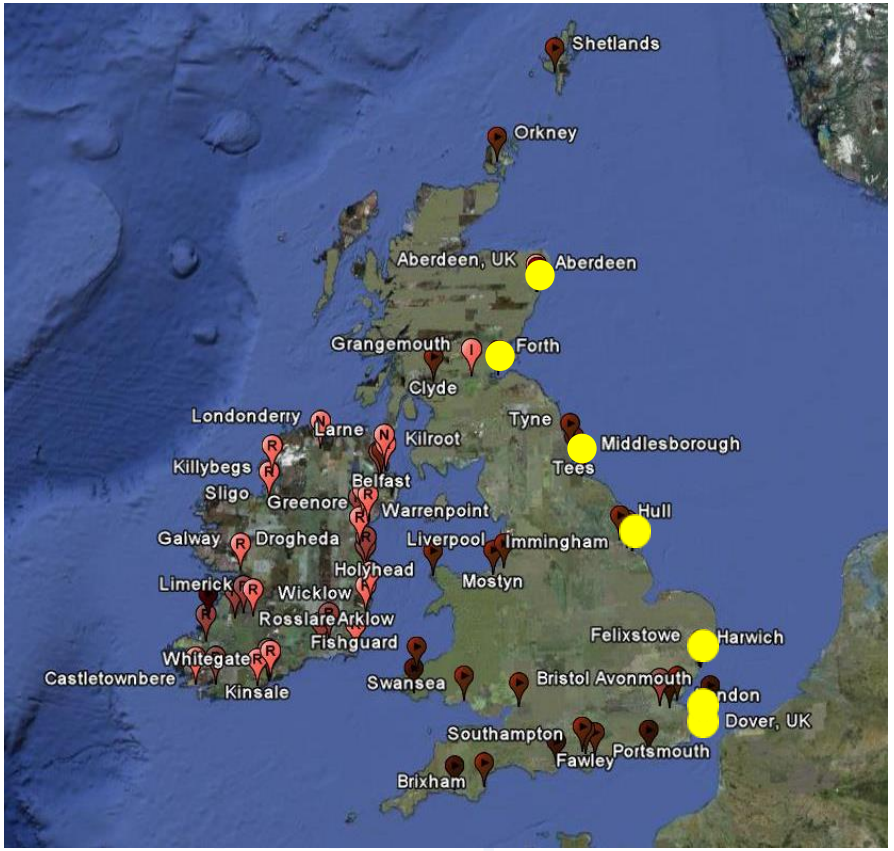

Green contour is 10m position accuracy (95%) achieving IMO requirement for **port and harbour approach**

eLoran in the UK and Europe

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- **Europe:** Eight out of nine Loran stations, and CCB, switched off at 1100 UTC 31 December 2015.
- **UK:** Anthorn is currently providing time and secure data (indoors) for several users and is running as both master (M) and secondary (Y) of the 6731 chain
- UK HMG has committed to funding Anthorn for two years for timing and data
- High level international political discussions are taking place to try to save the European physical infrastructure from destruction, with the proposal to run the European system under a commercial venture (***Taviga***) for timing and data

eLoran in the Rest of the World

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- **US:** *Taviga* focussing on preserving Loran-C infrastructure for its objective to provide a commercially operated assured LFPNT service, to secure US national critical infrastructure from cyber and other threats. Four transmitters in operation to provide timing and data across the CONUS
- **Republic of Korea:** Progressing their eLoran project to mitigate the GNSS based cyber threat from the North
- **Russia:** Upgrading Chayka to eChayka, and continue to develop Skorpion (military terrestrial system), to ensure national security in respect of radionavigation
- **China**: Upgrading Loran-C to eLoran, experimenting with data channels
- **Saudi Arabia** and **India** also planning eLoran work

GPS PRN 32 Decommissioning

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- At 15:36 Greenwich Mean Time on 25th January 2016 GPS satellite SVN 23/PRN 32 became unusable. http://www.navcen.uscg.gov/?Do=gpsShowNanu&num=2016008
- Routine decommissioning – but reports from industry indicate some receivers immediately began to malfunction
- Impacts to receivers varied by type and manufacturer. Receiver models from at least four different manufactures failed while other models and products of other manufacturers were not impacted at all
- For timing receivers that failed, Caesium and rubidium backup clocks seem to have provided sufficient hold over for most, until technicians could respond
- Some 18 hours after the malfunctioning satellite was taken off line, some receivers were still not able to reacquire time or location using the other 30 good satellites
- Air Force GPS Operations Centre said there was a “software problem” associated with the decommissioning. This software problem was fixed at 11:17 GMT 26 Jan 16.

According to the Air Force, some receivers may need to be rebooted, but all should work normally thereafter. A message describing the incident for the public was promised.

GPS PRN 32 Decommissioning

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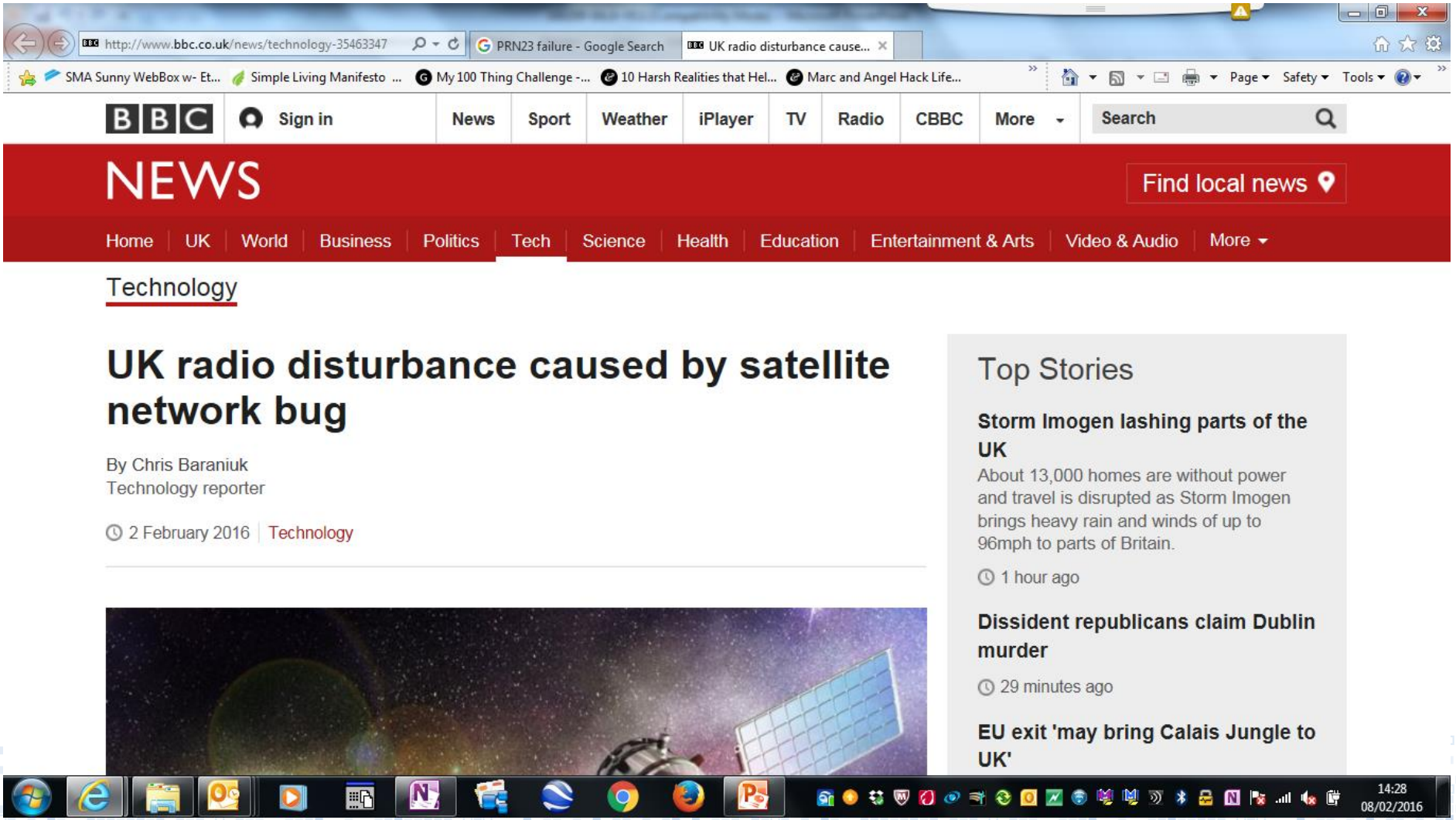

Resilient PNT and the UK?

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- **eLoran:**
  - Anthorn continues to provide timing and data services under public funding for now
  - Plans to move to commercial operation in the future
  - Recognised as able to support Critical National Infrastructure
  - eLoran is technically ready and capable for deployment
  - No positioning capability and no International agreement means there is no remit for GLA to spend new money from the GLF
  - But we are able to act as technical consultants
  - GLAs are investigating some other forms of resilient PNT capability

- **R-Mode:**
  - Medium Frequency DGPS radiobeacons, 300kHz groundwave
  - AIS (VHF), 160Mhz line-of-site
  - Takes advantage of existing transmitters with upgraded modulators
  - Lots of things to do!

- **Radar Absolute Positioning:**
  - eRacon/NT Radar combination – trial performed under ACCSEAS
  - Radar return pattern/feature matching – needs extra processing capability
  - Can provide ‘P’ and ‘N’, but no ‘T’

Radar Absolute Positioning Trials

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- Radar positioning trials have been carried out as part of the Resilient PNT stream of the ACCSEAS Project.
- The trials were performed off the East coast of England using an experimental, solid-state radar provided by Furuno and enhanced racons provided by Tideland.
- The racons were installed at Southwold and Lowestoft lighthouses.
- The radar was installed on THV Alert and this vessel was used for the trials.
- The trials were carried out at distances up to 10 M off the coast.

Radar Positioning Trials

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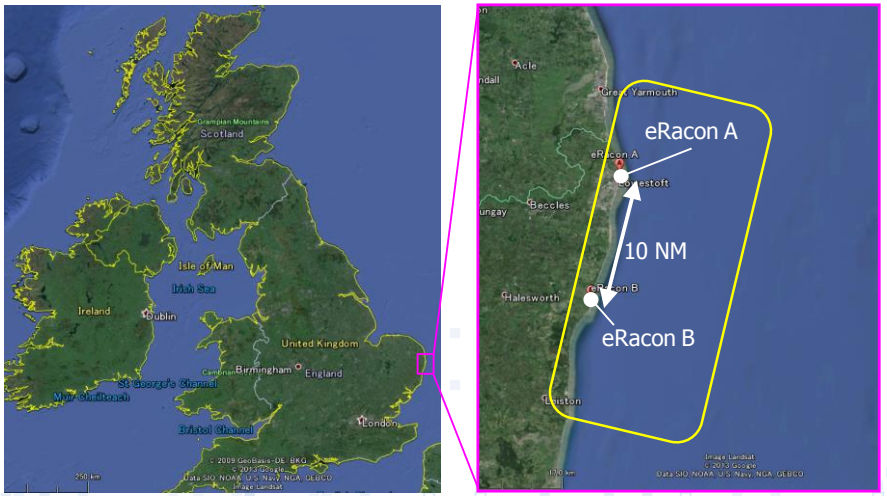
- Trial radar installed onboard THV Alert
  - Furuno solid-state
  - Additional processing

- Racons installed at Lowestoft & Southwold
  - enhanced racons
  - encoded positions



Radar Absolute Positioning Trials

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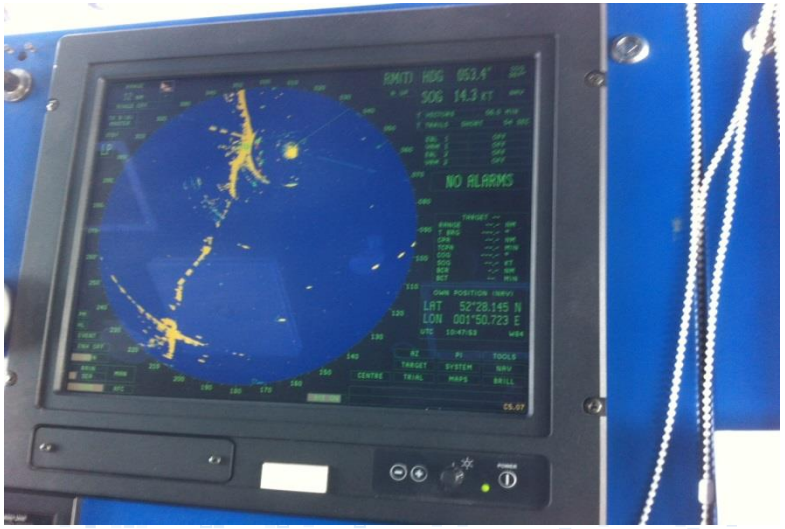
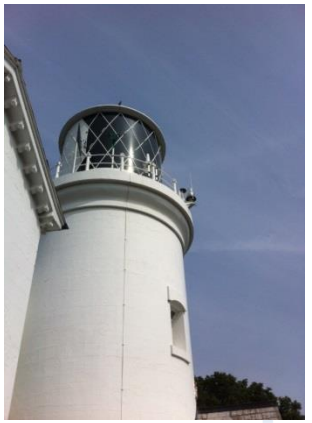
1. Effective range of the experimental radar used with the modified racons was about 10 NM
2. Accuracy achievable with two LOPs and good geometry was 5-10 m
3. Accuracy with a single LOP was 50-100 m





RADAR Positioning by Image Processing/Recognition

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- Radar returns from coastal terrain
- Return images are possibly unique enough that an automated image-recognition algorithm would be able to associate a particular image with a geographical location
- Russell Technologies in Vancouver ~1980/90s
- The aim is to derive latitude and longitude electronically, and automatically, from a received radar image
- Eventually built up a “library” of return images, OR use a terrain model - Digital Terrain Elevation Data (DTED)
- Obtain simulated return from DTED data, compare and match using Least Squares optimisation to a real world radar return

Simulated Harwich Approach Test

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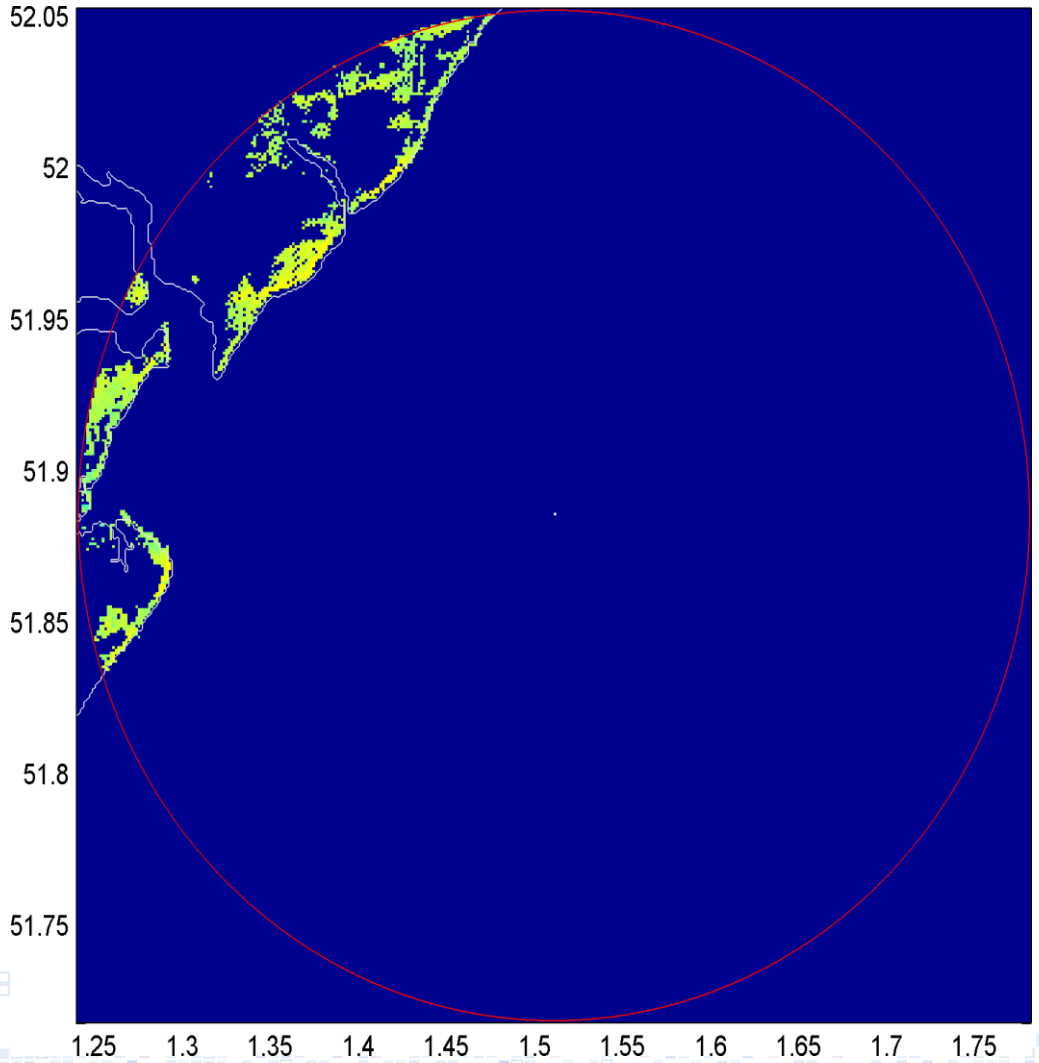
- No real-life radar data yet, but we are liaising with radar manufacturers
- We wanted to demonstrate the technique so…
- GPS ground truth data from THV Alert ASF measurement trial
- Generate simulated RADAR return – this is a **simulated "real-life"** mage
- Perturb the ground truth position by adding a random radial offset – initial position estimate
- Use this initial position offset to obtain a **modelled** radar return from the DTED database
- Adjust the "model" image by least squares fitting to the "real-life" image and derive the position solution, which should be close to the ground truth position
- Actual real-life data would contain noise and clutter



Positioning Example

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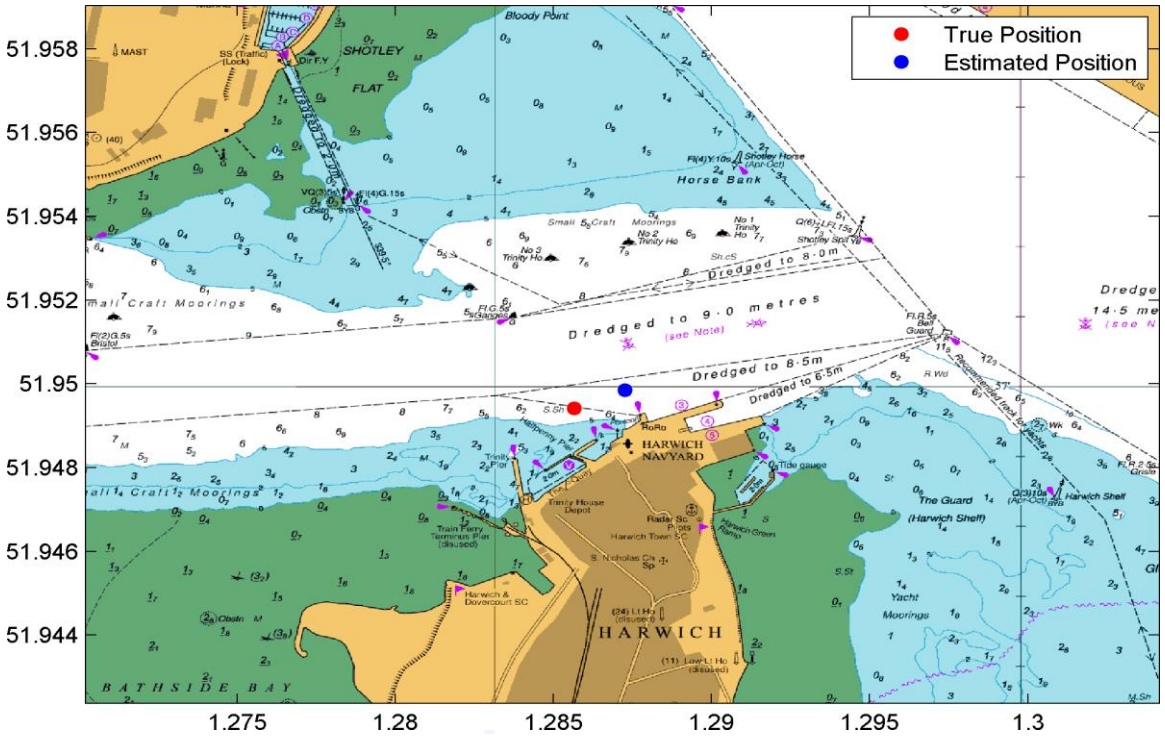

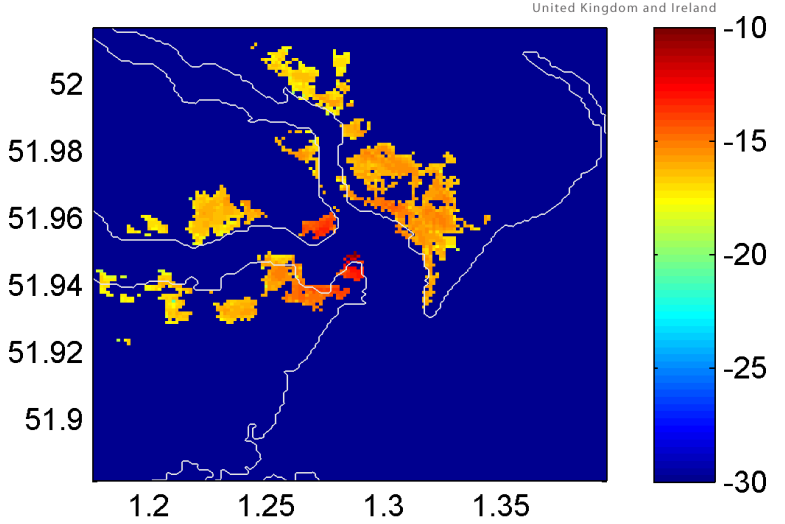

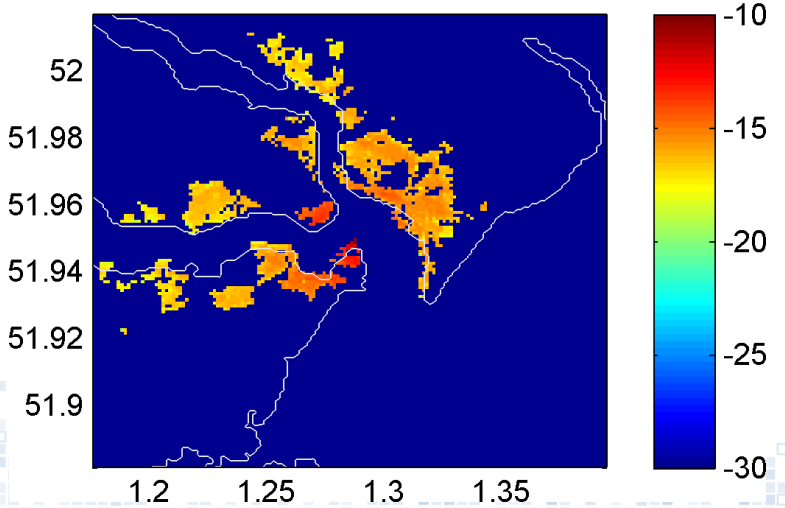

Positioning Example

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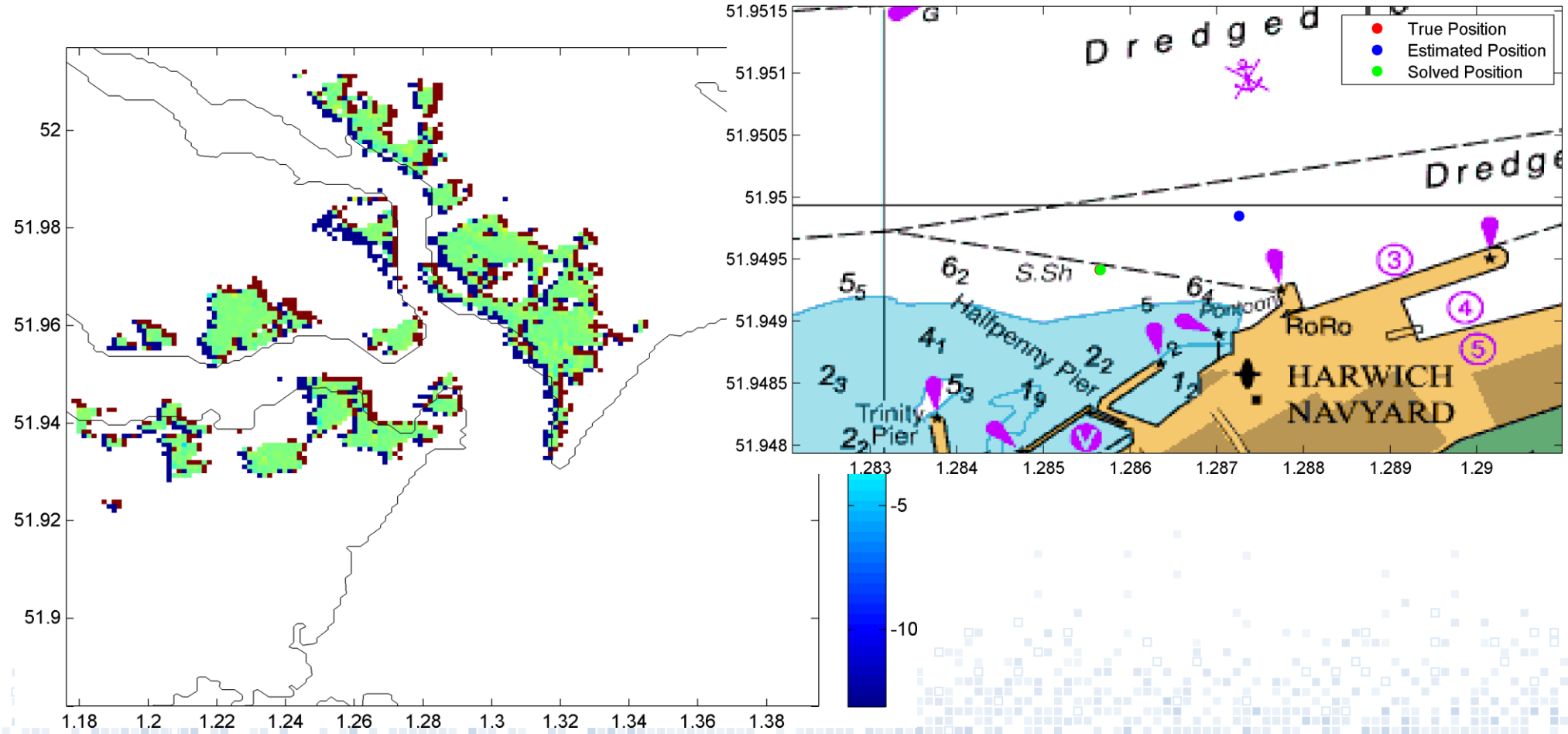
- 1 m accuracy after 10 iterations



Feasibility Comparison

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E-Racons with New Technology Radar	Image Pattern/Feature Matching
One e-Racon every 10NM, or concentrated around port approaches	Terrain with natural features augmented with passive reflectors
Economical for critical areas only, cost could be spread over number of years	Serves larger areas of coastline and is cost effectively
Requires new or modified radar	Requires additional processing module
Good accuracy potential	Accuracy may depend on features within radar return
Charts may need added reference points – survey costs – (e-Navigation service!)	
Regulations and standards need to be developed	
Maritime only system with no support for other critical national infrastructure	
Position and Navigation, but no Time!	

Best approach would likely be a radar system combining BOTH techniques where appropriate.

Combined R-mode and Radar

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- R-Mode for Coastal Voyage Phase
- Radar for Port Approach

	System level parameters				Service level parameters			
	Absolute Accuracy	Integrity			Availability % per 30 days	Continuity % over 3 hours[3]	Coverage	Fix interval (seconds)
	Horizontal (metres)	Alert limit (metres)	Time to Alarm[2] (seconds)	Integrity Risk (per 3 hours)				
Ocean	1000	2500	60	10^{-4}	99	N/A[2]	Global	60
Coastal	100	250	30	10^{-4}	99	N/A[2]	Regional	15
Port approach and restricted waters	10	25	10	10^{-4}	99	99.97	Regional	2
Port	1	2.5	10	10^{-4}	99	99.97	Local	1
Inland Waterways	10	25	10	10^{-4}	99	99.97	Regional	2

Notes:

1. This table is derived from IMO Resolution A.915(22)
2. Continuity is not relevant to ocean and coastal navigation
3. Continuity service level for port applications may be considered over a shorter Continuity Time Interval of 15 minutes; it is proposed that all maritime applications will adopt this revised CTI.
4. This table should be read in conjunction with paragraph 2.1 and 2.2. Although these are suggested minimum requirements, a Risk Assessment will include many variables that may alter the minimum requirements. Refer to IALA Guideline on the Provision of Aids to Navigation for Different Classes of Vessels, including High Speed Craft, Dec. 2003 for details of the variables of different waterways, ships and environments

'IALA Recommendation R-129 'On GNSS Vulnerability and Mitigation Measures Edition 2 December 2008

Other Technologies

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- Inertial sensors
- Cold atoms
- MEMS
- E-Pelorus
- GLA R&Rnav “Technology watch”

Thank you!

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