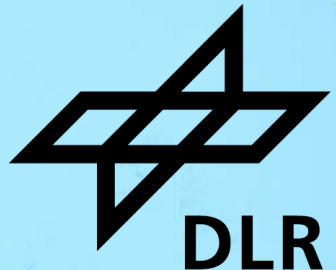


LEVERAGING MARITIME AUTOMATION FOR EFFICIENT AND SUSTAINABLE PORT MAINTENANCE

Mirjam Bogner, Matthias Steidel, Anna Austel

8th INTERNATIONAL CONFERENCE ON MARITIME AUTONOMOUS SURFACE SHIPS (ICMASS)

2025-10-09

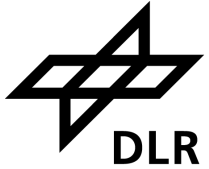


Motivation

- Port maintenance essential to ensure safe ship navigation
- Maritime automation addresses skilled labour shortage & enhances efficiency
- Need for V&V to prevent incidents in regular operations
- Port maintenance provides a clearly constrained operating area



Advanced Port Maintenance: Intelligent, Sustainable, Innovative and Automated Dredging

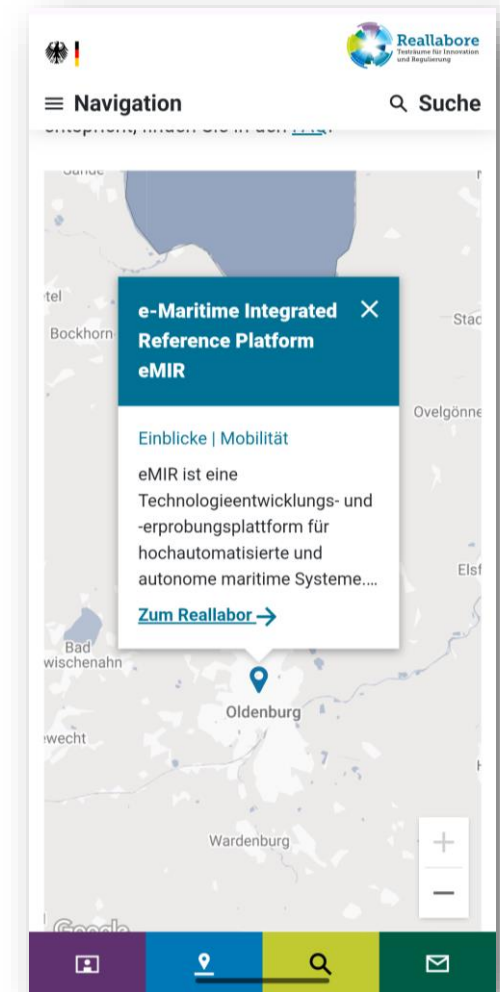


[Konzept für autonomes
Baggerschiff steht - DLR.de](#)

- **Automation Concepts** for a hopper dredger in the port of Emden
- 3 degrees of automation
- **Verification and Validation** methods
- **Application** in sea trials
- **Feasibility study**: realize automated dredger with **State of the Art technologies available on the market**

Regulatory Aspects

- Regulatory framework for MASS still under development
- IMO regulatory scoping exercise 2021: 4 degrees of automation
- Mandatory MASS code expected 2035
- SOLAS requires a minimum number of crew members
- AROS class launched by DNV 01/2025
- Germany: Regulatory Sandboxes Law (Reallaborgesetz) expected to simplify testing and certification processes for MASS



State of the Art

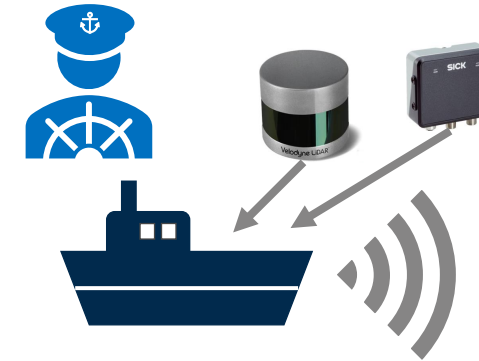
- Remote operation/supervision requires situational awareness
- Cameras not sufficient for distance estimation
- Radar and LiDAR widely used for collision avoidance of automated vessels, e.g. [1], [2], [3], [4]



[1] [10.1109/SCIS-ISIS.2018.00119](https://doi.org/10.1109/SCIS-ISIS.2018.00119) [2] [10.23919/FUSION59988.2024.10706500](https://doi.org/10.23919/FUSION59988.2024.10706500) [3] [10.1109/USYS56283.2022.10073415](https://doi.org/10.1109/USYS56283.2022.10073415) [4] [10.1109/OCEANS.2018.8604803](https://doi.org/10.1109/OCEANS.2018.8604803)

AMISIA: Automation Concepts

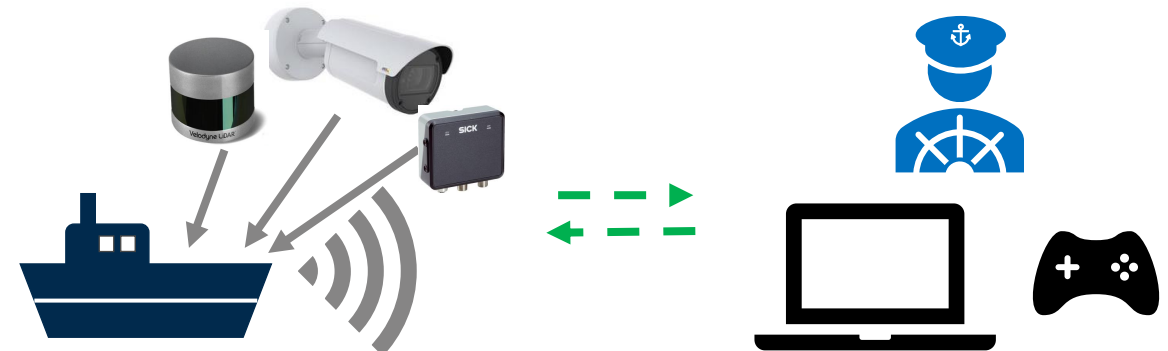
- **Degree I:** on-board operation with decision support



- **Degree II:** remote operation with seafarers on board

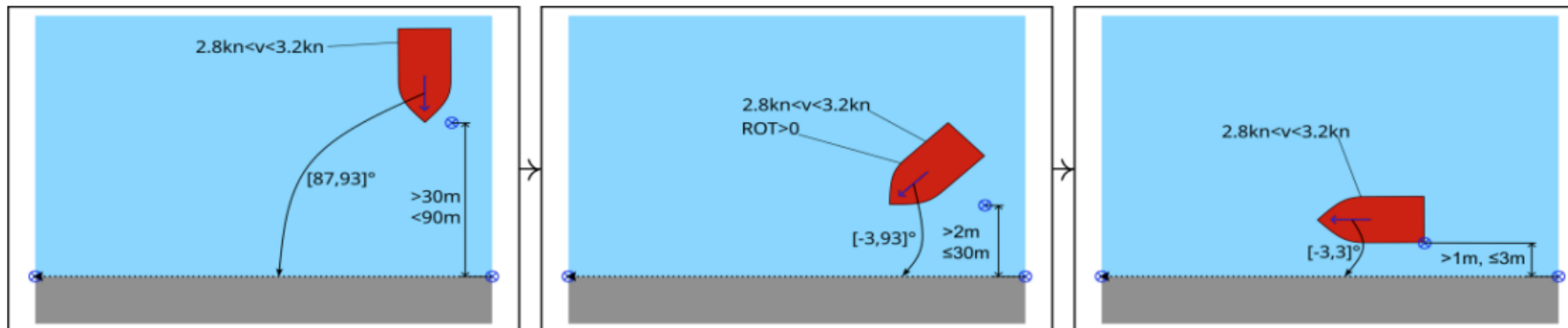


- **Degree III:** remote operation without seafarers on board



V&V: Identification and Formalization of Test Scenarios

- Distance-based test methods not sufficient for highly automated systems
- Scenario-based testing: examine system behavior across a carefully selected, representative range of operating conditions
- Automation risk analysis to identify critical scenarios
- Traffic Sequence Charts (TSCs) for scenario formalization



Sea Trials: Experimental Setup

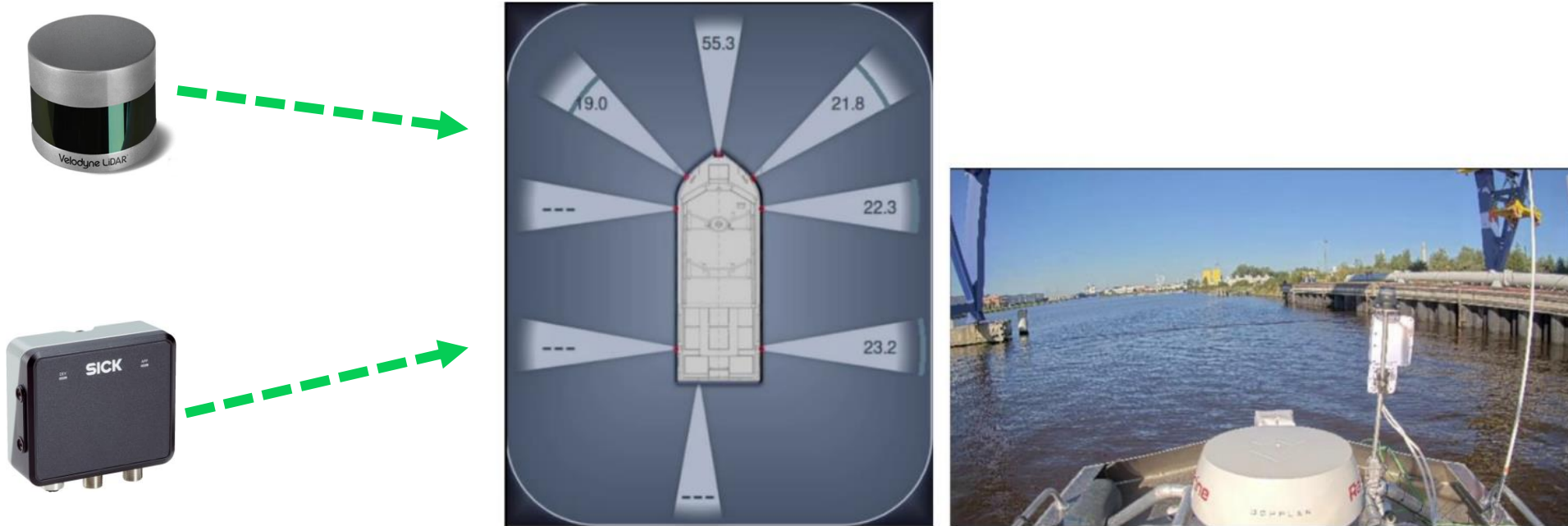


[Reallabore Innovationsportal](#)

eMIR eMaritime Integrated
Reference Platform



Sea Trials: System under Test (I)

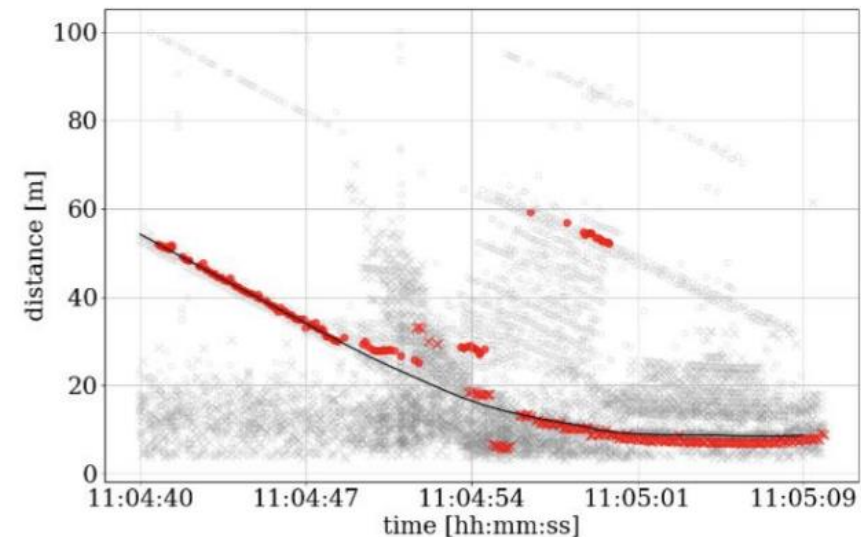
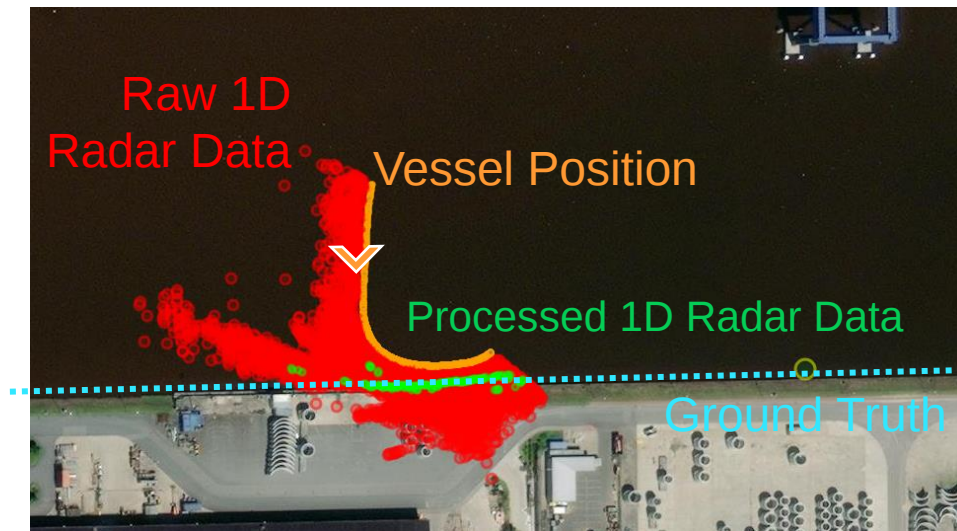
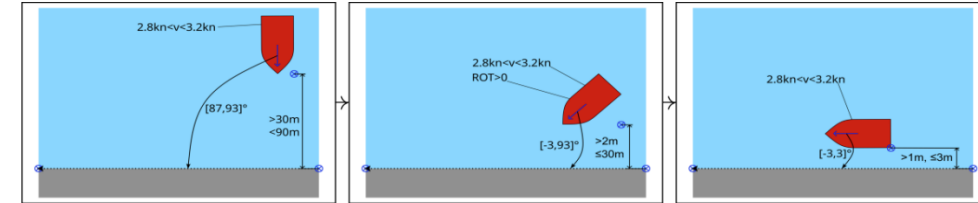


How precisely can distances be determined using 1D Radars and a 3D LiDAR?

Domain-specific challenges: reflections from water surface, rain,...

Sea Trials: Conduction and Evaluation

- Several trials 2023-2025 in the port of Emden
- Scenarios based on automation risk analysis and formalized with TSCs

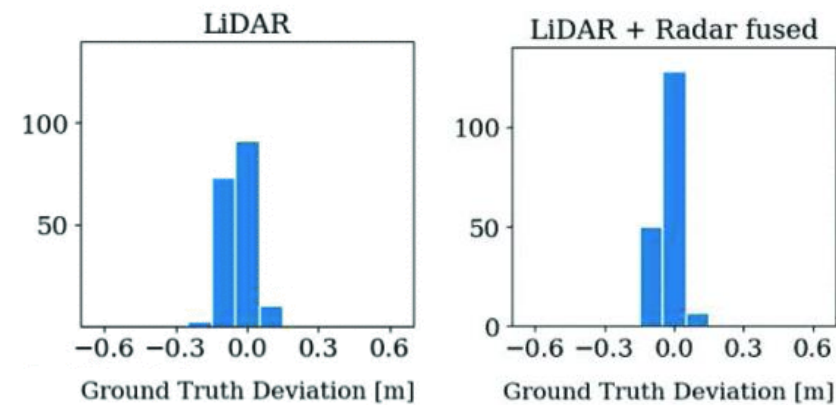
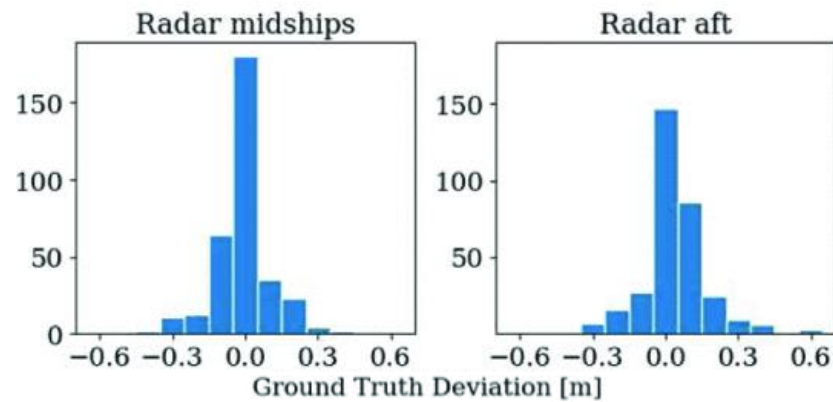
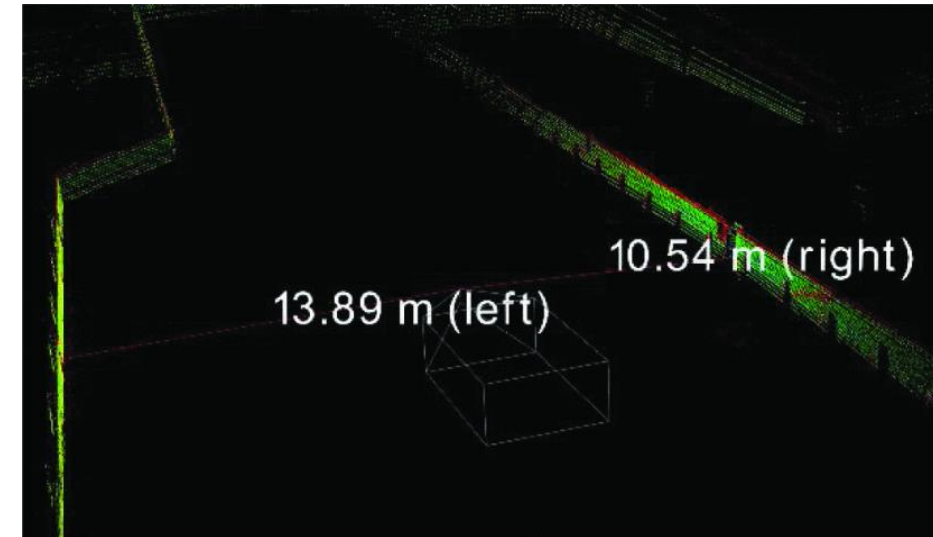
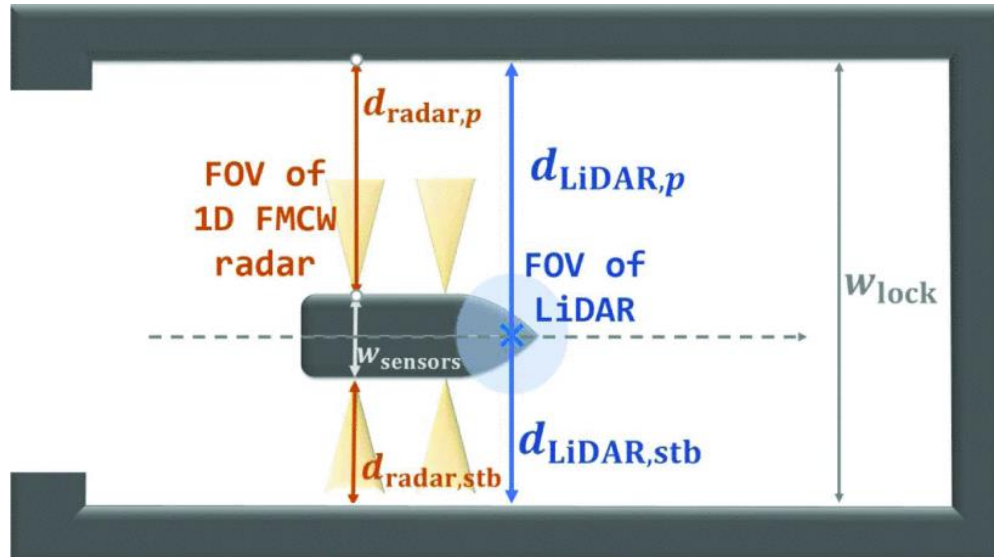


Comparison of distances measured with 1D Radar sensors to Ground Truth. Fig. from [1].

[1] M. Bogner, F. Pieper, C. Steger, M. Steidel, J. A. Piotrowski and S. Feuerstack, "Utilizing 1D FMCW Radar Data for Distance Estimation to Port Infrastructure," doi: 10.23919/FUSION59988.2024.10706500.



Sea Trials: Lock Entry



Figures from M. Bogner, F. Pieper, M. Steidel and J. A. Piotrowski, "3D LiDAR and 1D Radar Distance Determination for Safe Navigation of Automated Vessels in Lock Basins," doi: 10.1109/MARIS64137.2025.11139454



Sea Trials: System under Test (II)

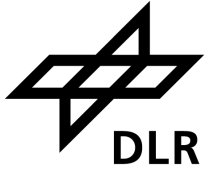
- Track Control System with ship-to-ship collision avoidance that is available on the market
- Physical sea trials with simulated AIS targets as described by [1]
- Harbor environment poses specific challenges to ship-to-ship CA
- Evasive maneuvers of system in some situations prone to misinterpretation
- Dredger in operation has right of way



[1] J. A. Piotrowski, C. Steger, and A. Hahn, "Open testbed vessel—Reusable and generic test carrier architecture for maritime testbeds," <https://doi.org/10.1016/j.oceaneng.2025.120747>



Summary and Conclusion



- Conducted feasibility study and V&V
 - Automation concept and assistance systems for hopper dredger in IMO degree I to III
 - Tools and methods for system verification & validation
 - Application in sea trials
 - Tested assistance systems for distance determination to obstacles
 - Domain-specific challenges; fusing LiDAR and Radar data enables more precise distance determination
 - Tested track control system with ship-to-ship collision avoidance
 - Confined harbor environment challenging; special requirements for dredger under operation
- ➔ Automated dredger can mostly be realized with SotA technologies; some minor caveats

Thank you for your attention!



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