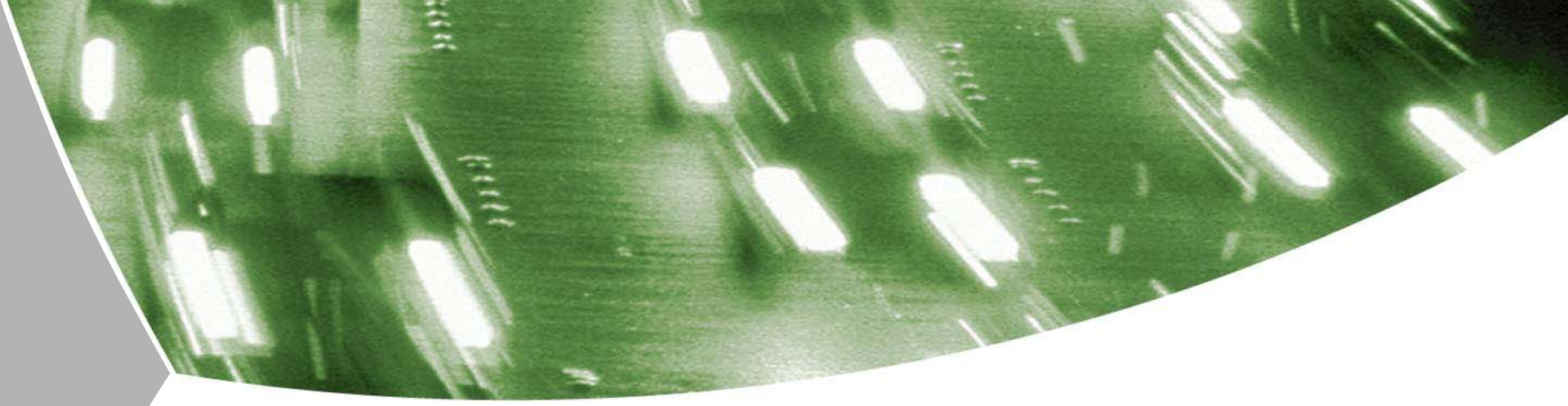

Resilient PNT:

Vision and mission

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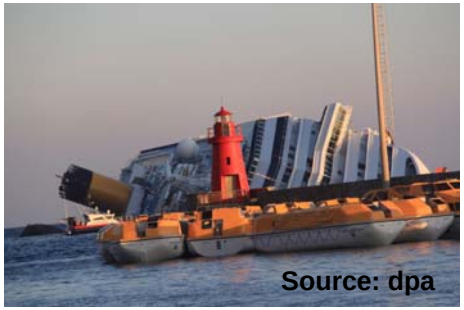
Overarching Challenge

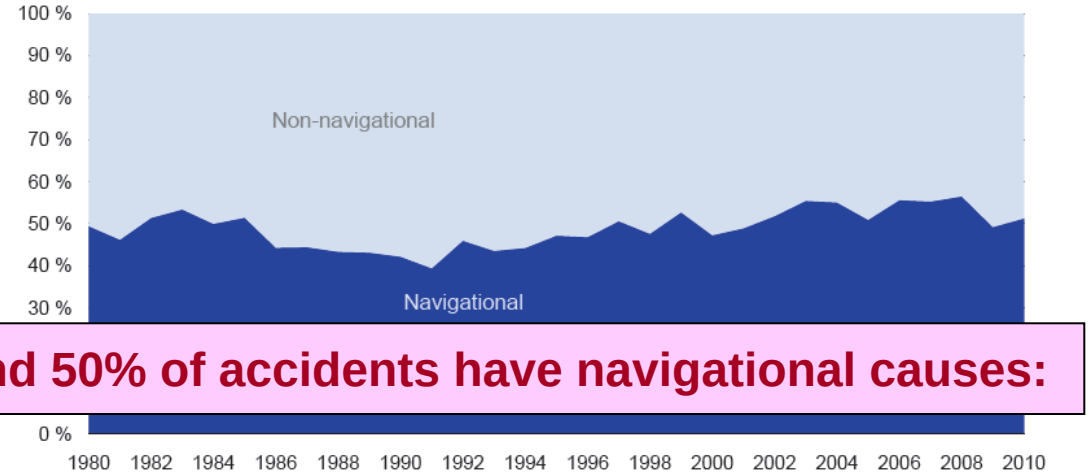
Safe, secure and efficient realization of maritime traffic processes

2011: Container Ship „Rena“

2012: Cruiser „Costa Concordia“



Study of Det Norske Veritas (2011):

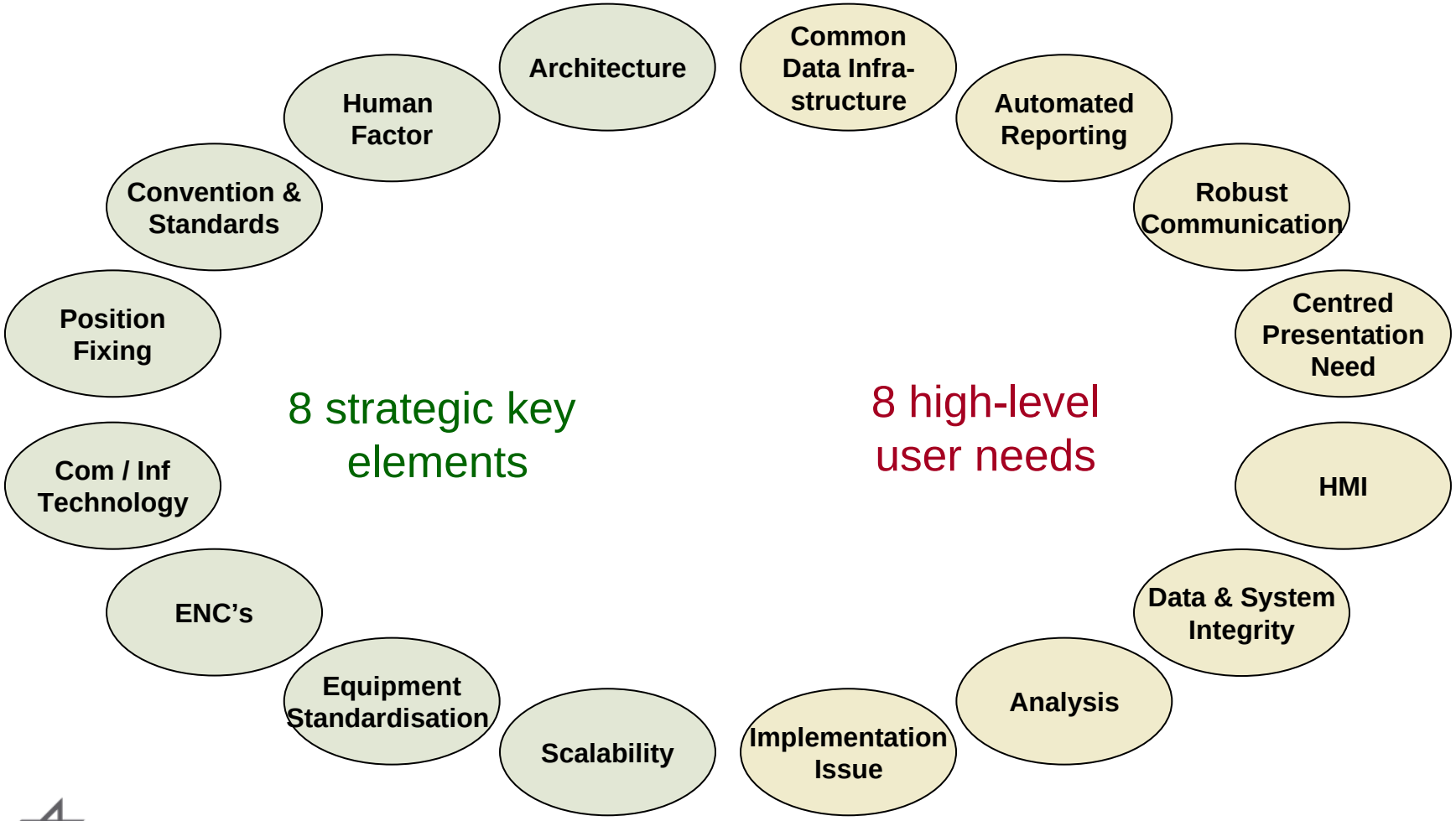


Around 50% of accidents have navigational causes:

- 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

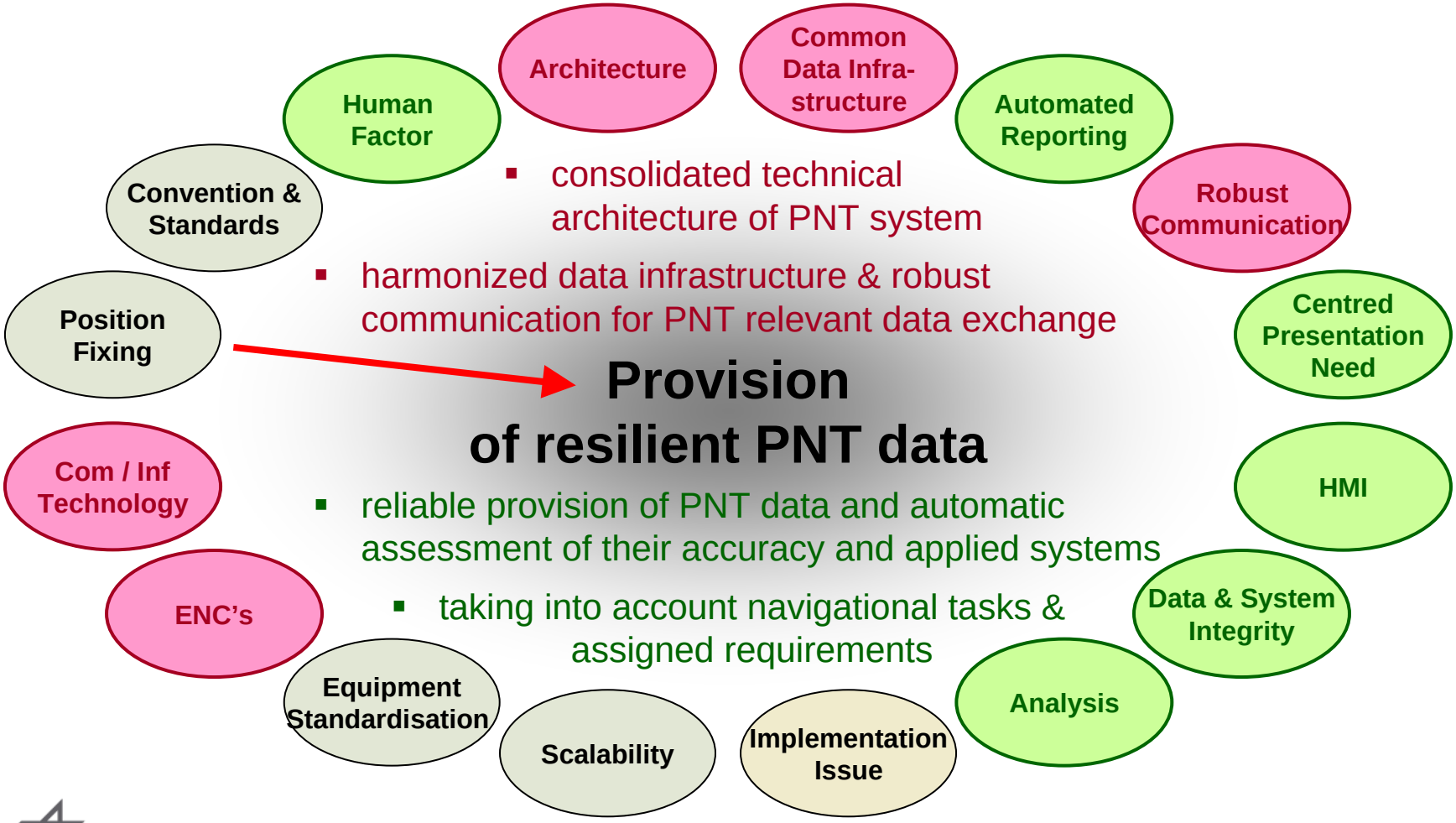
IMO's E-Navigation Strategy

International Framework (MSC 85/26)



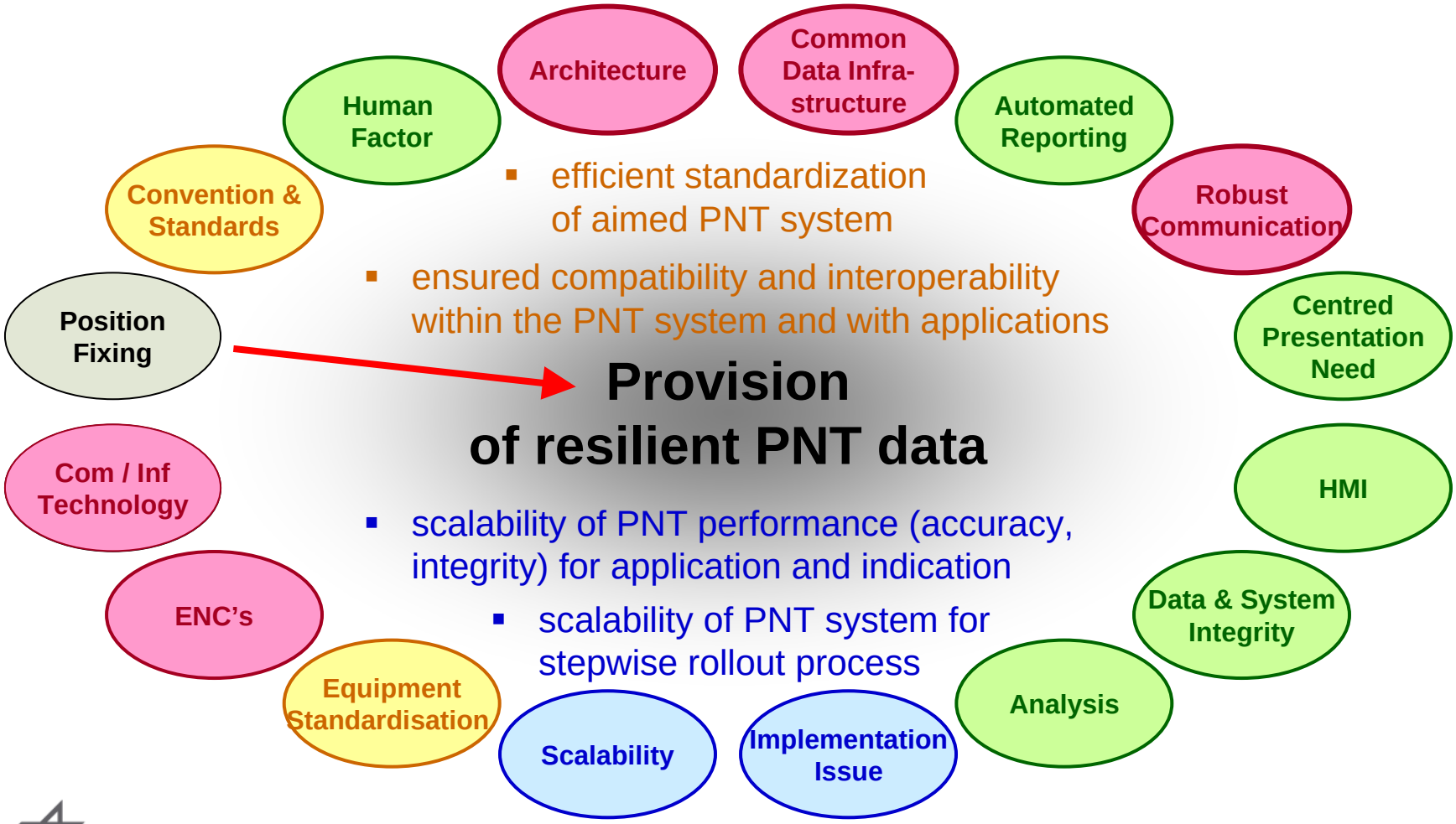
Resilient PNT

Part of IMO's E-Navigation Strategy (MSC 85/26)



Resilient PNT

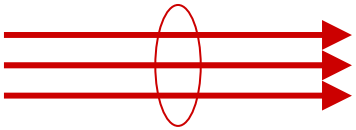
Part of IMO's E-Navigation Strategy (MSC 85/26)



What means resilient PNT?

System Layer:

External disturbances



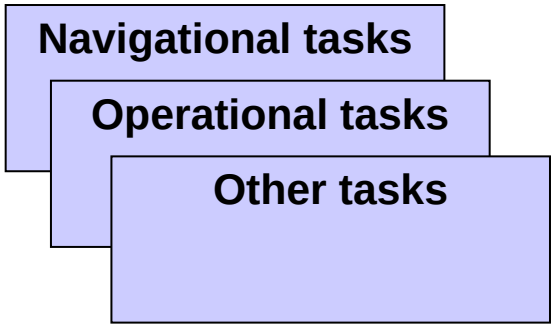
The **“Integrated PNT System”** is the **required overlay** of satellite based, ashore and aboard components, whose integrated use ensure the accurate and reliable provision of ships’ position, navigation, and time (PNT) data during all phases of vessel navigation to applications like ECDIS, INS, AIS….

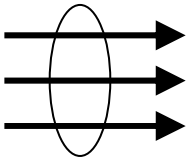
Internal failures and malfunctions

Resilience (system level):

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

Data Layer:





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)

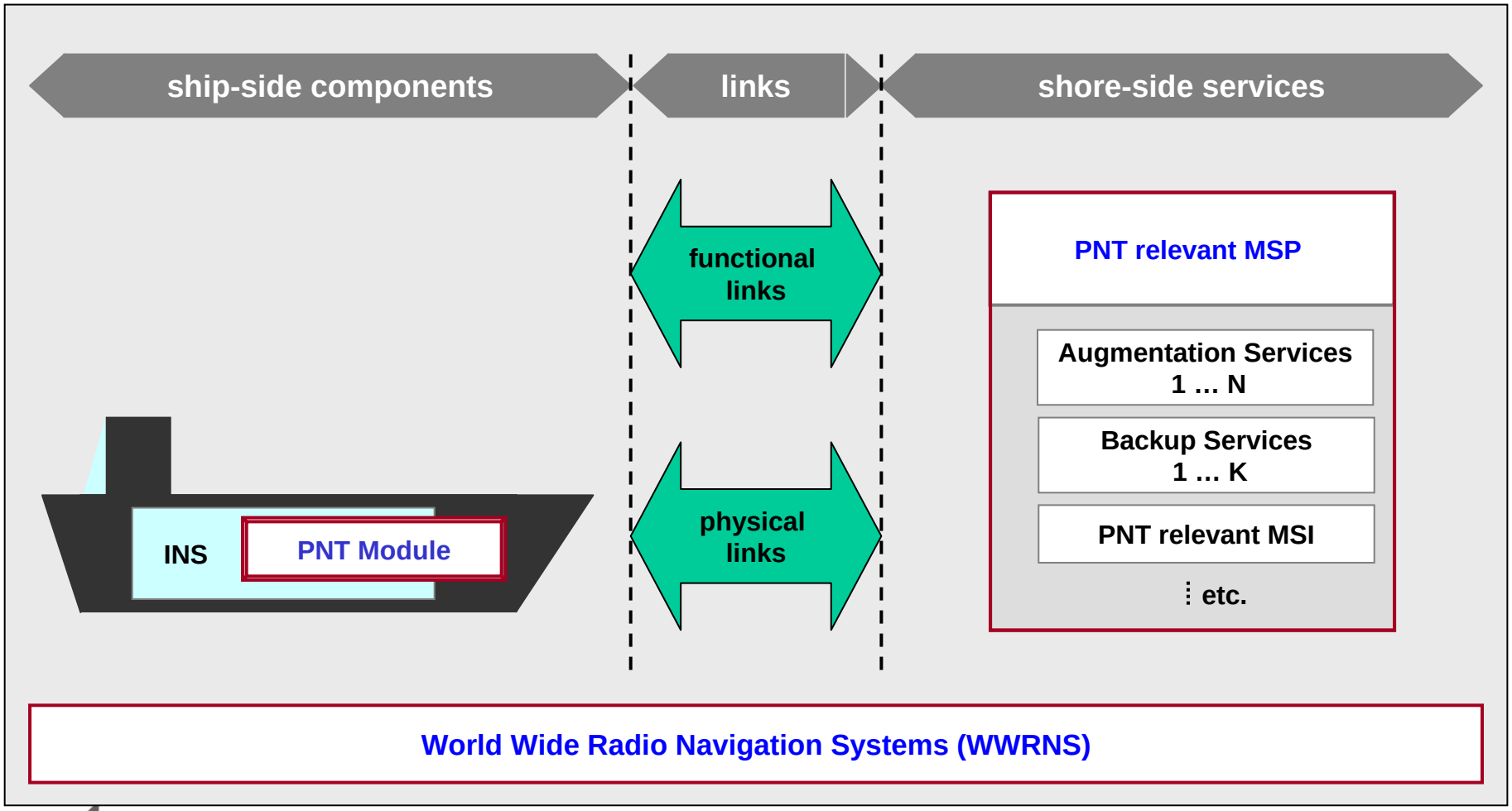
IMO MSC.233(83) intends the application of **RAIM** to assess the GNSS based provision of PVT data.

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.

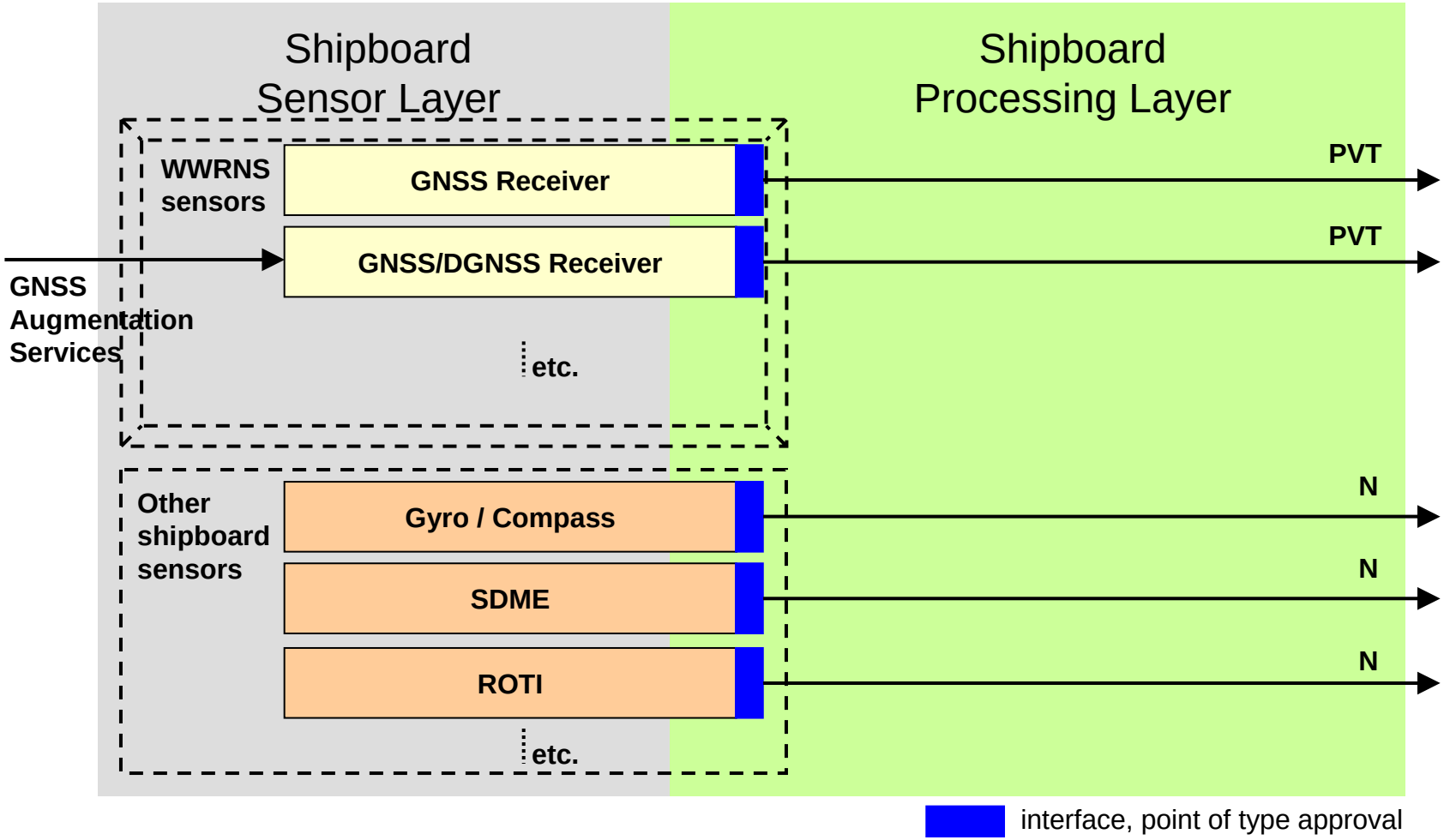
- Level of integrity depends on applied tests and functionalities (scalability)
  - Plausibility (large errors)
  - Consistency (relative errors)
  - Assessed accuracy (absolute error)
  - Assessed integrity (reliability of integrity information)
- Harmonization (decidedness)
- System operating with distributed components requires a management of integrity
- Provision of integrity information (reporting, alert, central presentation)

PNT System

Generic Architecture

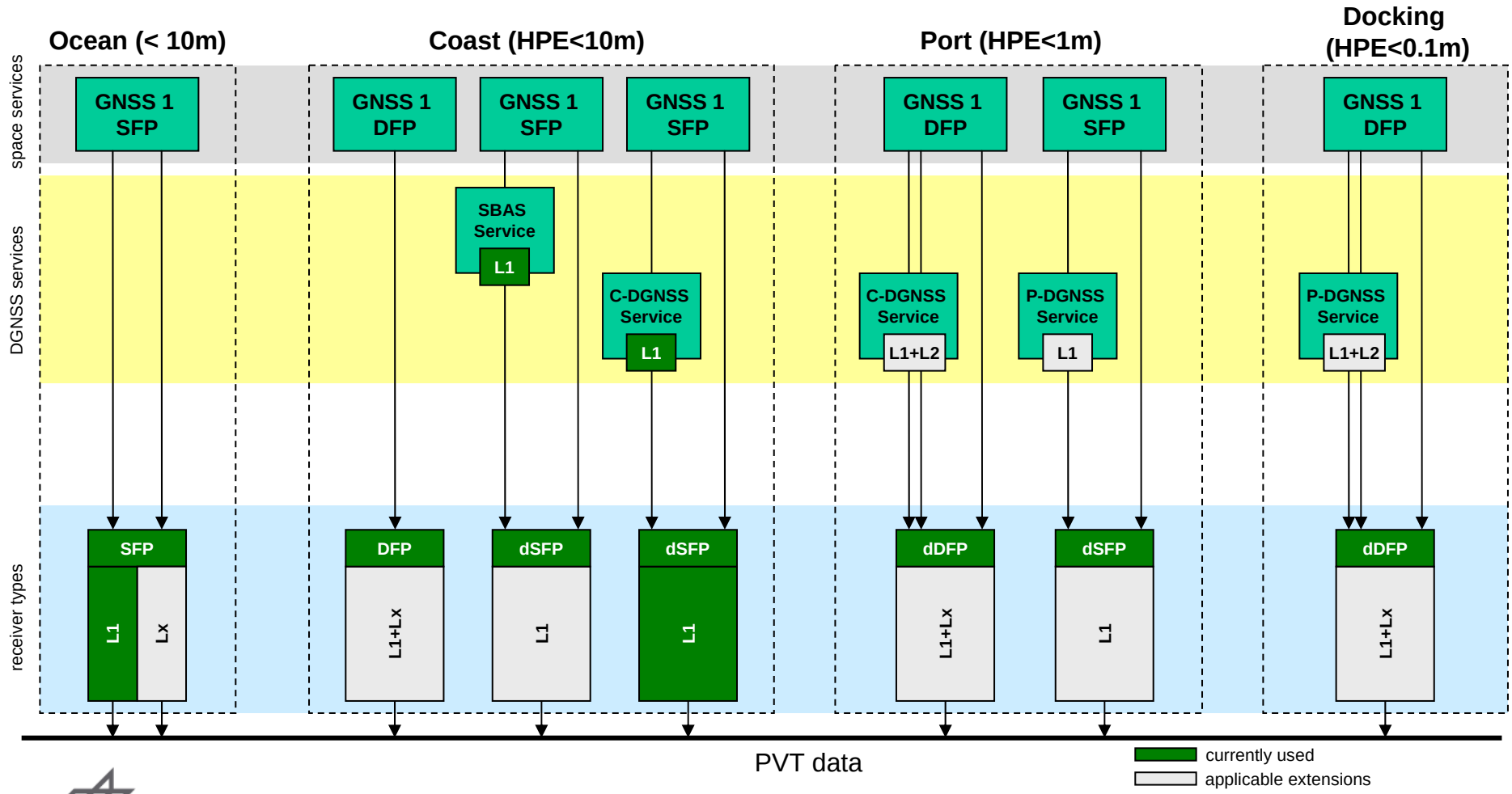


Classic Approach (Status)



GNSS Utilization

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



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

PNT System

Selected Challenges on Design

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

Modular, scalable, and extendable concept for ship-side resilient PNT data provision is still open.

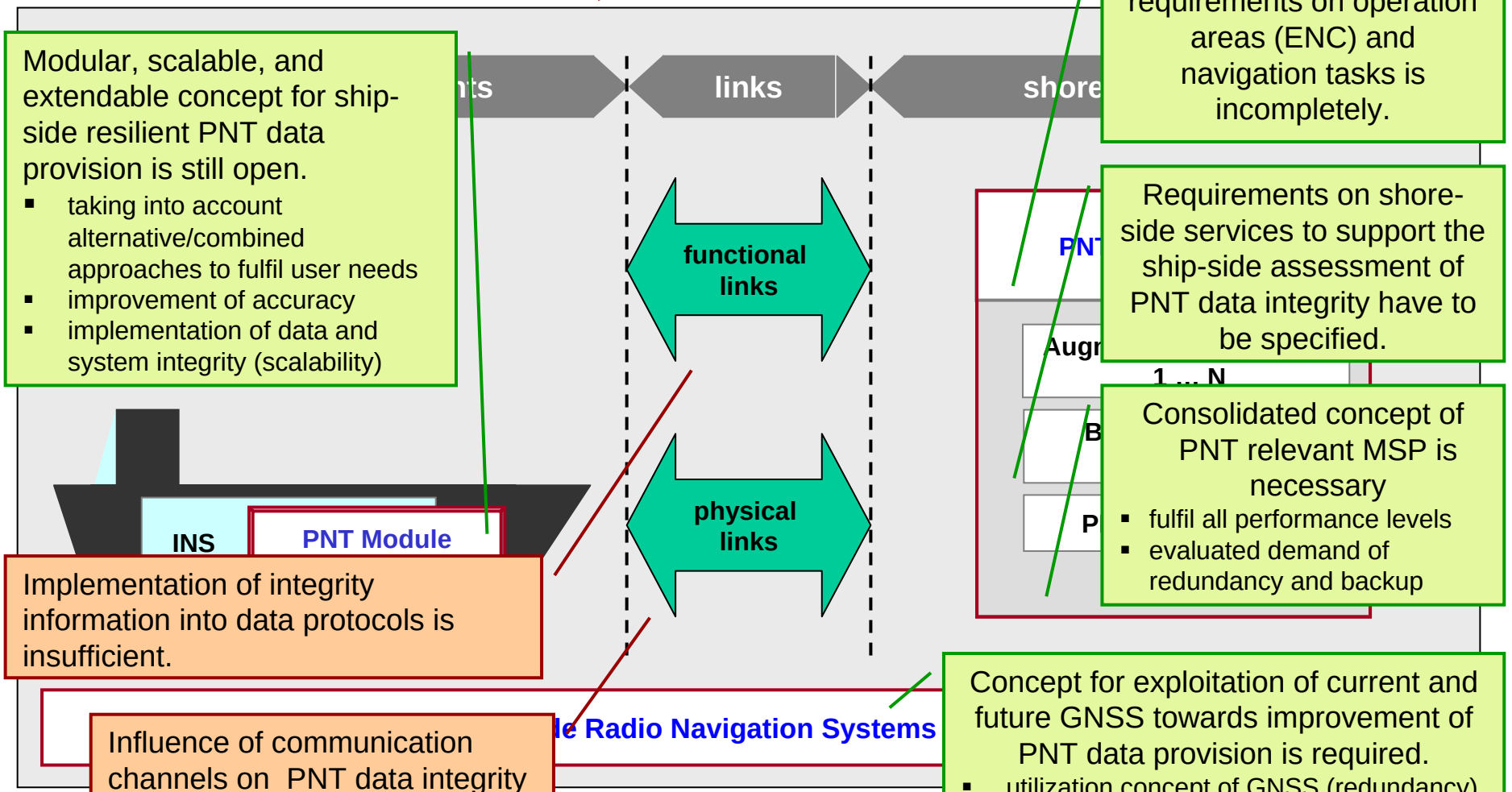
- taking into account alternative/combined approaches to fulfil user needs
- improvement of accuracy
- implementation of data and system integrity (scalability)

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



Implementation of integrity information into data protocols is insufficient.

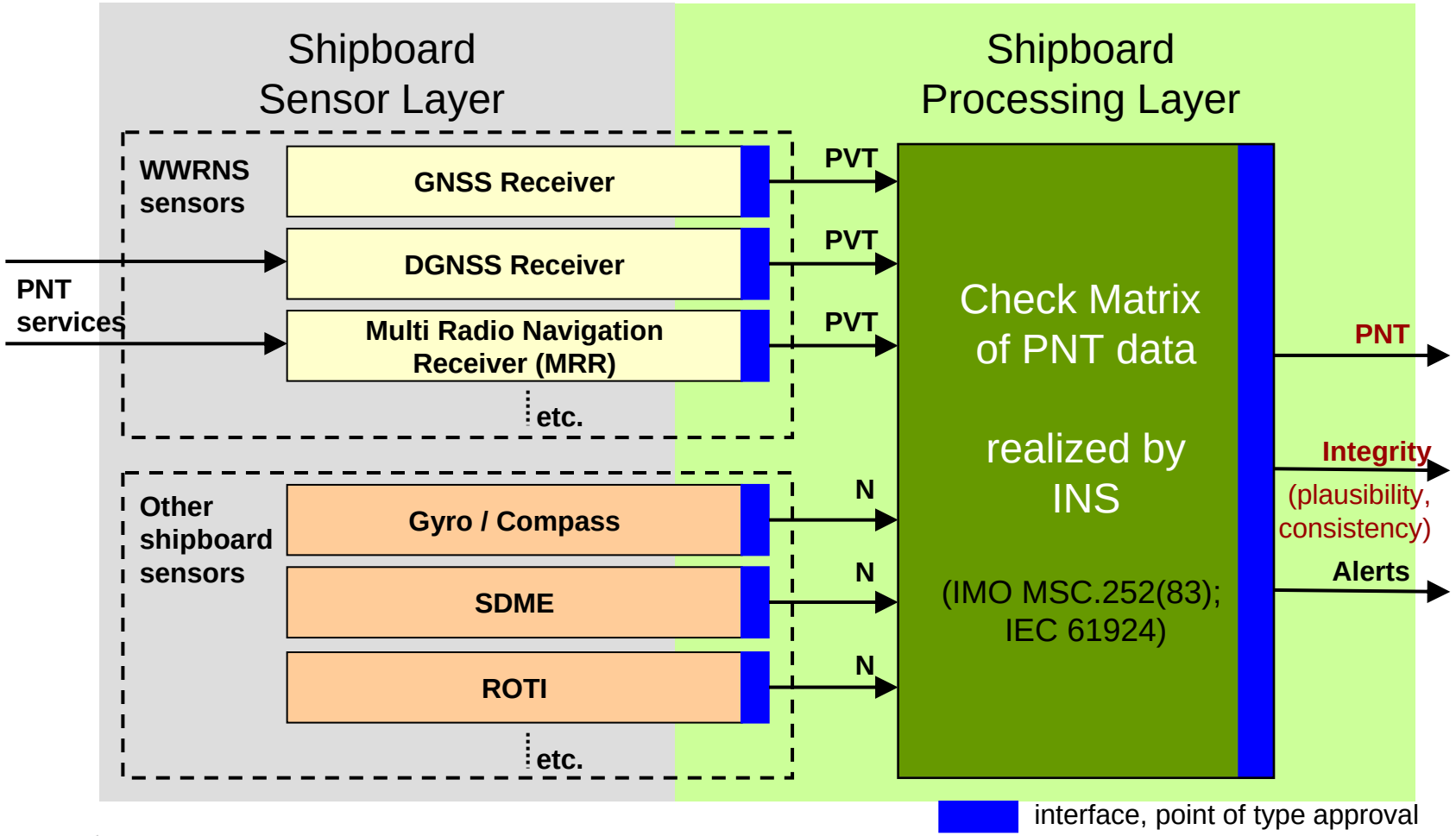
Influence of communication channels on PNT data integrity at user site is still open.

Concept for exploitation of current and future GNSS towards improvement of PNT data provision is required.

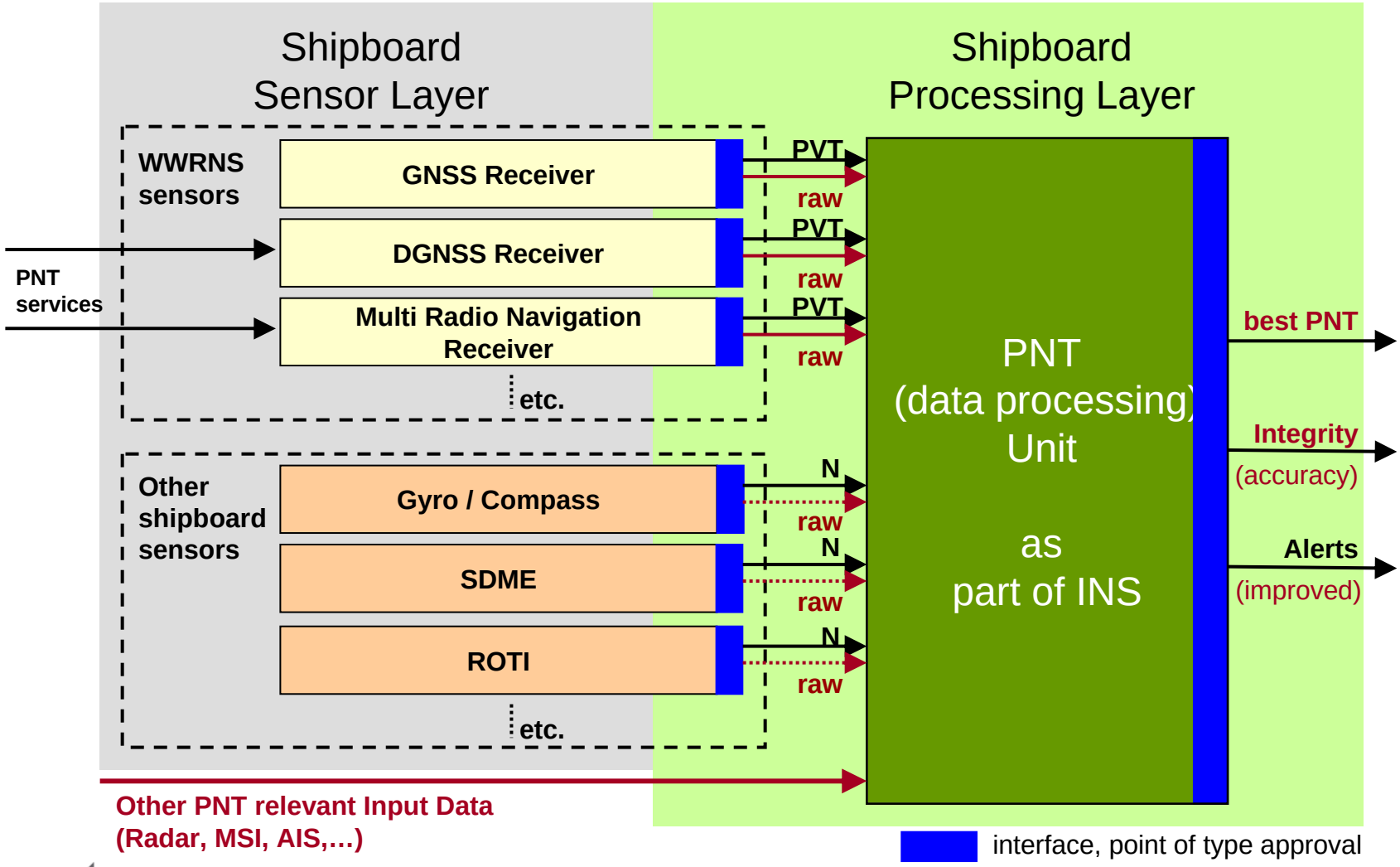
- utilization concept of GNSS (redundancy)
- assessment of different approaches
- implementation and rollout plan

INS Approach (with MRR)

Initial Integrity Monitoring

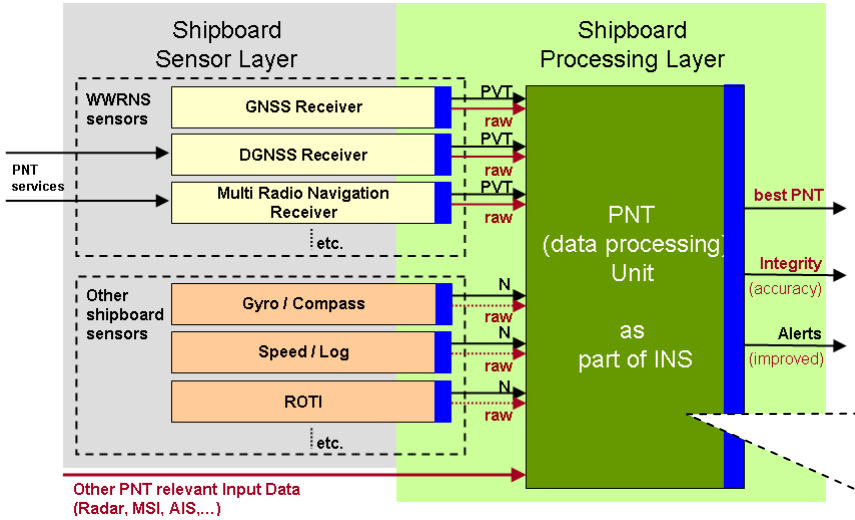


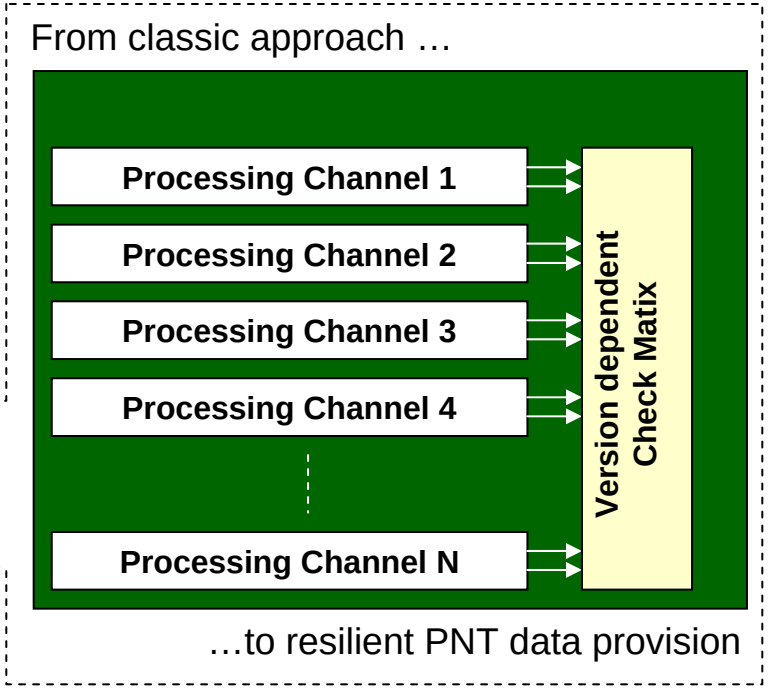
Modular PNT Unit Approach



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

Identification of user needs | **Architecture & system analysis**

Assumption, that user needs include safety requirements from profession

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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