

# Felhőalapú kooperatív érzékelés és automatizált járműirányítás



BME  
**AUTOMATED  
DRIVE**

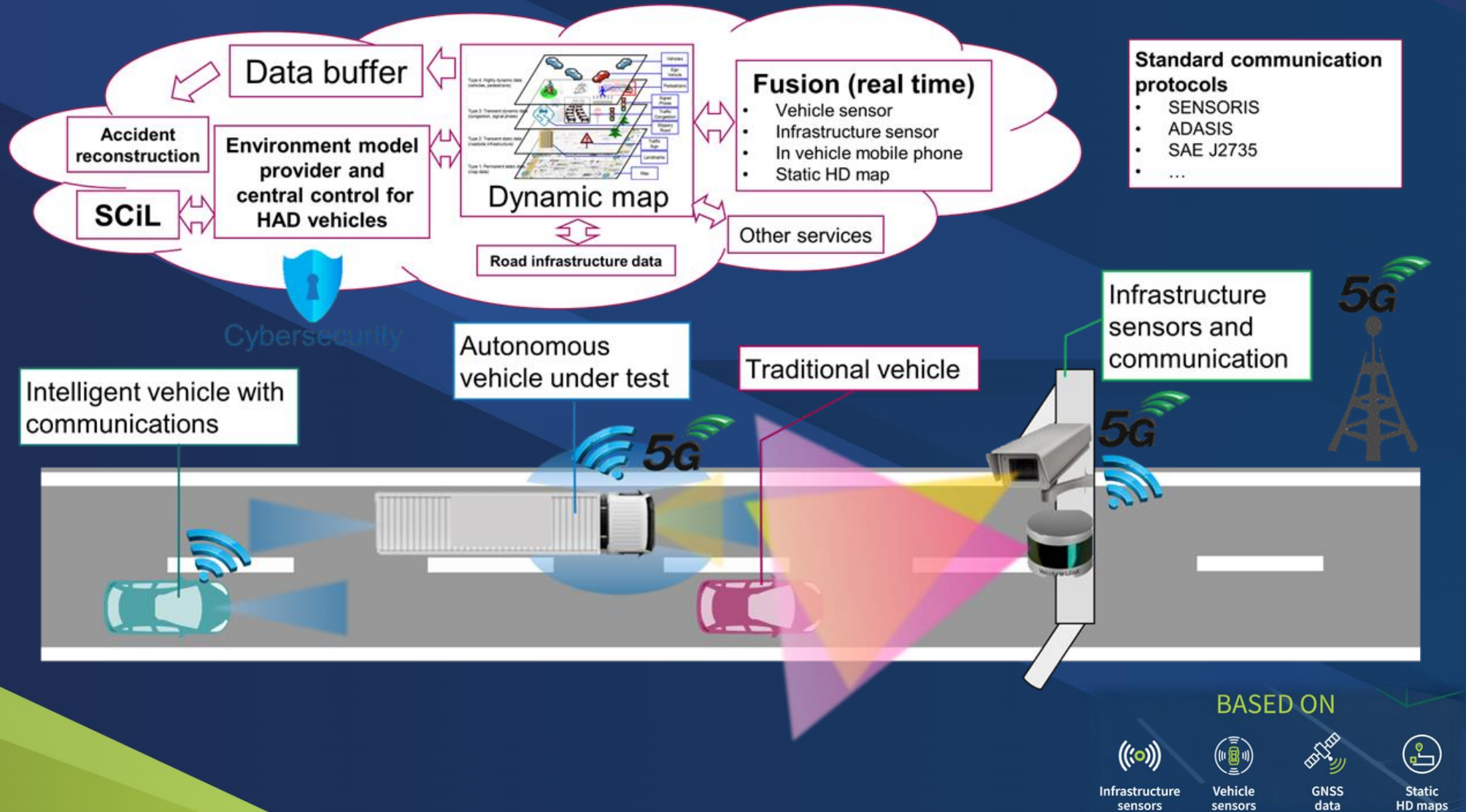
Dr. Szalay Zsolt

# Miért?



Source: Jordan Parker, Nora Mishanec, “Driver hits woman in S.F., then Cruise driverless car runs her over”, San Francisco Chronicle, Oct. 2, 2023

# Cooperative Perception and Control



# Central System – First Results in 2020

Station1



Vehicle

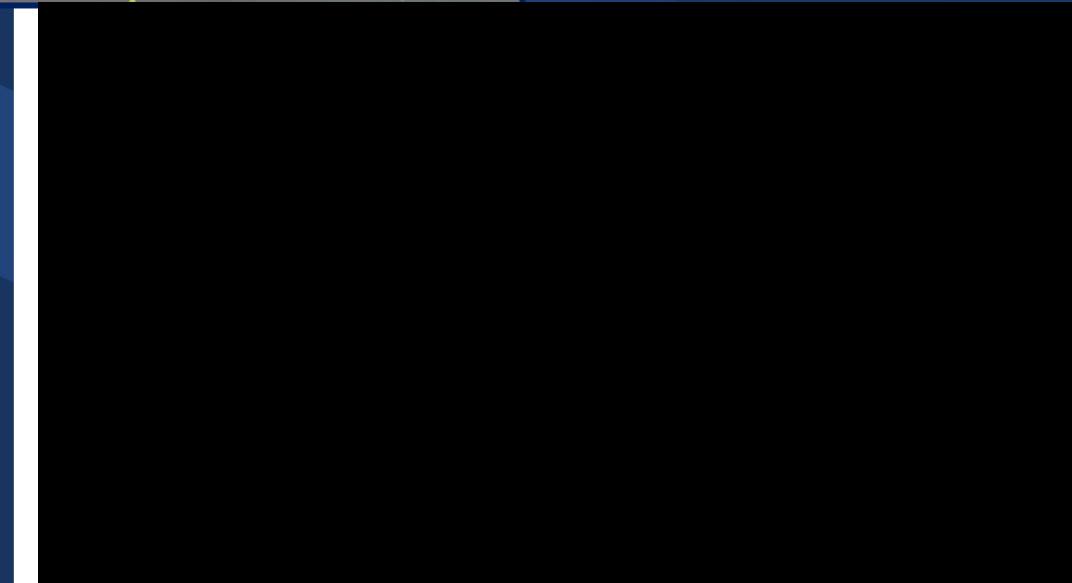
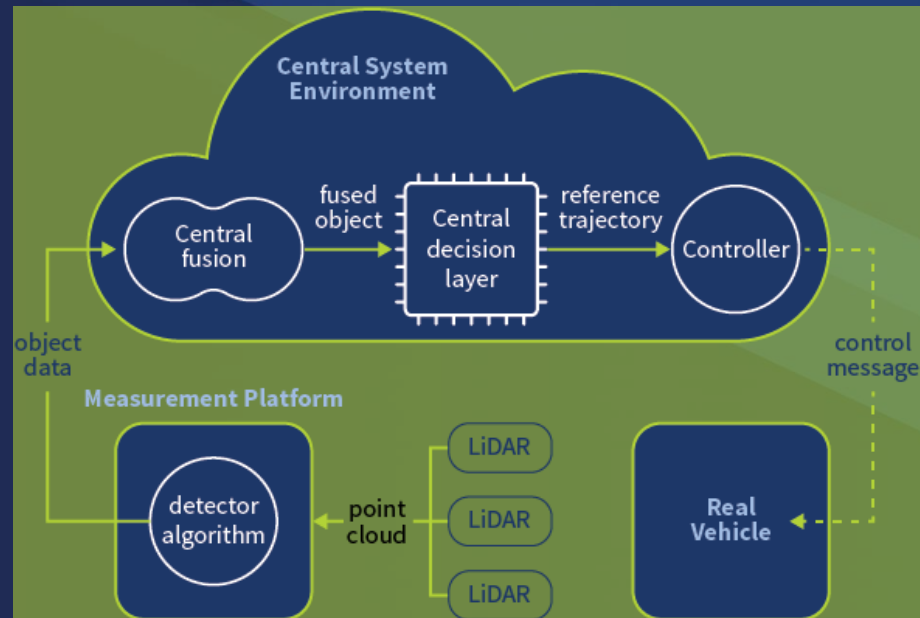


Station2

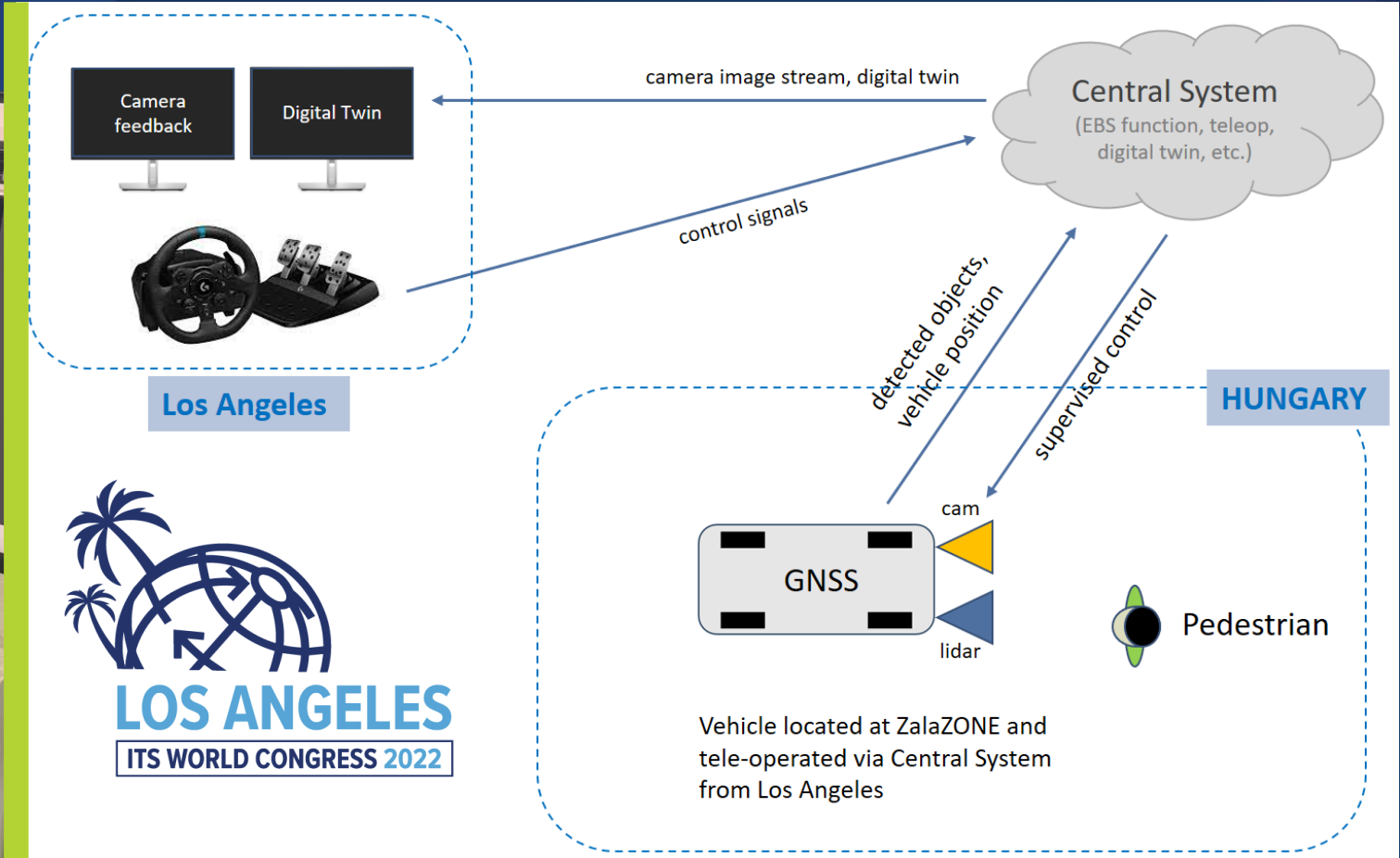


Digital Twin

# Central System - Cloud Control



# Central System – Teleoperation



# Central System – Teleoperation



# Central System – Mixed-Reality Testing

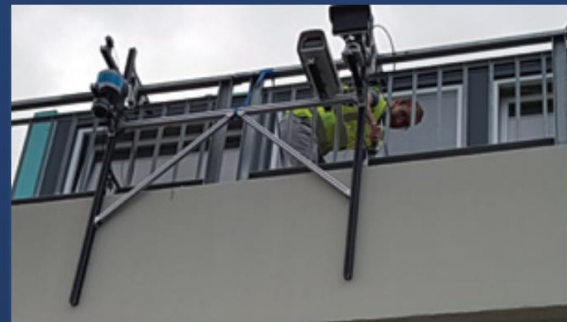


Mixed reality solution provides more freedom in testing

- Cheaper, safer and faster option for reproducible testing
- Scenarios contain real and virtual objects at the same time

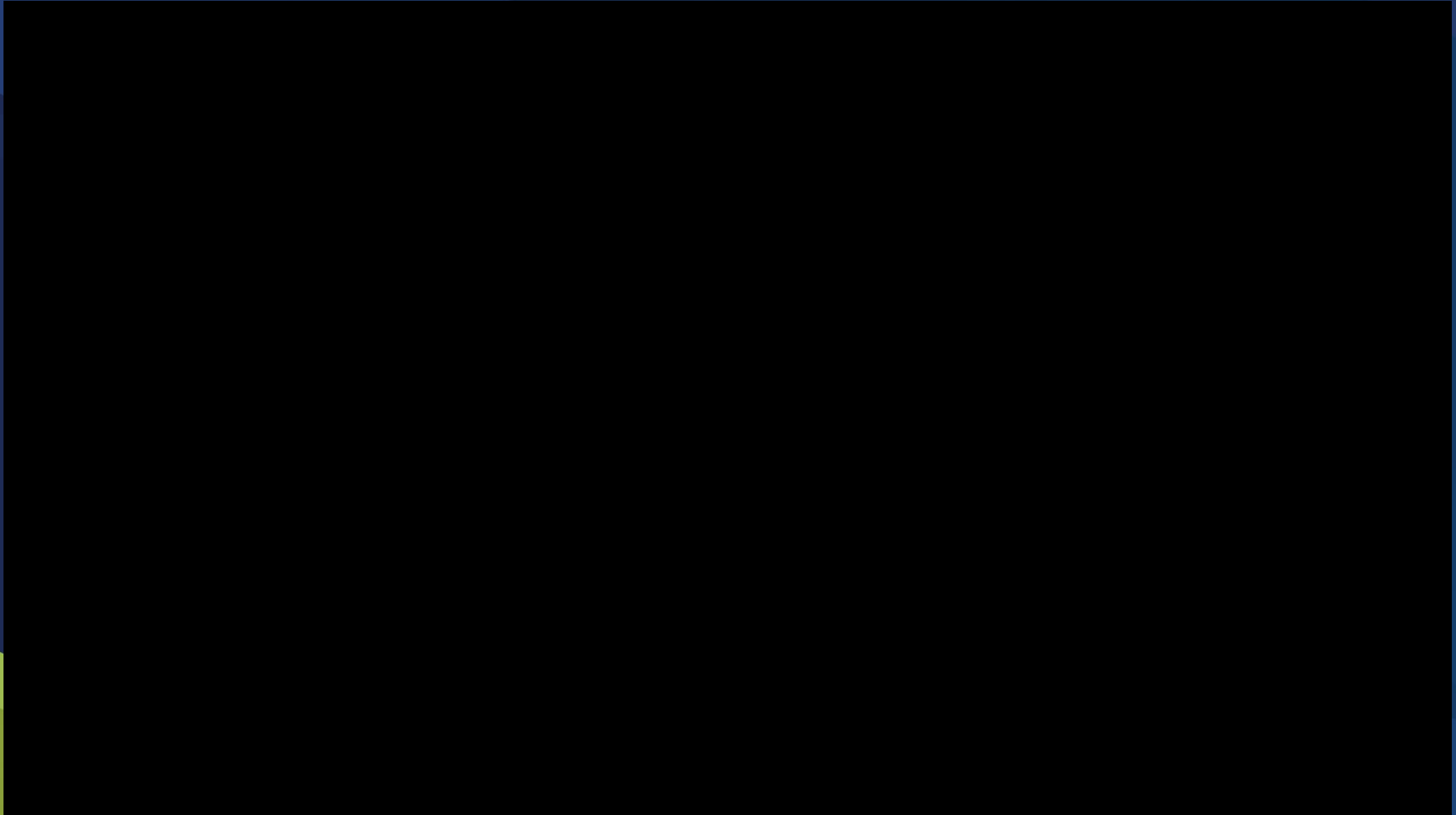
Scenario-in-the-Loop testing

- Real-time Digital Twin is running continuously
- Virtual objects can be injected into the scene, impacting the Vehicle Under Test's behavior
- System can control real test elements (ADAS targets, remote vehicles) at the same time



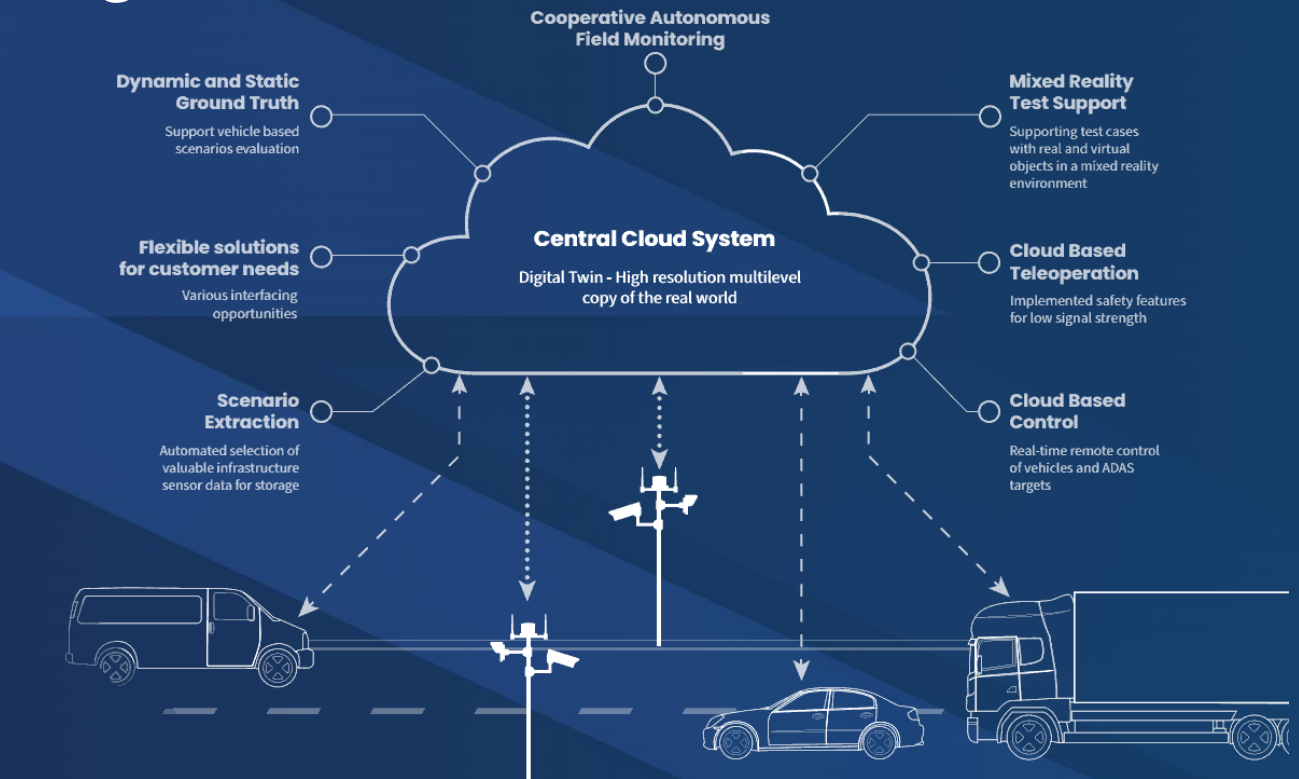


# Cooperative Perception and Control



# Dedicated BME Spin-off Company

- Increase public road safety through
  - Cloud-based
  - Real-time
  - Digital Twin technology



<https://drivebycloud.com/>

# Vehicle Dynamics and Control

- Optimal and robust control
  - Guaranteed robustness against uncertainties
- Model predictive control (MPC)
  - Direct utilization of models
- Reinforcement learning (RL)
  - Alternative approach with recent developments
- Motion planning
  - Searching based methods
  - Optimization
  - RL

Motion planning, motion control  
even at handling limits



# Vehicle Dynamics and Control



# PCT Patent – Vehicle Motion Control System

## SAVING LIVES by widening the potential Trajectory Field for Automated Vehicles


### Solution

- The motion control system enables the vehicle to maneuver automatically while following precise trajectories with one or more saturated tires by stabilizing intervention in the steering system and targeted wheel torques

Patent No.: [WO2022144559A1](https://patents.google.com/patent/WO2022144559A1) WIPO (PCT)

Method and system for an autonomous motion control and motion planning of a vehicle


Budapest University of Technology and Economics



M Ű E G Y E T E M 1 7 8 2

### VEHICLE MOTION CONTROL SYSTEM

PRECISE TRAJECTORY TRACKING AND NEW TRAJECTORIES FOR SELF-DRIVING CARS AT THE LIMITS OF HANDLING



The saturation of one or more vehicle tire grip causes a sudden change in the vehicle's dynamic behavior that cannot be handled by an average driver. Hence, currently used vehicle dynamics control systems (e.g. ABS, ESP) aim to eliminate such conditions as fast as possible by the intervention of brakes and the cut-off of the driving torque. Pulling back a vehicle from the handling limit is naturally restrictive as regards the potential trajectories. However, the unstable behavior of a car at friction limits can be stabilized with appropriate automatic control of the vehicle steering system and individual wheel torques (see, e.g., car drifting by professional drivers). In certain situations, the expansion of possible trajectories resulting from such maneuvers is a desirable outcome.

**SOLUTION**  
The motion control system developed by BME researchers, measuring the vehicle states and monitoring the road conditions, enables the vehicle to maneuver automatically while following precise trajectories with one or more saturated tires by stabilizing intervention in the steering system and targeted wheel torques. The system cooperates with the high-level behavior planner of an autonomous vehicle through a trajectory interface that realizes a two-way communication with the continuous calculation of feasible trajectories, in full knowledge of the car and actuator capabilities. This makes it possible to implement the path requested by the behavior planner unit.

The calculation and realization of new feasible vehicle trajectories beyond friction limits expand possibilities of vehicle dynamics in both critical driving situations and motorsport applications - in a way that no human could.

**TRL 5** Breadboard validation in relevant environment

**SEEKING** one or more industry partners for cooperative product development as well as potential licensees, such as Tier 1 OEMs / suppliers or vehicle manufacturers in the field of autonomous vehicles (AV) or motorsports. We are open to investors too for spin-off purposes.

**PUBLICATIONS** Zs. Szalay, Á. Bárdos et al.: Model building and validation for car drifting, Perner's Contacts, vol. XIX, no. Special Issue 2, pp. 217–228, May 2019  
Á. Bárdos, Zs. Szalay et al.: MIMO Controller Design for Stabilizing Vehicle Drifting, 2019 IEEE 19th International Symposium on Computational Intelligence and Informatics and 7th IEEE International Conference on Recent Achievements in Mechatronics, Automation, Computer Sciences and Robotics (CINTI-MACRO), Szeged, Hungary, 2019, pp. 187-192

**BENEFITS**

- Avoidance of accidents
- Vehicle stability at sudden changes in road conditions
- Precise control of vehicle motion
- Availability of new vehicle trajectories
- Fastest time driving across a given route
- Complete integration into AV control systems

**APPLICATION**

- Automotive industry (road safety, AV)
- Vehicles for rescue operations
- Motorsport (autonomous racing)
- Driver education
- Defence industry (on- or off-road vehicles)
- Entertainment (e.g. ringtaxi)

#### INVENTORS

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#### INTELLECTUAL PROPERTY

Priority HU patent application P2000452  
(filed on 30 December 2020)

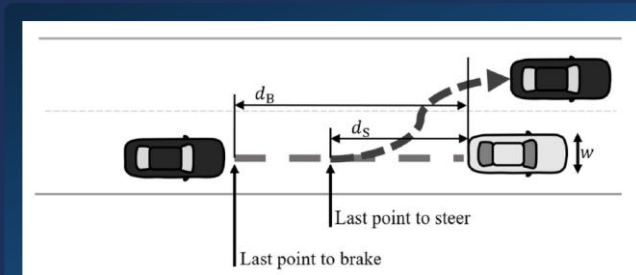
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# \*Better than any human



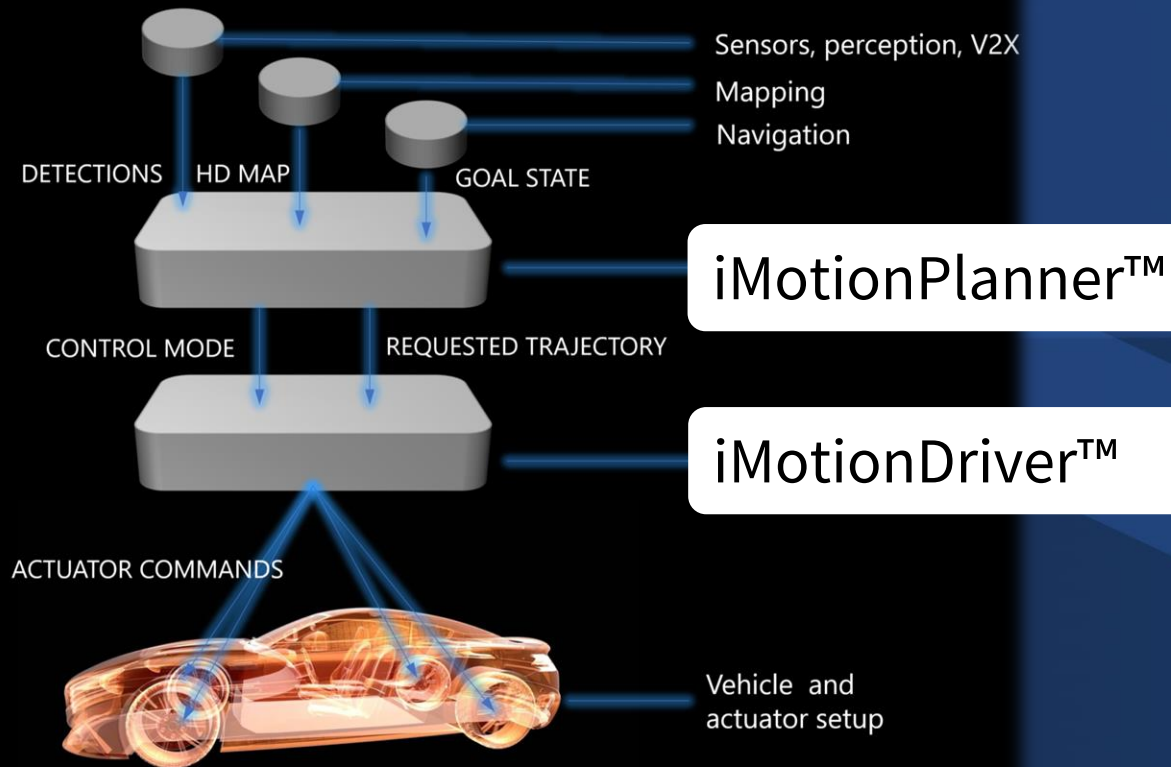
- 20-30% of Killed and Seriously Injured (KSI) originate from loss of control, that might have been avoided by appropriate driver intervention
- Automated Emergency Steering\*
  - Vulnerable Road Users
  - Partial Frontal Collision
  - Tyre Blowout
  - Aquaplaning



Patent No.: [WO2022144559A1](https://patents.google.com/patent/WO2022144559A1) WIPO (PCT)

Method and system for an autonomous motion control and motion planning of a vehicle

# Dedicated BME Spin-off Company



iMotionDrive is an automated driving software provider that helps vehicle manufacturers to operate their cars safely and predictably at handling limits, exploiting the full range of the vehicle's physical capabilities.

**IMOTIONDRIVE**

better than any human

[www.imotiondrive.com](http://www.imotiondrive.com)

# Thank You for your attention!



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**AUTOMATED  
DRIVE**

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