Resilient PNT:

Vision and mission

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Overarching Challenge

**Safe, secure and efficient** realization of maritime traffic processes

Study of Det Norske Veritas (2011):

Around 50% of accidents have navigational causes:

- malfunctions and failure of nautical equipment
- invalid or inaccurate nautical information
- misinterpretation of navigation relevant data
- incomplete situation awareness
- incorrect decision finding and managing
- human factor
IMO’s E-Navigation Strategy

International Framework (MSC 85/26)

8 strategic key elements

- Human Factor
- Architecture
- Common Data Infrastructure
- Automated Reporting
- Robust Communication
- Centred Presentation Need
- HMI
- Data & System Integrity
- Analysis
- Implementation Issue
- Scalability
- Equipment Standardisation
- ENC’s
- Com / Inf Technology
- Position Fixing
- Convention & Standards

8 high-level user needs

- Common Data Infra-structure
Resilient PNT
Part of IMO’s E-Navigation Strategy (MSC 85/26)

- consolidated technical architecture of PNT system
- harmonized data infrastructure & robust communication for PNT relevant data exchange

Provision of resilient PNT data
- reliable provision of PNT data and automatic assessment of their accuracy and applied systems
- taking into account navigational tasks & assigned requirements
Resilient PNT
Part of IMO’s E-Navigation Strategy (MSC 85/26)

- efficient standardization of aimed PNT system
- ensured compatibility and interoperability within the PNT system and with applications

Provision of resilient PNT data

- scalability of PNT performance (accuracy, integrity) for application and indication
- scalability of PNT system for stepwise rollout process
What means resilient PNT?

System Layer:
The “Integrated PNT System” is the required overlay of satellite based, ashore and aboard components, whose integrated use ensure the accurate and reliable provision of ships’ position, navigation, and time (PNT) data during all phases of vessel navigation to applications like ECDIS, INS, AIS.

External disturbances

Internal failures and malfunctions

Resilience (system level):
- fulfils system integrity (tasks & functionalities) also under disturbed conditions (detection, compensation)
- requires redundancy / backup
- quantified at output (data & identifier)

Data Layer:

Navigational tasks
Operational tasks
Other tasks

Which PNT data are needed?
Which performance quantities should be applied?
Required level of performance per single task?

Resilience (data level):
- data delivered at expected time interval
- data provided in required format
- data fulfils performance quantities
Technical Requirements on PNT

Consolidated technical specification of user needs

„Improvement of Reliability“ of PNT requires:

- measurability (nominal/actual)
- scalability (application / rollout)

IMO A.915(22) specifies minimum requirements on horizontal position data.

Requirements are given in unambiguous terms of accuracy, integrity, continuity and availability.

- Equivalent specifications for other navigational data (e.g. SOG, STW, ROT, Heading, …) are missed.

- A unambiguous specification of requirements (e.g. accuracy, integrity) taking into account tasks and their temporal and spatial dependencies (ocean, coast, port,..) supports
  - Scalability of requirements
  - Classification of requirements
  - Prioritization for implementation
Technical Requirements on PNT
Consolidated technical specification of user needs

„Indication of Reliability“ of PNT requires: unambiguous measurable (current state) & scalable (current task)

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) intends the application of plausibility and consistency checks to assess the PNT data provided by several ship-side sensors.

- Level of integrity depends on applied tests and functionalities (scalability)
  - Plausibility (large errors)
  - Consistency (relative errors)
  - Assessed accuracy (absolute error)
  - Assessed integrity (reliability of integrity information)

- Harmonization (decidedness)

- System operating with distributed components requires a management of integrity

- Provision of integrity information (reporting, alert, central presentation)
PNT System
Generic Architecture

World Wide Radio Navigation Systems (WWRNS)
Classic Approach (Status)

Shipboard Sensor Layer
- GNSS Receiver
- GNSS/DGNSS Receiver
- etc.

Shipboard Processing Layer
- PVT
- PVT
- N
- N
- N

WWRNS sensors
- GNSS Augmentation Services

Other shipboard sensors
- Gyro / Compass
- SDME
- ROTI
- etc.

interface, point of type approval
GNSS Utilization

[MSC.112(73); MSC.113(73); MSC.114(73); MSC.115(73) & MSC.233(83)]

Ocean (< 10m)
- GNSS 1 SFP
- SBAS Service
- C-DGNSS Service

Coast (HPE<10m)
- GNSS 1 DFP
- dDFP
- C-DGNSS Service

Port (HPE<1m)
- GNSS 1 SFP
- dSFP
- P-DGNSS Service

Docking (HPE<0.1m)
- GNSS 1 DFP
- dDFP
- P-DGNSS Service

SFP - single frequency processing
DFP - dual frequency processing
dSFP - differential SFP
dDFP - differential DFP
C-DGNSS - DGNSS with range corrections
P-DGNSS - real time kinematic
PVT data

Currently used
Applicable extensions
Modular, scalable, and extendable concept for ship-side resilient PNT data provision is still open.
- taking into account alternative/combined approaches to fulfil user needs
- improvement of accuracy
- implementation of data and system integrity (scalability)

Implementation of integrity information into data protocols is insufficient.

Influence of communication channels on PNT data integrity at user site is still open.

The assignment of PNT requirements on operation areas (ENC) and navigation tasks is incompletely.

Requirements on shore-side services to support the ship-side assessment of PNT data integrity have to be specified.

Consolidated concept of PNT relevant MSP is necessary
- fulfil all performance levels
- evaluated demand of redundancy and backup

An overarching concept for resilient PNT data provision and integrity management is needed.
(tasks, responsibilities, data exchange).

Concept for exploitation of current and future GNSS towards improvement of PNT data provision is required.
- utilization concept of GNSS (redundancy)
- assessment of different approaches
- implementation and rollout plan
INS Approach (with MRR)

**Initial Integrity Monitoring**

**Shipboard Sensor Layer**
- GNSS Receiver
- DGNSS Receiver
- Multi Radio Navigation Receiver (MRR)
- etc.
- WWRNS sensors
- PNT services
- Other shipboard sensors
- Gyro / Compass
- SDME
- ROTI
- etc.

**Shipboard Processing Layer**
- Check Matrix of PNT data
  - realized by INS
  - (IMO MSC.252(83); IEC 61924)

**Interface, point of type approval**

**Integrity** (plausibility, consistency)

**Alerts**
Modular PNT Unit Approach

Shipboard Sensor Layer
- GNSS Receiver
- DGNSS Receiver
- Multi Radio Navigation Receiver
- Gyro / Compass
- SDME
- ROTI
- etc.

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

Shipboard Processing Layer
- PVT (data processing)
- Unit as part of INS
- PNT (data processing)
- Unit as part of INS
- best PNT
- Integrity (accuracy)
- Alerts (improved)

interface, point of type approval

PNT services

WWRNS sensors

other PNT relevant Input Data (Radar, MSI, AIS,...)
Modular, scalable, and extendable Approach

Concept is open regarding current and future sensor/service combinations.

Selection of applicable sensor/service combination per performance class (e.g. accuracy, integrity)

Sum of supported performance classes determines version of check matrix.

Achieved level of safety (ALS) < Target level of safety (TLS)
modelled and quantified risk at present
aimed residual risk
From User Needs…
...to evaluated implementation plan

**Formal Safety Assessment in e-Navigation**

<table>
<thead>
<tr>
<th>Identification of hazards</th>
<th>Assessment of risks associated to hazards</th>
<th>Ways of managing the risks</th>
<th>Cost benefit assessment of options</th>
<th>Selection of options for implementation</th>
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**Identification of user needs**
Assumption, that user needs include safety requirements from profession

**Architecture & system analysis**

**Gap analysis**
At present: discussion of single approaches without clarification of requirements on “resilient PNT data”

**Cost-benefit and risk analysis**

**Implementation plan**
- consolidated technical requirements
- alternative applicable solutions
- validated solutions regarding benefit
- system architecture, responsibilities & functionalities, interaction…
- residual risks

2015
Summary & Conclusions

- Proposed steps towards resilient PNT data provision:
  - achieve a harmonized meaning of resilient PNT data provision
  - transform / map user needs into measurable technical requirements
  - identify technical gaps comparing achieved and aimed level of safety based on measurable performance quantities such as accuracy and integrity
  - work out schedule covering development and assessment activities

- Unambiguous specification of technical requirement on “resilient PNT data” is the needed basis
  - to quantify the demand on PNT system enhancement (accuracy and integrity)
  - to reflect the variety of requirements coming from tasks under consideration of their spatial and temporal dependencies (scalability of performance)
  - to identify suitable solutions per aimed performance class (scalability of applicable system approaches: redundant approach or backup approach)
  - to assess the benefit of solutions per performance class
  - to select and prioritize solutions for implementation
Summary & Conclusions

- An overarching concept (system approach) of resilient PNT data provision is necessary
  - to reflect, describe and assess processing chains (from data sources up to frontend) per aimed performance class
  - to clarify functionalities and responsibilities in the PNT system operating with distributed components
  - to organize integrity monitoring and integrity management in a distributed system

- A modular, flexible and extendable design of technical architecture for the PNT system should be aimed
  - to represent the current and aimed PNT system
  - to support the stepwise implementation and rollout process of selected processing chains (system scalability)
  - to ensure the unambiguous specification of internal and external interfaces (maritime data model)
  - to enable the efficient utilization and standardization of ongoing modernization in radio navigation systems and equipment, maritime service portfolio as well as ship-side sensors
  - to be open for new challenges
Thanks for Attention

More Information?
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