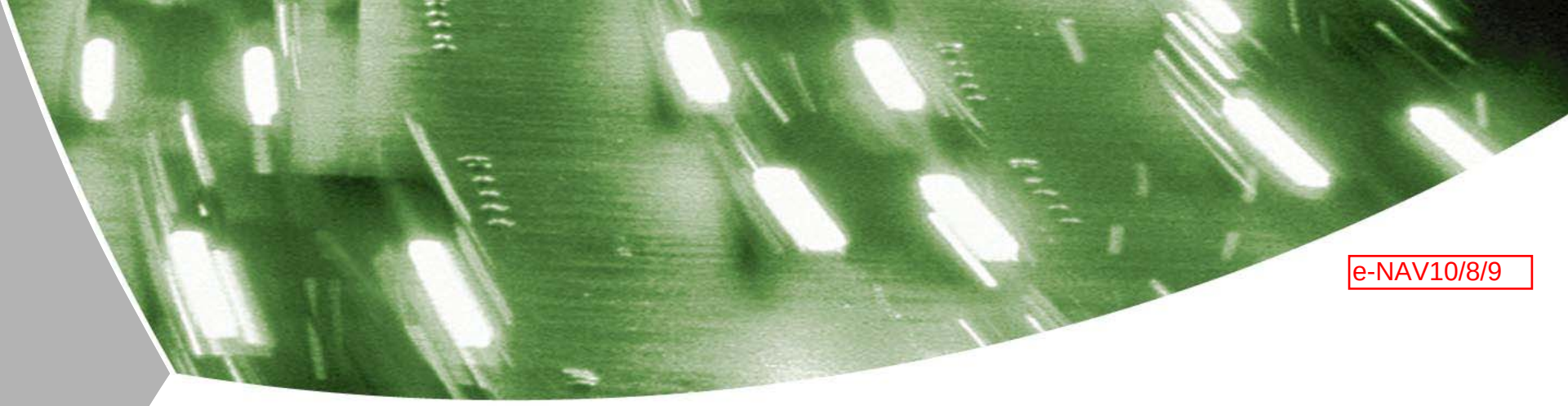


e-NAV10/8/9

Maritime Integrated PNT System

Part 1

Topics

Background and objective of the discussion

Action Item 1: Integrated PNT System

- AI 1.1: Definition of “Maritime Integrated PNT System” and specification of primary PNT output data
- AI 1.2 Requirements on PNT output data

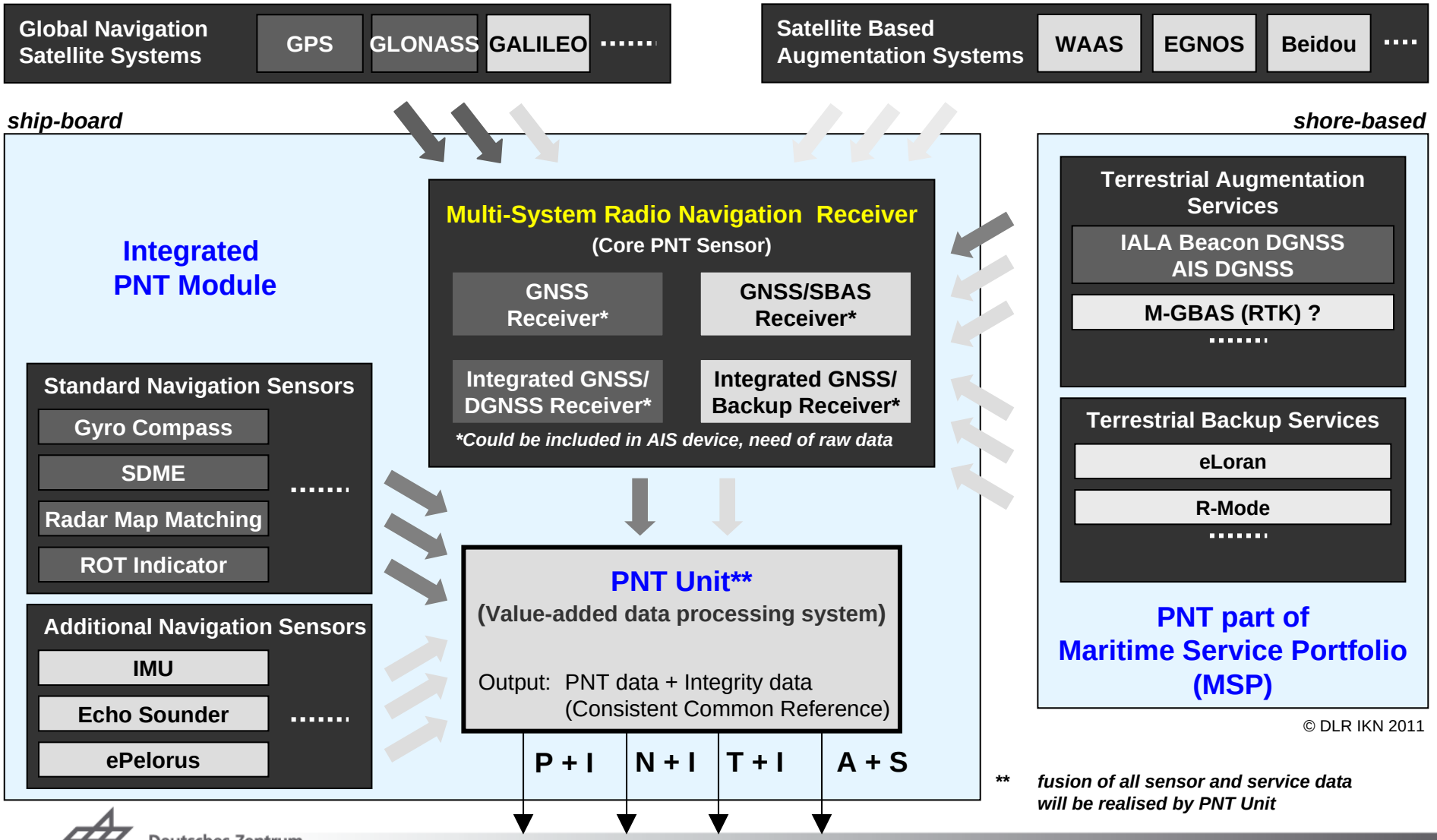
Action Item 2: PNT development

- AI 2.1 Current Architecture (sensors and services) and Gaps
- AI 2.2*) Approaches and demand on development

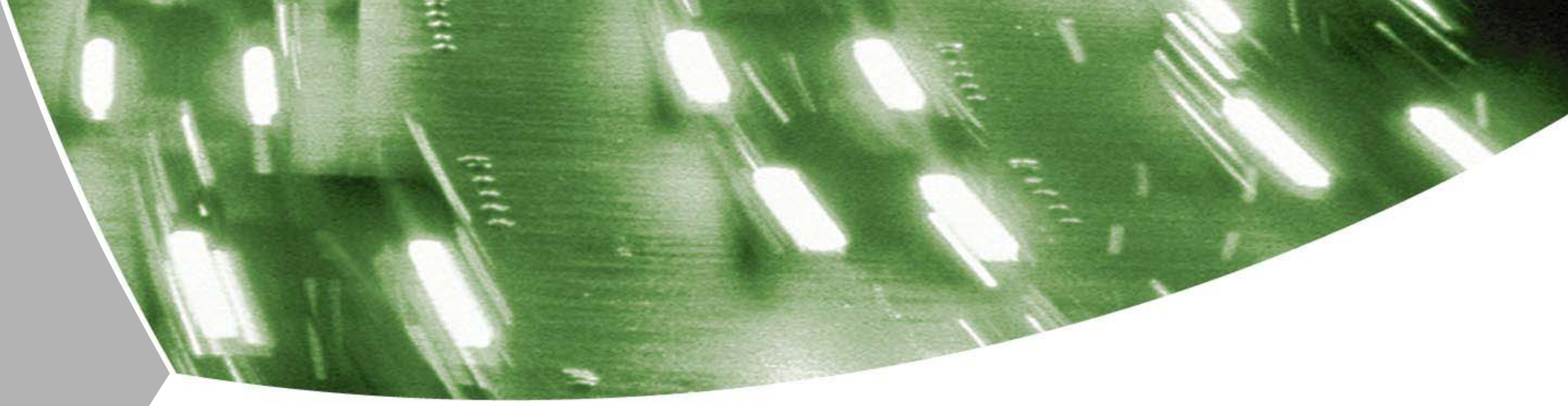
Summary and conclusions*)

**) are not yet discussed at WG2 Intersessional Meeting*

Overview of PNT components



** *fusion of all sensor and service data will be realised by PNT Unit*



Maritime Integrated PNT System

Background & Objectives of Discussion

Background – 1

(common)

IMO:

- GNSS recognized as global core element for position fixing
- IMO A.915(22) specifies position related requirements on future GNSS (minimum)
- Responsible to identify and develop related performance standards
- .....

E-Navigation:

- framework **bringing harmony and interoperability into maritime information systems** to enhance safety and operations
- **Utilisation of all electronic means**
  - to generate a comprehensive situation awareness
  - to coordinate the information exchange between ships as well as ships and services
  - to integrate these information into ship navigation systems and vessel management systems

Background – 2

(common)

IALA:

- WWRNP
- IALA Beacon DGNSS and its modernisation
- AIS DGNSS

- Additional augmentation and correction services under discussion
  - Terrestrial backup (future earth bound ranging)
    - E-Loran (backup coast)
    - R-Mode (backup coast)
    - …..?
  - High-precision services for ports (M-GBAS,…)

- Harmonisation between provided services and ship-side users (equipment)

Background –3

User Needs *[IMO NAV56-WP.5 E-NAV report]:*

Examples

Identification of Reliability

- **Automatically assessment of accuracy** and integrity of hydrographical data, **position fixing data**, radar data, and other **navigation relevant data**;
- Graphical indication of assessment results;

Improvement of Reliability

- **Reduction of failures and malfunction** of electronic equipment
- Assessment and quantification of **reliability**

Alert Management

- Coordination and **weighting of bridge alerts**
- Support of **decision making** without undue diversion

Approaches

- **Data and System Integrity**
- **Analysis**
- **Redundancy**
- **Backup**
- **Common Maritime Data & Information Structure**
- **Harmonised Meaning of Assessment Results**
- **……**

Background – 4

(high priority)

IMO NAV 57: Development of an e-navigation implementation plan: Resilient Position, Navigation and Timing (PNT)

NAV 57/6/2 (submitted by Republic of Korea):

- report on decreased GNSS signal reception around Yellow Sea /DGPS station Eochung-do and Honkong

NAV 57/6/4 (submitted by IALA):

- data validity, plausibility and integrity of PNT data is necessary
- vulnerability of GNSS requires backup system

NAV 57/6/6 (submitted by UK):

- summary of UK study: preferred option on purely economic grounds is maritime eLoran

NAV 57/6/7 (submitted by Australia):

- comments to NAV 57/6/2: global consistent approach for PNT data provision
- inclusion of all ship-side information (NT radar, e-pelorus, improved AtoN, GNSS receivers), and improved alerting of GNSS jamming and interference… for PNT data provision

Aimed Objectives

Background and objective of the discussion

Action Item 1: Integrated PNT System

- AI 1.1: Definition of “Maritime Integrated PNT System” and specification of primary PNT output data
- AI 1.2 Requirements on PNT output data

Action Item 2: PNT development

- AI 2.1 Current Architecture (sensors and services) and Gaps
- AI 2.2*) Approaches and demand on development

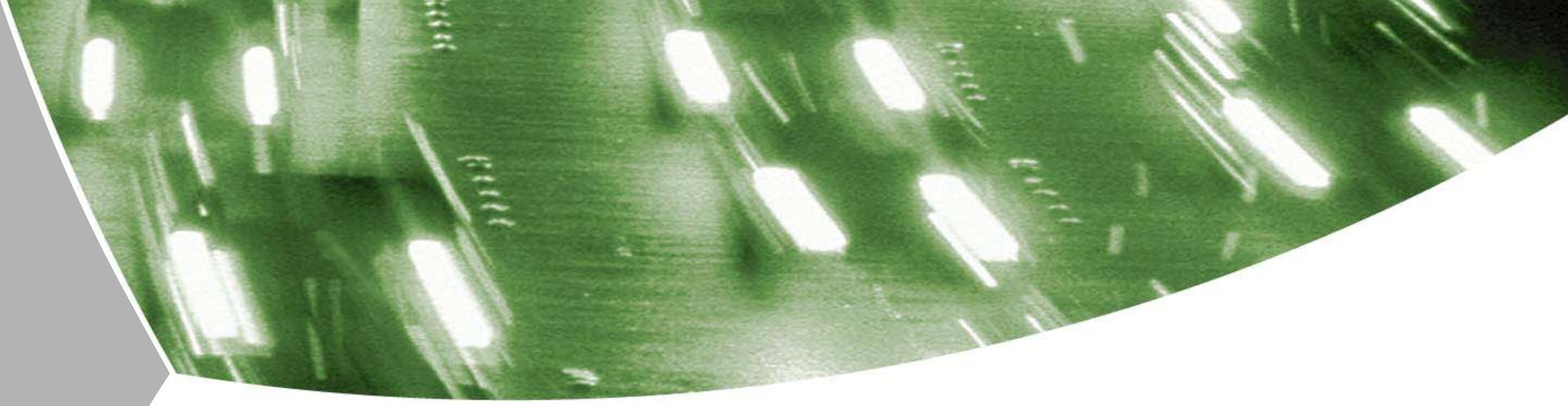
Summary and conclusions*)

**) are not yet discussed at WG2 Intersessional Meeting*

Contributions to detailed architecture design and gap analysis of PNT (summarised as input paper to Enav 10)

Progress in conceptional design of future Integrated PNT System

Specification and scheduling of next action items (WG 2)



Action Item 1.1

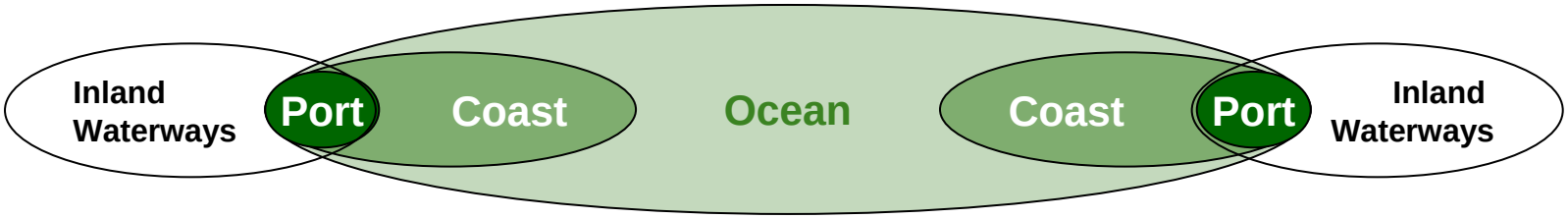
Definition of “Maritime Integrated PNT System”
and
specification of output data

Definition of Item
“Maritime Integrated PNT System”

Suggestion:

The Maritime Integrated PNT System is the **overlay of satellite based, ashore and aboard components**, whose integrated use can ensure the accurate and reliable provision of ships’ position, navigation, and time (PNT) output data to applications during all phases of vessel navigation.

Condition 1: all phases of vessel navigation



Condition 2: global solutions for all phases of vessel navigation with changing processing chains

Primary PNT Data

(output data provided to applications)

Suggestion:

P = Position data: → **Latitude** | **Longitude** | **Altitude**

- **in a specified coordinate and timing system (data attributes)**

N = Navigation data: → **Velocity** | **Acceleration** | **Attitude**

- **SOG**
- **ROT**
- yaw, pitch and role rates
- ?
- **Heading**
- **COG**
- yaw angle
- pitch angle
- role angle

T = Timing data: → **Time**

= in a common timing system (data attributes):

Primary PNT data for vessel navigation (red)
Future extension of PNT data (black)

Comment 1:
STW, air draught and depth (UKC) are navigation relevant data which will be derived by applications in combination with further externally provided data (tidal, ENC…)

Further PNT Output Data - 1

User Needs *[IMO NAV56-WP.5 E-NAV report]:*

Identification of Reliability:

Automatic assessment of accuracy and integrity of … position fixing data, … and other navigation relevant data;

Improvement of Reliability:

Reduction of failures and malfunction of electronic equipment;
Assessment and quantification of reliability;

Alarm Management:

Coordination and weighting of bridge alerts;
Support of decision making without undue diversion

- ➔ Assessment results of accuracy of primary PNT data
- ➔ Assessment results of integrity of primary PNT data
- ➔ Assessment results of integrity of the integrated PNT system in use
- ➔ Identification of “best” PNT output data

- ➔ reduction of failures and malfunctions can be achieved by redundancy and fusion of available sources of data

- ➔ Provision of integrated PNT system (in use) relevant alerts to vessel alarm management systems
- ➔ The fusion of PNT system data minimises user workload.
- ➔ Support of decision making by automatic selection of best result of primary PNT data

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 2

(derived from INS performance standard under development)

- **Accuracy**
  - **degree of conformance between the estimated or measured parameter value at a given time and its true parameter value at that time**

Comments:

- The true value is not always available
- Requires techniques to estimate the accuracy of primary PNT output data
- Requires access of PNT module to raw data of used sensors
- Applicable techniques depends on usable sensors and services (configuration and included redundancy)
- Therefore different performance degrees of accuracy estimations can be expected (scalability)

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 3

(derived from INS performance standard under development)

- **Alert**
  - **announcing abnormal situations and conditions requiring attention, decision or action. Alerts are divided in three priorities: alarms, warnings and cautions**

Comments:

- Alerts coming from PNT module configuration in use (HW and SW with respect to their functionalities)
- Alerts coming from availability and estimated performance of primary PNT data in comparison to current requirements
- Alerts coming from availability of further PNT data (completeness of PNT output data provision)
- PNT relevant alarms, warnings and cautions should be specified (to align with INS alarm provision)
- The alarm system design of the Integrated PNT System requires consideration and integration with the PNT module alarm system requirements.
- The possibility of incorrect alarms should be minimised
- Includes information about degraded condition (both Integrated PNT System and PNT Module)

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 4

(derived from INS performance standard under development)

- **Configuration in use**
  - **sub-systems (e.g. sensors and sources, automatic control function, etc.) selected (or available) for use and tasks (e.g. set of sensors and services for PNT data provision)**

Comments:

- Describes the operational status of integrated PNT system (in use) with respect to the provided PNT output data
- Includes information about available and used sensors and services
- Includes information about applied data processing techniques and their configuration
- Includes information about applied control function including thresholds and decision logic
- Regular case: not used for navigation purposes
- Relevant for accident analysis (VDR) and certification by recording of detailed status information of integrated PNT system
- Relevant for maintenance and fault finding (built version and standard, fault status…)

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 4

(derived from INS performance standard under development)

- **Consistency**
  - **consistency can be proved by means of model theory (model characteristics)**

Comments:

- Not output
- The output contributes to integrity and accuracy
- Can support the integrity estimation
- Can be considered as an input for determination of integrity

- Consistency is essentially an assessment of the single sensor input against the fused PNT module output taking account of the expected sensor accuracy
- Therefore PNT internal data, can be considered as additional status information for recording purposes.

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 5

(derived from INS performance standard under development)

- **Degraded condition**
  - reduction in system functionality resulting from failure

Comments:

- Not direct output, contained in alert messages
- Complementary status information with respect to “configuration in use”, if current “configuration in use” (HW and SW) will be described

- **Expected precision**
  - deviation between the measured value and the true value that is normally not exceeded by a typical system

Comments:

- Potentially this can overlap the accuracy data as discussed earlier
- Each input to the PNT module should have an expected precision which can be combined to derive the expected precision of the primary PNT data – this expected precision determines the suitability of the current primary PNT data to the current phase of navigation.

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 6

(derived from INS performance standard under development)

- **Indication**
  - display of regular information and conditions, not part of alert management

Comments:

- Status and mode of PNT module is reported to INS.
- The design of status and modes (and allowed transitions, also includes configurations) is to be specified.

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 7

(derived from INS performance standard under development)

- **Integrity [here system integrity]**
  - ability of the INS to provide the user with information within the specified accuracy in a timely, complete and unambiguous manner, and alerts within a specified time when the system should be used with caution or not at all

Comments:

- Consolidation of different integrity items is necessary:
  - system integrity
  - data integrity
  - integrity functionalities
    - integrity monitoring
    - integrity modelling

- System integrity depends on status of system functionalities and the performance of provided primary PNT output data and assigned integrity data

Explanations

Integrity

Data Integrity

Desired data are provided completely, undisturbed and accurately.

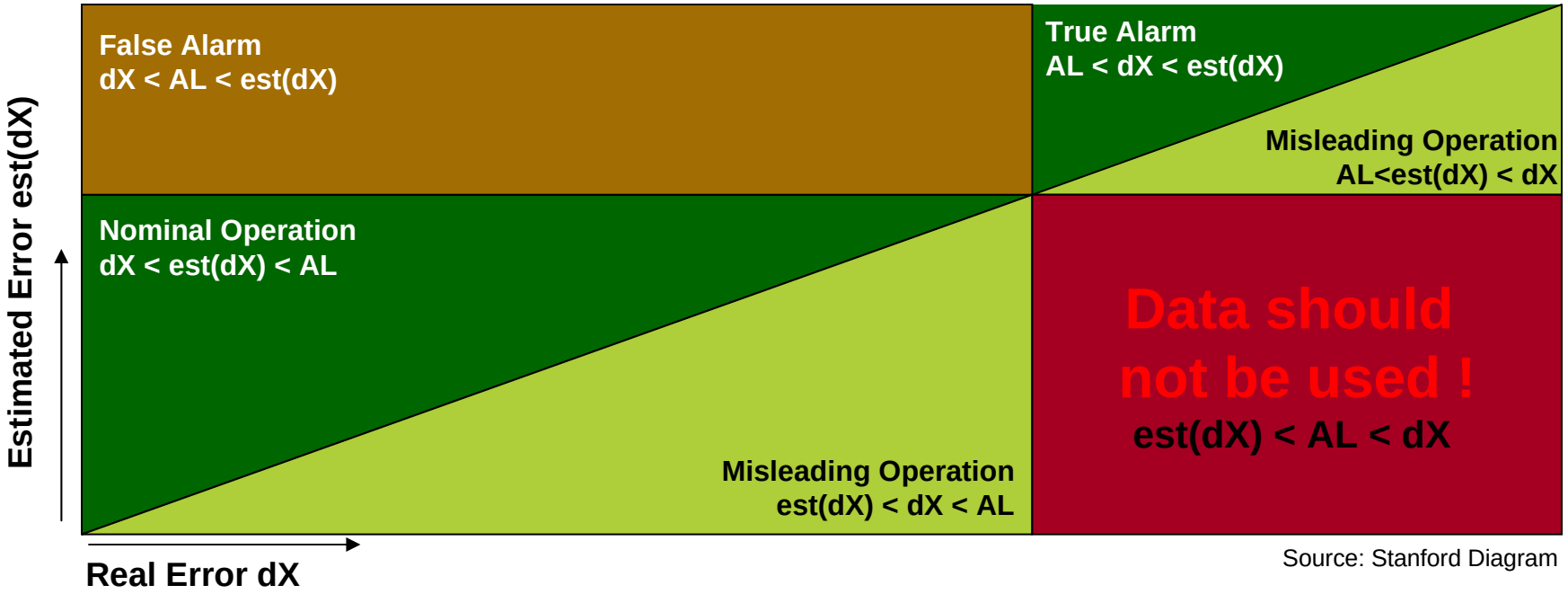
$$X = "true" \quad or \quad "accurate"$$

System Integrity

Fulfillment of specified functionalities and related requirements.

$$State = F\{y_1, y_2 \ldots y_N\} = "reliable"$$

y: *stands for results of different tests (availability, accuracy, completeness…)*



Source: Stanford Diagram

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 8

(derived from INS performance standard under development)

- **Data Integrity (per primary PNT output data)**
  - is an additional information, which is provided in a timely, complete and unambiguous manner to the users to describe, if the specific data should be used or not under consideration of accuracy requirements for each navigation phase

Comments:

- Data integrity is given, if the specific output data
  - is delivered at the expected time interval
  - is provided in the specified formats
  - fulfils the specific accuracy requirements (application specific (dynamic) thresholds)
  - optional: is delivered in time with the required data attributes (e.g. time stamps)
- Estimation of data integrity requires the implementation of assigned integrity functionalities
- Integrity functionality depends on
  - degree of redundancy inside the system used for data generation
  - the applicable methods for accuracy estimation
  - achievable degree of accuracy assessment (type of integrity functionality)
- Different capabilities of integrity functionalities requires the scalability of integrity results
- Provision of data integrity to users requires the specification of further PNT output data

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 9

(derived from INS performance standard under development)

- **System Integrity (user view on integrated PNT system)**
  - ability of the integrated PNT system to provide the user with **all** required information in a timely, complete and unambiguous and **accurate** manner, and alerts within a specified time when the system should be used with caution or not at all.

Comments:

- System integrity is given, if
  - data integrity is fulfilled for all primary PNT output data
  - output data (or attributes) describing the data integrity are provided in a timely, complete and unambiguous and accurate manner (data format and content)
  - additional secondary PNT output data (e.g. status messages, configuration in use) are provided in a timely, complete and unambiguous and accurate manner (data format and content)
  - optional: reiteration of received system integrity data from other systems (MSI, ..)
  - optional: all information are delivered in time with the required data attributes (e.g. time stamps)
- Estimation of system integrity requires the implementation of assigned system integrity functionalities based on unambiguous specification of conditions and thresholds
- Capability of system integrity functionality depends on data integrity functionalities
- Different capabilities of integrity functionalities requires the scalability of integrity results

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 10

(derived from INS performance standard under development)

- **Integrity monitoring**
  - ability of a system to provide the user with information within the specified accuracy in a timely, complete and unambiguous manner, and alarms and indications within a specified time when the system should be used with caution or not at all

Comments:

- Not output
- Included in system integrity data

- Functionality realising the assessment of data and/or system integrity
- Application of different methods:
  - monitoring by virtual users (integrity monitoring stations) – shore-side
  - by error models with static or dynamic model parameters – ship-side
  - by consistency and plausibility checks (relative accuracy assessment)

- Time of Alarm (ToA, TTA-Time to Alert) describes the time delay between occurrence of errors and transmission of alarm message to the user (application).
- ToA is a design parameter of integrity functionality.

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 11

(derived from INS performance standard under development)

- **Latency**
  - time interval between an event and its result (at the boundary of the PNT module), including time for reception, processing, transmission and display

Comments:

- Not output data
- Generally: measurement of time delay between two events
- Mainly: design parameter
- Can be managed by time reference of data
- Precise definition depends on the implemented system
- Latency of provision of primary PNT output data can be different, but more stringent than that for secondary data.
- PNT services:
  - time delay between reception of GNSS signals and provision of corrections
  - time delay between provision of corrections by the service and reception at the user
- Ship-side PNT module:
  - time delay between reception of GNSS signals and provision of PNT output data to applications and services
  - in regular case lower that the inverse update rate of PNT output data

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 12

(derived from INS performance standard under development)

- **Plausibility of data**
  - the quality representing, if data values are within the normal range for the respective type of data

Comments:

- Not output
  - the output contributes to integrity and accuracy
  - can support the integrity estimation
  - can be considered as an input for determination of integrity
  - requires the specification of normal values ranges or thresholds per considered data type (input, internal, and output)

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 12

(derived from INS performance standard under development)

- **System Alerts**
  - alerts related to equipment failure or loss (system failures)

Comments:

- Depends on architecture, needs to be specified (management of alerts from sensors etc.)
- Type of alert depends on relevance of sensors for current nautical functions based on requirements
- Number of alerts should be optimised, depends on equipment
- This could be achieved by crossover from equipment related alerts to data driven alerts based on data and system integrity

high priority (red)
aimed (black)
real need? (grey)

Further PNT Output Data - 13

(derived from INS performance standard under development)

- **Validity of data**
  - conformity of information with formal and logical criteria, or the marking of data as being good or no good (valid or invalid) for the intended use

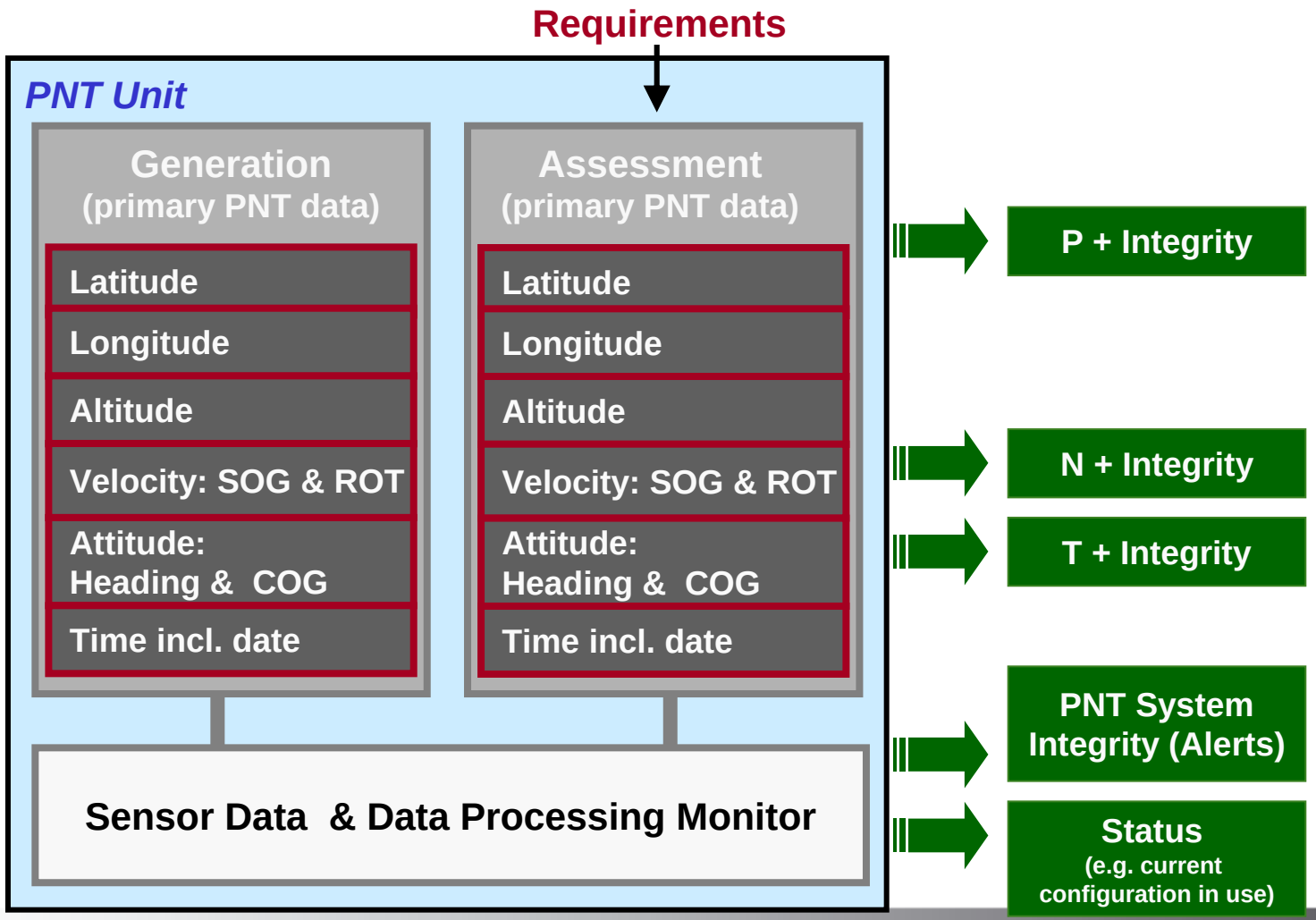
Comments:

- The provision of validity of output data is realised by overarching integrity of primary PNT output data.
- Incoming data from sensors and services are checked for validity of data structure and content.

Specification of PNT Data

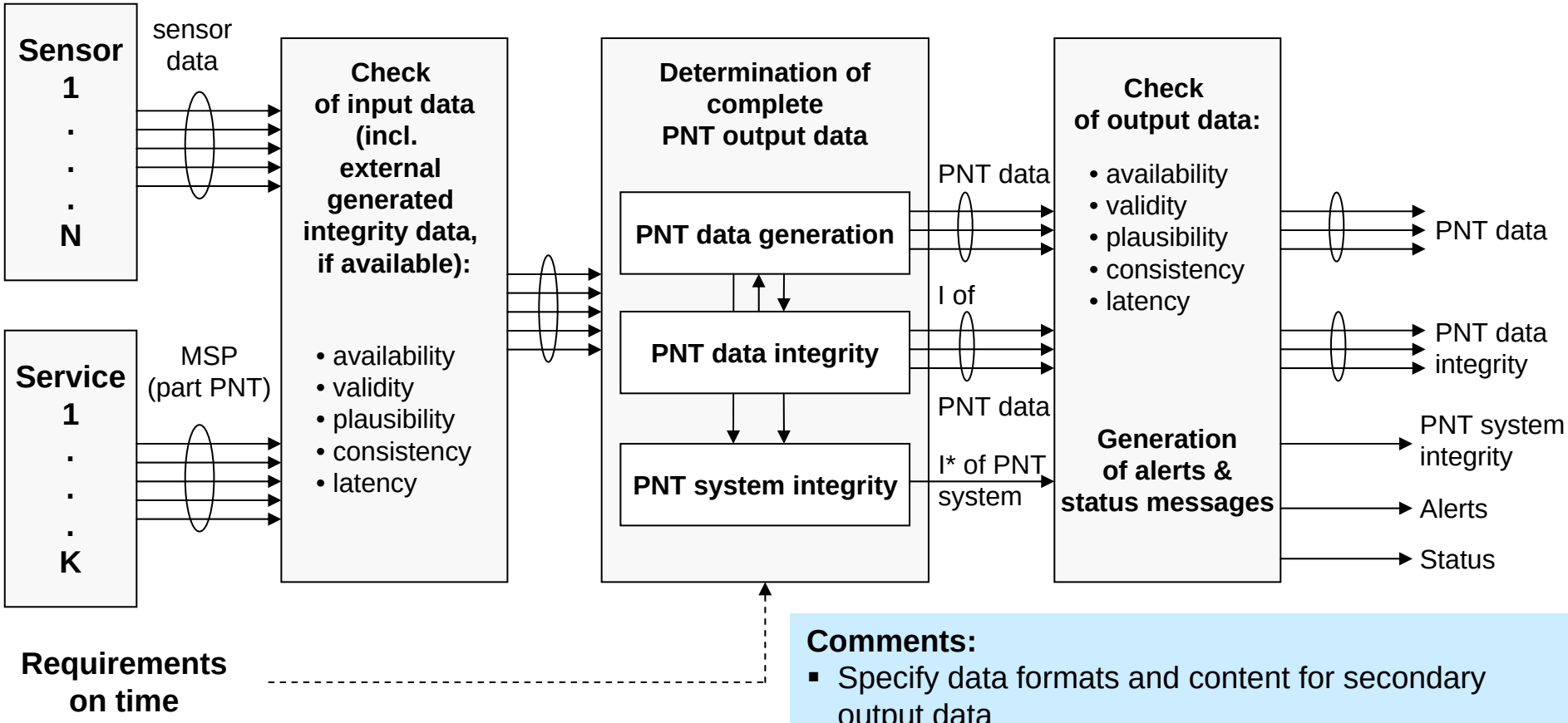
(aimed output data to applications/user)

Suggestion:



Generic data flow for PNT data provision

(Suggestion)



Comments:

- Specify data formats and content for secondary output data
- Coordinate and timing system should be harmonised.
- Integrity rules need to consider influence of GNSS on other sensors on all data inputs.

Conclusion - 1

Extended Suggestion for Definition:

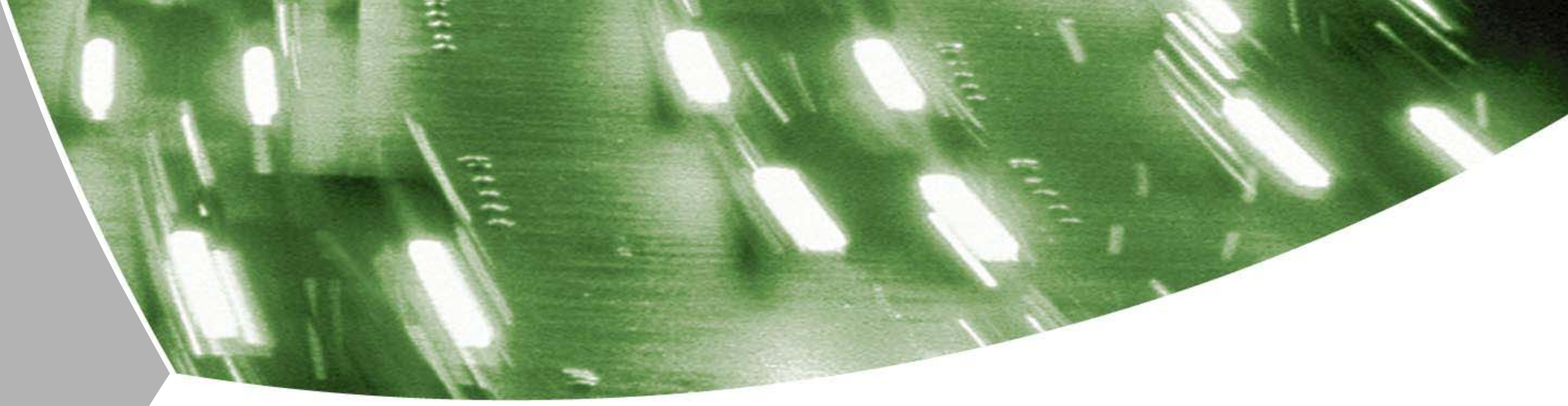
The “Integrated PNT System” specifies the required **overlay of satellite based, ashore and aboard components**, whose **integrated use** ensure the accurate and reliable provision of ships’ **position, navigation, and time (PNT) data** and **assigned integrity data (PNT system and data integrity)** to applications during all phases of vessel navigation in a timely, complete and unambiguous manner.

The “Integrated PNT System” **monitors the current HW and SW configuration in use as well as the complete PNT output data** to generate PNT relevant alerts and to provide PNT status messages (reporting) in a timely, complete and unambiguous manner.

Conclusion - 2

Extended Suggestion for Data Products (PNT frontend):

- **Position data** describes the latitude, longitude and altitude of ship's consistent common reference point (CCRP) in a global coordinate system (WGS84).
- **Navigation data** describes SOG, STW, ROT, Heading and COG of vessel in the minimum.
- **Timing data** describe the momentary time in a common time system (UTC).
- **Integrity of position data** describes either the estimated accuracy of position data or indicates the fulfilment of momentary accuracy requirements, if these are available.
- **Integrity of navigation data** describes either the estimated accuracy of navigation data or indicates the fulfilment of momentary accuracy requirements, if these are available.
- **Integrity of timing data** describes either the estimated accuracy of timing data or indicates the fulfilment of momentary accuracy requirements, if they are available.
- **Integrity of PNT system** describes either the usability of the PNT data products in a scalable manner or the fulfilment of all current requirements, if they are available.
- **Alerts** announces abnormal situations and conditions of the "Integrated PNT System" requiring attention, decision or action in the frame of ship navigation. Alerts are divided in three priorities: alarms, warnings and cautions.
- **Status messages** describes the current HW and SW configuration in use (or their change) for automatic reporting and certification purposes.



Action Item 1.2

Requirements on PNT output data

Requirements on future GNSS

only given for HPE

IMO A.915(22): Minimum Requirements on future GNSS

	System Level Parameters				Service Level Parameters			
	Absolute Accuracy	Integrity			Availability (%) per 30 days	Continuity (%) over 15 min	Coverage	Fix Interval[2] (s)
	Horizontal (m)	Alert Limit (m)	Time to Alarm[2] (s)	Integrity Risk (per 3h)				
Ocean	**10**	**25**	**10**	10^{-5}	**99,8**	**N/A[1]**	**global**	**1**
Coastal	**10**	**25**	**10**	10^{-5}	**99,8**	**N/A[1]**	**global**	**1**
Port approach and restricted waters	**10**	**25**	**10**	10^{-5}	**99,8**	**99,97**	**regional**	**1**
Port	**1**	**2,5**	**10**	10^{-5}	**99,8**	**99,97**	**local**	**1**
Automatic Docking	**0,1**	**0,25**	**10**	10^{-5}	**99,8**	**99,97**	**local**	**1**

1 - Continuity is not relevant for ocean and coastal areas
2 - More stringent requirements may be necessary for ships operating above 30 knots

Accuracy and Integrity Requirements for Altitude ?
Needed for UKC ….

Requirements on Navigation & Timing Data

(GNSS)

From references such as [IMO MSC.112(73)], [IMO MSC.113(73)], [IMO MSC.114(73)], [IMO MSC.115(73)], and [IMO MSC.233(83)]:

- Several performance standards for ship borne GNSS and DGNSS receivers were developed and approved by IMO in the last decade: GPS, GLONASS, DGPS and DGLONASS, combined GPS/GLONASS, and GALILEO.

IMO MSC.233(83):

- Provide time referenced to universal time coordinated UTC (BIPM)*;
- Timing accuracy such that time is determined within 50ns of UTC;
- Integrity monitoring and alerting algorithms should be based on a suitable combination of the Galileo integrity message and receiver autonomous integrity monitoring (RAIM). The receiver should provide an alarm within 10 s Time to Alarm (TTA) of the start of an event if an alert limit of 25 m Horizontal Alert Limit (HAL) is exceeded for a period of at least 3 s
- Update rate 2 Hz (for HSC)

Unspecified:

- velocity, vertical error, …….
- type of RAIM (algorithm) and RAIM output (detection, identification, and/or adaption)

Requirements on Navigation Data

(see performance standards of other sensors)

IMO-A.382(X) MAGNETIC COMPASSES CARRIAGE AND PERFORMANCE STANDARDS	2.2 The directional error of the card, composed of inaccuracies in graduation, eccentricity of the card on its pivot and inaccuracy of orientation of the card on the magnetic system should not exceed 0.5° on any heading.
IMO-A. 424(XI) GYRO-COMPASSES	.3 The compass is said to be ''settled'' if any three readings taken at intervals of thirty minutes, when the compass is on a level and stationary base, are within a band of 0.7°. 5.2.4 The maximum divergence in reading between the master compass and repeaters under all operational conditions should not exceed ± 0.5°.
IMO MSC.116(73) PERFORMANCE STANDARDS FOR MARINE TRANSMITTING HEADING DEVICES (THDs)	Dynamic errors.* The dynamic error amplitude should be less than ±1.5°. The dynamic error frequency should be less than 0.033Hz equivalent to a period not shorter than 30s if the amplitude of the dynamic error exceeds ±0.5°; and

IMO MSC.96(72): PS for speed & distance devices
IMO MSC.74(69): PS for echo sounding
……

Conclusion – 3

(Gaps)

- **Performance standards** per sensor are the normal case.
  - Different documents with inhomogeneous description result into difficult comparability
  - The sensor based performance standards are improper to introduce/specify integrity requirements (only possible, if redundancy is available)
  - Improvement of reliability and indication of reliability requires the specification of a common set of requirement types, which should be applied to all navigation relevant sensors and systems: accuracy, precision, integrity, availability, continuity
  - Implicates the introduction of identifiers (parameters) describing the reliability in a common and unambiguous manner
  - Generally, accuracy requirements are given for specific output data (single P or N or T data).

Conclusion – 4

(Gaps)

- **Completeness of requirements** should be achieved:
  - A common meaning of data and system integrity is necessary
  - Introduction of a common performance requirement structure (accuracy, precision, integrity, availability, continuity)
  - A common definition of precision is necessary, if it is proposed as an additional requirement
  - A scalability of integrity is necessary with respect to the degree of applied facilities and services (downward and upward compatibility, presence and availability of equipments)

Conclusions – 5

(Approaches)

- **Sensor or output data driven (system driven approach) Performance Standards ?**
  - Sensor driven PS
    - Current situation – not necessarily the correct approach
  - Output data driven performance standards
    - supports the scalability and completeness of requirements
    - supports the establishment of the universal maritime data model
    - allows the application of different sensor and system combinations (modular and open architecture, minimum set of sensors)
    - supports the scalability with respect to service areas and applications
    - can reduce the number and the realisation process of PS in the frame of e-navigation
    - enables the crossover from current state (minimum) to e-navigation (maximum resp. user needs)
    - to achieve the desired improvement of PNT resilience, fallback modes (with reduced accuracy) should not be ruled out by this approach.

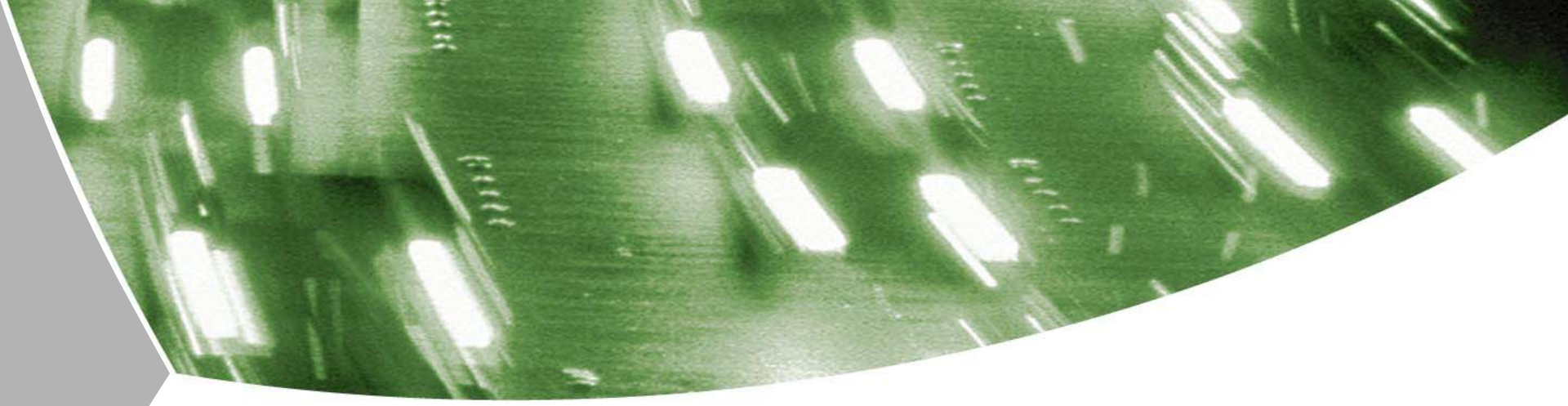
Conclusions – 6

(Approaches)

- **….continuation**

  Sensor or output data driven (system driven approach) PS?

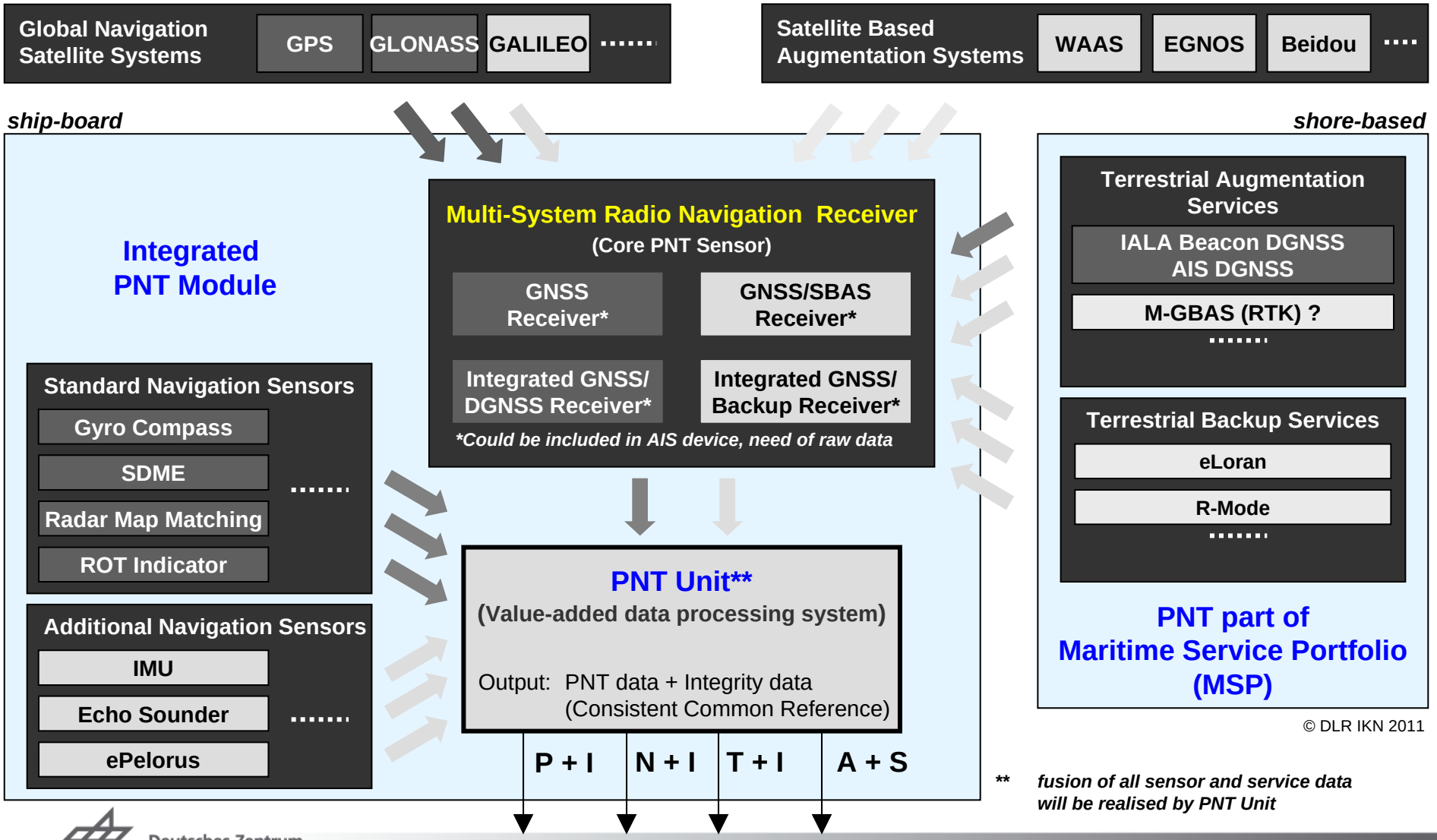
  - Introduction of output data driven performance standards requires rethinking of PS realisation and coordination with other PS activities e.g. INS
  - PNT source data can be influenced by single point failures (e.g. GNSS time) – this needs to be considered in the determination of overall output data integrity
    - To identify such single point failures, land-based reference PNT modules should be considered.



Action Item 2.1

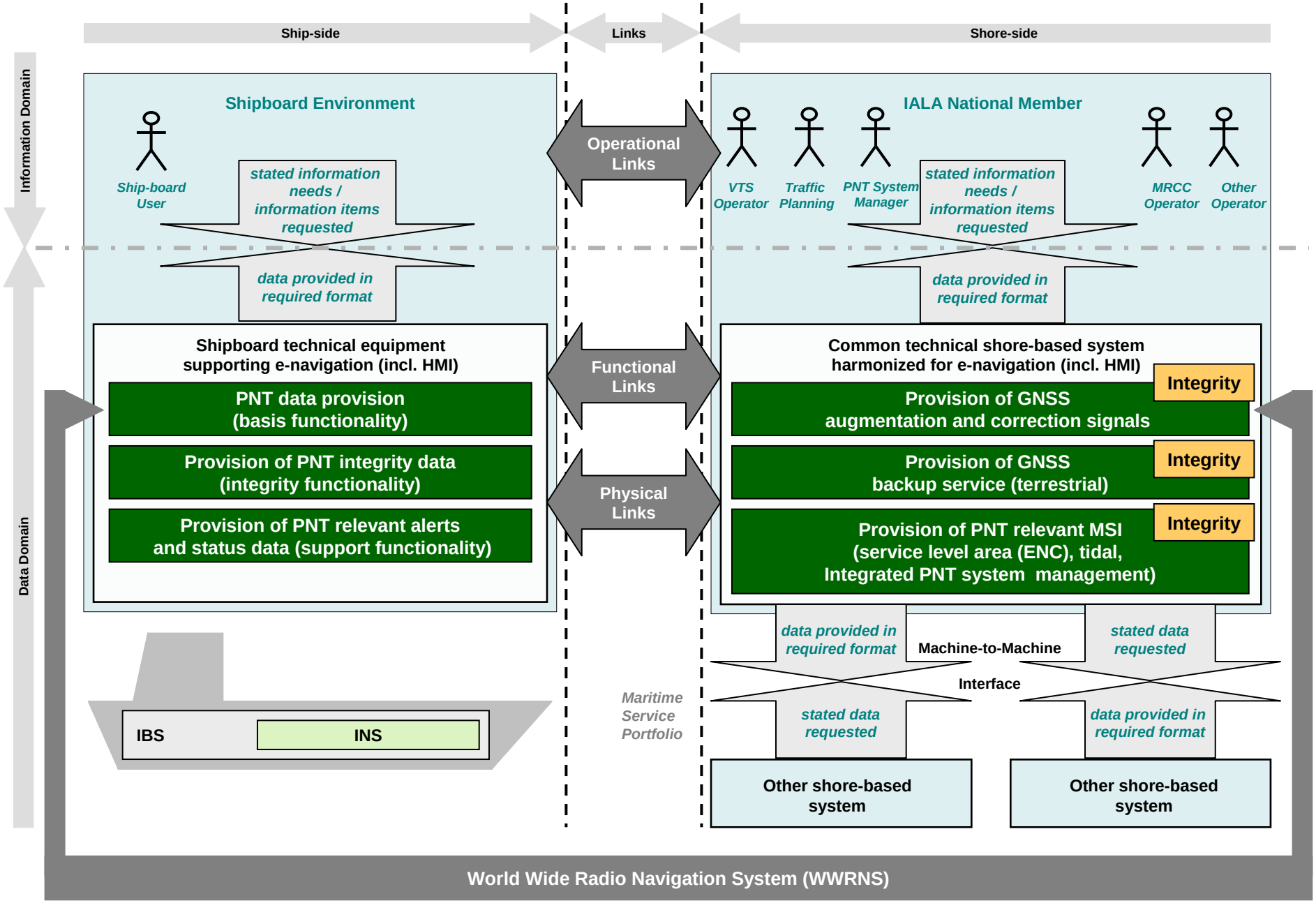
Current Architecture (sensors and services) and Gaps

Overview of PNT components

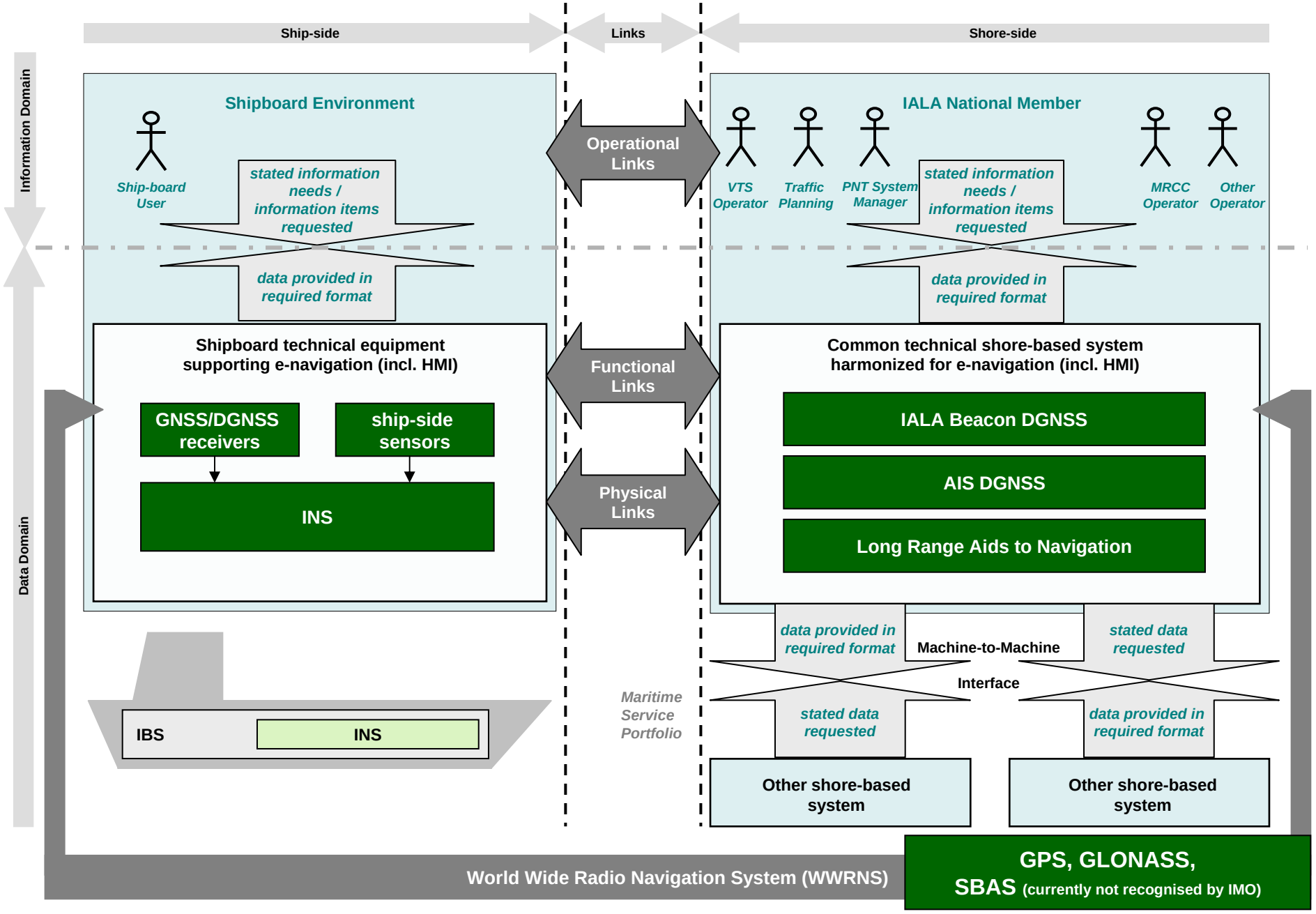


** *fusion of all sensor and service data will be realised by PNT Unit*

Target PNT Functionalities



Architecture (current state)



Sensors and services for PNT data provision

Current:
- GNSS Receiver
- Transmitting Heading Device
- Gyrocompass
- ROT Indicator
- Speed and Distance Measuring Equipment (SDME)

(Echolot, ENC, Radar are available)

In discussion or work:
- New INS standard under development.
- E-navigation user needs for PNT (improvement of resilience, etc.).
- AIS version 2 (next generation AIS)

Current:
- IALA Beacon DGNSS (coast)
- AIS DGNSS (coast, ports)
- Long Range Aids to Navigation

(SBAS is available, but not recognised)

In discussion or work:
- Modernisation of IALA Beacon DGNSS (e.g. VRS to fulfil coast and may be port requirements)
- M-GBAS (RTK) to fulfil port and docking requirements
- PPP
- GNSS backup (coast): eLoran, R-Mode

Approaches to fulfil user needs with respect to basis functionality and integrity functionality

Integrity by INS – 1

Source: IEC 61924-2 CD © IEC:2011 (80/10A /CD wg draft 0102)

(MSC.252(83)/5.5.1) ***The integrity of data* shall *be monitored and verified automatically before being used, or displayed.***

(MSC.252(83)/5.5.2) ***The integrity of information* shall *be verified by comparison of the data derived independently from at least two sensors and/or sources, if available.***

(MSC.252(83)/5.5.3) ***The INS* shall *provide manual or automatic means to select the most accurate method of integrity monitoring from the available sensors and/or sources.***

(MSC.252(83)/5.5.4) ***A clear indication of the sensors and sources of data selected for integrity monitoring* shall *be provided.***

(MSC.252(83)/5.5.5) ***The INS* shall *provide a warning, if integrity verification is not possible or failed.***

The results of integrity monitoring are:

- **Passed = integrity verification passed**
- **Failed = integrity verification not passed**
- **Doubtful = integrity verification not possible**

***yellow: primary output data**

In this standard handling of integrity is as minimum required for following navigation data: **position, heading, stw, sog, cog, depth.**

Integrity by INS – 2

Source: IEC 61924-2 CD © IEC:2011 (80/10A /CD wg draft 0102)

The system shall provide at least following methods for integrity monitoring.

- Position: comparison between two EPFS
- Position: comparison between EPFS and dead reckoning using ship's heading and SDME
- Heading: comparison between two heading sensors

The system shall provide at least one of following methods for integrity monitoring

- Speed through water: comparison between two STW sensors
- Speed through water: comparison with a SOG from SDME
- Speed through water: comparison with a SOG from EPFS

The system shall provide at least one of following methods for integrity monitoring

- Speed and course over ground: comparison between two longitudinal/transversal ground speeds from SDME together with a heading
- Speed and course over ground: comparison with a STW sensor together with a heading sensor
- Speed and course over ground: comparison with a SOG and COG from EPFS

The system shall provide at least one of following methods for integrity monitoring

- Depth: comparison with a second depth sensor
- Depth: comparison with data from largest available ENC chart

The system may provide following methods for integrity monitoring.

- Heading: comparison between heading sensor and COG sensor when SOG is high enough for reliable comparison

Integrity by INS – 3

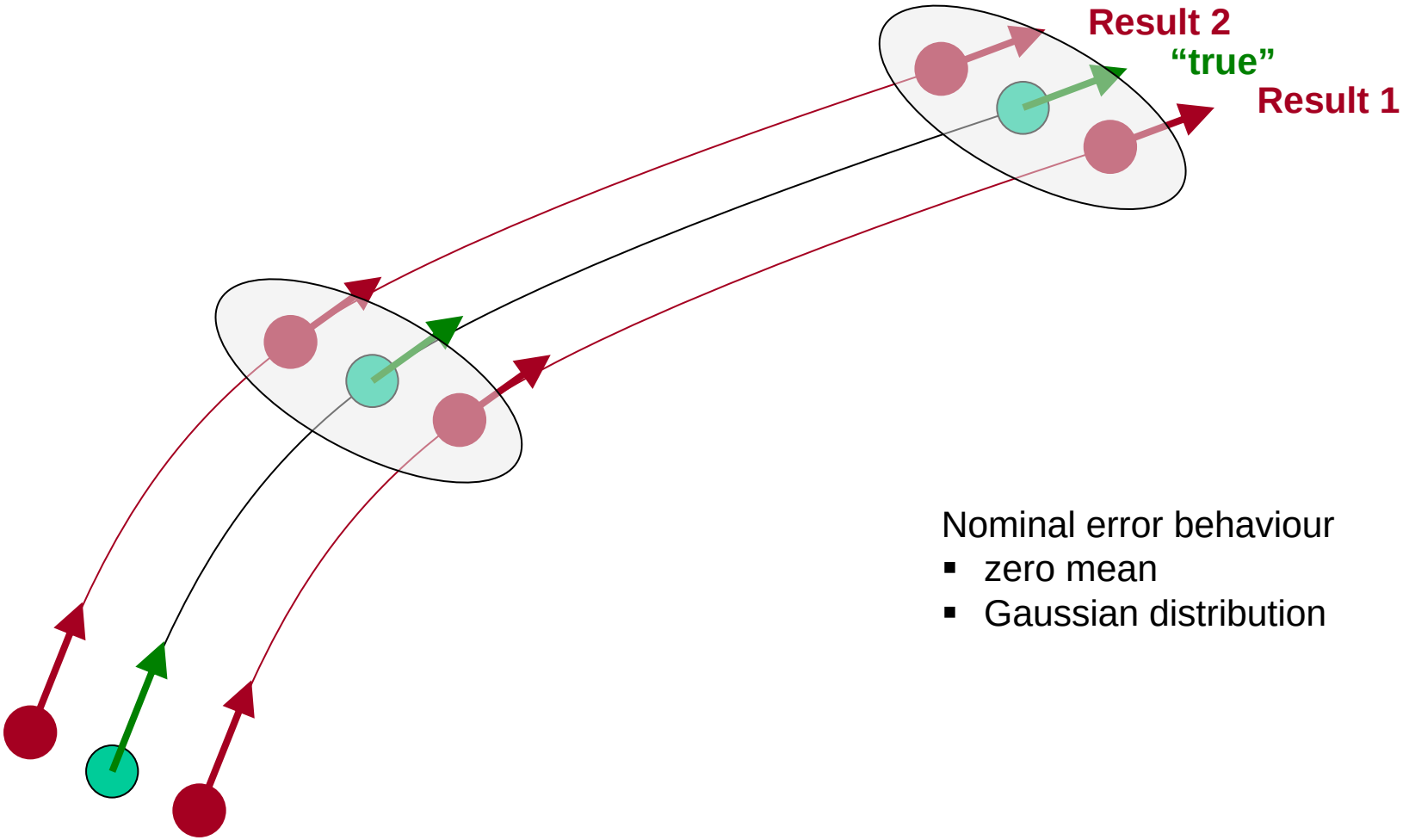
Source: IEC 61924-2 CD © IEC:2011 (80/10A /CD wg draft 0102)

- **(MSC.252(83)/5.5.6) *Data which fails the integrity monitoring function or data where integrity monitoring is not possible* shall *not be used for automatic control systems/functions.***
  - Note: In the above cases for track control the fall-back arrangements specified for unavailable sensor data have to be followed.
  - Note: If integrity monitoring of heading data or speed data is not possible the requirements of paragraph MSC.252(83)/12.7 for fallback arrangements and maintaining minimum basic operation shall be followed for heading control (see 6.7.1.9).

Demand on:

- **Harmonised specification of methods for**
  - **consistency and plausibility tests**
  - **selection routines (“best PNT result”)**
  - **accuracy assessment (integrity functionality)**

Error Scenarios



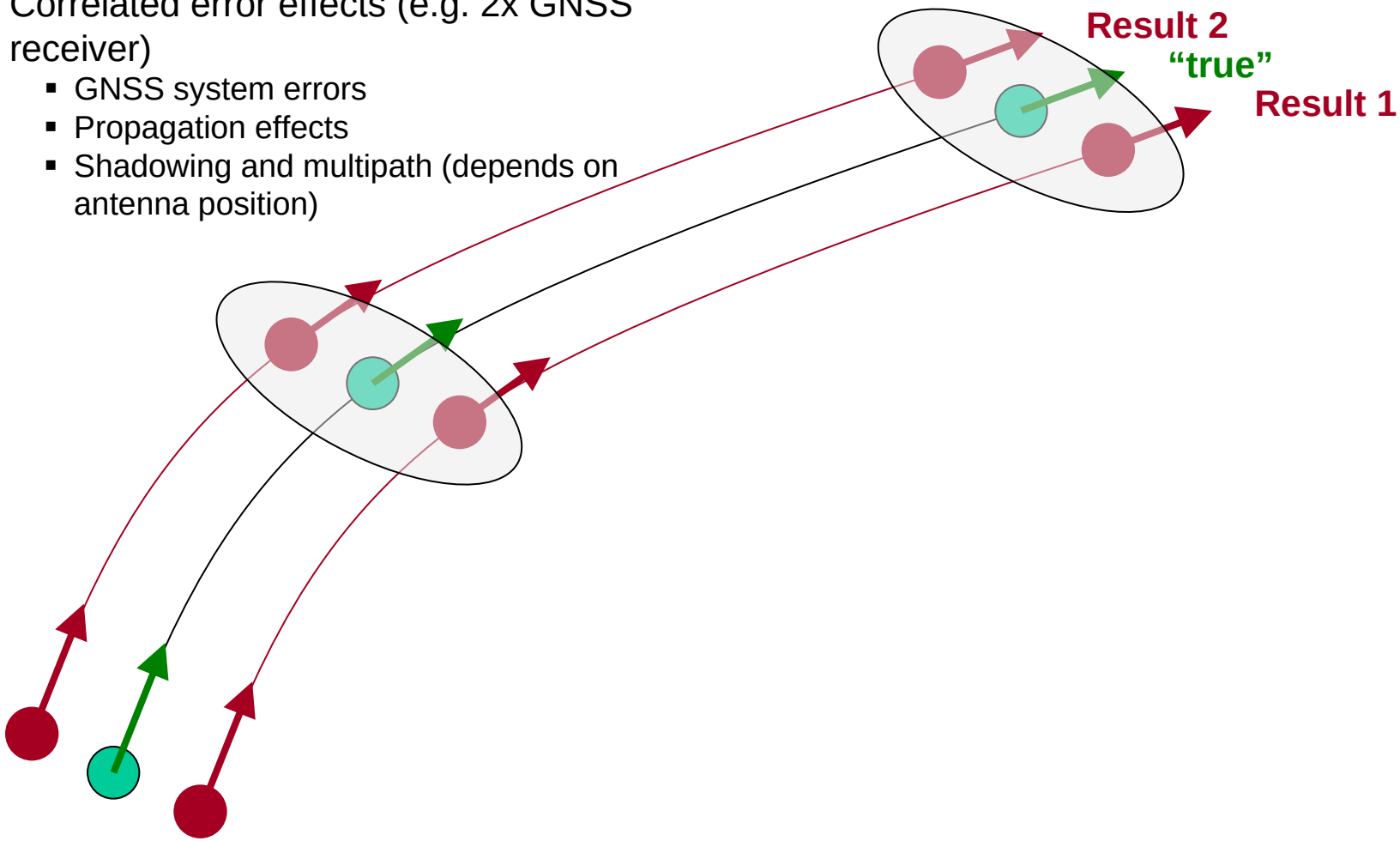
Nominal error behaviour

- zero mean
- Gaussian distribution

Error Scenarios

Correlated error effects (e.g. 2x GNSS receiver)

- GNSS system errors
- Propagation effects
- Shadowing and multipath (depends on antenna position)



Conclusions – 7

Gap: Scalability (level and complexity) of Integrity

Clarification is necessary, what does integrity really mean?

- **Lowest Level: Plausibility checks**
  - based on thresholds or value ranges
  - requires complete and fixed specification of thresholds and value ranges
  - enables only the detection of large errors outside the nominal error ranges

- **Medium Level: Consistency check based on comparison of results of different sensors:**
  - supports only the assessment of relative accuracy
  - uncorrelated (avoiding single point data propagation) measurement techniques should be aimed to improve the number of detectable errors in comparison to undetectable errors
  - an unambiguous result of consistency checks requires specified criteria based on identical determination methods ➔ harmonisation
  - for unambiguous identification of best PNT data and/or best integrity monitoring functionality the specification of selection method is necessary (indication of reliability)

Conclusions – 7 (continuation)
Gap: Scalability (level and complexity) of Integrity

Clarification is necessary, what does integrity really mean?

- **High Level: Estimation of accuracy and assessment:**
  - How the accuracy can be estimated: monitoring, measurement model, fusion engine to assume multiple hypotheses approach …?
  - Different methods can result in different integrity results: harmonisation?
  - How the terrestrial services could support the ship-side integrity monitoring?

- **The maturity of the chosen approach corresponds to the inverse of the integrity level – the complexity reflects the potential benefit.**

GNSS Augmentation Systems

(current)

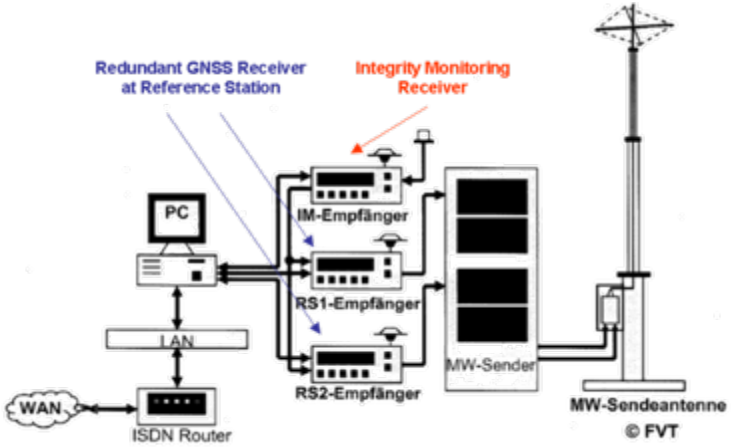
Aim

- Increase accuracy of GNSS based positioning by application of C-DGNSS
- Accuracy assessment (integrity) by monitoring of GNSS/DGNSS (LIM, FFIM)
- Provision of C-DGNSS related integrity information to fulfil coast requirements - port requirements can be fulfilled by multi-GNSS approach?

Practice

IALA Beacon DGNSS (IALA R-121):

- Fulfilment of IMO coast requirements
- Provision of C-DGNSS corrections (PRC, RRC) and integrity information



Completion

AIS Base Station (IALA A-124):

- Provision of C-DGNSS and integrity corrections via AIS VHF Data Link (Message 17)

Channel capacity !

Modernisation of IALA Beacon DGNSS:

- Exchange and modernisation of GNSS receiver equipment
- Cost-efficient approaches for services (VRS concept)

To be clarified:
Needs port an absolute or a relative position ?

Conclusions – 8

(Development demand and completion)

- **Modernisation of IALA Beacon DGNSS**
  - **running activity**
  - **should target the improvement of integrity functionality:**
    - demand on harmonisation of integrity monitoring concept (LIM, FFIM)
    - Specification of suitable message types for instance containing improved integrity information
    - unambiguous specification of assessment methods and applied thresholds
    - certification of safety-critical services (MSP) ?
  - **should support multi-GNSS approach (redundancy) and performance driven utilisation concept (scalability of accuracy and integrity)**
    - different single-frequency and multi-frequency services per available GNSS
    - different single-frequency and multi-frequency services per applicable GNSS combination

Harmonisation and modernisation of IALA Beacon DGNSS

Conclusions – 8

(Development demand and completion)

- **Completion of PNT relevant MSP**
  - **Identification and standardisation of new PNT relevant services**
    - to fulfil port and docking requirements in the future
    - to reduce the vulnerability of GNSS based services by provision of suitable backup services
  - **Introduction of new services results in additional requirements on ship-side radionavigation receivers**

Harmonisation of PNT relevant ship-side and shore-side developments: reliability, integrity, …