ZalaZONE PROVING GROUND

Zsolt SZALAY Ph.D.

Head of Research&Innovation

World Forum
for
Harmonization of Vehicle Regulations (WP.29)

UNITED NATIONS

zone

Disruptive changes

Technology change in the automotive industry

- AD vehicles are no longer separate entities
- Human driver is getting out of the control loop
- New algorithms (e.g. machine learning) current validation will not

„Conventional" vs AD vehicle testing and validation

- Vehicle dynamics testing in itself is not enough
- Testing vehicle environment perception capabilities
- Testing vehicle interaction to other vehicles and the infrastructure
- Connected vehicles require testing of communication technologies

Conclusion: new testing and validation methods thus dedicated proving grounds are necessary

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Decision on strategic R&D investment

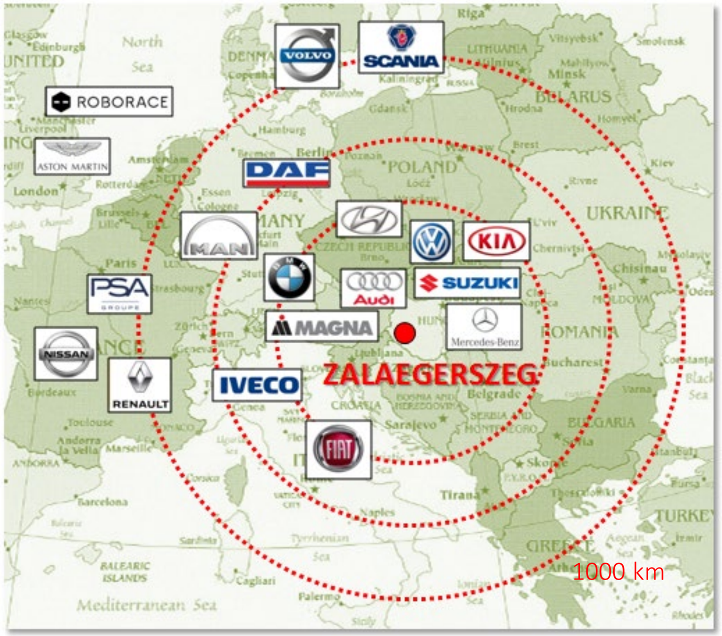
Unique test facility

Capacity constraints in Europe in area of vehicle dynamic testing

Technology change in vehicle industry – single vehicle vs. co-operative vehicle control: different development environment is required

Decision of Hungarian Government in 2016: „contribution to the European automotive community"

Test field for classic and automated and connected vehicles in Hungary



Co-operating industrial partners in requirement definition

Industry demand is fulfilled

Automotive Working Group, 2015:

AImotive, AVL, BME GJT, BOSCH, Commsignia, Knorr-Bremse, Continental, EVOPRO, NKH, NI, SZTAKI, ThyssenKrupp Presta, TÜV Rheinland, ZF

- Detailed **technical specification** of the classic elements of vehicle dynamics and physical structure of the automated vehicle tests
- Draft **specification of the autonomous environment** and related communication infrastructure
- Technical proposal for autonomous vehicle **public road testing**

ICT Working Group, 2017:

BME HIT, BME KJIT, BPC, Ericsson, HUAWEI, Kapsch, Magyar Közút, Magyar Telekom, NFM, NMHH, Nokia, Oracle, RWE, Siemens, SWARCO, T-Systems, Vodafone (compared to the new members of the automotive working group)

- Detailed specification of the autonomous vehicle environment and related **communication infrastructure**

Status of the project

zone

Layout of the Proving Ground

Traditional and CAV testing modules

Area: **265 ha**

Budget: **140 million EUR**

Standard vehicle dynamics testing and validation

Fully integrated autonomous vehicle testing and validation

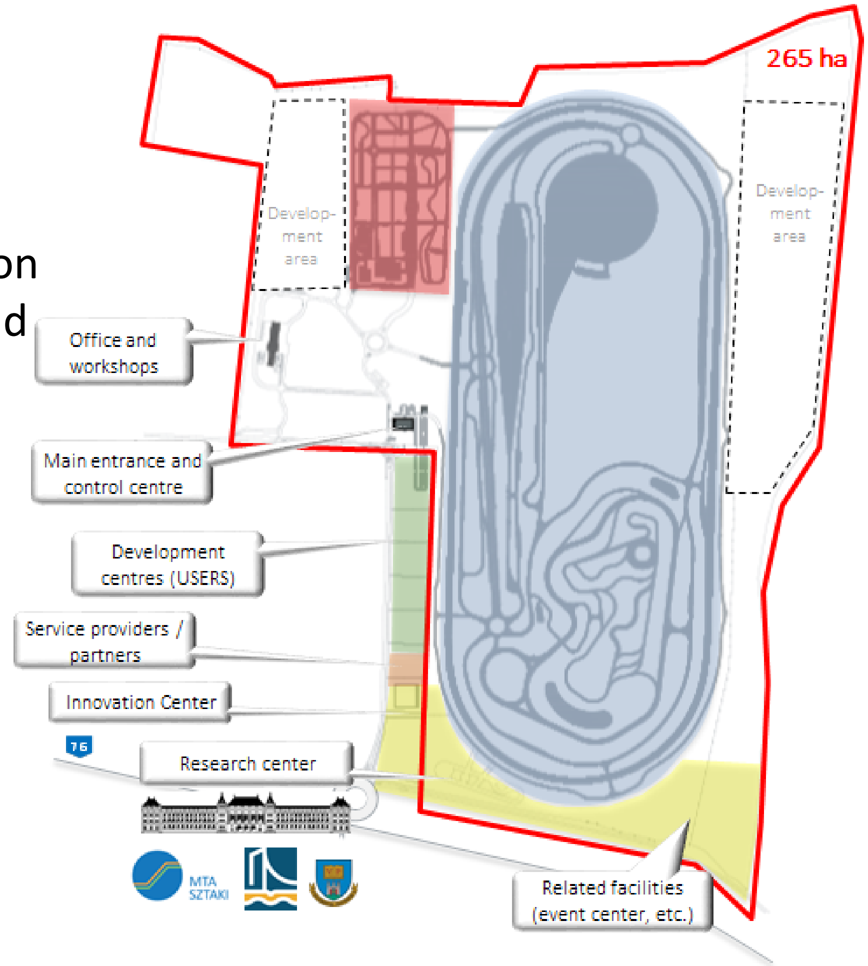
Environment preparation (obstacles, traffic signs, traffic control, other vehicles, vulnerable road users, etc.)

Complex driving and traffic situations

Smart City features

From prototype testing till series production testing and validation

- Not only automotive but telecom and IT test environment
- Not only road traffic but drone traffic, recovery and counter drone activities
- **8+1 Unique Testing Propositions**



Source: Szalay et al, PerPol TraspEng 2017

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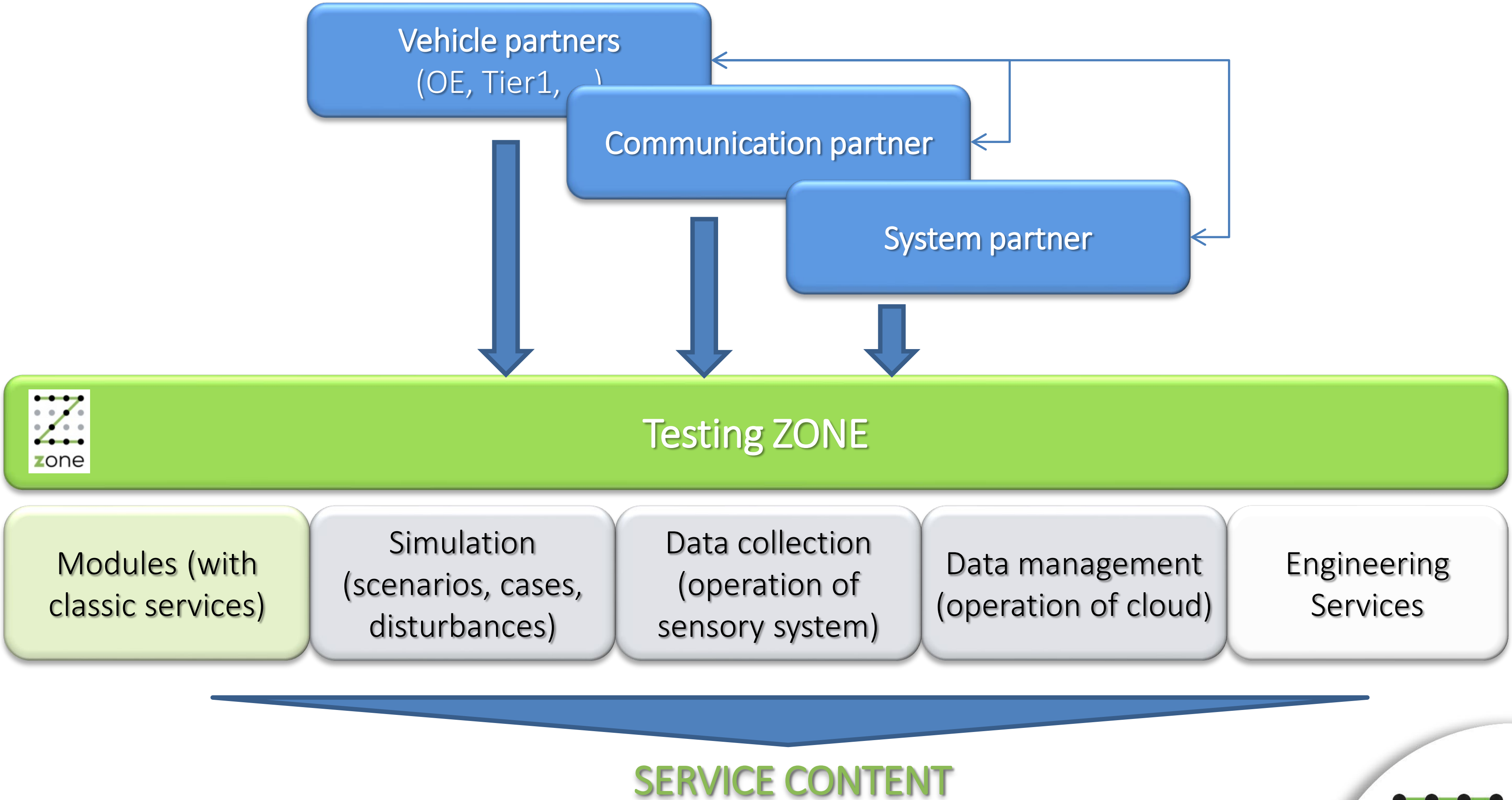
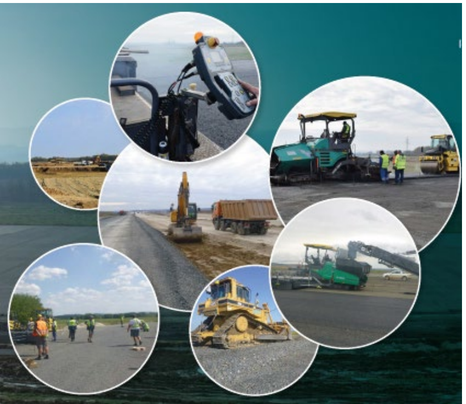
Business & Operation Model

Operation models will change



PROJECT DEVELOPMENT



Phases of the project

Phase 1: **2018**

- **Dynamic platform**
- **Braking surfaces**
- **Handling course – high speed**
- **Smart City basic road grid I**
- *Main entrance building*
- *Technical building*

(Innovation center – by industrial park)

Phase 2.a: **2019**

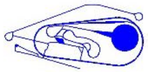
- Dynamic platform
- Smart City basic road grid
- Braking surfaces
- Handling course – high speed
- Rural road – Eastern section
- Smart City road grid II, facades, buildings
- Highway section
- Rural road – Eastern section
- *Main entrance building*
- *Technical building*
- *Control center*

Phase 2.b: **2020**

- Dynamic platform
- Smart City basic road grid
- Braking surfaces
- Handling course – high speed
- Rural road – Eastern section
- Smart City facades, buildings
- Highway section
- Rural road – Southern section
- Handling course – low speed
- Smart City technology+
- Further dynamic modules
- High-speed oval
- *Main entrance building*
- *Technical building*
- *Control center*
- *Research center*

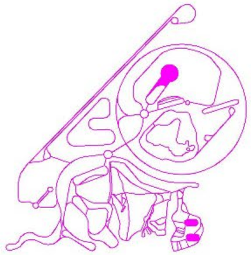
Proving Ground benchmarks

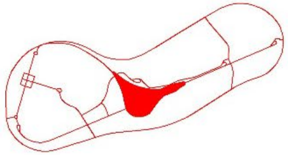

Mcity

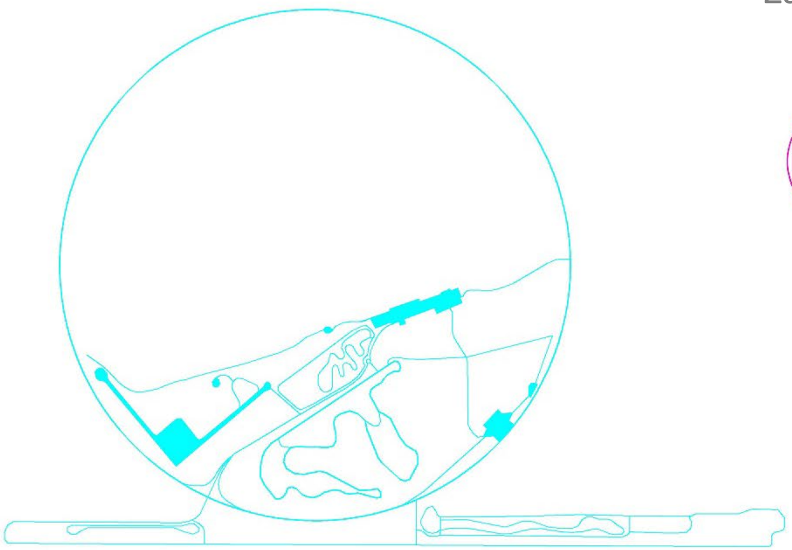

Aldenhoven

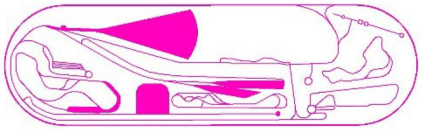
Boxberg


ZalaZONE

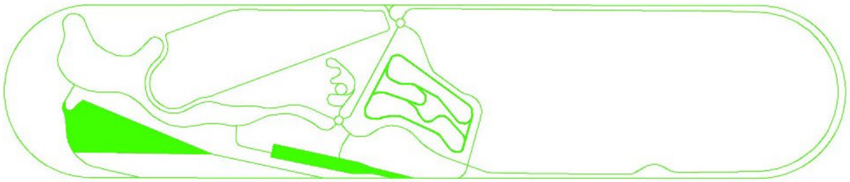

Millbrook


AstaZero

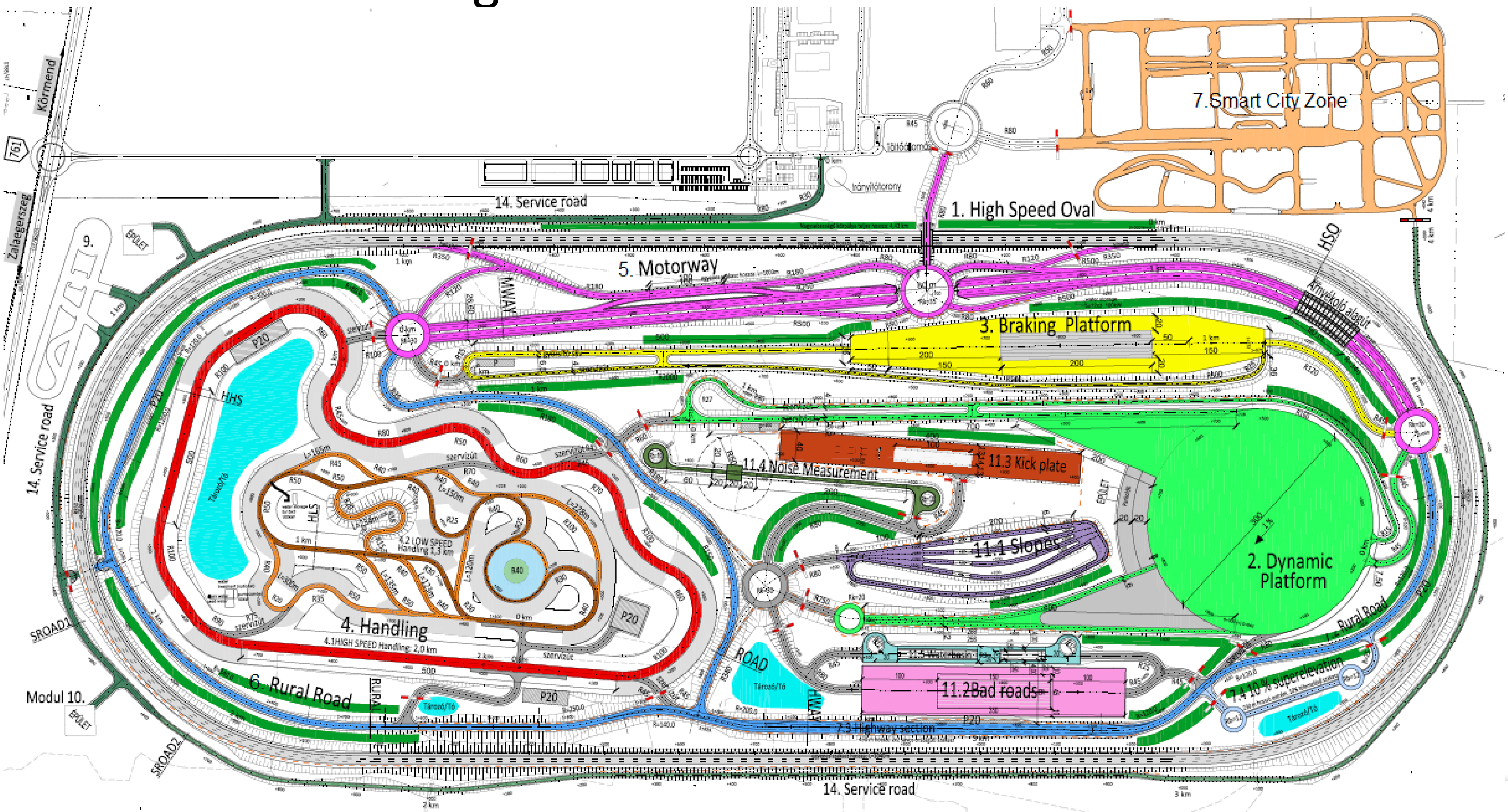

Nardó


Idiada

Horiba-Mira

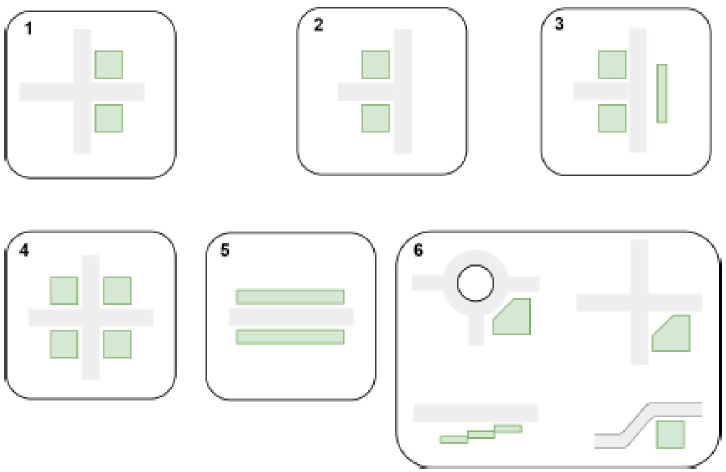

Papenburg

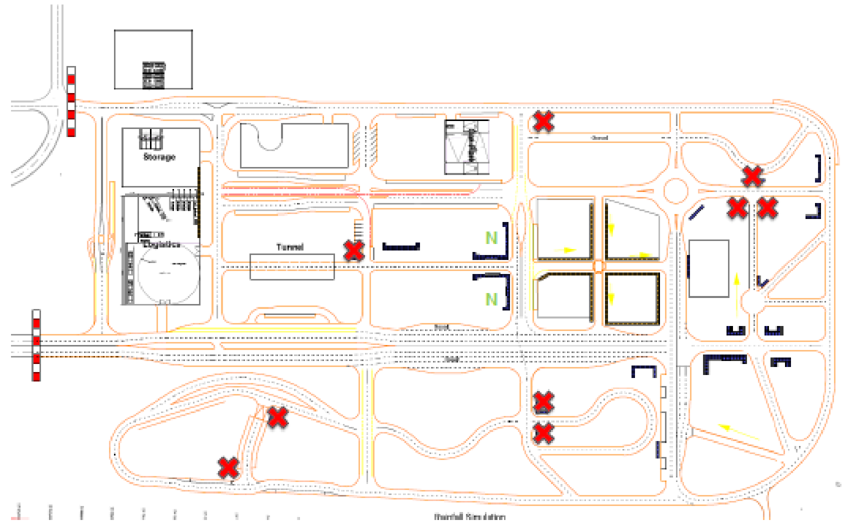
Automotive Proving Ground ZalaZONE

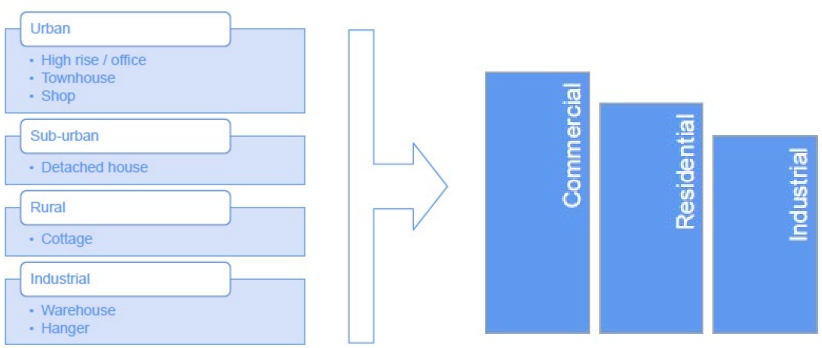


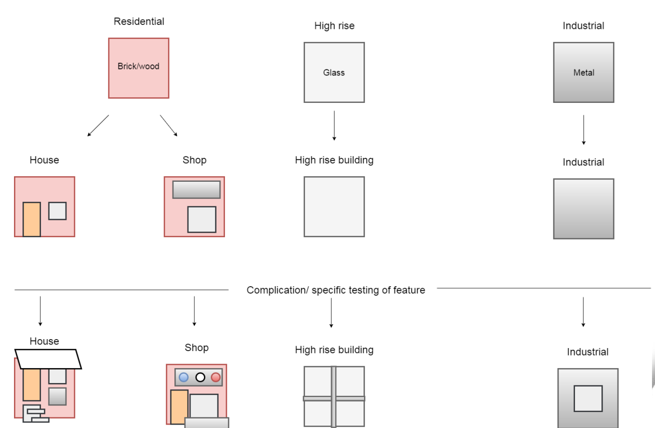
Construction of Complex Test Scenarios

SMART City Zone – Buildings





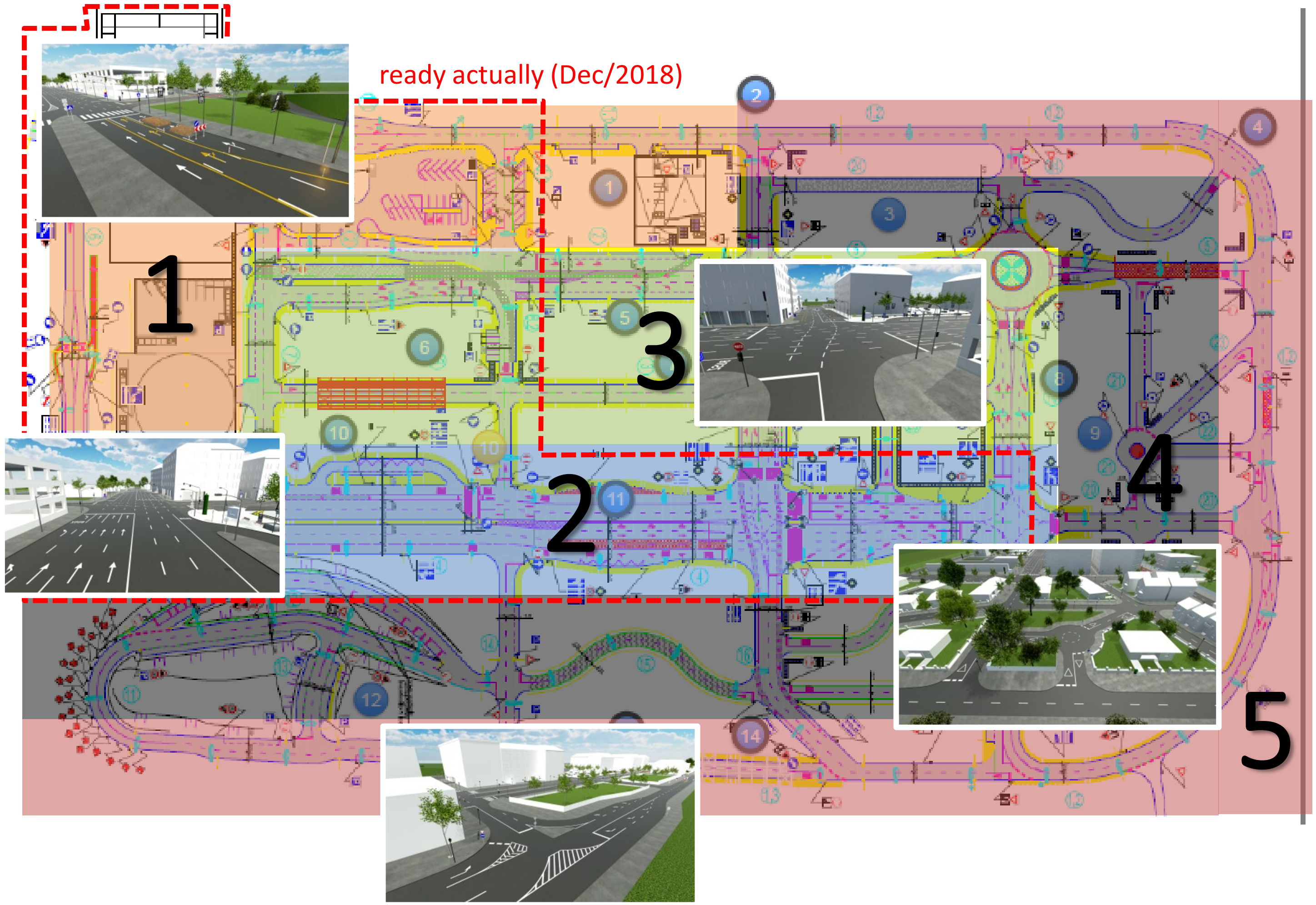




Details of the modules

Proving Ground Modules

SMART City Zone – Separated Function Zones



1. Low-speed, parking area
2. Multi-lane high speed area
3. Downtown area
4. Suburban area
5. T-junction area

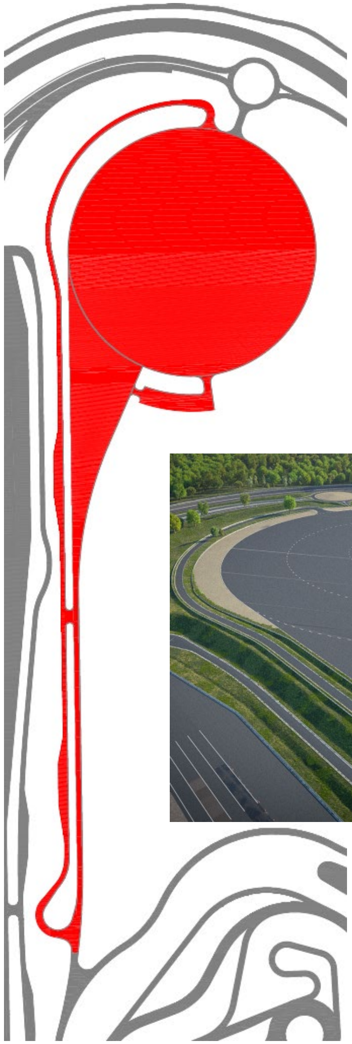
zone

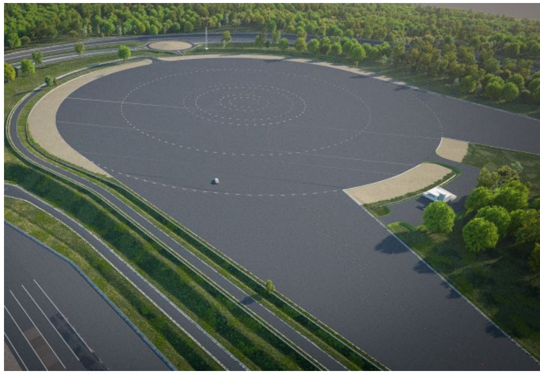
Proving Ground modules

Dynamic platform

Physical parameters:

- 300m diameter asphalt surface
- Acceleration lane 760m and 400m long
- 20m wide FIA emergency area
- Watered surface (optional)
- Watered basalt surface at eas acceleration lane (phase 2.)
- 1% inclination to south
- Separated return way





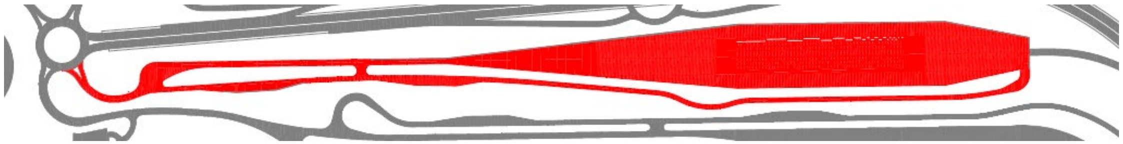
Autonomous vehicle test cases:

- Platooning at free trajectory
- Cooperative vehicle control at high and medium mue with different trajectories (double lane change, J-turn etc.) at stability limit (ABS, ESP activity)
- Fix position obstacle (dummy car or pedestrian)
- Euro NCAP scenarios

zone

Proving Ground modules

Braking platform



Physical parameters:

- 8 different surfaces:
  - *Chess surface: asphalt/tiles*
  - *Asphalt mue=~1 (optional watering)*
  - *Tiles mue=~0.1 (wet)*
  - *Blue basalt mue=~0.3 (wet)*
  - *Asphalt mue=~0.8 (optional watering)*
  - *Treated concrete mue=~0.6 (wet)*
  - *Asphalt mue=~0.8 (reserve surface)*
  - *Aquaplaning basin (max. 5cm wet depth)*
- 200m surface length
- 750m acceleration lane
- 20m safety area at both side, 150m at the end

Autonomous vehicle test cases:

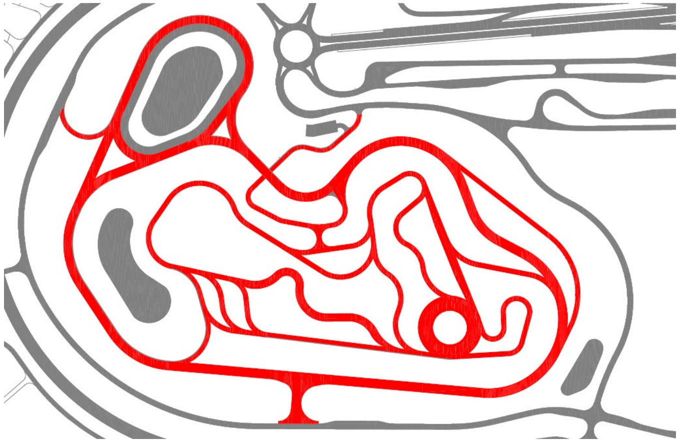
- Platooning at physical limits; drive through or braking at various surfaces up to high speed
- Cooperative vehicle control at physical limit, moving or static obstacle, at various speeds during ABS, ATC, ESP activity

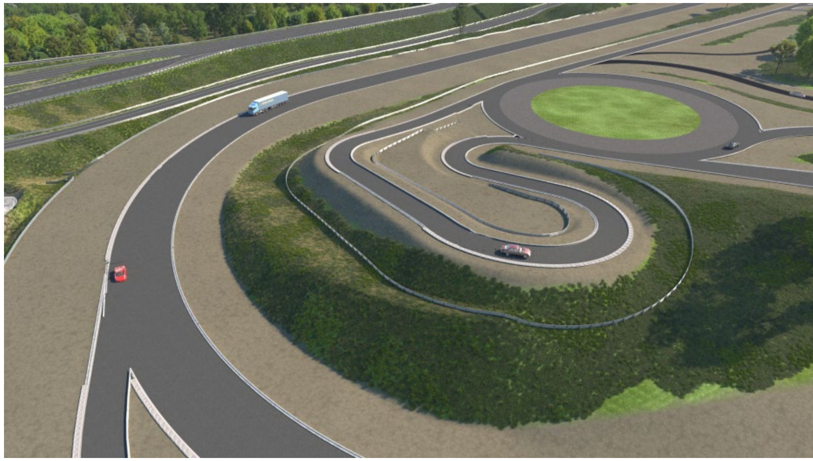
Proving Ground modules

Handling course

Physical parameters:

- Low (60km/h) and high speed (120km/h) section
- 1.300m and 2000m length
- width: 6 and 12m
- 20m wide gravel covered safety zones
- Various topography
- V2X coverage for communication tests at various terrain



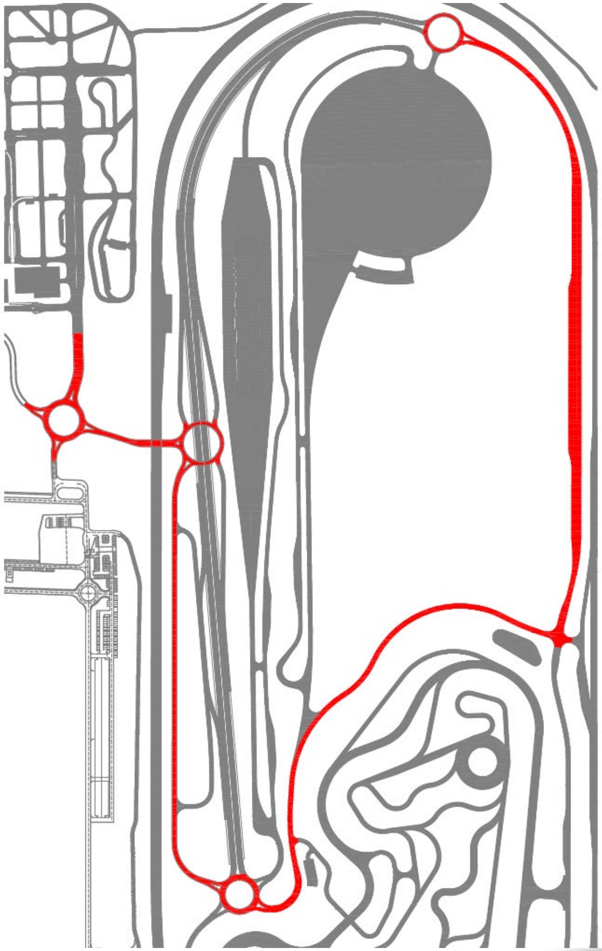


Autonomous vehicle test cases:

- Platooning at medium speeds at diverse topography
- Cooperative vehicle control at diverse topography and limited visibility

Proving Ground modules

Rural road



Physical parameters:

- 500m 2x2 lane motorway
- 2500m 2x1 lane rural road
- Partly watered surface
- 5G test network
- V2X communication coverage
- GPS base station
- Public road like layout (junctions, road surface, geometry)

Autonomous vehicle test cases:

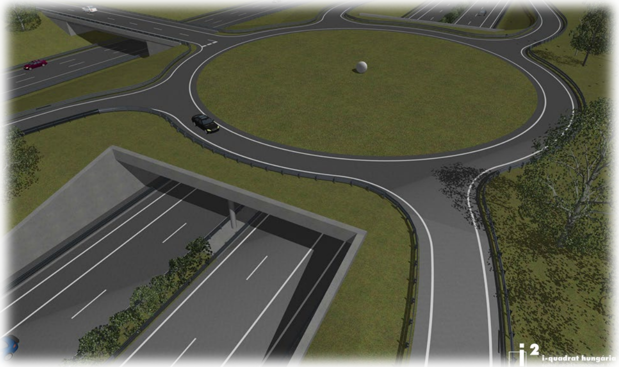
- Platooning on rural road at realistic conditions, various type of junctions, roundabouts
- Diverse lane layout: 2x1, 2x2, 2+1,
- Diverse topography
- Moving and static obstacles
- Construction site situation
- Various road side elements: trees, fences, grass etc.

Proving Ground modules

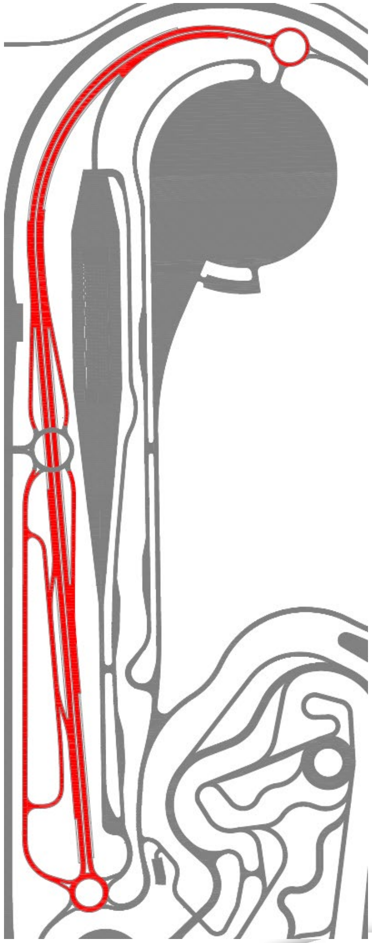
Motorway

Parameters:

- 1500m 2 x 2+1 lane motorway
- 100m real tunnel
- Partly watered surface
- VMS, 5G test network
- V2X communication coverage
- GPS base station
- Public road like layout (junctions, road surface, geometry)



Project Phase 1 2017-2018



Autonomous vehicle test cases:

- Platooning on motorway at realistic conditions, exits and entrances
- Platooning and cooperative control with limited communication (tunnel)
- Moving and static obstacles
- Construction site situation
- Multi level junction

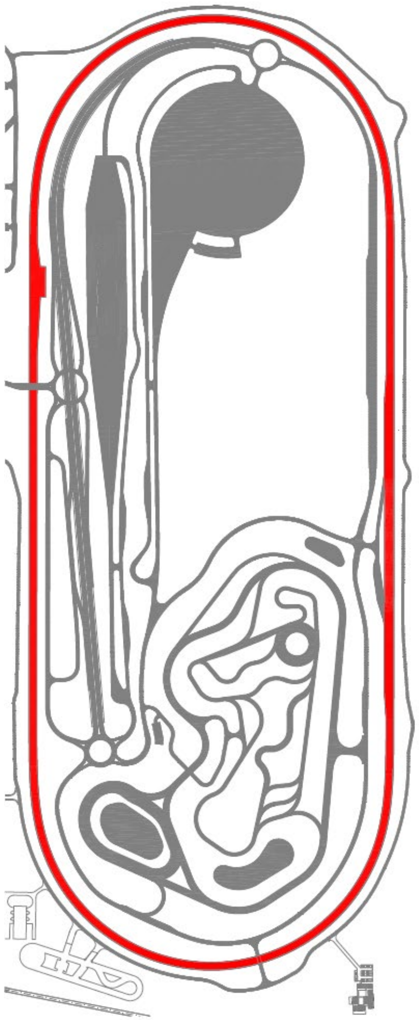
Proving Ground modules

High-speed oval

<u>Parameters</u>:

4.400m length

- 900m straight sections
- 350m curve radius
- 200km/h neutral speed at curves
- max. 250km/h at straights
- 1% inclination to south
- 4 lanes



<u>Autonomous vehicle test cases:</u>

- Platooning at high speed motorway situations
- Cooperative vehicle control at high speed
- Fix position and moving obstacles (dummy car or pedestrian)
- V2I, V2V communication tests at high vehicle speed

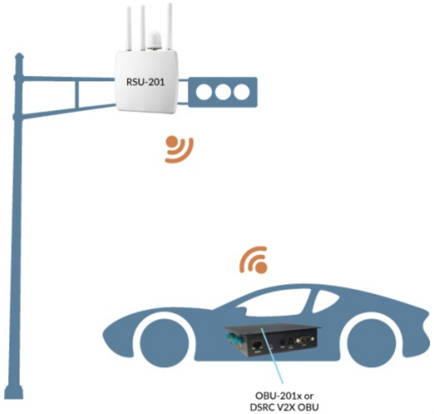
Proving Ground modules

Communication network

- 3 level approach:
  - 1st level: ITS G5 basic V2X test environment
  - 2nd level: V2X developer environment: freely configurable, open interface for application developers, full data logging infrastructure
  - 3rd level: fully customer defined test environment

- 5G cellular test network for future ITS applications

- Redundant layout for parallel customer networks



Education, Research&Innovation

zone

RECAR Program

- **RE**search **C**enter for **A**utonomous **R**oad vehicles (RECAR)

- Market Demand
  - Global trends and timing in automotive development
  - 4 OEMs and 15 TIER1s are in Hungary
  - Continuous need for qualified engineers

- Education and R&D initiatives - multidisciplinary cooperation
  - Academic sphere (BME, ELTE, MTA SZTAKI)
    - BME VIK, KJK, ÉPK, GPK
  - Industrial partners (Bosch, Knorr-Bremse, Continental)

- RECAR Education Program
  - ***Autonomous Vehicle Control Engineer*** MSc in English
  - ***Computer Science for Autonomous Systems*** MSc in English
  - ***Vehicle Test Engineer*** BProf in Hungarian

Autonomous Vehicle Control Engineer MSc

1	Numerical mathematics		ELTE	2	0	1	f	4	TT	IK
1	Control theory and system dynamics	Bokor József-Gáspár Péter	BME	2	0	2	v	4	TT	KJIT
1	Intelligent systems	Dobrowiecki Tadeusz	BME	3	0	0	f	4	TT	VIK
1	Compensation block			6	0	6	v f f	12	SZV	BME
1	Vehicle dynamics	Németh Huba	BME	2	0	1	v	3	SZI	GJT
1	Vehicle testing and validation	Szabó Bálint	BME	0	0	3	f	3	SZI	GJT
2	Industrial image processing	Vajta László	BME	3	1	0	v	4	TT	VIK
2	High performance microcontrollers and interface	Tevesz Gábor	BME	2	1	0	f	4	TT	VIK
2	Human factors in traffic environment		ELTE	2	0	0	f	2	GH	IK
2	Legal framework of autonomous vehicles		ELTE	2	0	0	f	2	GH	IK
2	Localization and mapping	Barsi Árpád	BME	2	0	2	f	4	SZT	EMK
2	Autonomous robots and vehicles	Kiss Bálint	BME	2	1	0	v	4	SZT	VIK
2	Automotive environment sensors	Bécsi Tamás	BME	2	0	2	v	5	SZI	KJIT
2	Automated driving systems	Szalay Zsolt	BME	2	0	2	v	5	SZI	GJT
3	Automotive R&D processes and quality systems	Wahl István	BME	3	0	0	f	4	GH	GJT
3	Project management		BME	2	0	0	f	2	GH	GTK
3	Machine vision	Szirányi Tamás	BME	2	0	2	v	4	SZT	ALRT
3	Safety and security in vehicle industry	Sághi Balázs	BME	2	0	0	f	3	SZT	KJIT
3	Design and integration of embedded systems	Majzik István	BME	2	1	0	v	3	SZT	VIK
3	Traffic modelling, simulation and control	Varga István	BME	2	0	2	f	4	SZT	KJIT
3	Automotive network and comm. systems	Szalay Zsolt	BME	2	0	2	v	4	SZI	GJT
3	Automated vehicle design project	Gáspár Péter	BME	1	0	2		3	SZI	KJIT
3		Németh Huba	BME	1	0	2	v	3	SZI	GJT
4	Diploma thesis			0	30	0	f	30	ÖP	

RECAR research program

Scientific Areas

Artificial Intelligence	Control Theory and Energy Management	Software and System Integration	Data Science and Communication Technologies	Safety, Security, Privacy
• Knowledge representation • Intelligent Data Analytics • Machine Learning and Conclusions • Human- Machine-Interaction	• Autonomous, Distributed, Hierarchic and Cooperative Modeling and Control • Human- Machine-Interaction • Energy Management	• Platforms and Standards • Design, Testing and Validation • Reliability • Virtualization	• Data Mining and Analytics • Cloud Technologies • Internet, IoT • Sensor Fusion • Mobile Technologies • Wired and Wireless Communication	• Functional Safety • Cyber Security • Data Ownership and Access Control • Privacy • Traffic Safety • Accident reconstruction

Research Directions

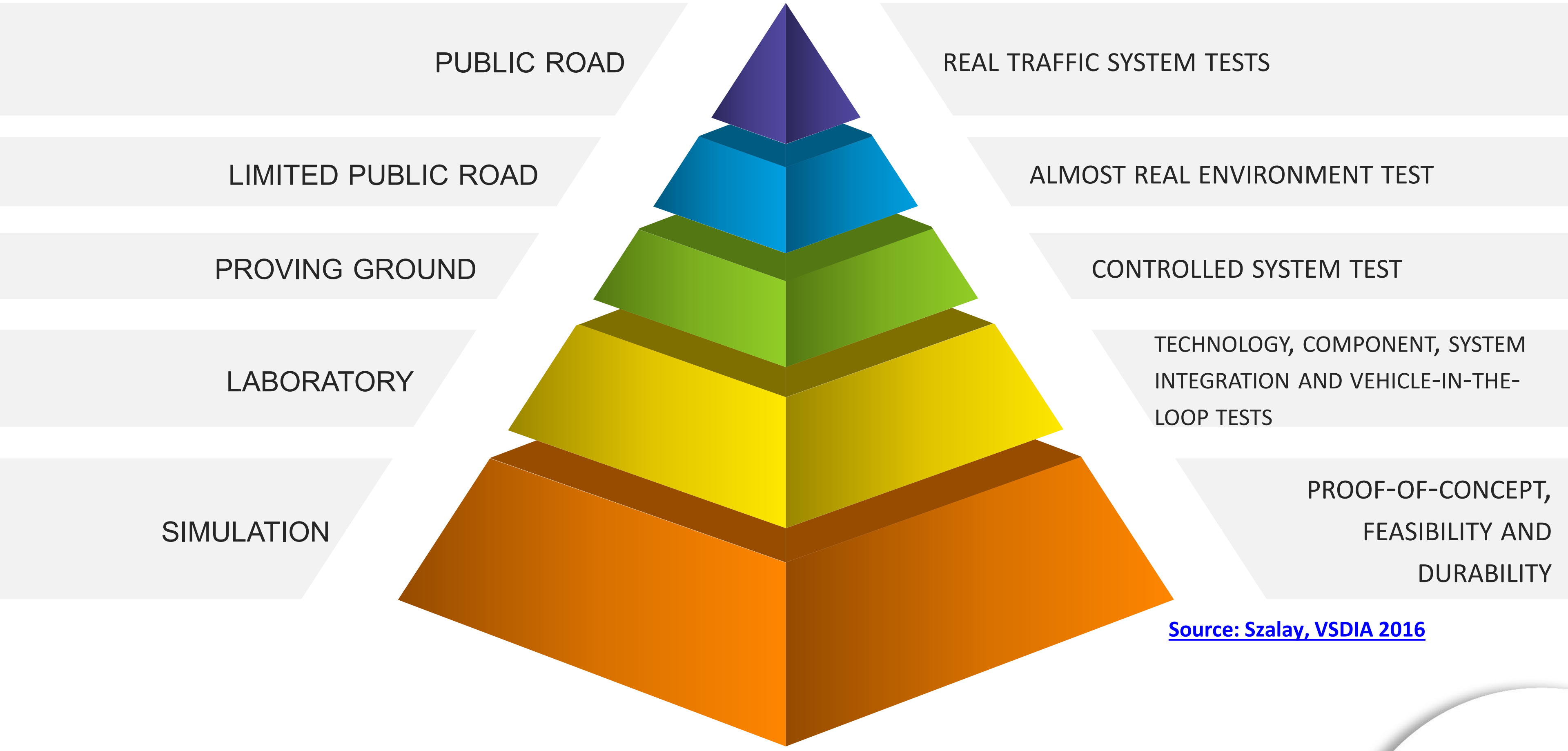
Research Directions
Vehicle • Automated Vehicle Control (Level2-5) • Drivetrain • Human Factors • Testing and Validation
Vehicle-Environment Connection • Environment Sensing • Cooperative Control • V2X Communication
Environment • Intelligent Transportation Systems • Mobile Communication Systems • Smart Infrastructure • Electromobility

Knowledge, Competence and Applications

Scientific Publications and Know-how

Multi-level testing environment

From computer to real traffic



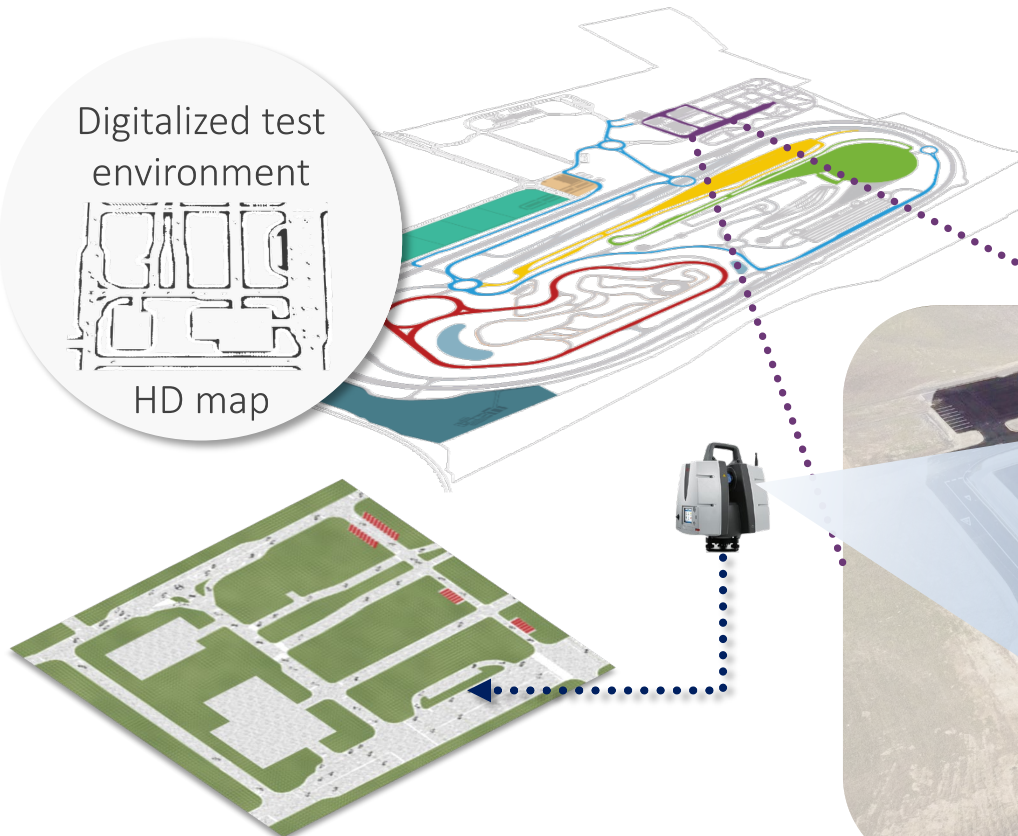
Source: Szalay, VSDIA 2016

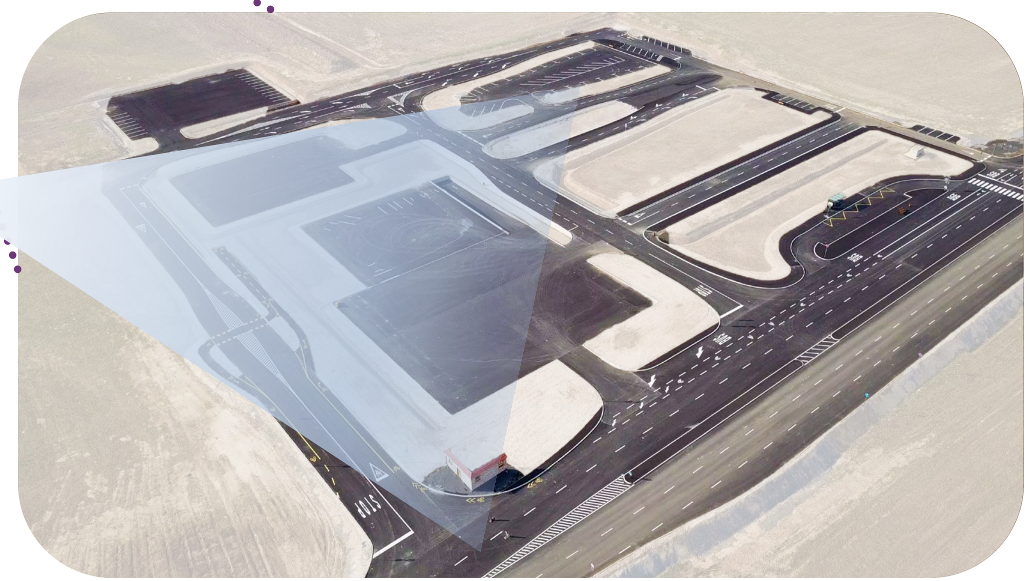
Autonomous Vehicle Testing & Validation Pyramid

Scenario-in-the-Loop concept

Digitalized test environment

The entire proving ground in its reality must be provided in the virtual simulation environment in which the positions and pathways of lanes are known and exactly correspondents to the real testing area.





To create this, the most effective way is surveying the track using laser scanning technology and generate a high definition 3D point cloud [9]. The results of the surveying should be readable for most simulation software, and therefore the “point cloud” must be converted into widely used industrial standards such as OpenDrive™ or OpenCRG™ or other open source file formats.

Scenario-in-the-Loop concept

The tested vehicle and its localization

Vehicle Under Test

The investigation of the Vehicle Under Test (VUT) or ego vehicle is the main target of the test scenario.

The VUT can be split in two groups depending on its SAE automation level.

If the ego vehicle falls below automation Level2 then the maneuver should be performed for good reproducibility by a driverless test system (DTS)

Above automation Level2 the tested ego vehicle has a certain self-driving capability and able to drive from location A to location B within the proving ground.

Localization

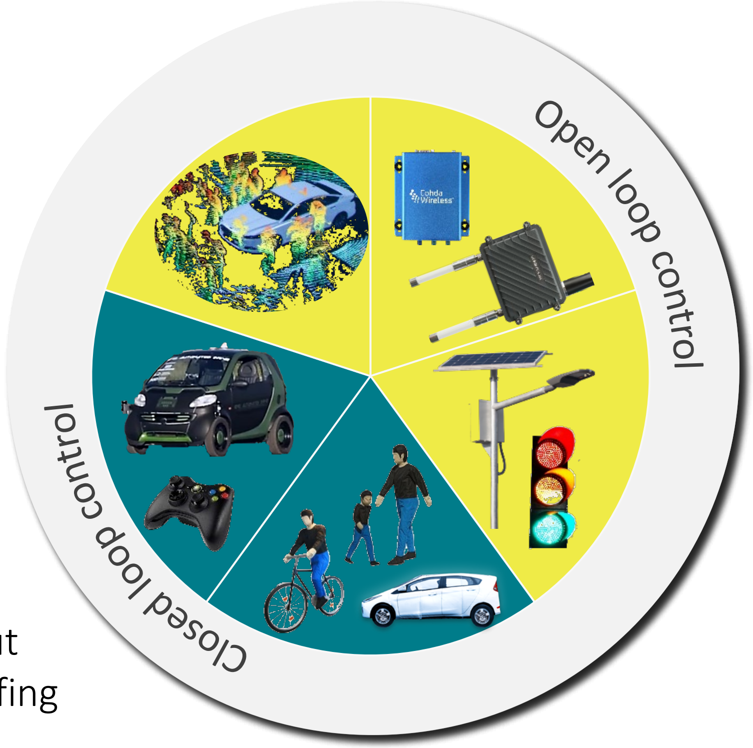
The VUT has to be registered with high precision by the traffic simulation as an active road user, which requires at least 2 cm accuracy in positioning. Currently by mounting an inertial measurement unit (IMU) linked with a differential GNSS to the real car, its position on the test track can be located with the desired accuracy. The combination of the IMU and DGNSS are commonly referred to as inertial satellite sensors (INS).

Scenario-in-the-Loop concept

Disturbances

The outputs of SciL processes are the potential disturbances, ergo every element which can affect the VUT's behavior.
There are five main type of disturbances:

- VUT Sensor spoofing
- V2X communication spoofing
- Infrastructure elements
- Moveable targets
- Full-control real vehicles



The disturbances can be categorized by three aspects:

- Real or virtual objects
  Real object can be perceived by the VUT own sensors, but virtual objects required sensor and communication spoofing

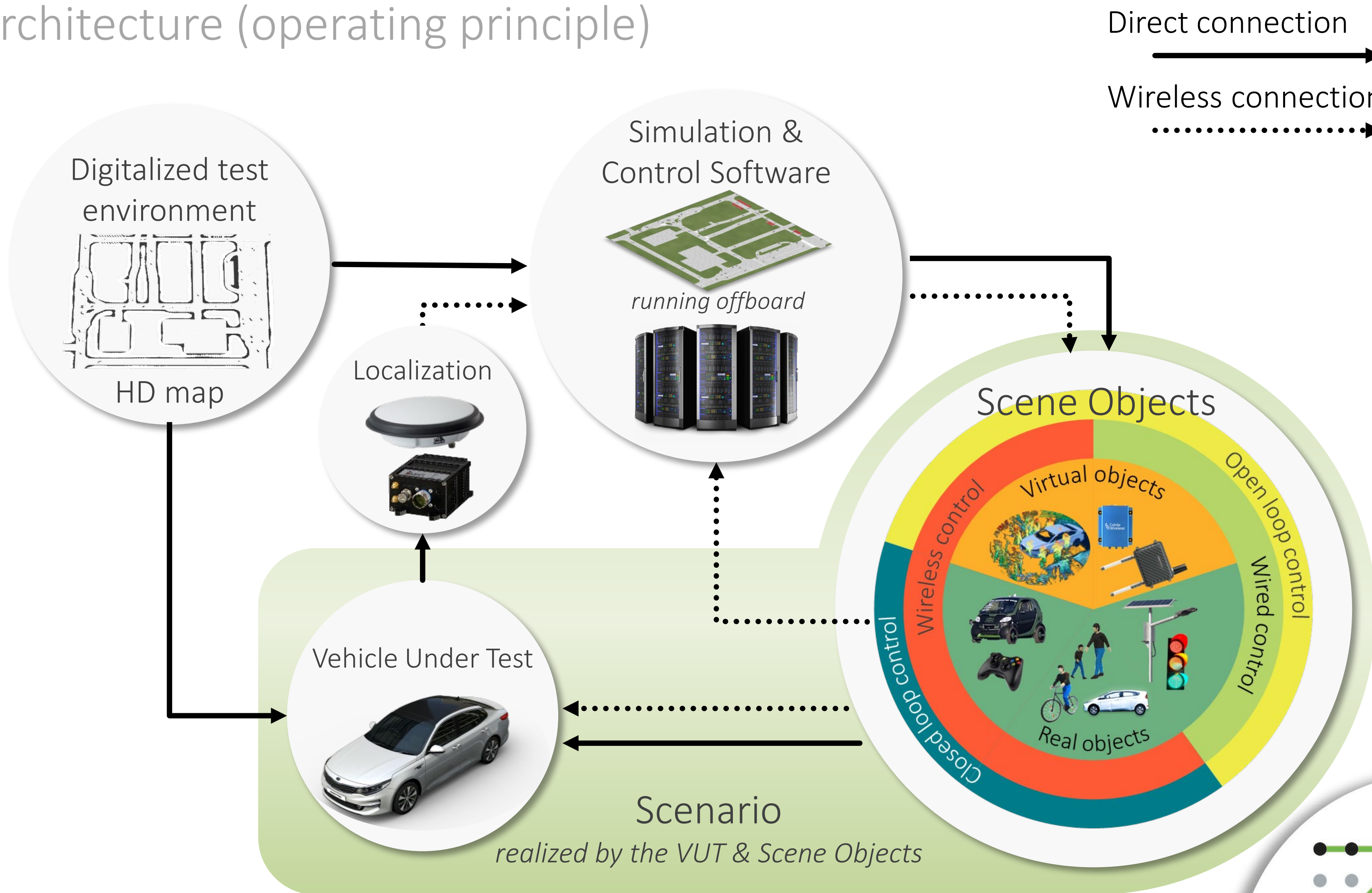
- Controlled by wire or wireless
  The communication between the disturbances and the control software can be carried out by wireless communication or directly by wire.

- Closed or open loop control
  The real-time acquiring of the actual status and position of the movable objects are also necessary for the continuous control of the defined scenario.

zone

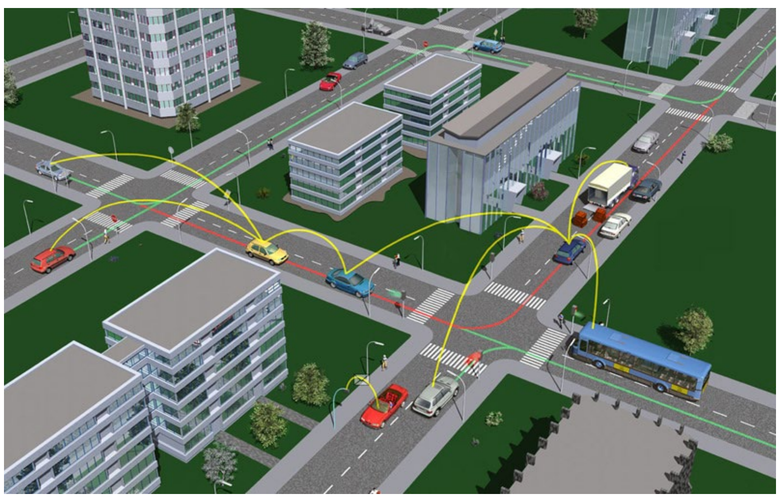
Scenario-in-the-Loop concept

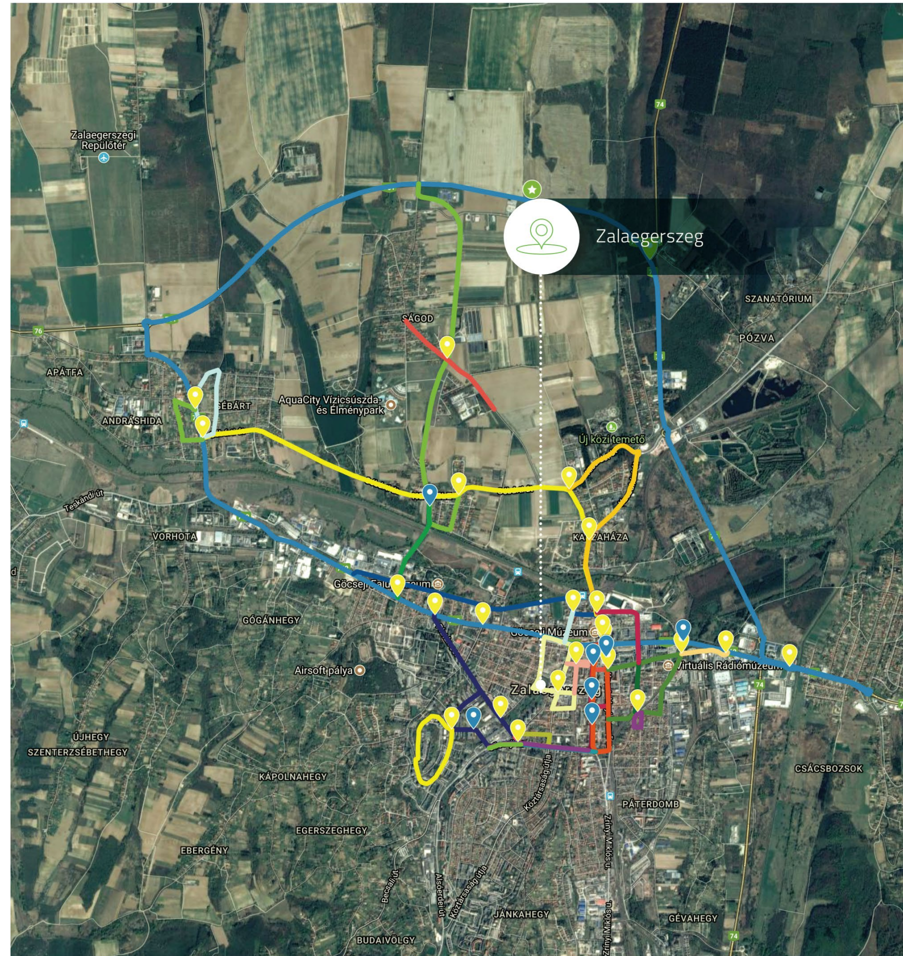
Architecture (operating principle)



Layer 4 - Limited Public Road Tests

- Dedicated Test Routes
- 5G Demo Network
- ITS G5 Coverage
- Smart City and Connected Car features

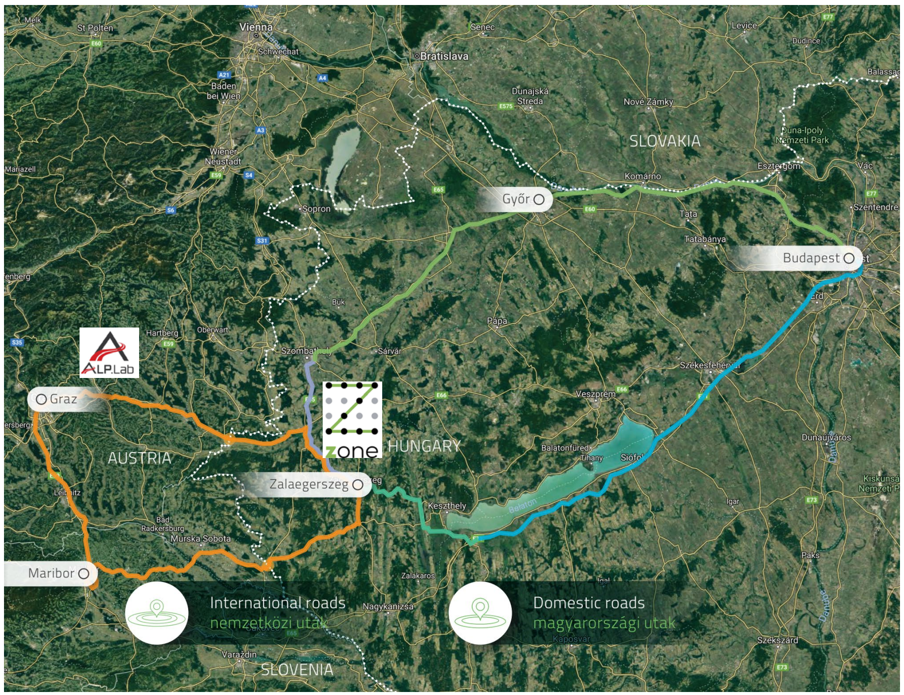




Layer 5 - Public Road Testing

Today…

Public road tests are allowed in Hungary since 12th of April
11/2017. (IV.12.) NFM decree (5/1990, 6/1990 KöHÉM)
Anywhere in Hungary for automotive R&D companies



… and tomorrow

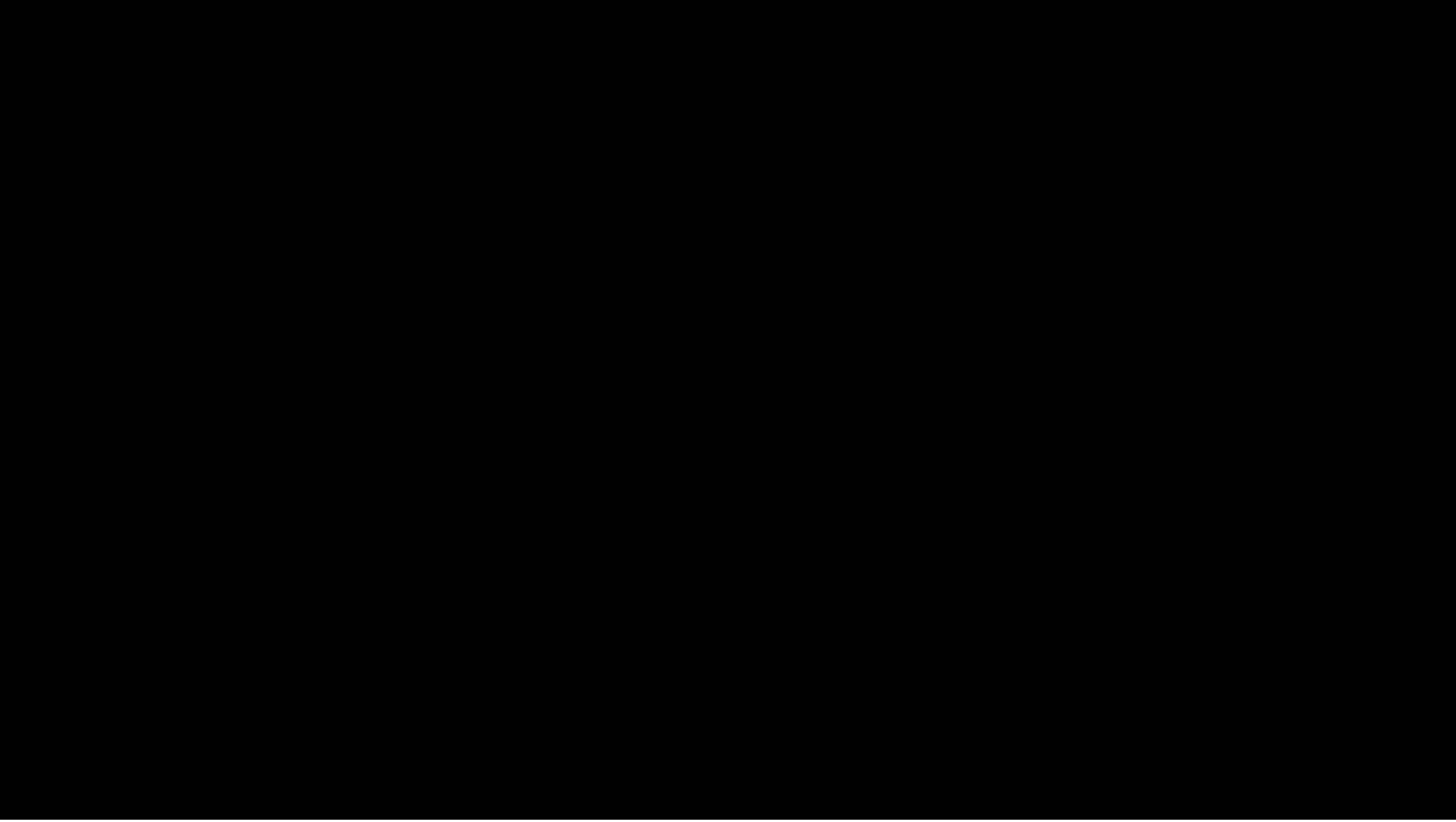
Specific routes on public road with enhanced services for CAV tests

Integration to Proving Ground in Zalaegerszeg

Smart city zone in Zalaegerszeg

Part of cross-border cooperation between Zalaegerszeg-Graz-Maribor

- 2018 Q2: M7 highway
- 2019: M70
- 2020: Zalaegerszeg smart city
- 2021-2022: R76 highway



ZalaZONE Construction Status

Comprehensive Approach of Hungary

Education and Research
Smart Road Infrastructure
Infocommunication Technologies
Legislation and Standardization

Working Groups

MOBILITY PLATFORM

Dr. Zsolt SZALAY

Tender/financial support

Secretariat
Mátyás HESZ

Communication
Nándor ÖTVÖS

Automotive Industry
- Proving Ground
- Univ. Research C.
- Industrial R&D C.
- Technology Park
- Next-door Services

Zoltán HAMAR

Public Road Infrastucture
- Road
  M76, M7, M70
  Cross-border
  TEN-T
- Smart Test City
- C-ROADS
- CROCODILE

Tamás A. TOMASCHEK

Legislation
- Automotive/Telco
- International
  GEAR 2030
- Hungarian
  5/1990, 6/1990
  EKTB

Dr. Alíz DÁVID

Vehicle Communication
- V2X-ITS G5
- Cellular (4G/5G)
- Smart City
- C-ITS Platform

Dr. László BOKOR

Data Management
- Data
  Storage
  Acces (Privacy)
  Analitics

Dr. Gábor MAGYAR

Vehicle Localization
- HD Maps
- Static, Semi-static,
  Semi-Dynamic,
  Dynamic Layers

András CSEPINSZKY

Homologation
- Type approval
- International
  WP.29/ITS-AD
  Euro NCAP
  ISO

Ferenc FINSZTER

ZALAZONE - Region Zala

zone