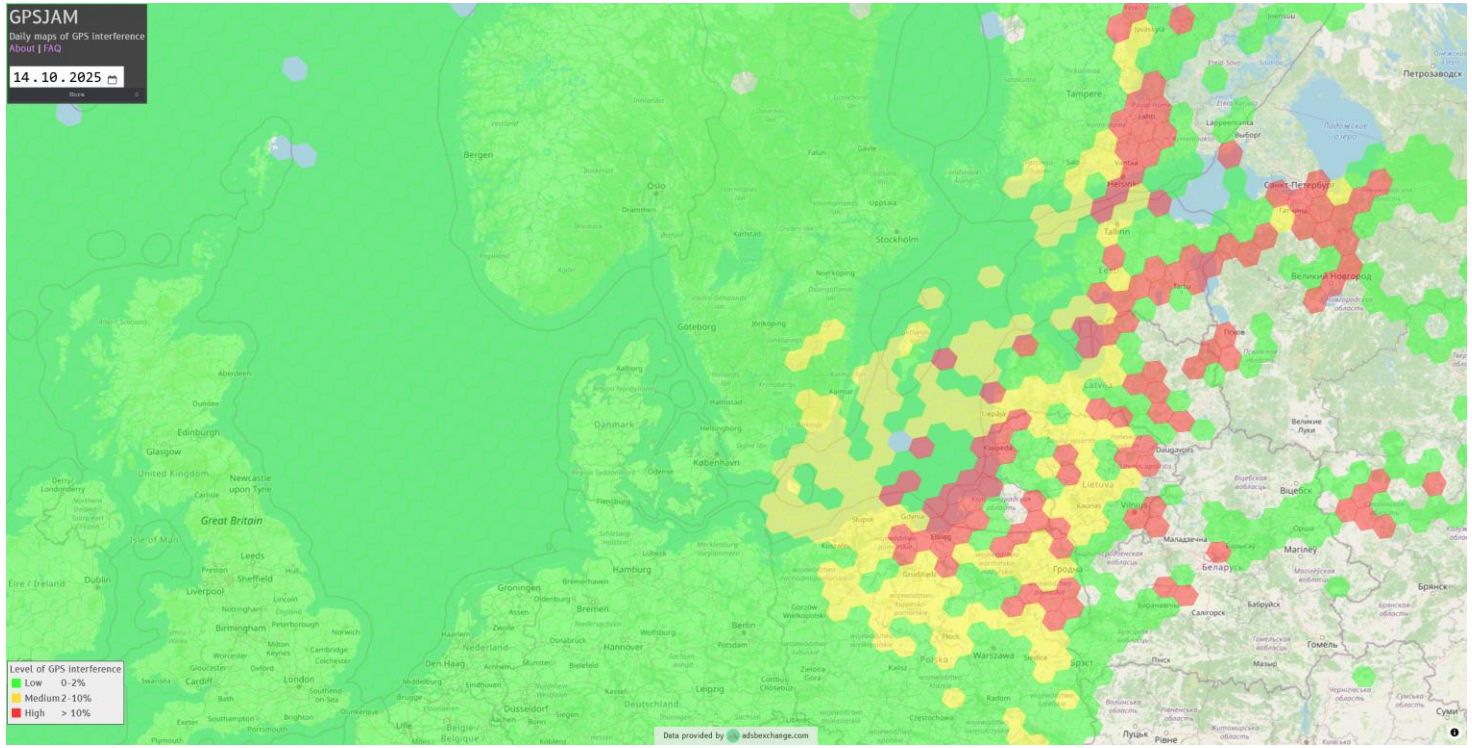
MARITIME AND INLAND WATERWAY APPLICATIONS AT DLR

Christoph Lass, Hakan Uyanik, Stefan Gewies, Lars Grundhöfer, Niklas Hehenkamp, Filippo Giacomo Rizzi

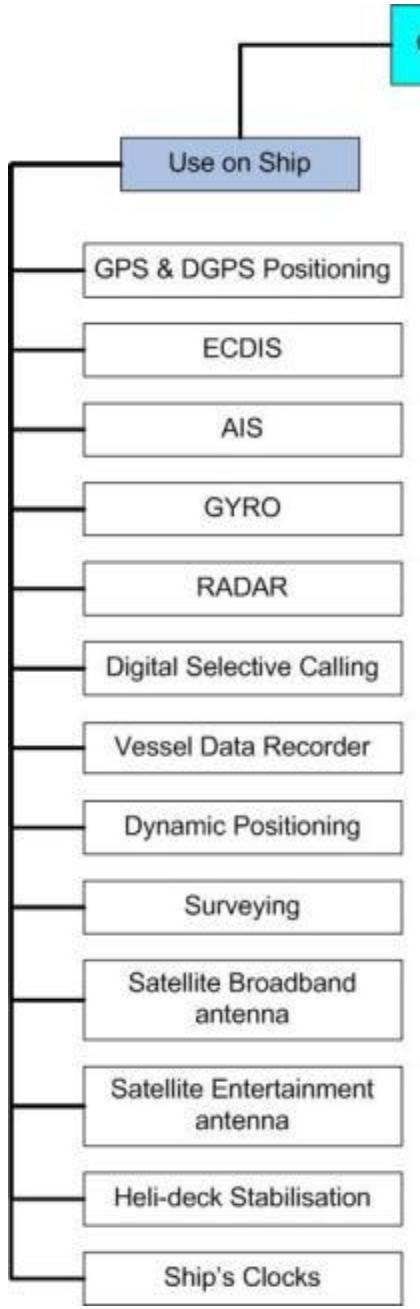
DLR

Dependency of shipping on GNSS

- GNSS provides position and timing for vessel systems
- Ships are prone to GNSS interferences
- Risk for collisions, groundings and disruption of operational processes



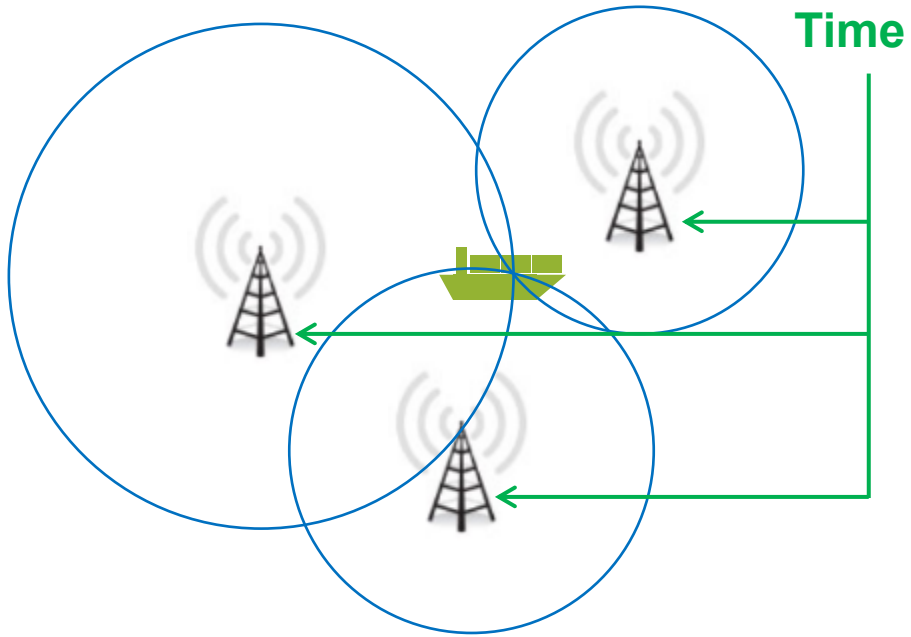
*Jamming attacks detected over the Baltic Sea Region on 14 October 2025 by using ADS-B reports. (**Source: gpsjam.org**).*



Missing alternatives to GNSS → R-Mode

R(anging)-Mode is a terrestrial positioning system that

- transmits timely synchronized ranging signals
- uses existing maritime radio infrastructure
- uses multilateration to determine position (2D)



Based on two subsystems:	
MF DGNSS IALA Beacons • FDMA @ 285.5-325 kHz • Ground-wave propagation • Coverage ~250 km • MF testbed operational in the Baltic Sea with 9 transmitters	**VHF Data Exchange System (VDES)** • TDMA @ 160 MHz • LOS propagation • Coverage depends on Tx-Rx height and obstacles

MF R-Mode positioning principles

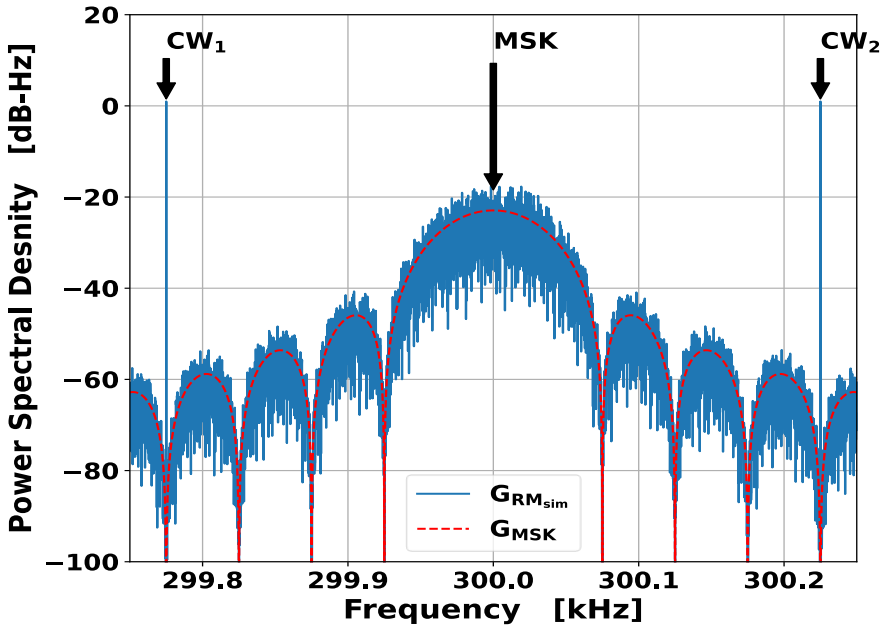
Transmitter

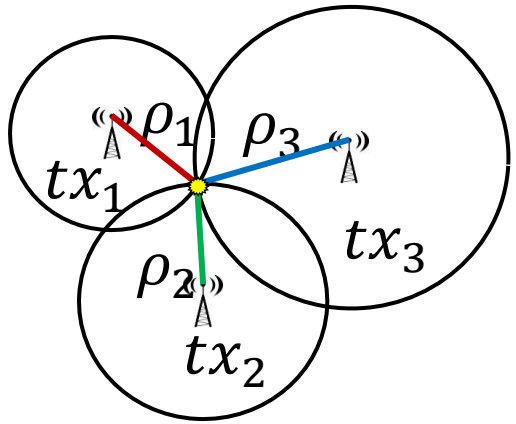
- Transmission of legacy DGNSS information with minimum shift keying (MSK)
- Synchronized transmission of continuous wave (CW) signals

Receiver

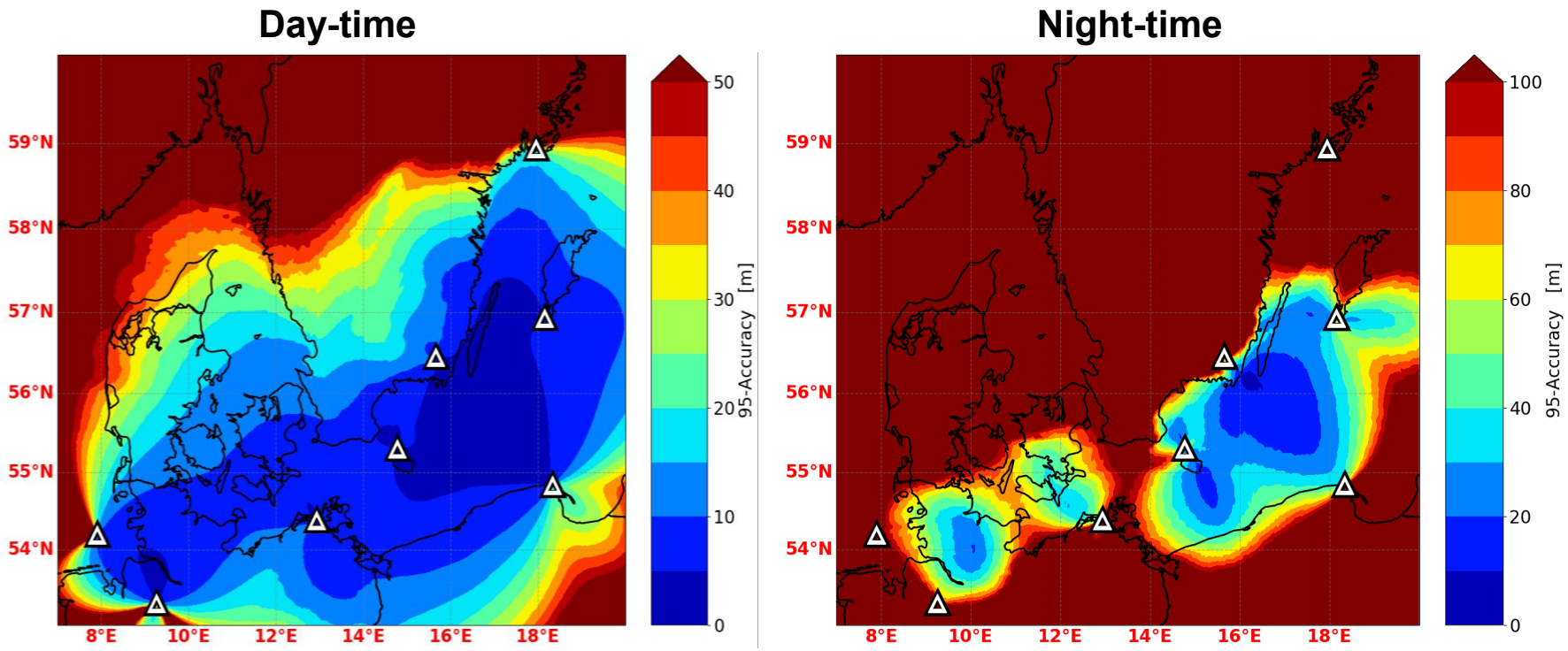
- Phase observations $(\phi_{CW_1}, \phi_{CW_2})$
- Ambiguity resolved by using beat signal phase or initial calibration (with a known location)
- Pseudorange are generated by tracking the phase

Position and time estimation with weighted least squares or Kalman filter





MF R-Mode test bed positioning accuracy prediction (95%) – Current transmitters



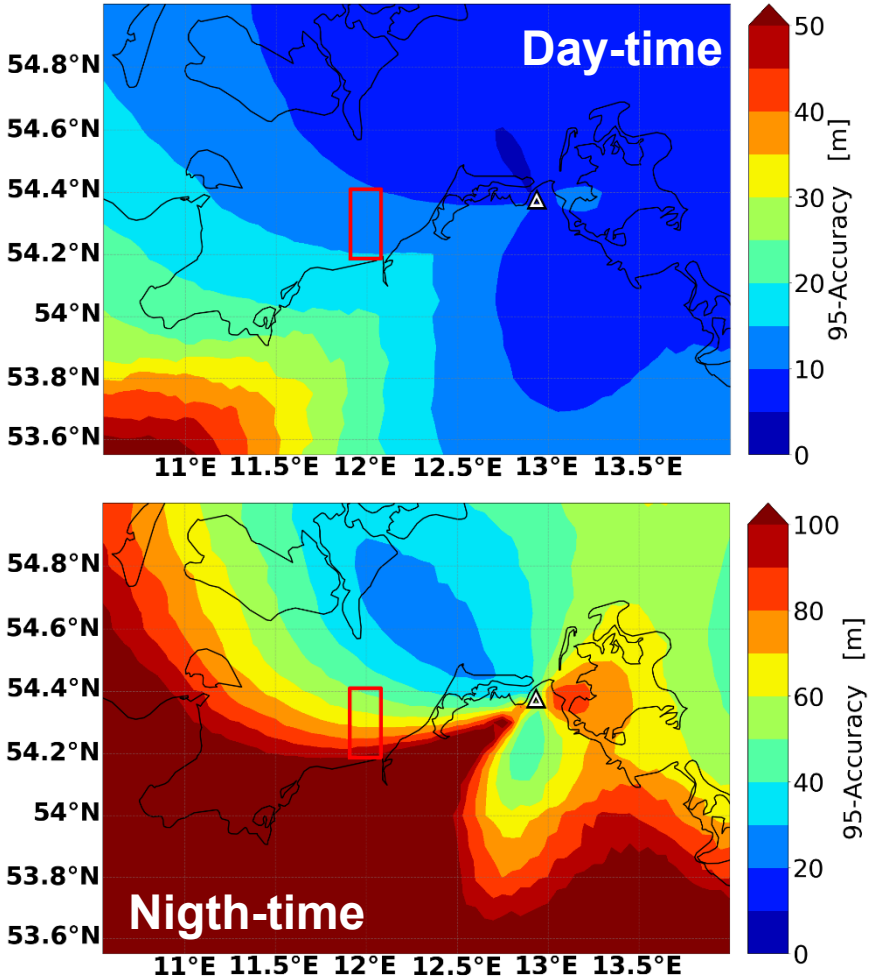
[1] Data source: MF/VDES R-Mode Coverage Prediction and Accuracy Estimation, GRAD, RPT-39-JSa-20, December 2020.

- Day: 10 m accuracy between Helgoland and Gotland
- Night: Reduced performance due to sky-wave induced fading and poor geometry

Dynamic MF R-Mode performance

- Performance assessment under dynamic conditions (95%) with estimation of biases at the beginning of the measurement
  - Day: 16 m
  - Night: 51 m

➢ **Theoretical bounds are comparable with measured performance**

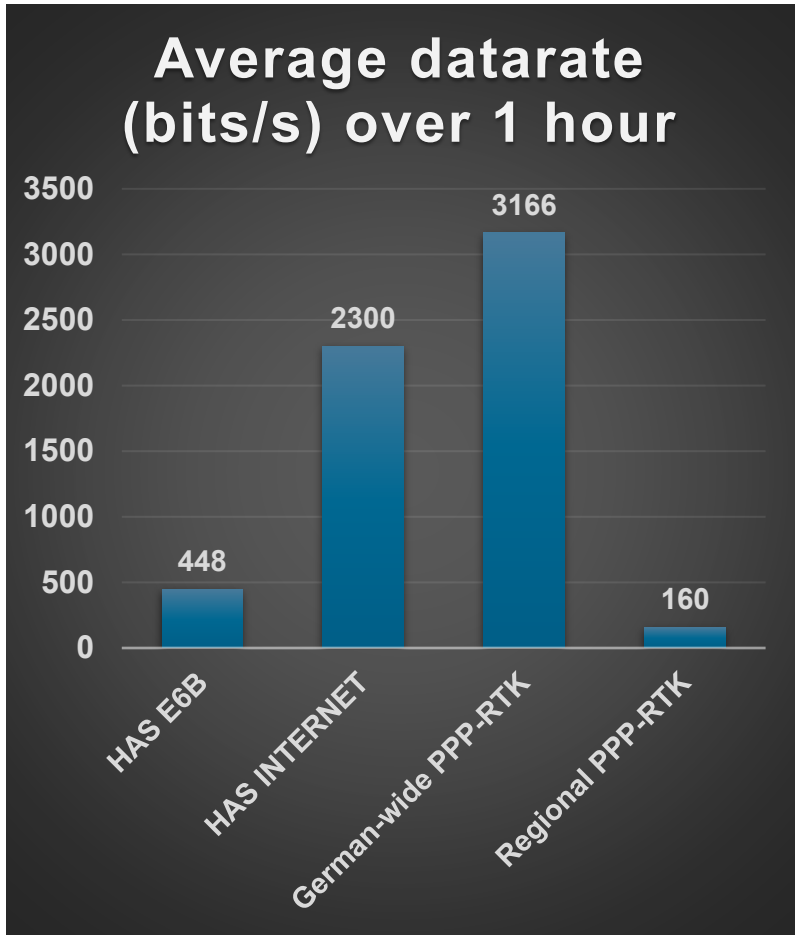


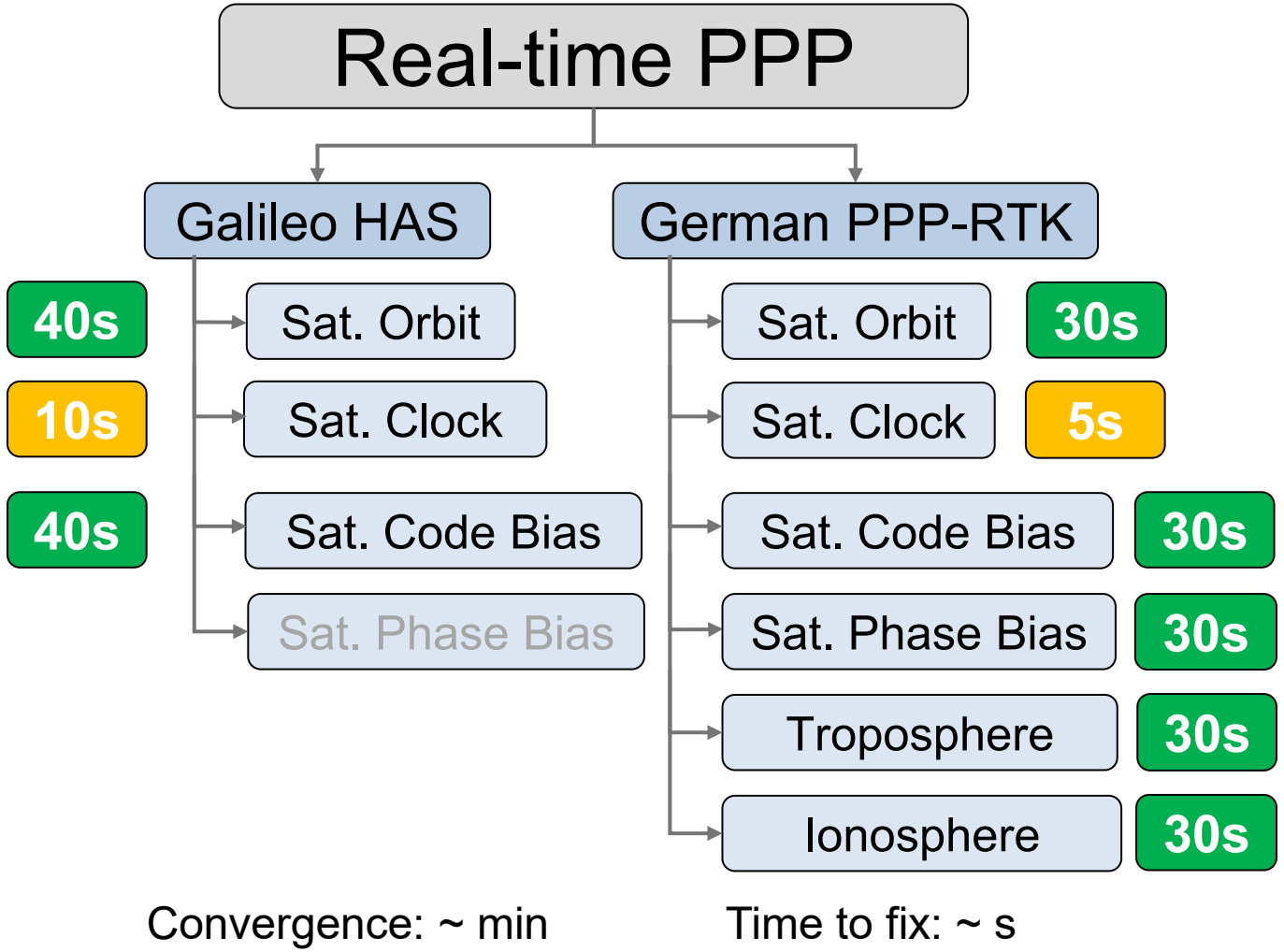
Project ORMOBASS

Operational R-Mode Baltic Sea System to support resilient navigation

- Project from 11/2023 to 10/2026
- Extension of MF R-Mode to Finland and Estonia
- Implementation of core functionalities (central monitoring, provision of navigation data for MF)
- First operational VDES base stations with R-Mode support
- GNSS interference detection system
- Prototype GNSS + MF R-Mode receiver
- Develop framework for joined operation of R-Mode in the BSR
- Research and validation
- Support R-Mode standardisation (IALA, IMO, RTCM, IEC, IUT-R)

Real-time PPP

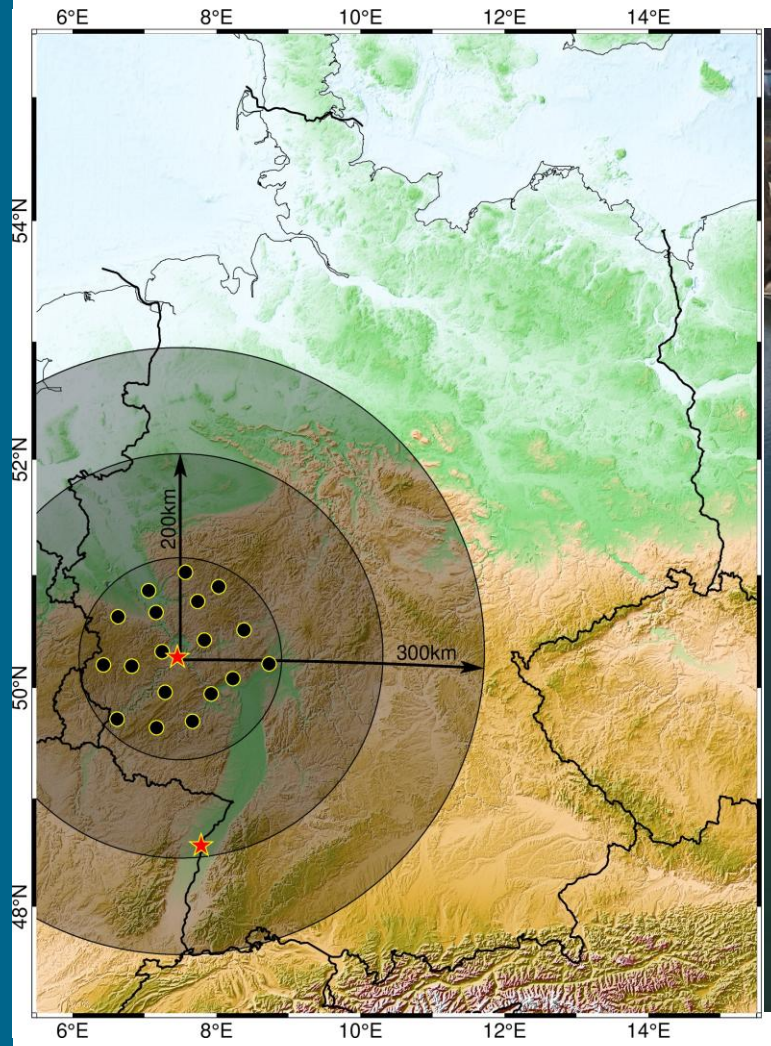




Convergence: ~ min

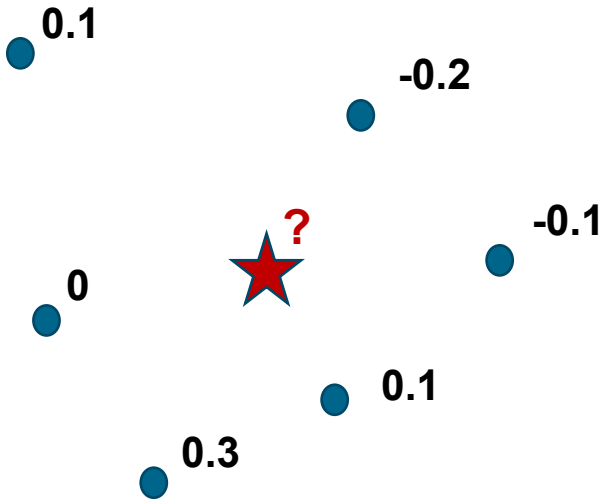
Time to fix: ~ s

First automated entering of a waterway lock using PPP-RTK GPS+GALILEO in Strasbourg

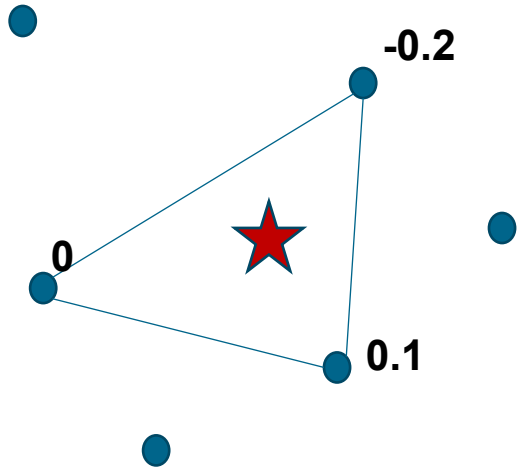


Gridded corrections and interpolation

- Gridded ionosphere and troposphere corrections only for stations‘ coordinates

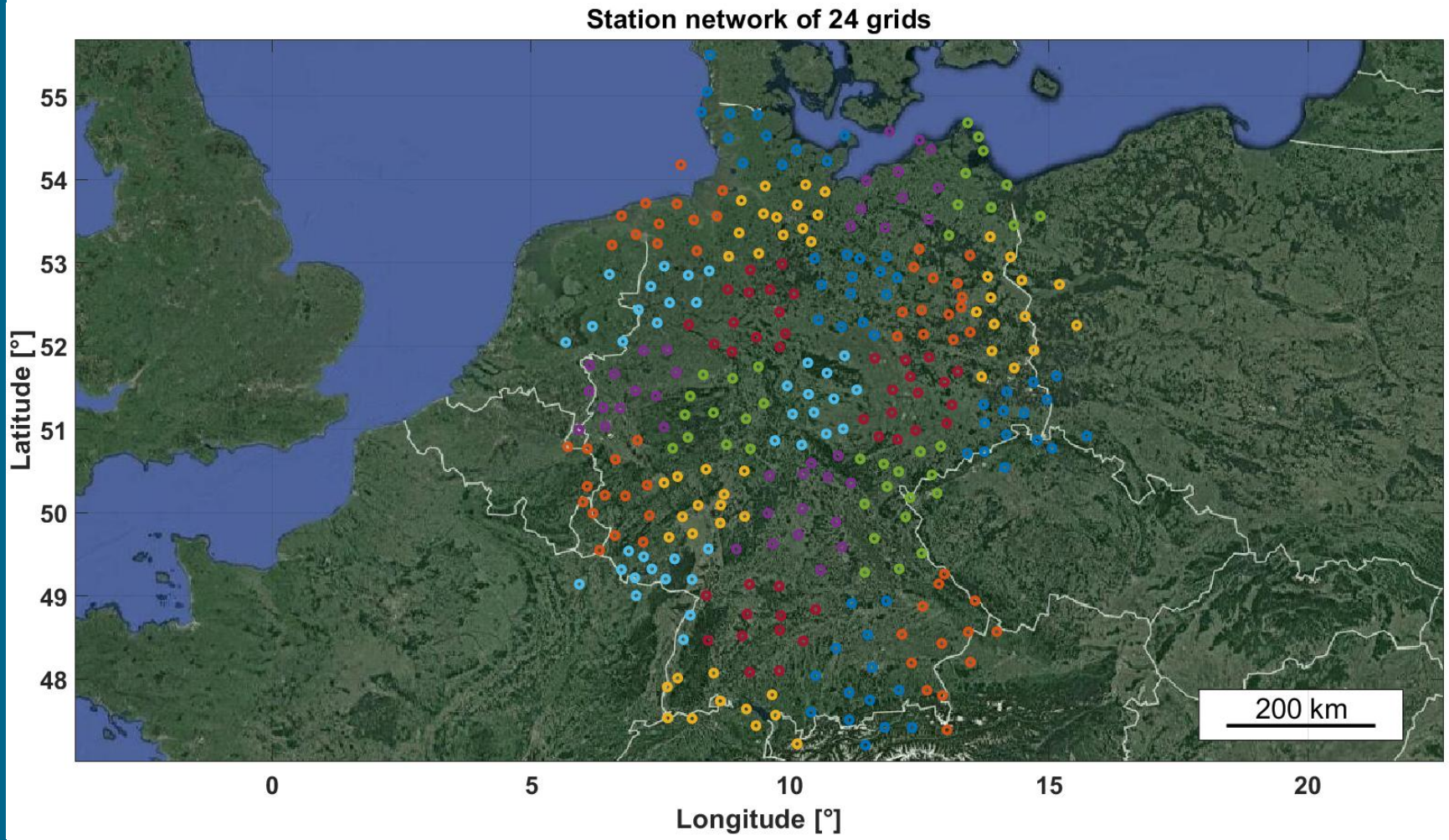


- Interpolation: Barycentric coordinates of user position based on triangle vertices



- Extrapolation: Use value of nearest station

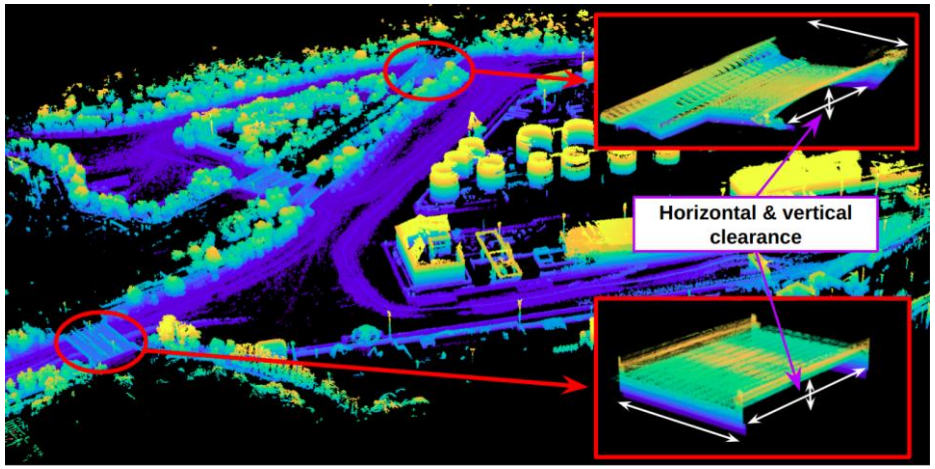
German-wide correction network



- German-wide station network consisting of 24 subgrids with a total of 313 stations for SSRZ corrections
- Same corrections as regional network
- Adapt algorithms → Chose best triangle from stations in 100 km radius

Combining GNSS with perception sensors

SLAM, HD Mapping & Feature Extraction



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GNSS Positioning

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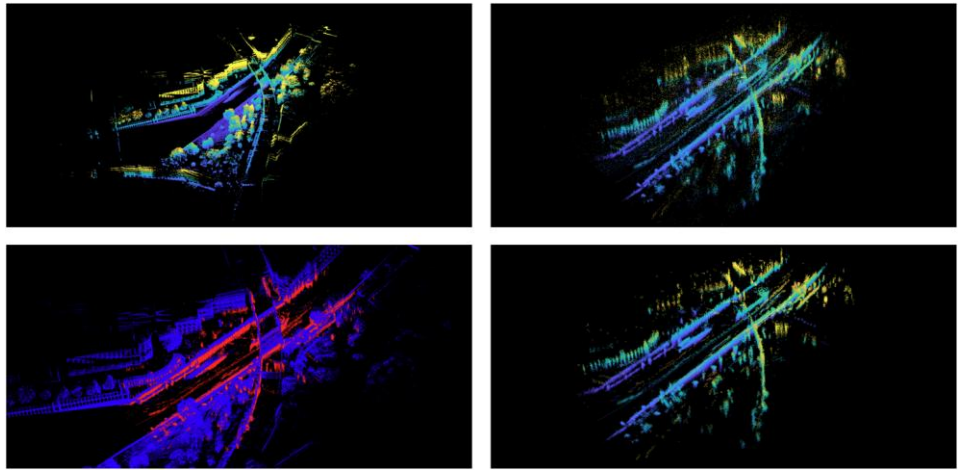
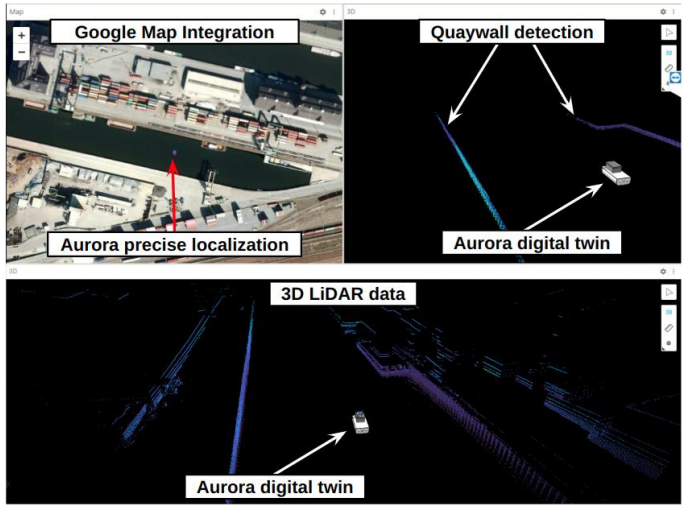
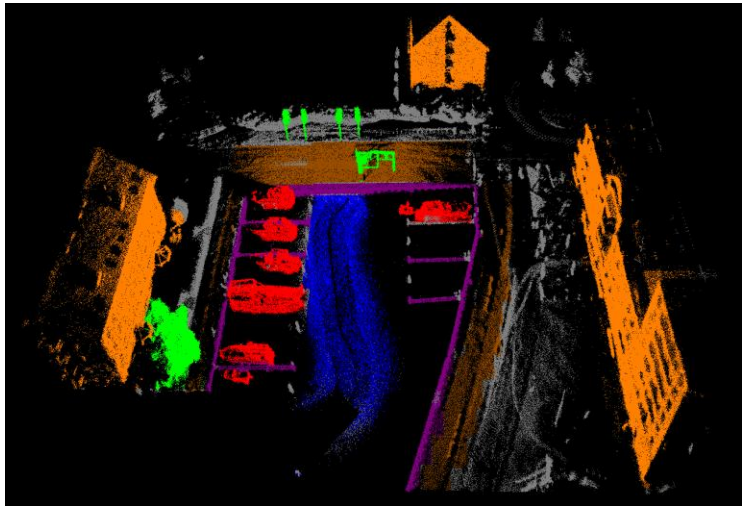
HD Mapping with Automotive Radars



Quaywall detection



LiDAR Semantic Segmentation



LiDAR-Camera Fusion

THANKS FOR THE ATTENTION!

christoph.lass@dlr.de

Impressum

Topic:	Maritime and inland waterway applications at DLR
Date:	22nd of October
Author:	Christoph Lass
Institute:	KN
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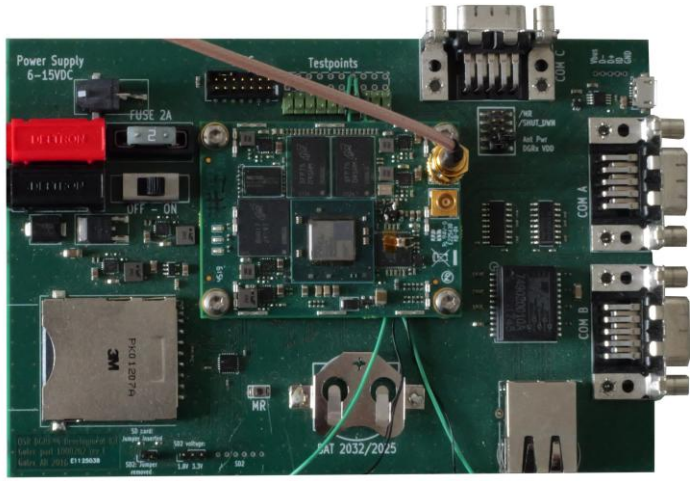
R-Mode on-board equipment



MF R-Mode and GNSS receiver

- Positioning with MF R-Mode
- Positioning with multi-frequency multi-constellation GNSS
- Positioning with MF R-Mode and GNSS
- Detection of GNSS unavailability => output to GNSS interference detection system
- Standardised output to bridge systems

R-Mode supported Portable Pilot Unit (PPU)

- PPU with integrated combined R-Mode and GNSS receiver