Resilient PNT:
From PNT-Unit concept to first realization

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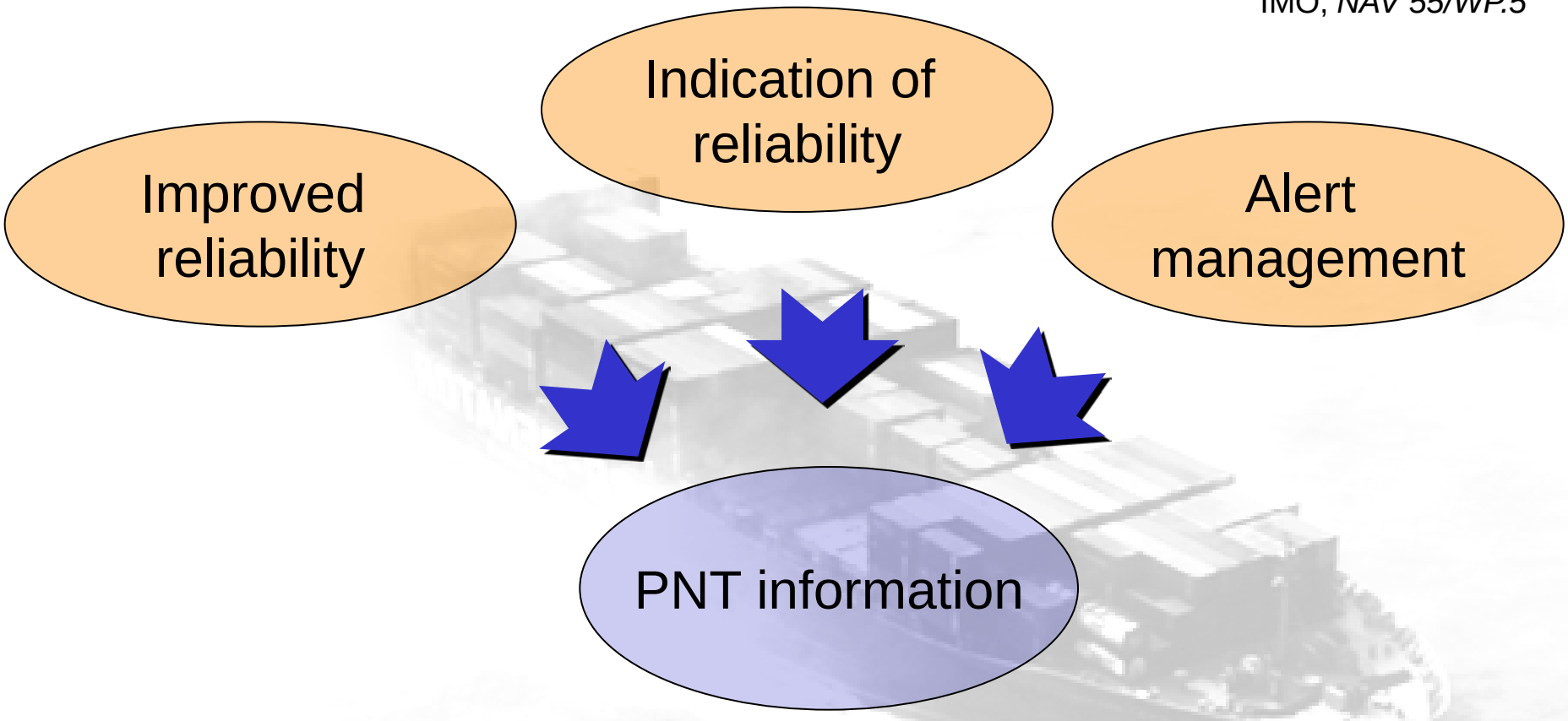
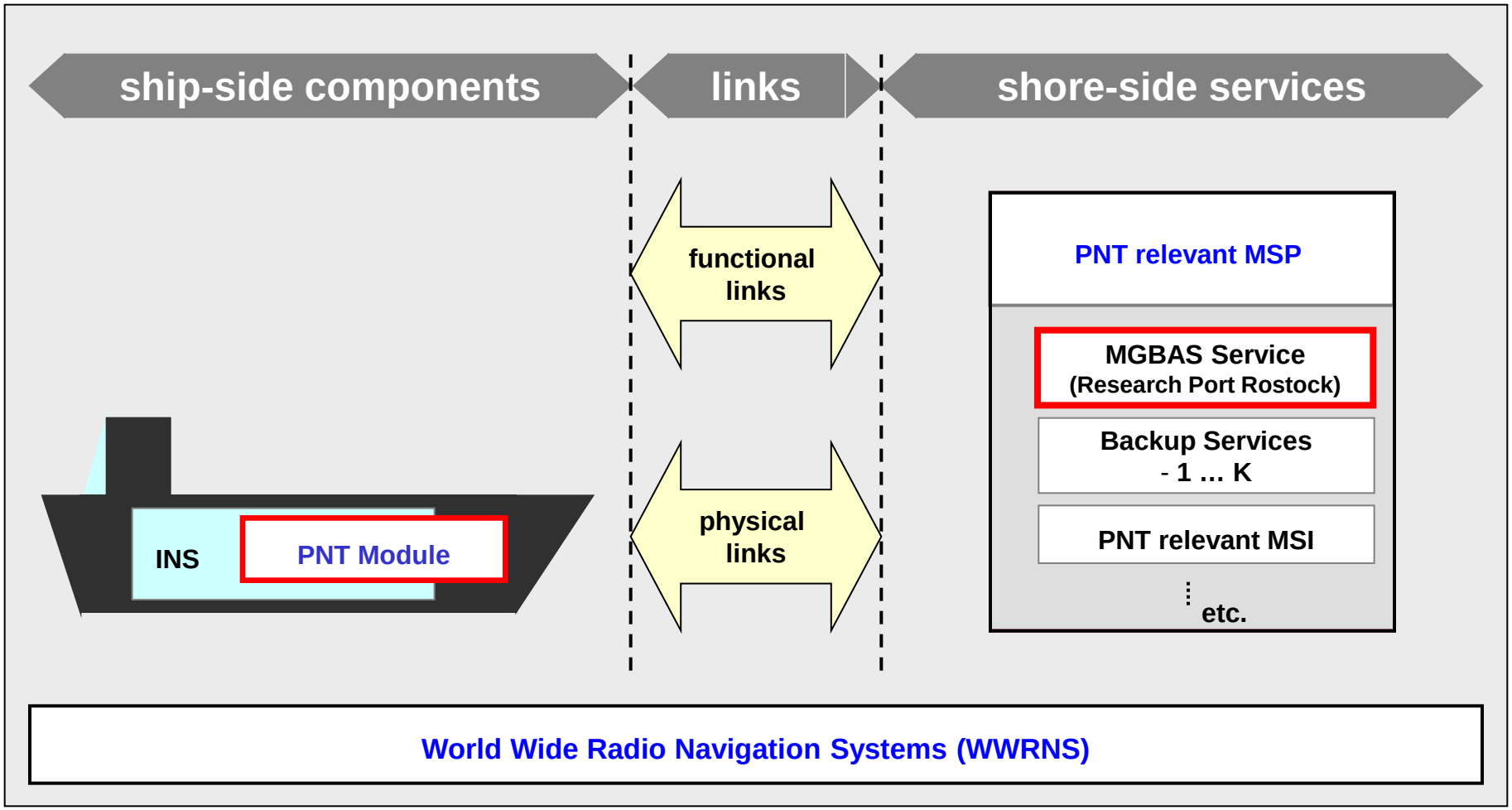
PNT relevant user needs within E-Navigation

IMO, *NAV 55/WP.5*



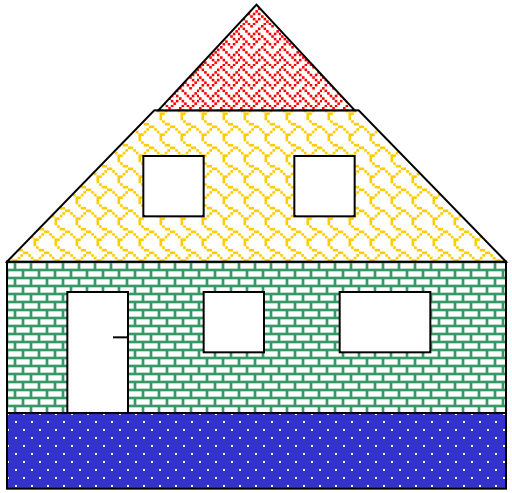
PNT System
Generic Architecture



Integrity definitions

- ***IMO Integrity Definition:*** (IMO Resolution A.915(22) Requirements for a future GNSS)
  The ability to provide users with warnings within a specified time when the system should not be used for navigation

General structure of GNSS service specification



Availability

Continuity

Integrity: timely (TTA) warning, based on accuracy estimation
⇒Protection level (PL): bounds true error under consideration of remaining integrity risk
⇒Available: PL < Alert limit (AL)

Accuracy: The degree of conformance between the estimated or measured parameter of a craft at a given time and its true parameter at that time. (95% confidence)

From service to user level integrity

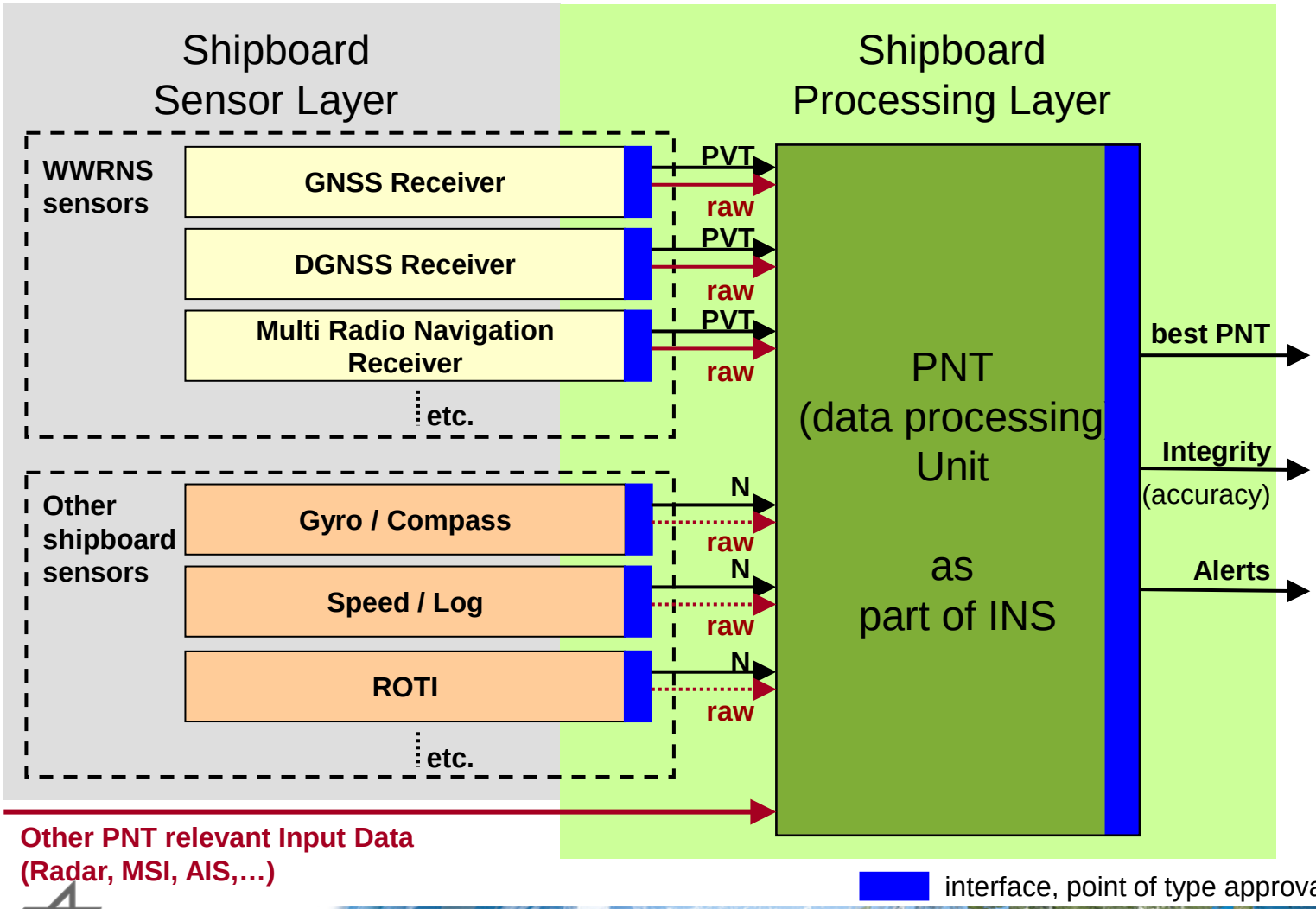
Current user level integrity definition

- ***IEC INS standard*** (61924:2006)
  property of information as being accurate and valid with regard to specified requirements and verified by comparing data from more than one independent source

large gap between service level integrity and user level integrity

1st. Approach: Establish user level integrity comparable to GNSS service specification (based on accuracy estimation) onboard the vessel
=> Over bound all possible errors (threads)

PNT Unit Approach



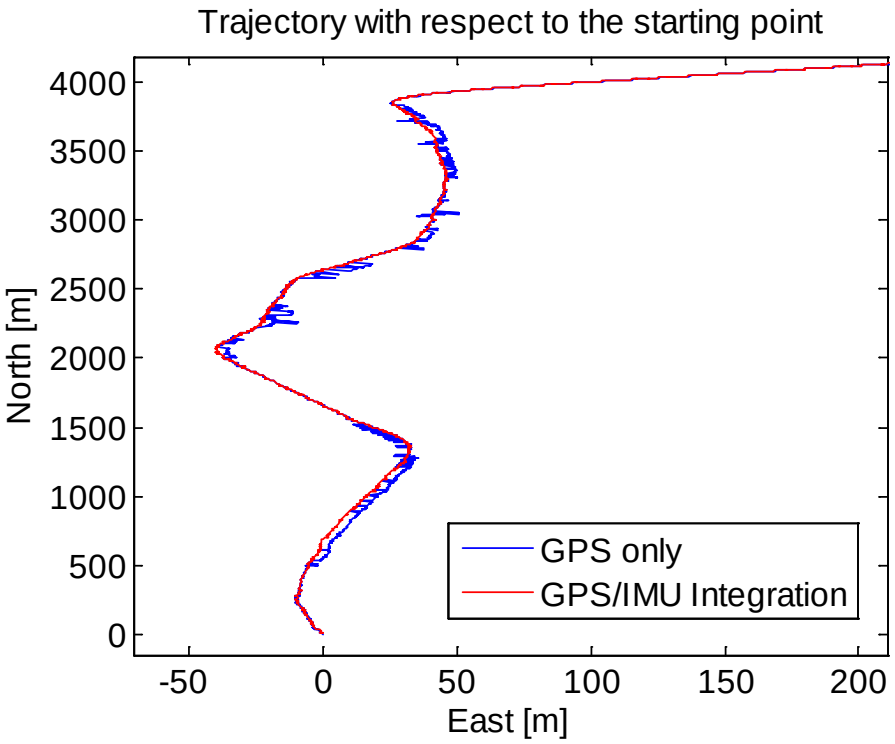
Measurement campaigns

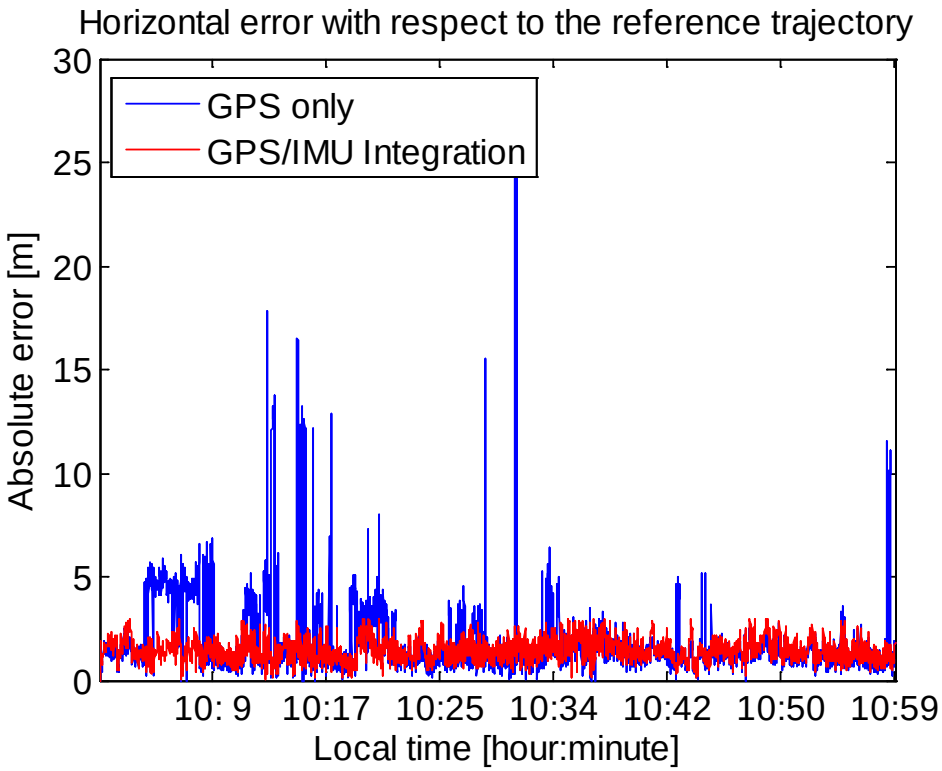
- Survey and research vessel DENEB (BSH)

Additional sensors

- Tactical grade IMU
- 3x GNSS receiver (dual frequency RTK)

Tightly coupled GPS/IMU

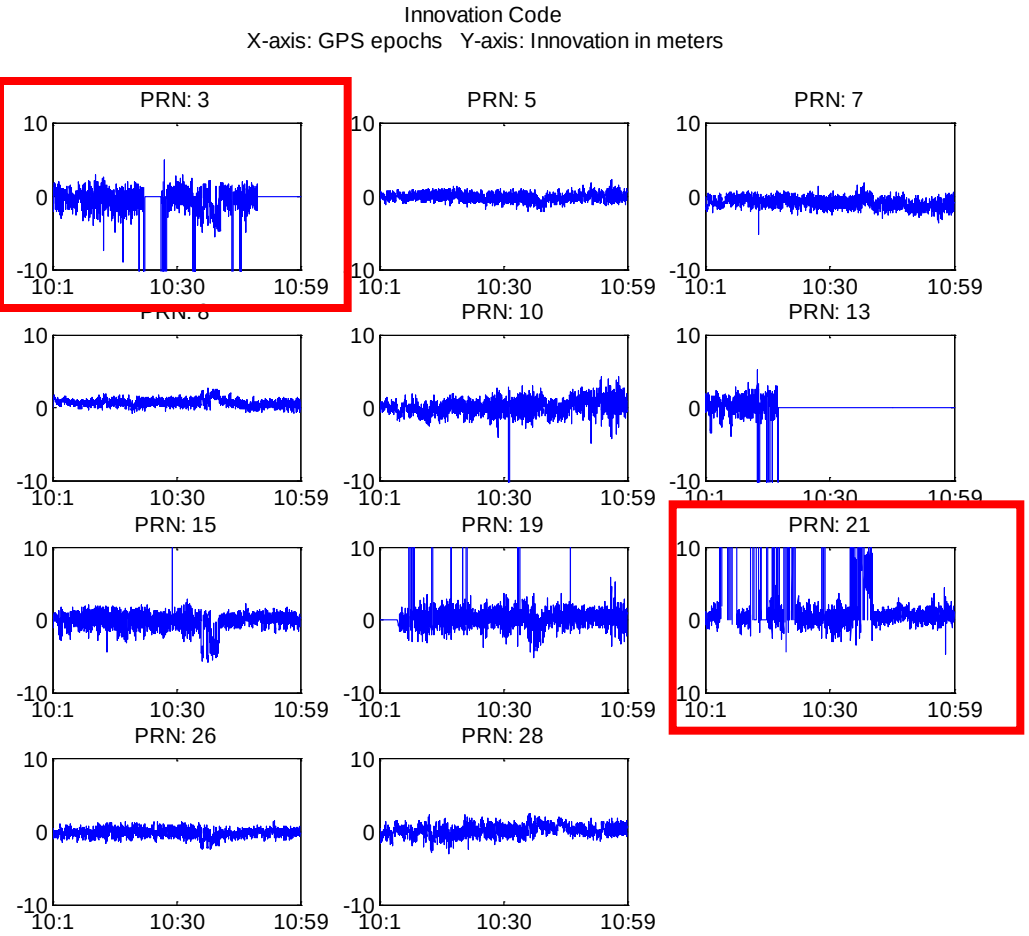


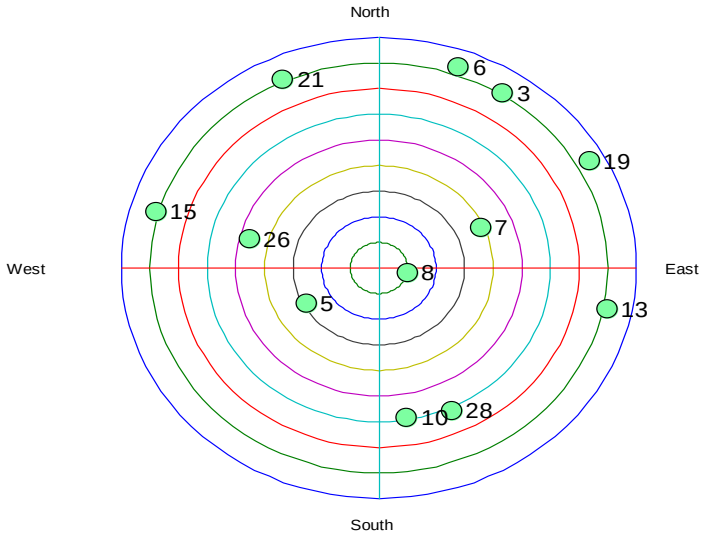


Tightly-coupled GPS/IMU integration with satellite filtering

Accuracy improvement

Innovation of satellites



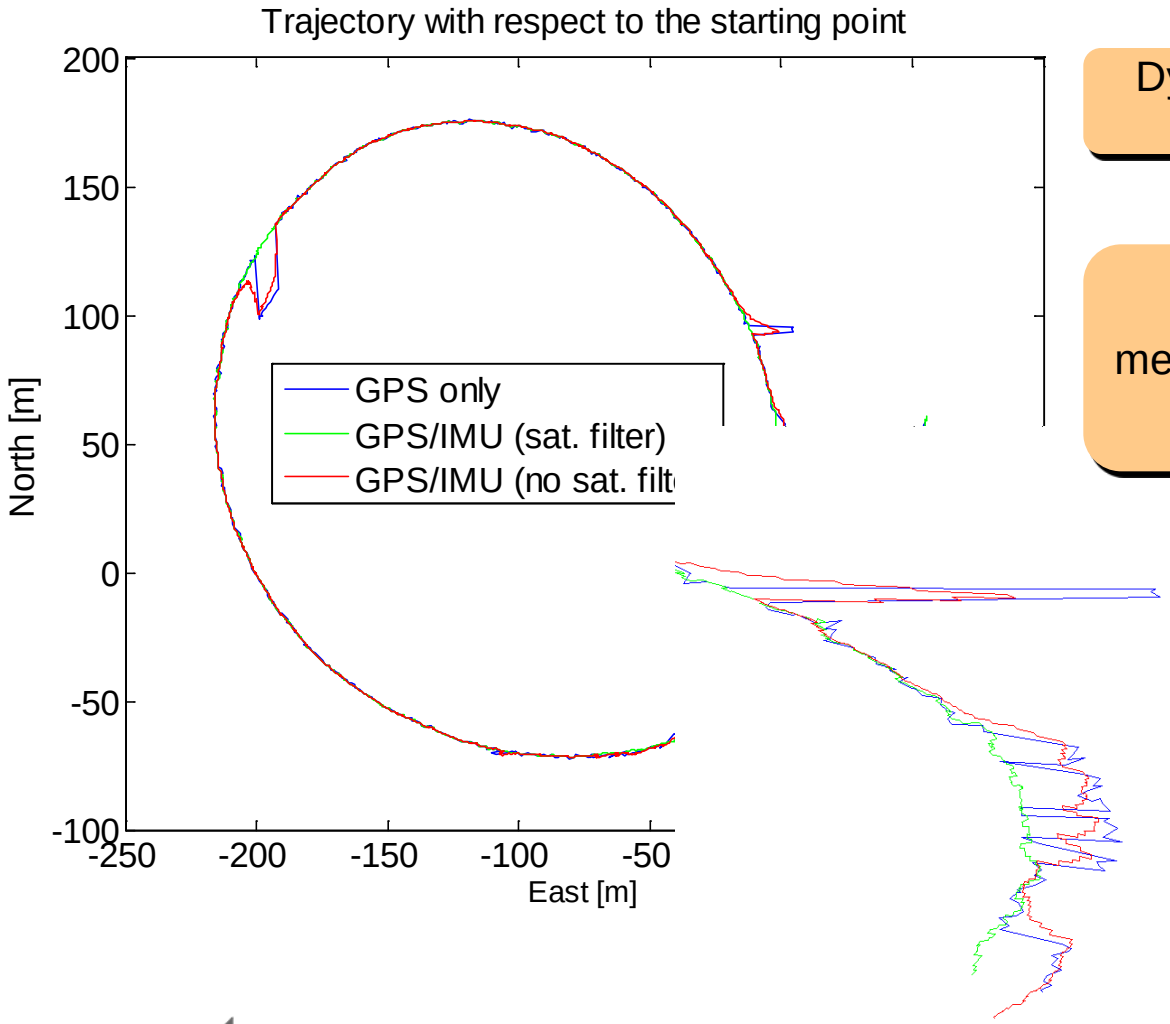


Satellites with low elevation angles

Spurious Measurements

Cancellation

Integration with/without satellite filtering



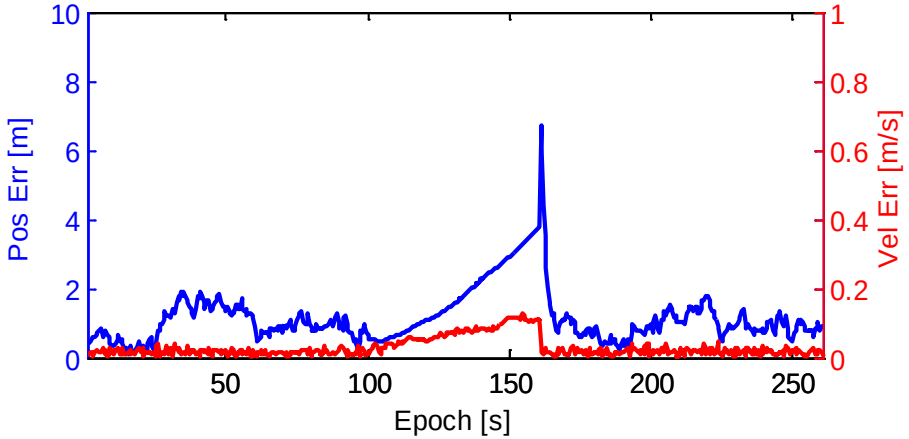
Dynamic model (herein IMU) can smooth the positioning results

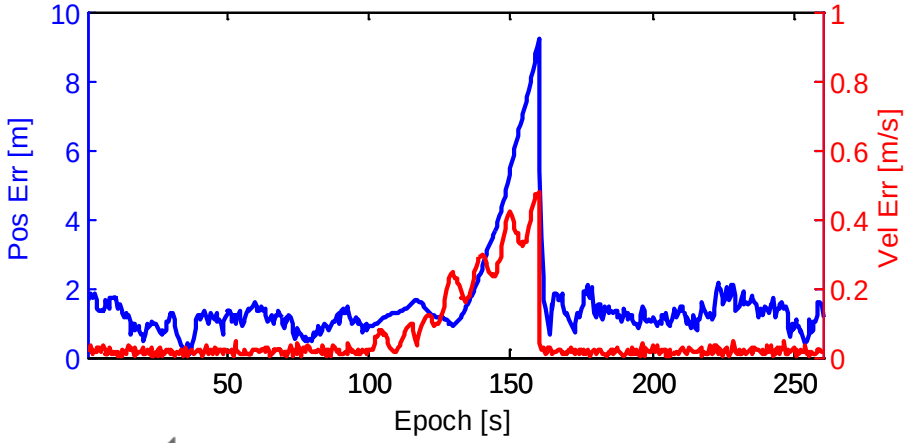
Integrity monitoring on each measurement has dominant effects in the accuracy improvement

IMU contingency functionality

- tightly coupled IMU / GNSS stand alone

-1 min GNSS outage





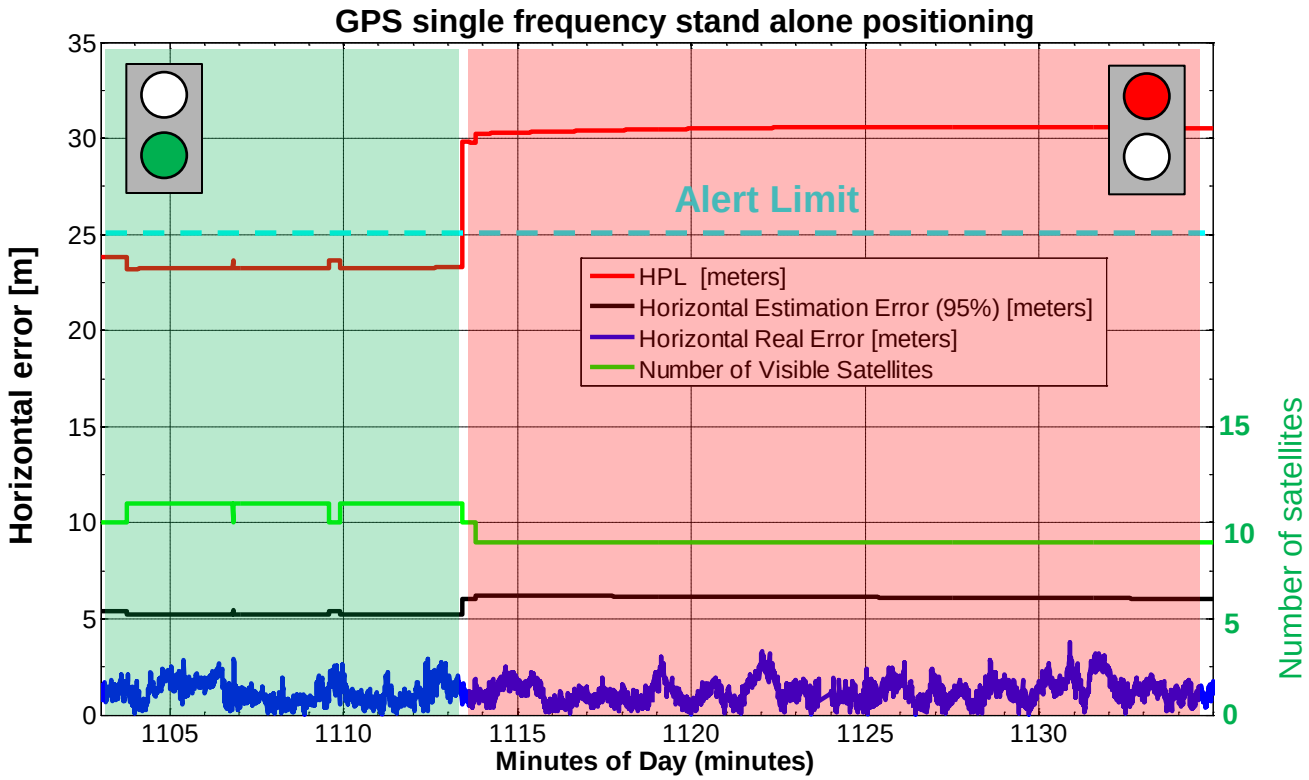
⇒ ~10m position error with tactical grade IMU

⇒ Next step: GNSS / IMU / speed log integration

Accuracy estimation

- adaptation of existing RAIM algorithm (developed for aviation sector) to maritime requirements

IMO A.915(22)	Absolute Accuracy	Integrity		
	Horizontal (m)	Alert Limit (m)	Time to Alarm[2] (s)	Integrity Risk (per 3h)
Ocean	10	25	10	10^{-5}
Coastal	10	25	10	10^{-5}



PNT Unit interface
Open question:

Input interface

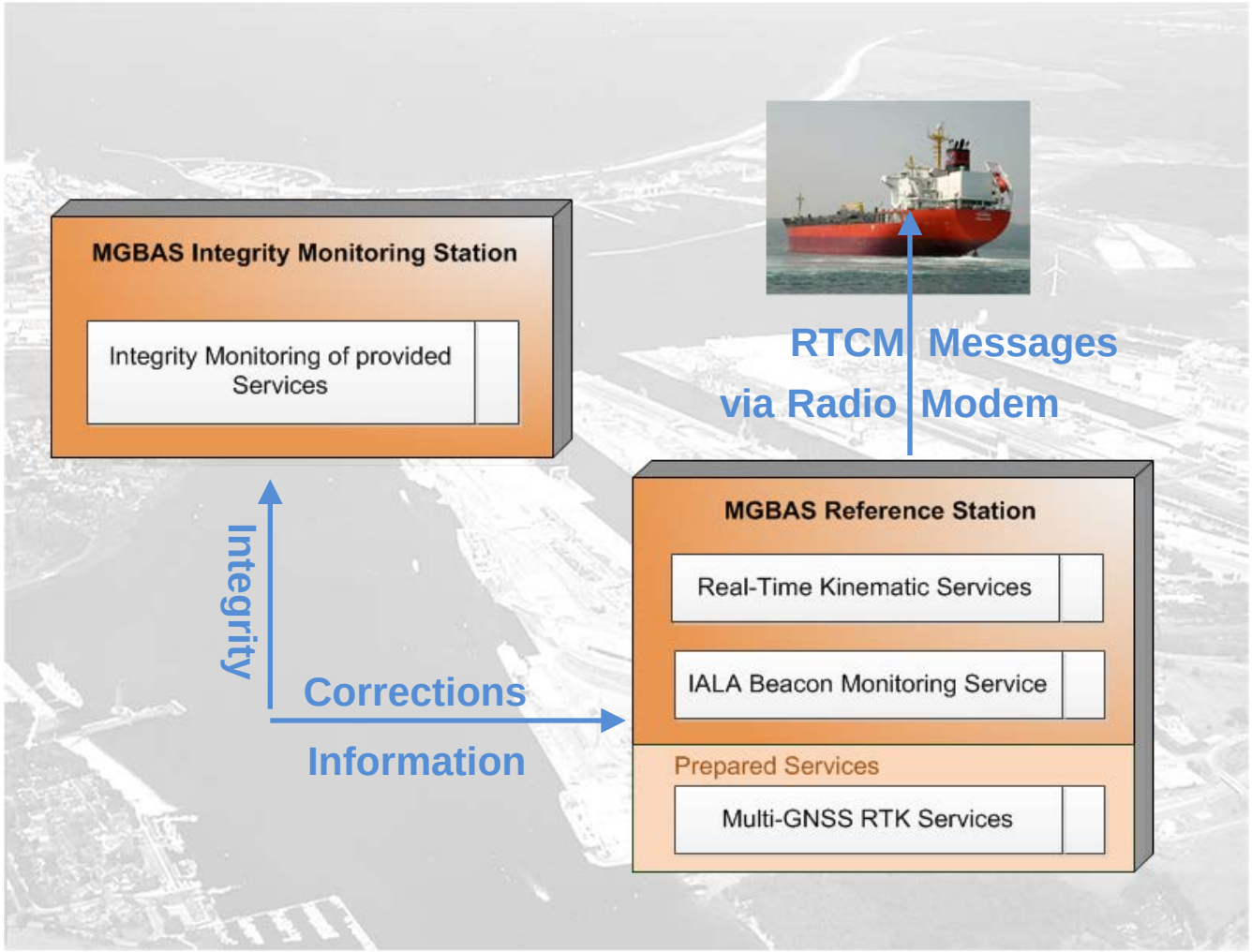
- accuracy, integrity, continuity, availability for all PNT paramter depended on the operational region

⇒How this information about current operational region is transferred to PNT Module?
- ENC layer ?

Output interface:

- What integrity information should be delivered how?

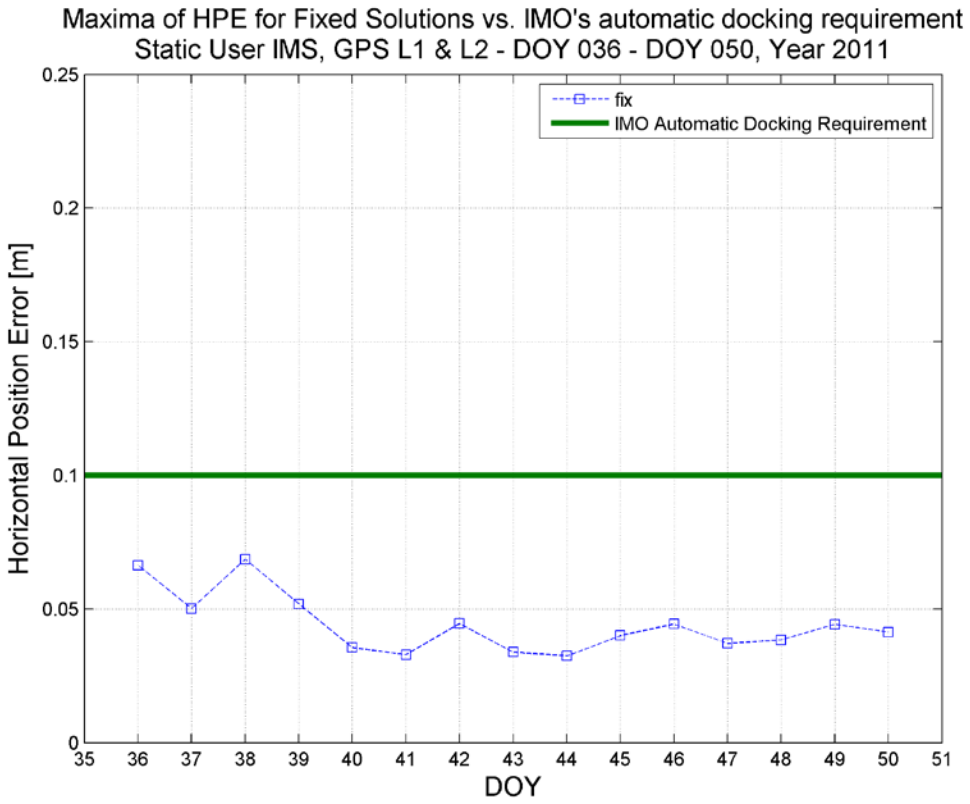
Currently available MGBAS Services at Research Port Rostock for Validation of aboard PNT-unit



MGBAS: RTK Services

- Goal: fulfill IMO's port requirements regarding accuracy, integrity, continuity and availability

- Status:
  - two GPS-based RTK services
  - GALILEO-based and multi-GNSS services in preparation

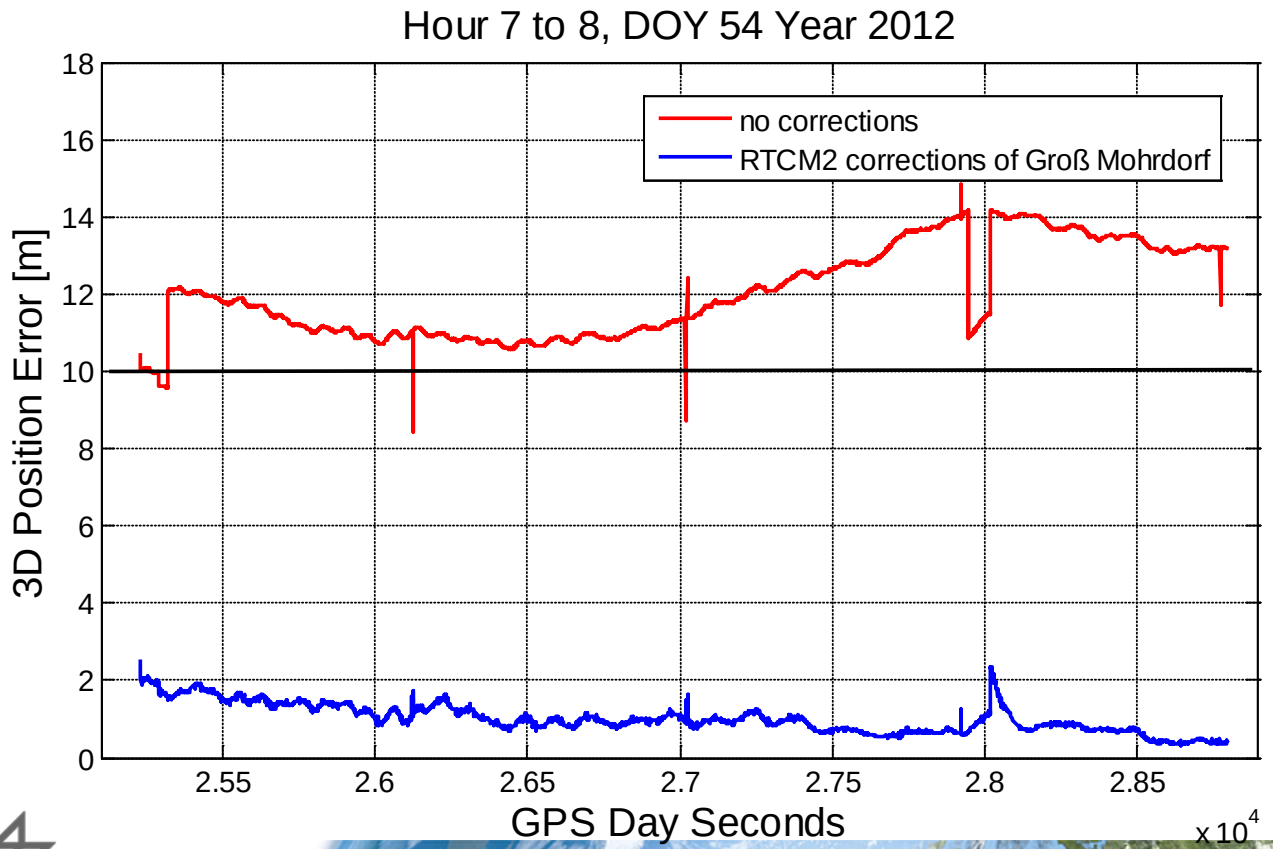


Minimum Requirements on Future GNSS
Extract of IMO A.915(22)

	System Level Parameters			
	Absolute Accuracy	Integrity		
	Horizontal (m)	Alert Limit (m)	Time to Alarm[2] (s)	Integrity Risk (per 3h)
Ocean	10	25	10	10^{-5}
Coastal	10	25	10	10^{-5}
Port approach and restricted waters	10	25	10	10^{-5}
Port	1	2,5	10	10^{-5}
Automatic Docking	0,1	0,25	10	10^{-5}

MGBAS: IALA Beacon Monitoring Service

- MGBAS as integrity monitor for RTCM2 messages
- Assessment of IALA beacon DGNSS corrections as backup for RTK services



Summary

- Initial realization of a sensor fusion based PNT Unit
  => improved integrity monitoring incl. accuracy estimation
  => IMU contingency functionality

- **Open questions:**
  - **clear definition of user level integrity**
  - **input: operational region**
  - **output: HMI for integrity information**

- Shore base services at Research Port Rostock
  - MGBAS (RTK) service for high precision application
  - IALA Beacon monitor

Thank You For Your Attention !

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