FINAL SHOWCASE EVENT

Sas van Gent

21 November 2023

THIS PROJECT IS PART OF THE 5G PUBLIC AND PRIVATE PARTNERSHIP
5G PPP WWW.5G-PPP.EU

Funded by the EU's Horizon 2020 programme under agreement nº 952189

WELCOME

Wim Vandenberghe

Project Coordinator 5G-Blueprint

Ministry of Infrastructure and Water Management

Wifi Network: **5G Blueprint**

Password: **Showcase!**

PROGRAMME

10.30 Plenary talk show with:
- Keynote speech Dutch Ministry of Infrastructure and Water Management
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- Project highlights
- Panel session with project partners

11.30 Demonstrations:
- Teleoperation of a car seamlessly crossing the border
- Teleoperation and auto docking of a truck

12.30 Lunch, information market at the museum

13.20 Start demonstration carousel:
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- Teleoperation of a barge seamlessly crossing the border
- Enabling functions

15.15 Informal closure with drinks and snacks

16.15 End of program

KEYNOTE

Kees van der Burg

Director General for Mobility and Transport

Ministry of Infrastructure and Water Management


5G BLUEPRINT

KEYNOTE

Jan Noelmans

Counselor logistics, regional airports and rail

Cabinet of the Flemish Minister for Mobility and Public Works


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PROJECT HIGHLIGHTS

Johann Marquez-Barja

Technical project coordinator 5G-Blueprint

Professor at imec

5G-BLUEPRINT IN A NUTSHELL

Driven in autonomous mode:
98.2 % of the trajectory*

27 years of R&D later …

2% issue

Edge & corner cases

5G-Blueprint approach

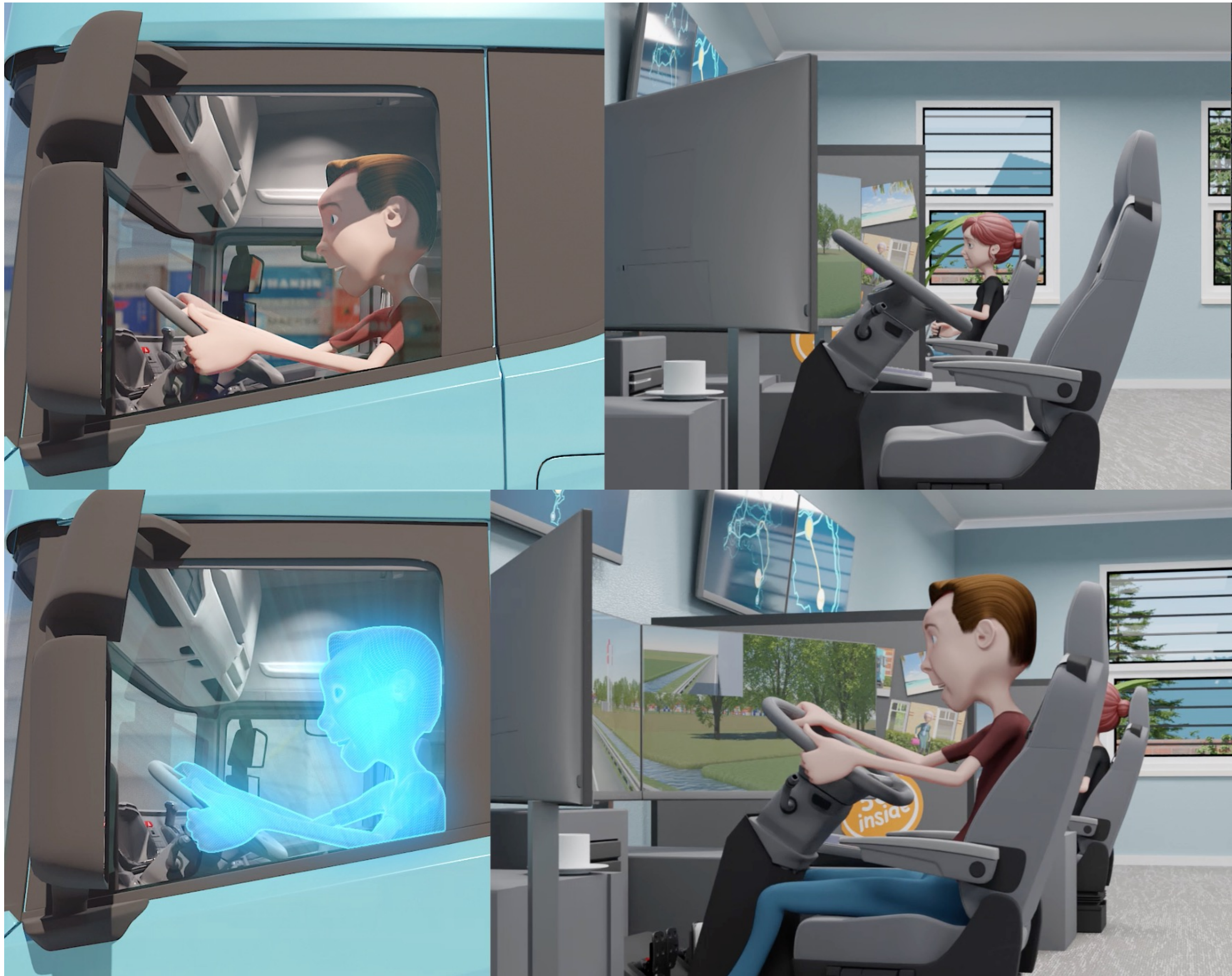
* https://www.cs.cmu.edu/~tjochem/nhaa/

5G-BLUEPRINT ULTIMATE GOAL

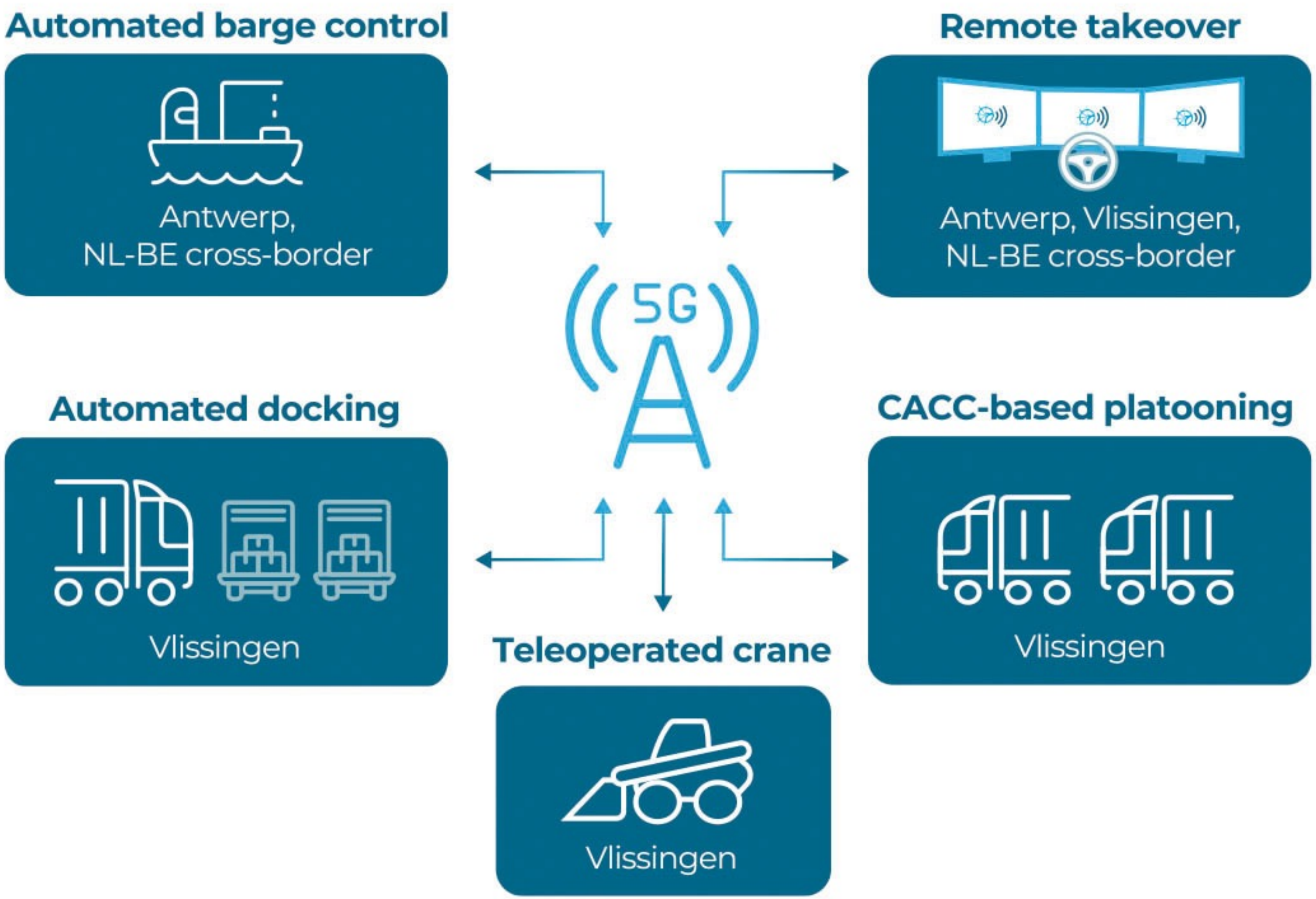
5G-Blueprint designs and validates:

- **technical architecture**
- **business**
- **governance model**

for uninterrupted cross-border teleoperated transport based on 5G connectivity.



USE CASES

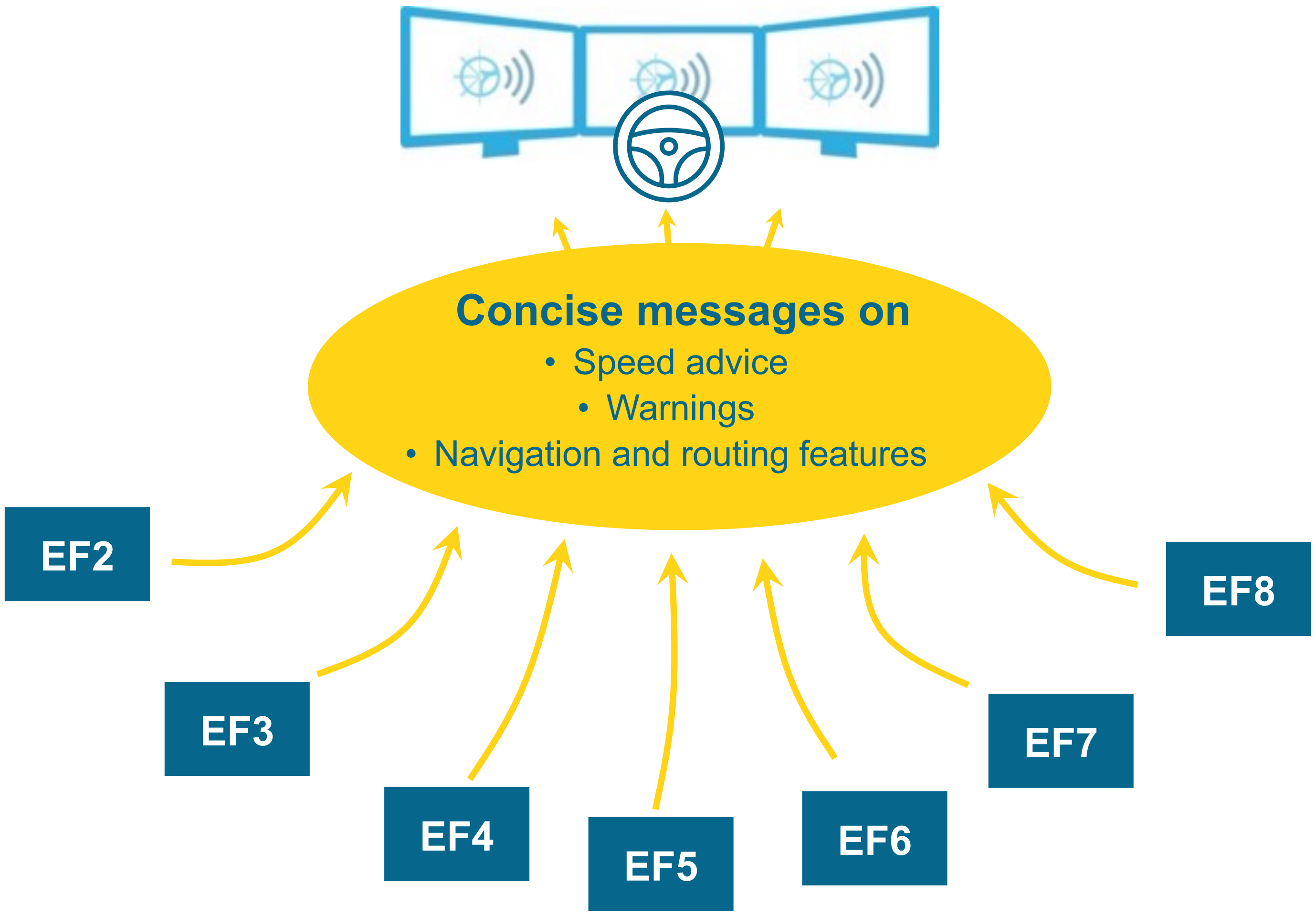


Tested in real-life environments such as busy ports and public roads

EXTRA FUNCTIONALITY TO IMPROVE SAFETY

EF1	Enhanced awareness dashboard
EF2	Vulnerable Road User interaction
EF3	Timeslot reservation at intersections
EF4	Distributed perception
EF5	Active collision avoidance
EF6	Container ID recognition
EF7	ETA sharing
EF8	Scene analytics

TELEOPERATION COCKPIT



USE CASES MAPPED TO PILOT SITES

5G BLUEPRINT

Vlissingen pilot site (NL)

Automated docking
Vlissingen

Teleoperated crane
Vlissingen

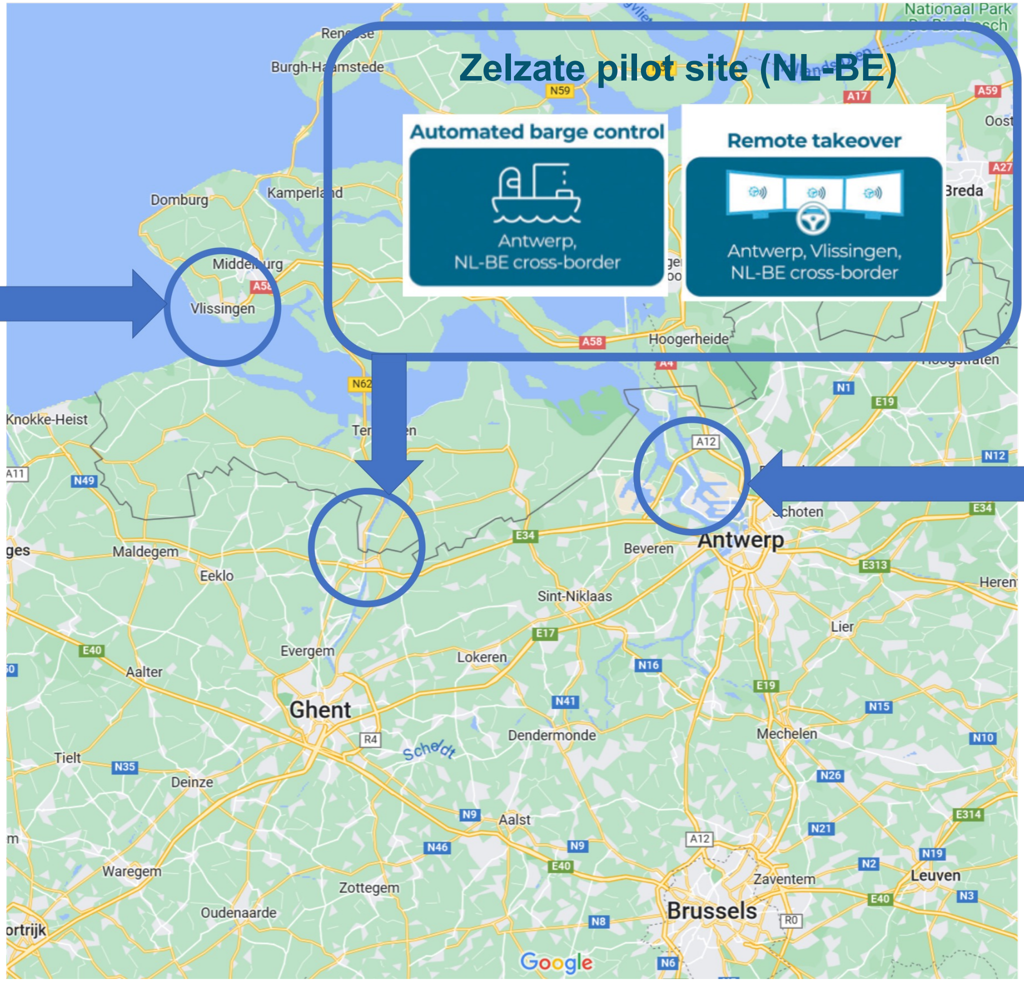
CACC-based platooning
Vlissingen

Remote takeover
Antwerp, Vlissingen, NL-BE cross-border

Zelzate pilot site (NL-BE)

Automated barge control
Antwerp, NL-BE cross-border

Remote takeover
Antwerp, Vlissingen, NL-BE cross-border



Antwerp pilot site (BE)

Automated barge control
Antwerp, NL-BE cross-border

Remote takeover
Antwerp, Vlissingen, NL-BE cross-border

CHALLENGES AND REQUIREMENTS

- Connectivity latency
- Connectivity session and service continuity (handover)
- Connectivity bandwidth
- Time to reconect
- Steering and pedal accuracy
- Overridability
- Maximum safe speed
- Safe stops

ID	UC1-CAM	UC1-SCI	UC1-DDS
Description	HD Camera stream	Ship control interface	Distance/depth sensor on ship
Service Type	Uplink	E2E	Uplink
5G Network Latency	One way <22ms	Round trip <35ms	One way <100ms
Network Service Interruption	<30s	<200ms	<1s
Bandwidth Requirement	>5Mbps <25Mbps	<2Mbps	<1Mbps
Slice Type	eMBB	URLLC/ hMTC	V2X
No. Flow	6 per ship	1 per ship	1 per ship

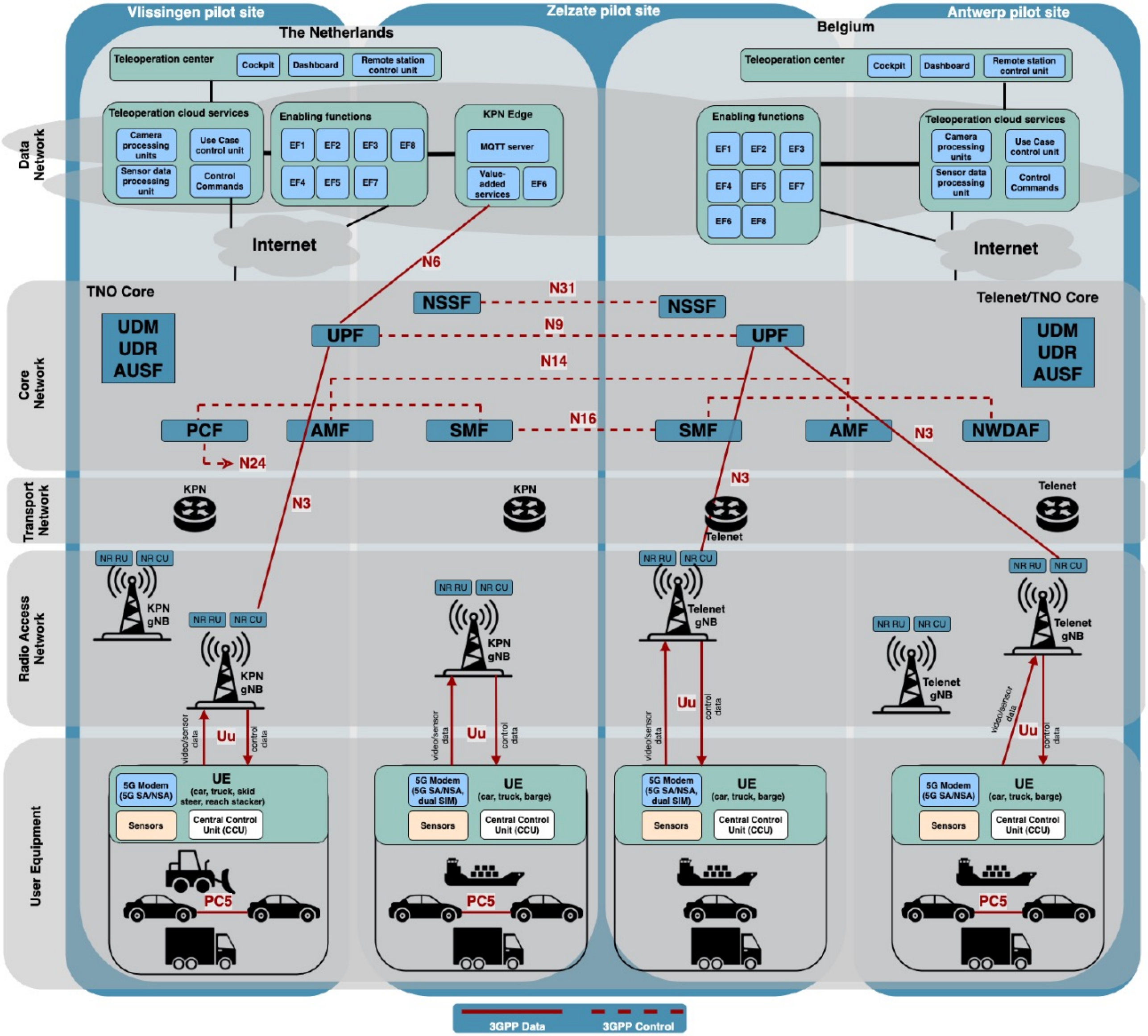
Table 1: Requirements for Automated Barge Control

ID	UC2a-CAM	UC2a-VCI	UC2a-TEL
Description	HD Camera stream	Vehicle control interface	Telemetry sources
Service Type	Uplink	E2E	Uplink
5G Network Latency	<50ms	<35ms	<100ms
Network Service Interruption	<150ms	<150ms	<1s
Bandwidth Requirement	>5Mbps <25Mbps	<2Mbps	<1Mbps
Slice Type	eMBB	URLLC/ hMTC	V2X
No. Flow	3 per vehicle	1 per vehicle	1 per vehicle

Table 2: Requirements for Automated Driver-in-Loop Docking

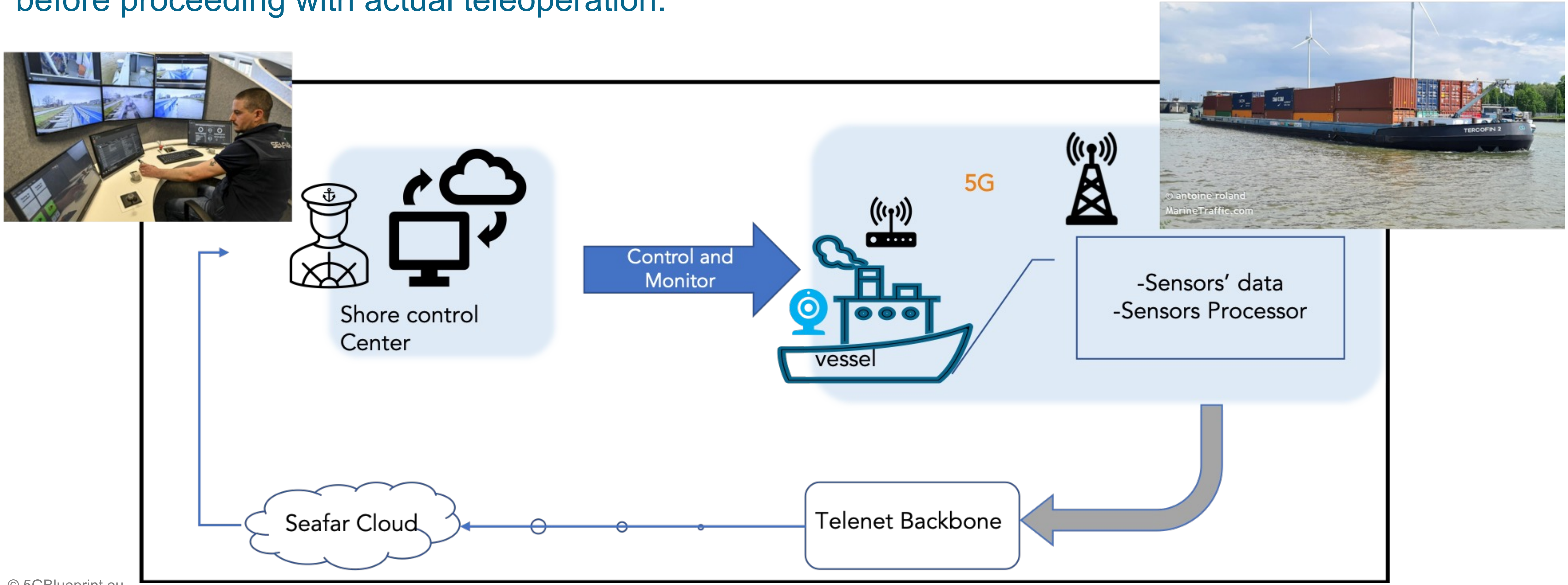
CONNECTIVITY SOLUTION

- 5G SA (Release 16) deployed in three pilot sites
- Seamless handover
- 5G ecosystem:
  - UE (trucks, vehicles, vessels, skid steers)
  - 5G NR and Core
  - Data network (Enabling functions and Use case components)



SHADOW MODE TESTING

Shadow mode testing of remote barge control is essential for testing 5G SA capabilities before proceeding with actual teleoperation.



TELEOPERATED DOCKING

Truck-Trailer combination

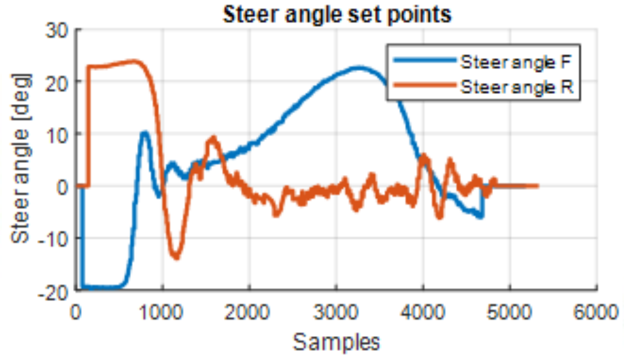
Teleoperator view

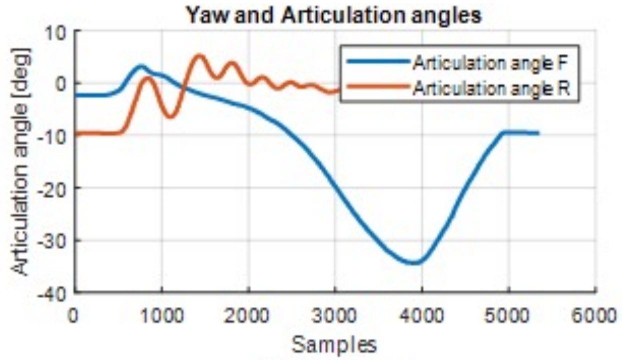
Cabin

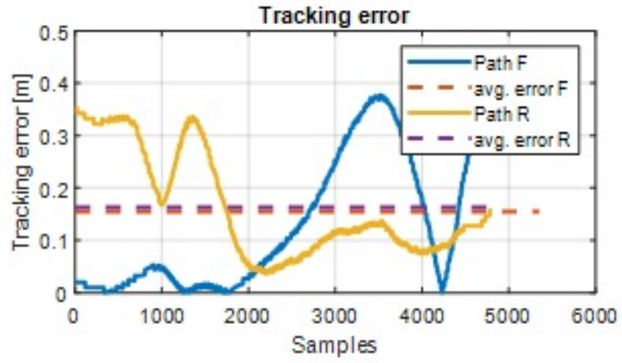
TRACKING ERROR

Average tracking error 0.16m
Target values less than 0.5m

An example test run
at MSP Onions







Samples

Final docking state error:

- A = 3.6cm, required < 10cm
- B = 8.4cm, required < 10cm
- C = 0.4deg, required < 2deg

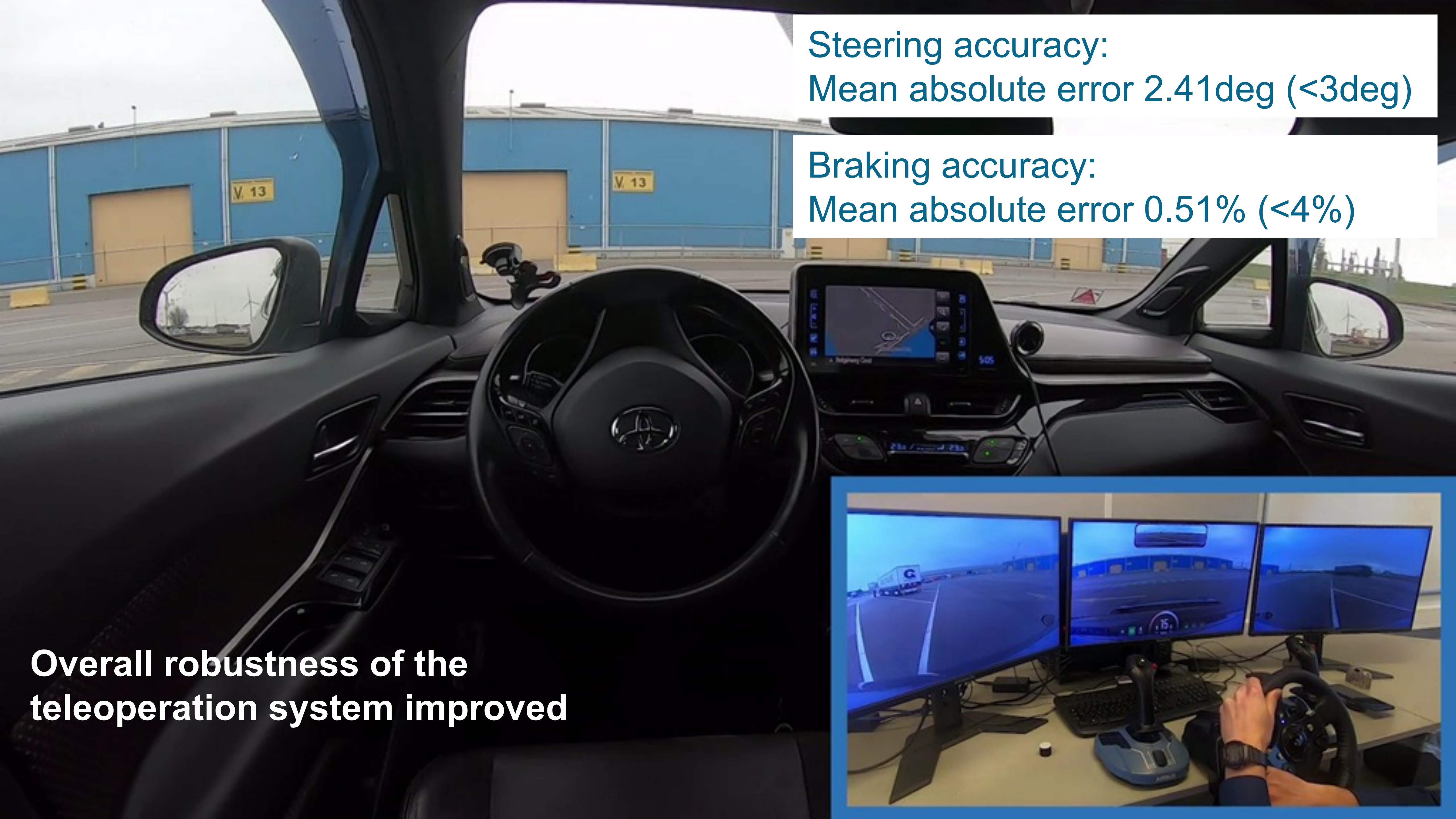
Overall robustness of the teleoperation system improved, full takeover of real truck achieved

Steering accuracy:
Mean absolute error 4.83deg (<6deg)

Braking accuracy:
Mean absolute error 0.72% (<4%)

Steering accuracy:
Mean absolute error 2.41deg (<3deg)

Braking accuracy:
Mean absolute error 0.51% (<4%)



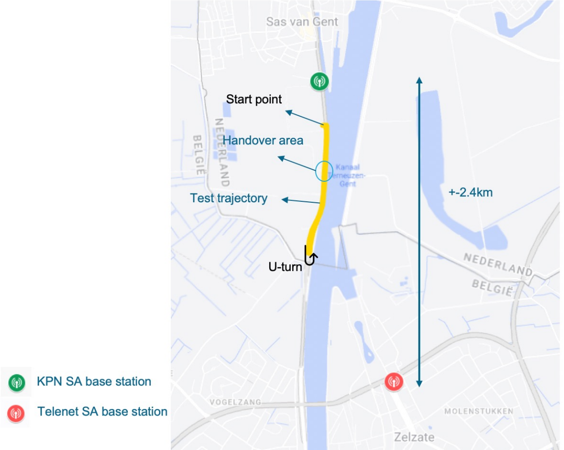
Overall robustness of the teleoperation system improved

ROAMING

Roaming procedures can be optimized by combining home routed SA principles with N14-based roaming.

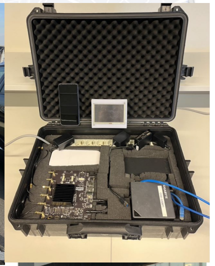
N14 vs N2

Seamless cross-border N14 handover performs similar to the N2 handover, the main difference is that it depends on the latency between the cores.



Lab results

- N2 handover: 100-120ms
- N14 handover: 100-150ms

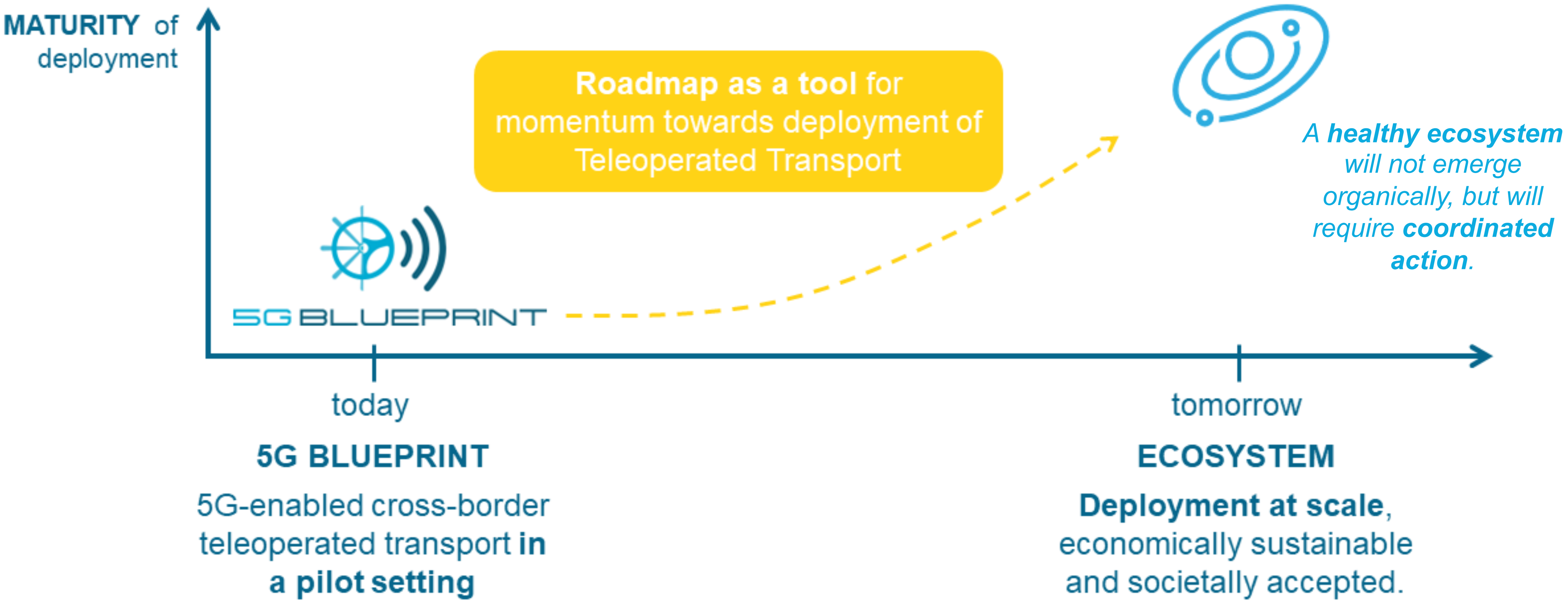


Field results

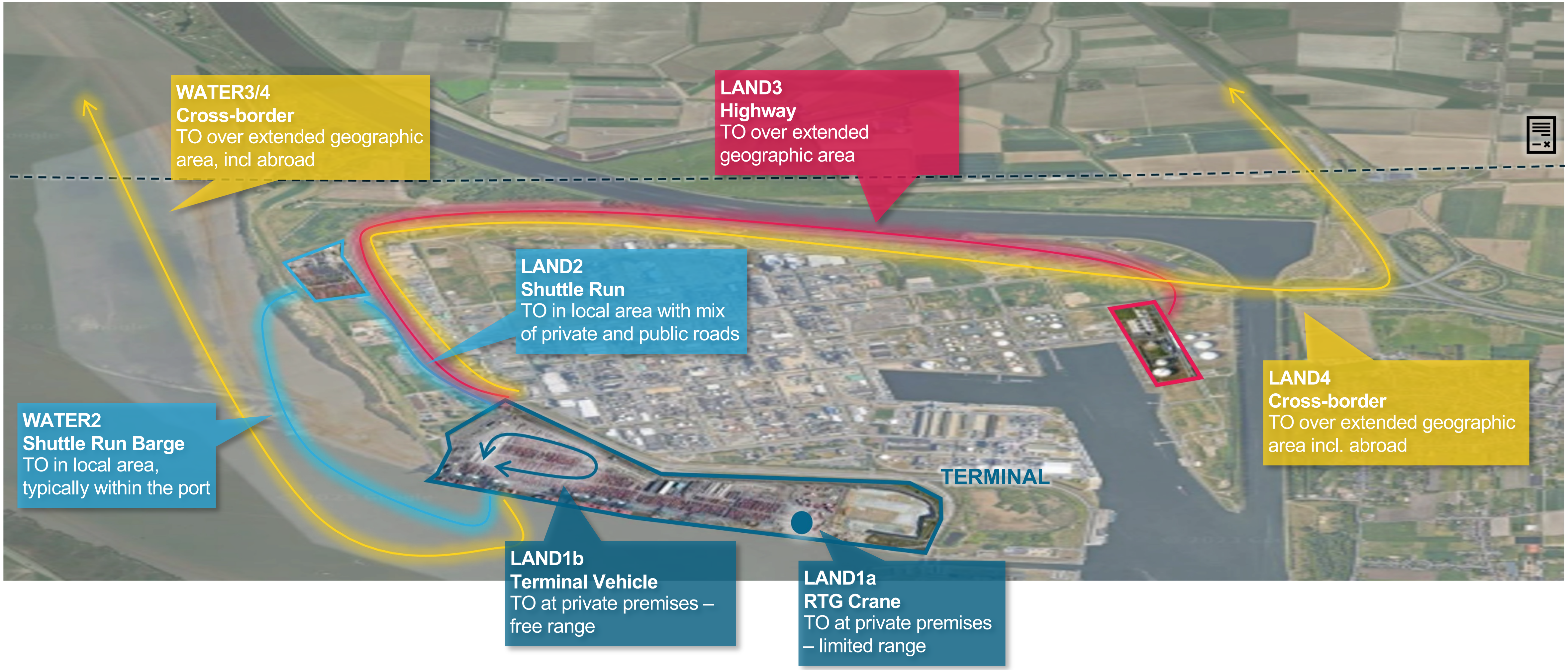
- Uplink throughput: 32.4 Mbps
- Downlink throughput: 145 Mbps

- N14 handover: ~100ms
- Latency between 2 cores: ~7ms → small impact compared to the other latency components

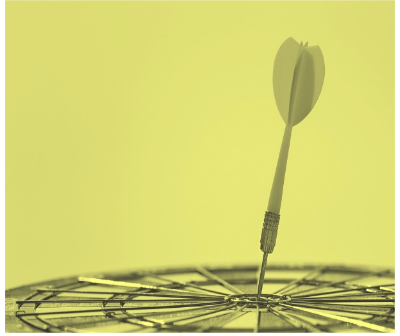
A ROADMAP FOR DEPLOYMENT



7 WORKING SCENARIOS



Key learnings



UC-dependent

Which 5G deployment approach is best depends on the scope of TO deployment.

Anticipate scaling up

Assess and approach potential customers and network operators; seek investment kickstarters.

OPEX matters

OPEX is the key cost element to target for reducing total cost of ownership.

Anticipate labour market shift

Realize upsides of unmanned transport for labour market while mitigating downsides.

LESSONS LEARNED

Teleoperation of vehicles and vessels

- **Teleoperation of vehicles** (cars, trucks and skid steers) **and barges** successfully tested over 5G SA in the national sites (BE, NL)
- Network testing demonstrated that its performance enables **safe teleoperation across borders**
- Handover-caused **interruption times sufficient** for cross-border teleoperation

Seamless cross-border roaming

- Service interruption time significantly reduced **(<150ms)**
- Vast amount of **configuration parameters → to be automated** in future work
- **Standardization potential**: new procedure to enable Home-Routed Seamless roaming in 5G SA

Business and Governance Analysis

- **Avoid big bang** deployment of teleoperation
- **Involve all stakeholders**
- **TO follows** connectivity
- Tag along with **Automated Driving**


5G BLUEPRINT

PANEL DISCUSSION

Jan Cools
CEO – Be-Mobile

Muriel Desaeger
General Manager R&D Technology Strategy Planning & Incubation – Toyota Motor Europe

Jakub Juza
CEO – Roboauto

Geerd Kakes
Director Fieldlabs – KPN

Peter Van Parys
COO – North Sea Port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STATEMENTS

If I would be working in a confined area,
such as a port terminal or a factory,
and teleoperation would be introduced in the vehicles around me
(skid steers, reach stackers, yard tractors, etc),
I would feel comfortable with continuing my job.

STATEMENTS

Teleoperation is a solution that tackles the driver shortage problem by increasing the efficiency of the usage of the scarce drivers we have.
It is not intended to replace humans, and hence job loss is not a concern to me.

STATEMENTS

I find the 5G seamless roaming solutions developed in this project also very interesting for other use cases that I make use of in my daily life.

STATEMENTS

I look forward to learning more about the project with some nice demonstrations.


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DEMO

Teleoperation car seamlessly crossing border using 5G

Rakshith Kusumakar

V-tron


5G BLUEPRINT

Automated driver in the loop docking

Bas Hetjes

Researcher

Hogeschool van Arnhem en Nijmegen (HAN)

CURRENT SITUATION & CHALLENGES

- Growing shortage of drivers
- Unused road capacity during off-peak hours
- Wasted terminal waiting time due to poor digital insight

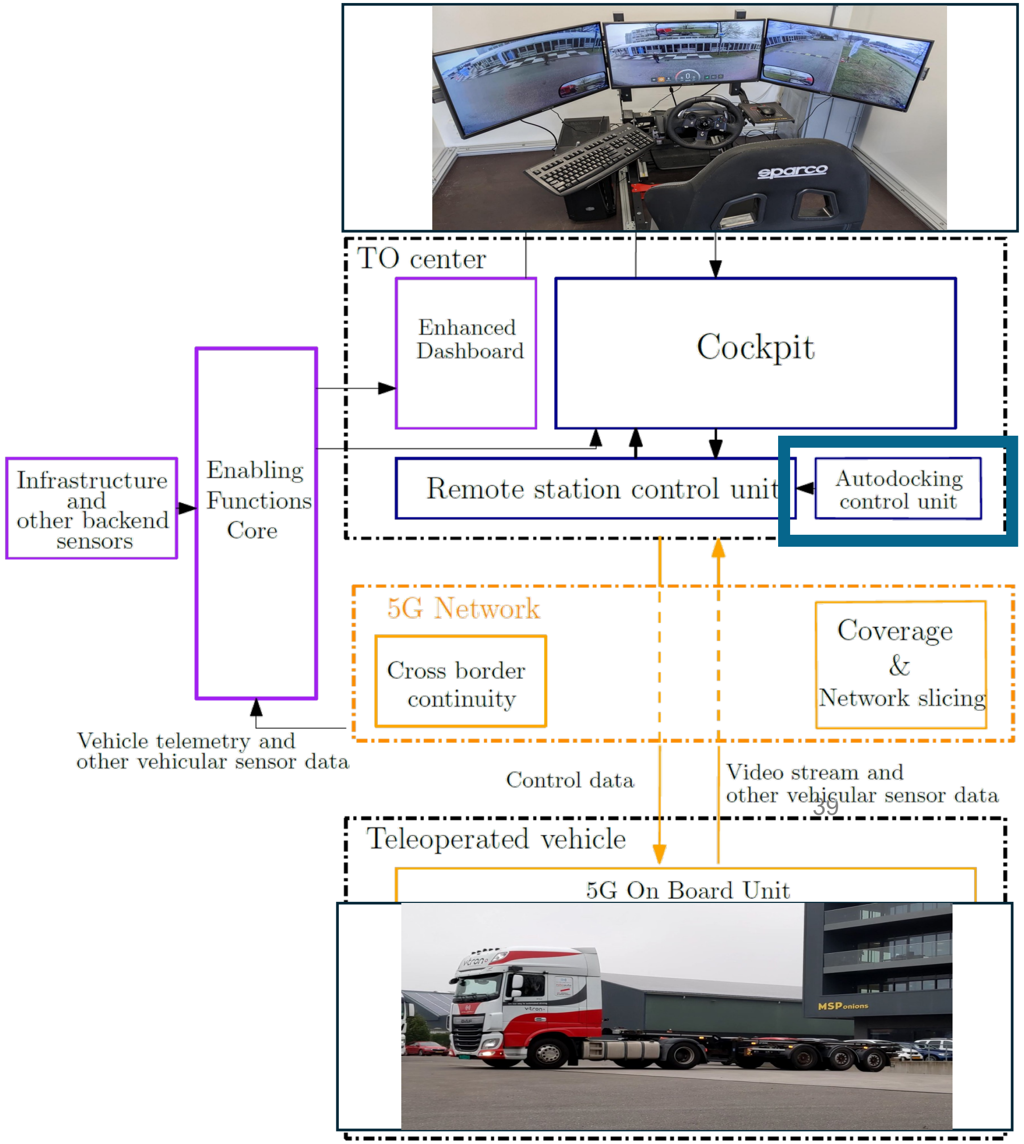
±€100 mil/year
loss in NL & BE

Every trip ends with parking/docking

Video speed (4x)

COMBINING TELEOPERATION & AUTOMATION

- Automate the critical task, i.e. less risks
- Truck driver can/will be more efficient
- Also possible for super eco combis



TELEOPERATION CENTRE

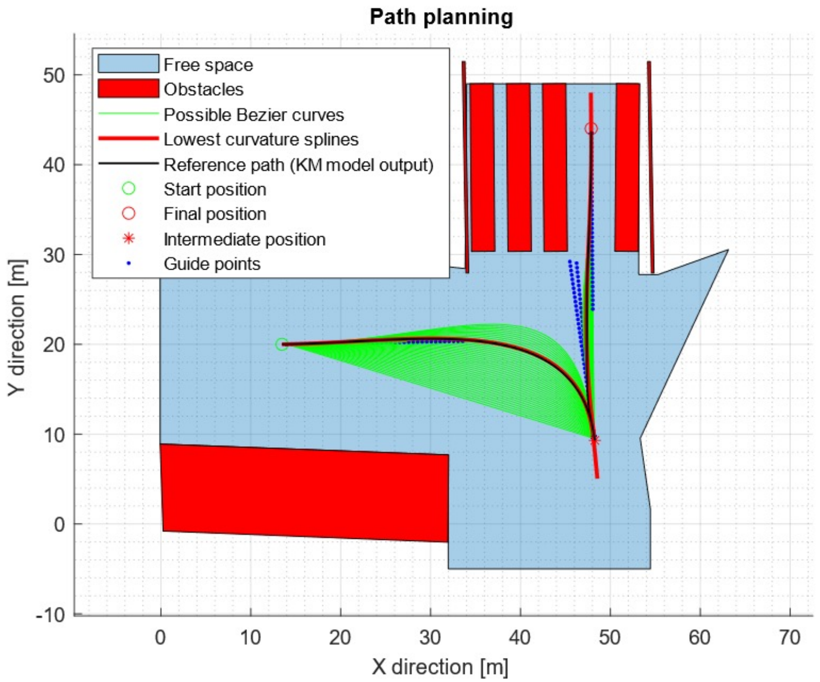
AUTODOCKING TECHNOLOGY

Path Planner

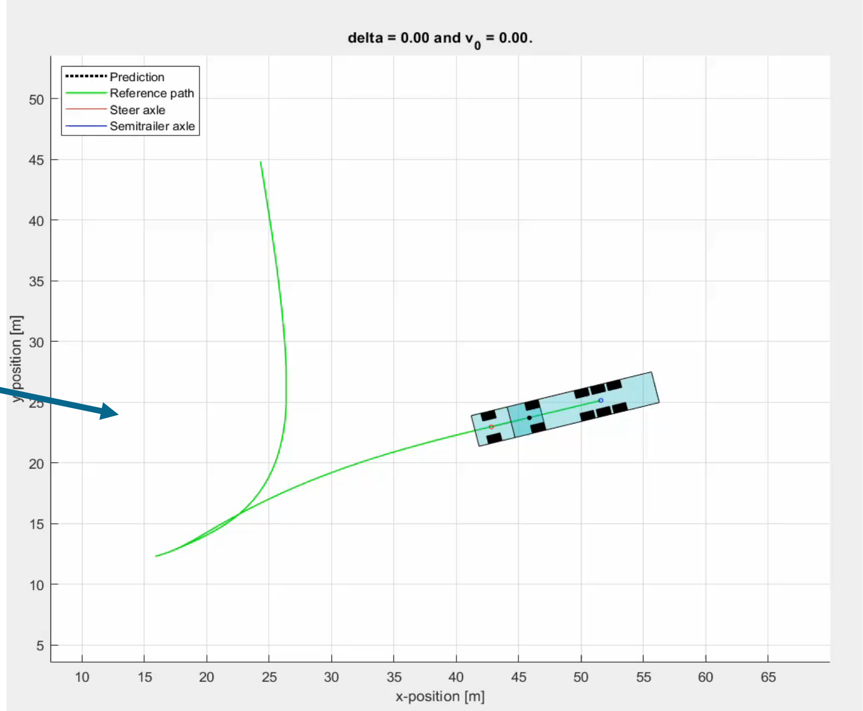
- Creates path from initial pose to desired dock
- Respects kinematic vehicle behaviour
- Considers environment layout
- Bidirectional functionality

Path Following Controller

- Provides steering angle and throttle to follow the reference path with minimal the tracking error
- Robust against disturbances and noises
- Nonlinear Model Predictive controller



Localisation (RTK GPS)



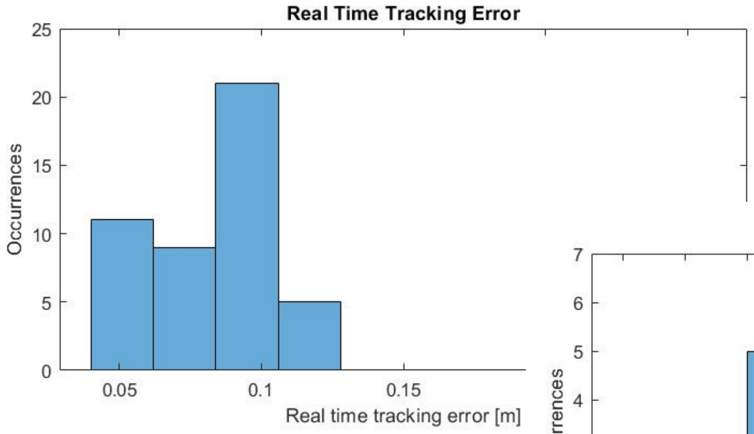
TESTING & RESULTS

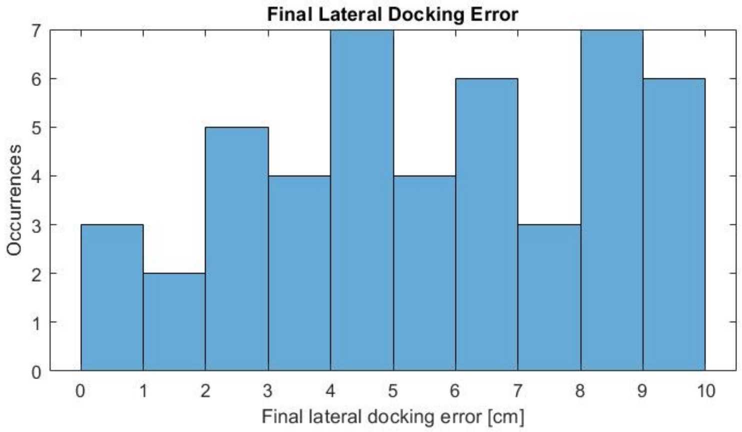
Testing

- Various start places & end locations
- Various environmental conditions
- Various locations (logistic sector)
- >100 autodocking tests

Results

- All tests within dock limits of 10cm
- Average Tracking Error less than 9 centimetre
- Average Final Docking error =less than 5 centimetre





FINAL PRODUCT

CONCLUSIONS & NEXT STEPS

Conclusions

- TRL 6-7 demonstrator for Tractor-Semitrailer autodocking has been established using 5G connectivity between teleoperation control centre and the vehicle
- New concept of the path planner and path following controller has been developed
- Functionality of the system has been verified by extensive testing in real conditions

Future plans / projects

- Active collision avoidance system will be added (already tested on scaled level)
- Implementing longitudinal position controller
- Deploy the concept in a pilot operation
- Localisation based on 5G network

DEMO TIME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THE PARTNERS

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#CAM

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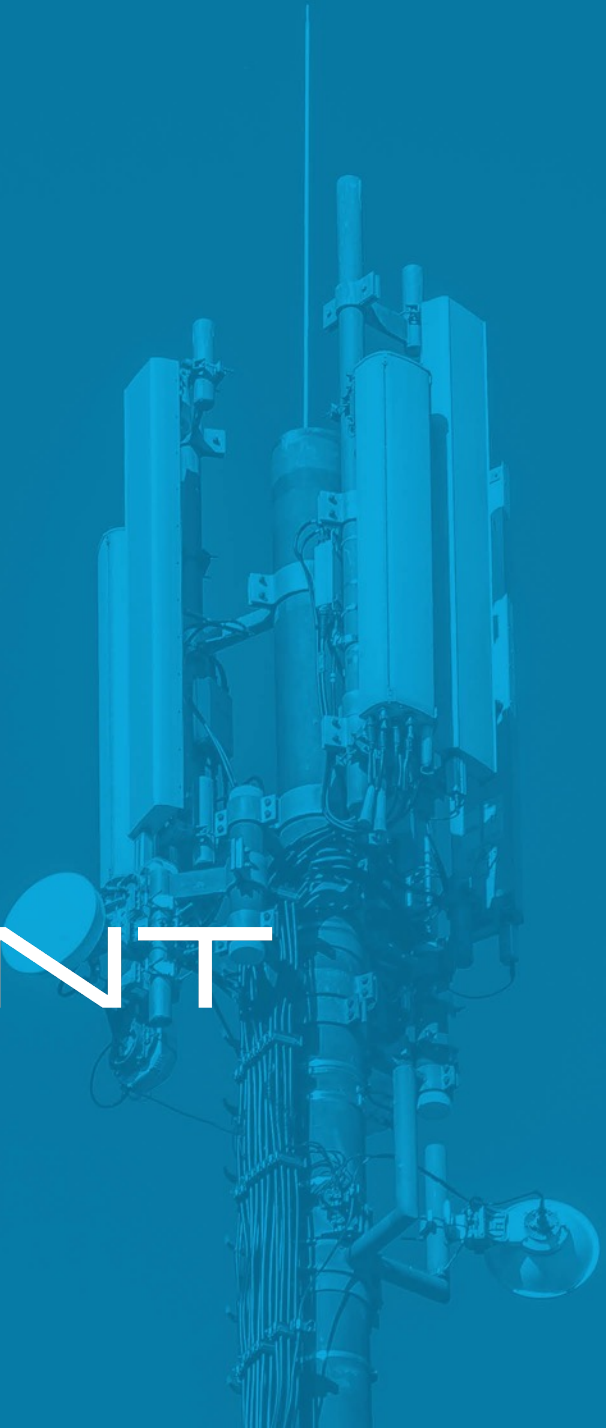


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Sayonara
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THERMO KING


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