Resilient PNT as a Critical Asset for all e-navigation Solutions

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Two Weeks of Traffic Density

Density Statistics Plot

Area: JSE Nordsoe
Start: 1st May, 2011 00:00
End: 14th May, 2011 23:59
Cell resolution: 0.848417 Nautical Miles

The Interreg IVB North Sea Region Programme

European Union The European Regional Development Fund

ACCSEAS

Investing in the future by working together for a sustainable and competitive region
Shipping Challenges of the North Sea Region

- Increased density of shipping
- Reduced sea space / manoeuvrability
- Growth of offshore installations
  - Windfarms
  - Oil and gas platforms
- Traffic pinch-points at approaches to:
  - major ports and constrictions
  - Baltic/Skagerrak, Dover Straits
  - inland waterways (e.g. Kiel Canal)
- Risks of collision and grounding
- Safe and efficient access to the North Sea Region
Use of GPS in the maritime sector

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

The level of integration onboard is different for each vessel depending on equipment fitted.

But GPS is everywhere!
GPS Vulnerabilities

System Failures
On 1 January 2004, the third and final atomic clock in GPS satellite SVN23 failed. The GPS system took nearly 3 hours to warn mariners’ receivers to ignore the faulty satellite. Position errors built up silently to more than 10 kilometres.

Natural Events
On 6 December 2006, the Sun started to emit radio noise so intense that GPS receivers, deafened by it, stopped working across the entire sunlit side of the earth. In the US, aircraft landing systems using WAAS lost vertical guidance and showed alarms. For most mariners, this flare - the most powerful ever recorded - came without warning.

Man-made (Unintentional)
In 2007 maritime GPS was lost, suddenly and for two hours, across San Diego harbour due to interference caused by a US Navy vessel. And in the city, 150 mobile phone sites using GPS timing were affected, including those serving the first responders to the incident. There was no warning of this accidental event.
A small jammer on this cliff-top disrupted GPS on vessels out to ranges as wide as the Dover Strait
N. Korea accused of jamming commercial flight signals

By Julie Yoo, NBC News in Seoul, and msnbc.com news services
e-Navigation needs resilient PNT

- For e-Navigation (2018-2020 timeframe), IMO says:
  - “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 Position, Navigation and Timing (PNT) needs to meet maritime requirements for accuracy, integrity, availability and continuity

≠ resilient PNT due to GNSS vulnerability...
ACCSEAS’ Potential Solutions

1. Augmented reality HUDs
2. Maritime Service Portfolios
3. Tactical Route Exchange Service
4. Mariners Notification Service (MNS)
5. Individual Under Keel Clearance Advice Service (IUKCAS)
6. Route Topology Model
7. Harmonized Data Exchange Service (IVEF)
8. Multi Source Positioning Service (Resilient PNT)
Resilient PNT Possible Solutions

- Prototype an Integrated Navigation System (INS)
  - recognising multiple GNSS constellations (including Galileo)
- Inertial technologies
- Harden GNSS
  - Detection/mitigation
  - Better receivers
  - Beam steering
- Enhanced AtoNs
  - Synchronised lights
  - Radar AtoNs – Absolute RADAR positioning
- Complementary PNT systems
  - R-Mode (DGPS & AIS)
  - eLoran
Test-Bed: Resilient PNT Stream

• Mitigation of GNSS vulnerability to natural and deliberate interference
• Independent and complementary backup system to GNSS
  – seamless positioning in GNSS outages
  – avoid giving hazardously misleading information
Architecture of Maritime Integrated PNT

- **ship-side components**
- **links**
- **shore-side services**

- PNT relevant MSP
  - Augmentation Services 1 ... N
  - Backup Services 1 ... K
  - PNT relevant MSI
  - etc.

Ship-side Resilient PNT With Data Processing Element

Diagram showing the shipboard sensor layer and shipboard processing layer. The sensor layer includes WWRNS sensors, GNSS receiver, DGNSS receiver, multi radio navigation receiver, gyro/compass, speed/log, and ROTI. The processing layer includes PNT (data processing) element as part of INS. Other PNT relevant input data (Radar, MSI, AIS, etc.) is also shown.
Candidate Resilient PNT Systems for Test/Implementation in ACCSEAS

- R-Mode (Ranging Mode) on radiobeacon MF DGPS broadcasts and VHF AIS
  - Feasibility studies taking place

- eLoran
  - Prototype up and running in Port of Dover and part of the Dover Strait, Harwich and Felixstowe approaches

- Radar absolute positioning
  - Trial in early stages of planning
Candidate System 1: R-Mode
Candidate System 1: R-Mode

- Each ranging signal requires synchronising to UTC, or other common system time
- Requires a suitable signal structure for tracking purposes
- Propagation effects need to be taken into account
- Modification of existing beacons and transponders

- Feasibility study to be performed
- Pre-tender announcement has been made
Candidate System 2: Prototype eLoran

Prototype eLoran consists of:

- Terrestrial signals broadcast from existing Loran C stations
- Additional Secondary Factors
- Differential Loran reference stations

eLoran provides:

- Complementary and dissimilar PNT service to GNSS
  - **eLoran**: high power, ground based, low frequency
  - **GNSS**: low power, space based, ultra high frequency
- Precise synchronisation, locked to UTC
  - Stratum 1 frequency source
GLAs’ Maritime eLoran – Road Map

- Initial Operational Capability (2014)
  - Covers 7 major ports on the east coast of the UK with Port Approach Level, 10m (95%) accuracy eLoran

- Full Operational Capability (2019)
  - Covers all major ports in UK and Ireland plus Traffic Separation Schemes and UK SW Approaches
Candidate System 3: Radar Absolute Positioning

- New Technology (NT) radar
- Absolute positioning
- Coastal infrastructure
  - Radar reflectors
  - Target enhancers
- NT compatible radar beacons (Racons)
- Independent of GNSS
- GLA trial planned
ACCSEAS Resilient PNT Architecture – Ship-Side

PNT Services
- Signal-in-Space
- Differential Corrections
  - Aiding data
- Additional Secondary Factor (ASF) maps
- Differential Loran Corrections
- Integrity messages
- Propagation Correction maps
- Differential R-Mode Corrections

WWRNS Sensors
- Optional Multi-system Receiver
  - GNSS Receiver
  - eLoran Receiver
  - R-Mode Receiver

PNT Data Processor
- Incorporates:
  - GNSS interference detection
  - Automatic switch over of PNT source
    - eLoran position solution
    - eLoran Integrity checking (HPL)
    - R-Mode Integrity Checking (HPL) - TBD

PNT
Integrity
Alerts
Harwich Resilient PNT Demonstration
The Jamming Zone

Two passes:

- without the prototype system enabled
- with the prototype system enabled
What we saw?

For the first time EVER a prototype PNT Data processor unit supplied the bridge systems with resilient PNT data derived from eLoran!

- Systems remained operational during GPS denial
  - Resulting in continued, seamless operation that allowed the mariner to keep navigating safely and efficiently
  - The system also picked up low level GPS jamming, which would NOT have alarmed and so would have produced Hazardously Misleading Information!
  - Potential for confusion on bridge was removed

- In another first, the vessel broadcast its location over AIS using eLoran

A DVD of the event will be available soon!
Short video soon to be available at: www.gla-rrnav.org
The Multi Source Positioning Service (MSPS)

- MSPS is a service (or portfolio of services) that provides, distributes and applies Resilient PNT information throughout e-Navigation for
  - portrayal to the mariner
  - integrity assurance for many other e-Navigation services

- MSPS uses multiple sources of positioning including terrestrial backup systems to GNSS
  - distributed across ship (INS) and shore (infrastructure)
  - robust position uncertainties not just position
MSPS Benefits

- MSPS is a critical service for safety and efficiency
  - provides required performance of PNT (accuracy, integrity, availability and continuity) appropriate to each e-Navigation service or function
  - Indicates bounds of uncertainty associated with the estimated accuracy of PNT that can be relied upon by the mariner and by other e-Navigation services

- Examples of use:
  - ECDIS display of safety margins to prevent groundings/collisions
  - use of uncertainties in avoiding ‘no go’ areas and in calculations of intended routes
MSPS Service Levels and Coverage

- MSPS needs associated service attributes to define
  - geographic coverage
  - service level provided for different parts of coverage area
  - service levels provided on legs of the route topology
- MSPS service levels must recognise
  - requirements of portrayal and other e-navigation services
  - e-navigation services do not all have the same integrity requirements
  - variable quality of the positioning, especially that accuracy of MSPS PNT under GNSS interference conditions may be less than under normal GNSS conditions
- Use a dependable estimate of the position error associated with the integrity requirements of each application
MSPS Integrity and Error Estimation

- Implement an ‘integrity equation’ for the combined multi source position
- HPL statistical over-bound of the estimated errors in position
- Raise an integrity alert when the HPL exceeds the Horizontal Alert Limit (HAL) that is specific for each e-Navigation application or service
- Avoid the presentation or use of Hazardously Misleading Information
MSPS Test and Evaluation

- A balance of practical demonstration (within the physical test-bed) and simulations
- Recognise the importance of simulation to support the evaluation of human factors and to investigate scenarios with multiple vessels
- Carried out on the back of tests and demonstrations of other ACCSEAS e-navigation services
- Consideration of live GNSS jamming demonstration
Resilient PNT Next Steps and System Requirements

For the practical implementation of the ACCSEAS Resilient PNT Service we need to:

▪ Determine potential coverage of PNT services at the locations of the ACCSEAS test-bed

▪ For R-Mode
  - Complete the feasibility study
  - Decide what radiobeacons will be modified for R-Mode capability
  - Consider R-Mode propagation corrections in candidate port locations and approaches
  - Investigate the need for differential reference stations
  - Procure equipment, ship time, other services

▪ For eLoran
  - Determine where to measure ASFs in candidate port locations and approaches
  - Determine where to install differential-Loran reference stations if needed
  - Liaise with other European partners also performing eLoran trials, for example, Dutch Pilots in the Port of Rotterdam, Netherlands
  - Procure equipment, ship time, other services

▪ Complete the radar positioning trial
Thank you!

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