A new Modular and Open Concept for the Maritime Integrated PNT System

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PNT

\( P = \text{Position} \)
\( N = \text{Navigation} \)
\( T = \text{Time} \)

<table>
<thead>
<tr>
<th>PNT System</th>
<th>( \rightarrow ) ashore &amp; aboard components for navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNT Module</td>
<td>( \rightarrow ) one part of the INS for navigation related issues</td>
</tr>
<tr>
<td>PNT Unit</td>
<td>( \rightarrow ) the kernal (SW) of the PNT module</td>
</tr>
</tbody>
</table>
Safe Navigation under all conditions – The main questions

What is the **position**, **velocity** and **course** of my own **vessel**?

Where are the **other vessels** and do they crossing my route?

Are there other **obstacles** along the fairway?

**How reliable are these information?**
The Modern Bridge

- Fire Detection Panel
- GPS
- SpeedLog
- Rudder Angle Indicator
- ECDIS
- Echosounder
- Radar
- Engine Controls
- Switch Panels
- AIS
- Magnetic Compass
- SAR-Transponder
- Gyro Compass

Source: Kongsberg

www.DLR.de • Chart 4 • MTS-2012 • Maritime Integrated PNT Unit • Thoralf Noack • Institute of Communications und Navigation • Nautical systems • 22.09.2012
Navigation related Sensors on the Modern Bridge

- Fire Detection Panel
- GPS
- SpeedLog
- Rudder Angle Indicator
- ECDIS
- Echosounder
- Radar
- Engine Controls
- Switch Panels
- AIS
- Magnetic Compass
- SAR-Transponder
- Gyro Compass

Source: Kongsberg
Navigation related Parameters on the Modern Bridge

Everything is measurable!
But can we really trust the information we get?
Challenges

Around 20% of accidents are induced by technical factors*

Reasons are
- **malfunctions** and **errors** in nautical systems
- **imprecise, incomplete or falsified** provision of **nautical information**
- **misinterpretations** of navigation relevant data

Higher Transport volume leads to increasing traffic densities and increasing vessel size with higher potential in collision and groundings.

* Source: HELCOM Report on shipping accidents in the Baltic Sea area during 2011
Consolidated technical specification of user needs

**Reliability should be measurable and scalable!**

IMO MSC.233(83) intends the application of **RAIM** to assess the GNSS based provision of PVT data.

The INS (IMO MSC.252(83); IEC 61924) applies **plausibility and consistency checks** to assess the PNT data provided by several ship-side sensors.

IMO A.915(22) specifies **minimum requirements** on horizontal position data given in unambiguous **terms of accuracy, integrity, continuity and availability**.

- Harmonized meaning of integrity information
- Management of integrity within systems operating with distributed components and services
- Equivalent specifications for other navigational data (e.g. SOG, STW, ROT, Heading, …)
- Crossover from minimum to scalable requirements (accuracy, integrity) by consideration of specific tasks and their temporal and spatial dependencies
Generic Architecture of the whole PNT System

**ship-side components**

**links**

**shore-side services**

- **PNT relevant MSP**
  - Augmentation Services $1 \ldots N$
  - Backup Services $1 \ldots K$
  - PNT relevant MSI
    - etc.

The PNT Portfolio

Global Navigation Satellite Systems
- GPS
- GLONASS
- GALILEO

Satellite Based Augmentation Systems
- WAAS
- EGNOS
- Beidou

ship-board

Integrated PNT Module

Standard Navigation Sensors
- Gyro Compass
- SDME
- Radar Map Matching
- ROT Indicator

Additional Navigation Sensors
- IMU
- Echo Sounder
- ePelorus

Multi-System Radio Navigation Receiver
(Core PNT Sensor)
- GNSS Receiver*
- GNSS/ SBAS Receiver*
- Integrated GNSS/ DGNSS Receiver*

*Could be included in AIS device, need of raw data

Integrated GNSS/Backup Receiver*

PNT Unit**
(Value-added data processing system)

Output: PNT data + Integrity data
(Consistent Common Reference)

P + I  N + I  T + I  A + S

shore-based

Terrestrial Augmentation Services
- IALA Beacon DGNSS
- AIS DGNSS
- M-GBAS (RTK) ?

Terrestrial Backup Services
- eLoran
- R-Mode

PNT part of Maritime Service Portfolio (MSP)

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** fusion of all sensor and service data will be realised by PNT Unit
Current approach 1: single sensor based PNT determination

Captain is responsible for fusion of information from different sensors and displays
Current approach 2: Integrated Navigation System (INS)

INS is not a mandatory system, but if it is installed it can replace single sensor requirements
The new PNT Unit Approach

Shipboard Sensor Layer

- WWRNS sensors
- GNSS Receiver
- DGNSS Receiver
- Multi Radio Navigation Receiver
  - etc.

Shipboard Processing Layer

- PNT-Unit
  - Data Processing Layer of PVT, N & raw data
    - as part of INS

Other shipboard sensors

- Gyro / Compass
- Speed / Log
- ROTI
  - etc.

Other PNT relevant Input Data
(Radar, MSI, AIS, …)

Interface, point of type approval

Best PNT

Integrity (accuracy)

Alerts
Position, Navigation and Timing Unit

Processing chains based on selected sensor set and accuracy assessment in real time
Estimation of reliable position with/without satellite filtering

Dynamic model (herein IMU) can smooth the positioning results

Integrity monitoring on each measurement has dominant effects in the accuracy improvement
Implementation Approach of PNT Unit in INS

[Diagram showing the implementation approach of a PNT unit in an INS system]

- Navigation Task Layer
  - Collision Avoidance
  - Route Monitoring
  - Alert Management

- Data Processing Layer
  - CCRS Module

- Sensor & Data Source Layer
  - PNT Sensors
  - Radar Sensors
  - Depth Sensor
  - Vessel Data
  - ENC
  - COM Interface

- INS Communication

- e.g. AIS
Generic Architecture of the whole PNT System

**ship-side components**

- INS
- PNT Module with PNT Unit

**links**

- functional links
- physical links

**shore-side services**

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

World Wide Radio Navigation Systems (WWRNS)
Maritime Ground Based Augmentation System (M-GBAS)

IMS = Integrity Monitoring Station
RS = Reference Station
GUT = GBAS User Terminal
M-GBAS Integrity Message Monitor

Maritime GBAS - GNSS Integrity Message Monitor

**Application Area**
- Ocean / Coastal SAR
- Galileo Sols.
- Port
- Automatic Docking

**Accuracy Requirements**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Positioning [m]</th>
<th>Integrity [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode 1 (M1)</td>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td>Mode 2 (M2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 3 (M3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 4 (M4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 5 (M5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 6 (M6)</td>
<td></td>
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</tr>
</tbody>
</table>

**Type of Service Mode**
- GBAS Status
- Positioning Status

**Mode Selection for Satellite Status**
- GPS Dual Frequency
- Galileo Single Frequency
- Galileo Dual Frequency
- Multi GNSS Single Frequency
- Multi GNSS Dual Frequency

**Satellite Status**
- GPS L1 (CA Code)
- GPS L2 (P Code)
- Galileo E1
- Galileo E1 & E5a
- Multi GNSS L1 & L2 (P Code)
- Multi GNSS E1 & E5a

**Positioning Monitor (Positioning Error of Virtual User)**

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Using of M-GBAS at ship-board site

The effectiveness of applied integrity monitoring functionalities has been demonstrated that requirements on automatic docking can be fulfilled.
Concept of Integrated PNT System

Integrated Navigation System

World Wide Radio Navigation System (WWRNS)

GNSS Receiver
DGNSS Receiver
Multi Radio Navigation Receiver
Radar Map Matching
Gyro / Compass
Speed / Log

PNT Module

P/I
N/I
T/I
A/S

Integrated PNT System

Legend:
- Product specification
P/I - Position and Integrity Data
N/I - Navigation and Integrity Data
T/I - Time and Integrity Data
A/S - Alert and Status data

Needed basis to exploit existing and future redundancy for integrity assessment.

Compliant with modular INS approach.

Supports the crossover from sensor specific PS to tasks / output data based PS.
Do things in an international framework → E-Navigation

Definition

“e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment”

Core Elements (IMO NAV 24/15)

- Architecture
- HMI
- Convention & Standards
- Positioning Fixing
- Communication & Information
- ENC’s
- Equipment Standardisation
- Scalability

Position, Navigation and Timing Unit

Trajectory with respect to the starting point

Horizontal error with respect to the reference trajectory

Difference between measured and estimated pseudoranges:

- GPS PRN 7
- GPS PRN 8
- GPS PRN 26
Real Time Traffic Situation Assessment Demonstrator

Development of own graphical tools and user interfaces for analysis and demonstration
Summary

- Proposal: Integrated PNT System with PNT processing Unit
  - DLR initiative within IALA / IMO (E-Navigation)

- Integrity monitoring concept based error estimation using capabilities of sensor fusion techniques

- Integration of shore-site components to improve the reliability of used systems and services
  - Prototype of Maritime GBAS system at Research Port Rostock

- Status: PNT Unit demonstrator development
  - Different measurement campaigns
  - Characterization of single sensors
  - Algorithm development and test
Many thanks for your Attention

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... and always a good journey!