ZalaZONE PROVING GROUND

Zsolt SZALAY Ph.D.
Head of Research & Innovation
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**
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:**
- Almotive, 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*
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
Business & Operation Model

Operation models will change

Vehicle partners (OE, Tier1, ...)

Communication partner

System partner

Testing ZONE

Modules (with classic services)

Simulation (scenarios, cases, disturbances)

Data collection (operation of sensory system)

Data management (operation of cloud)

Engineering Services

SERVICE CONTENT
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
- Idiada
- Horiba-Mira

- Nardó
- Papenburg
- AstaZero
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

ready actually (Dec/2018)
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

Details of the modules
Proving Ground modules

Braking platform

Physical parameters:

• 8 different surfaces:
  • Chess surface: asphalt/tiles
  • Asphalt $\mu_e=\sim1$ (optional watering)
  • Tiles $\mu_e=\sim0.1$ (wet)
  • Blue basalt $\mu_e=\sim0.3$ (wet)
  • Asphalt $\mu_e=\sim0.8$ (optional watering)
  • Treated concrete $\mu_e=\sim0.6$ (wet)
  • Asphalt $\mu_e=\sim0.8$ (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)

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

Details of the modules
Proving Ground modules

High-speed oval

Parameters:
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

Autonomous vehicle test cases:
• 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
RECAR Program

- **REsearch Center for Autonomous Road 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
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<th>Course Title</th>
<th>Code</th>
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<td>Numerical mathematics</td>
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<td>Industrial image processing</td>
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<td>Automotive R&amp;D processes and quality systems</td>
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<td>Control theory and system dynamics</td>
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<td>High performance microcontrollers and interface</td>
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<td>Human factors in traffic environment</td>
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<td>Localization and mapping</td>
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<td>Design and integration of embedded systems</td>
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<td>Vehicle testing and validation</td>
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**Diploma thesis**
## RECAR research program

### Scientific Areas

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<td>Platforms and Standards</td>
<td>Data Mining and Analytics</td>
<td>Functional Safety</td>
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<td>Human-Machine-Interaction</td>
<td>Design, Testing and Validation</td>
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<td>Energy Management</td>
<td>Reliability</td>
<td>Internet, IoT</td>
<td>Data Ownership and Access Control</td>
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<td>Sensor Fusion</td>
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<td>Mobile Technologies</td>
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<td>Wired and Wireless Communication</td>
<td>Accident reconstruction</td>
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### Research Directions

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<th>Vehicle</th>
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<td>Automated Vehicle Control (Level2-5)</td>
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<td>Drivetrain</td>
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<td>Human Factors</td>
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<td>Cooperative Control</td>
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<td>V2X Communication</td>
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<th>Environment</th>
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<td>Intelligent Transportation Systems</td>
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<td>Mobile Communication Systems</td>
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<td>Smart Infrastructure</td>
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<td>Electromobility</td>
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### Scientific Publications and Know-how
Multi-level testing environment

From computer to real traffic

- PUBLIC ROAD
- LIMITED PUBLIC ROAD
- PROVING GROUND
- LABORATORY
- SIMULATION
- REAL TRAFFIC SYSTEM TESTS
- ALMOST REAL ENVIRONMENT TEST
- CONTROLLED SYSTEM TEST
- TECHNOLOGY, COMPONENT, SYSTEM INTEGRATION AND VEHICLE-IN-THE-LOOP TESTS
- PROOF-OF-CONCEPT, FEASIBILITY AND DURABILITY

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 corresponds 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.
The investigated vehicle under test (VUT) or ego vehicle is the main target of the test scenario.

The VUT can be split into two groups depending on its SAE automation level. If the ego vehicle falls below automation Level 2, then the maneuver should be performed for good reproducibility by a driverless test system (DTS). Above automation Level 2, the tested ego vehicle has a certain self-driving capability and able to drive from location A to location B within the proving ground.

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.
Scenario-in-the-Loop concept
Architecture (operating principle)

- Digitalized test environment
- HD map
- Vehicle Under Test
- Localization
- Simulation & Control Software running offboard
- Scene Objects
- Wireless connection
- Direct connection
- Virtual objects
- Open loop control
- Wired control
- Real objects
- Closed loop control

Scenario realized by the VUT & Scene Objects
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
Comprehensive Approach of Hungary

Education and Research
Smart Road Infrastructure
Infocommunication Technologies
Legislation and Standardization

Working Groups

Dr. Zsolt SZALAY

Tender/financial support
Secretariat
Communication

MOBILITY PLATFORM

Tender/financial support
Secretariat
Communication

MOBILITY PLATFORM

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

Public Road Infrastructure
- 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. Aliz DÁVID

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

Data Management
- Data Storage
  Acces (Privacy) Analytics
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

www.mobilitasplatform.hu

www.zalazone.hu
ZALAZONE - Region Zala