Session 3 : Validation of Driving Automation Systems

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AI for Good Global Summit

Future Networked Car Symposium

FNC2026

Intelligent, connected, automated and safe

8–9 July 2026
Geneva, Switzerland

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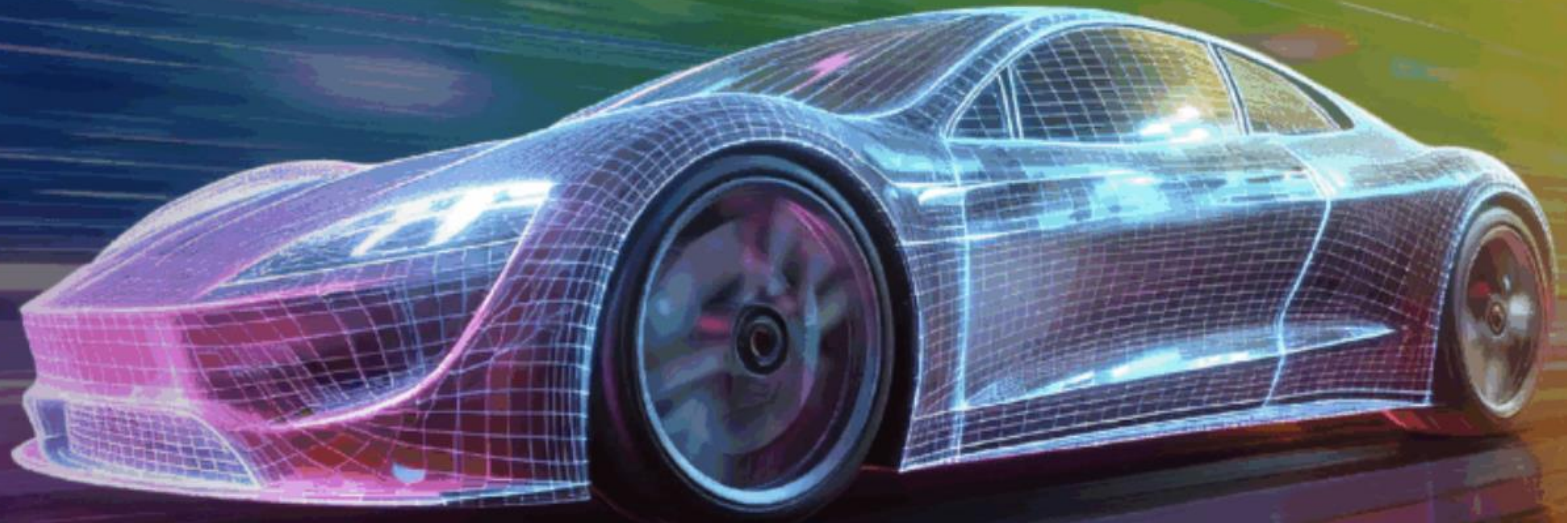
AI-driven Virtual ADS Validation Status and Challenges



You-Jun CHOI, Ph.D. (ychoi@katech.re.kr)

Principal Researcher / Lab leader

Automated Driving System Research Center

Korea Automotive Technology Institute (KATECH)

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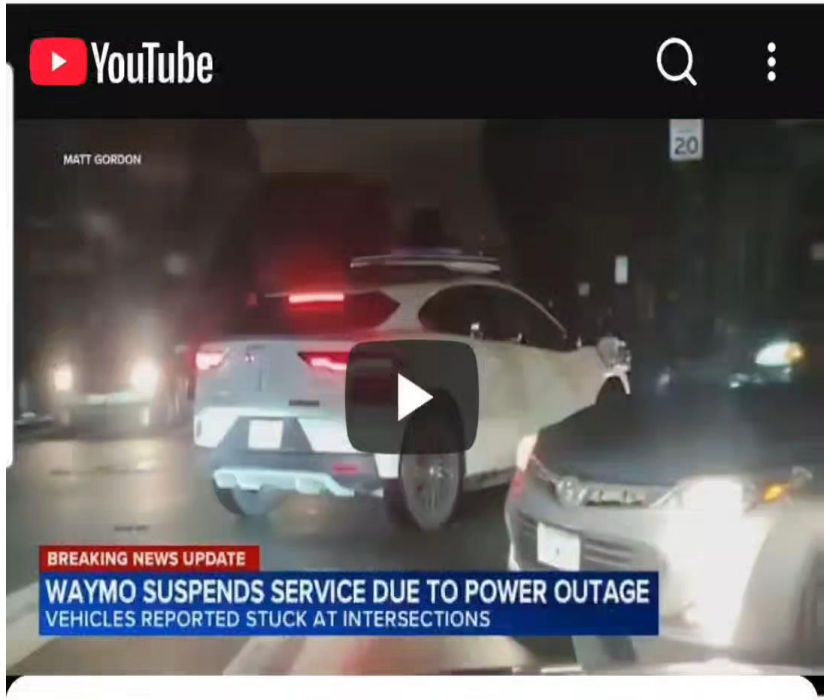
Issues on ADS service in Real World

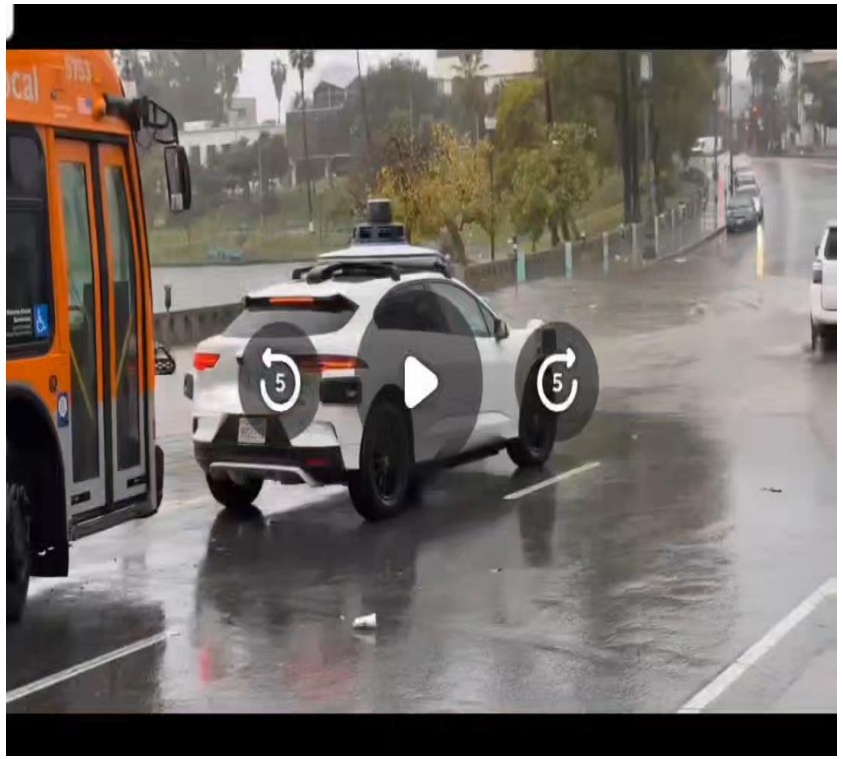
Autonomous mobility service is not just about driving. It is a complete system :
ADS-equipped Vehicle + remote management + structured procedures + on the ground daily operations.



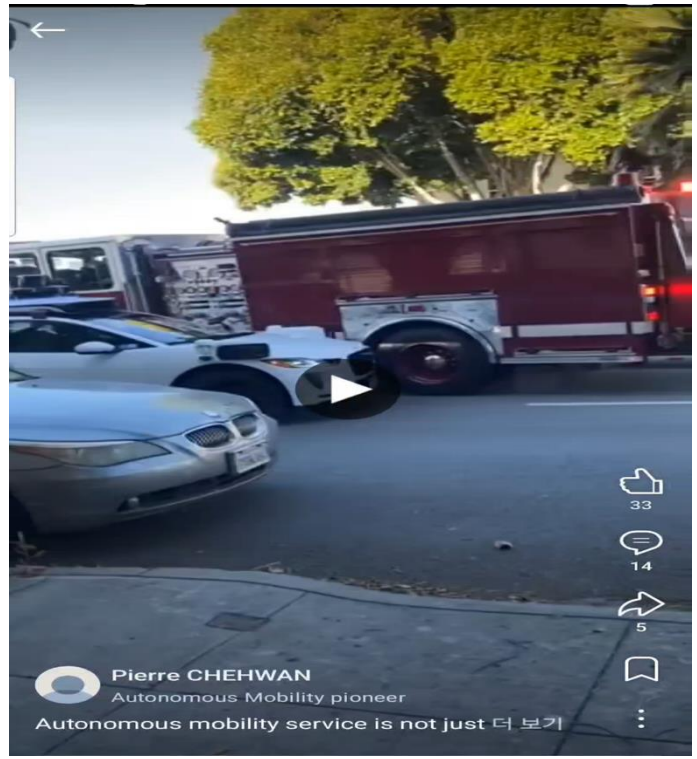
Videos show Waymo cars stuck at San Francisco intersections during massive power outage

30K views · 1 month ago

#waymo #poweroutage #sanfrancisco ...more



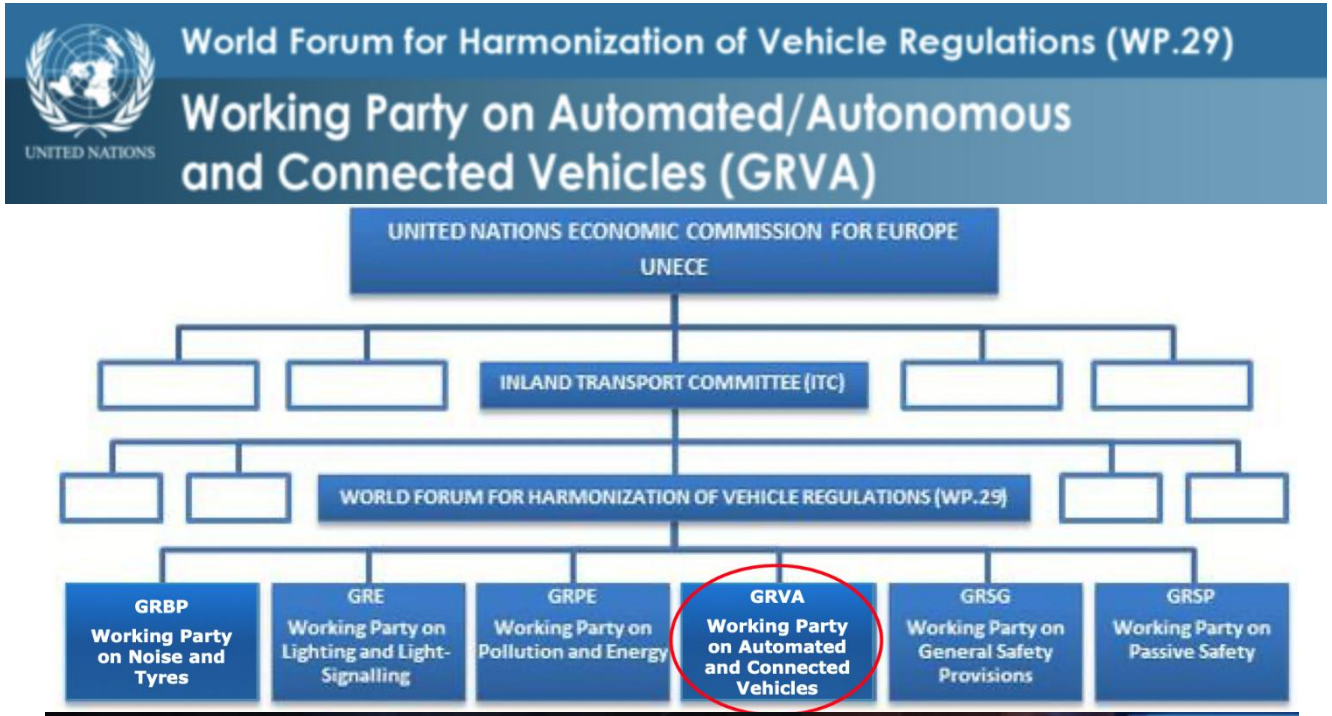
Waymo cars couldn't overcome the overflowing rain



🚒 An emergency responder (e.g. a fire truck) is in action, and a Waymo vehicle is blocking the way.

🚦 It's up to the remote management system to detect the situation and the remote manager can trigger the appropriate procedure, for example, sending a mission to the vehicle to safely clear the road.

UNECE WP29/GRVA/VMAD(Validation Method for Automated Driving)



*"… develop assessment methods, including scenarios, to validate the safety of automated systems, based on a **multi pillar approach** including auditing, simulation, virtual testing, test track testing, real world testing…"*

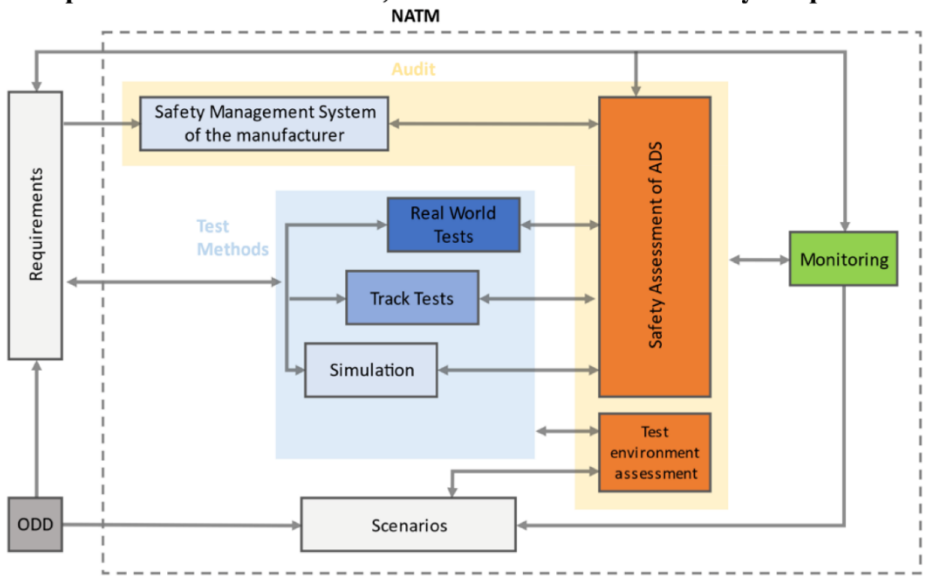
- **Working Party on Automated/Autonomous and Connected Vehicles (GRVA)**
  - Automated Driving System (ADS)
  - Cyber Security and (OTA) software updates (CS/OTA)
  - DSSAD / EDR
  - Acceleration Control for Pedal Error (ACPE)
  - Advanced Emergency Braking System (AEBS)
  - Task Force on fitness for ADS of GRVA Regulations and GTRs (TF on FADS)
  - ADAS
  - Past activities
    - Task Force on Automated Vehicle Categorization (TF AVC)
    - FRAV/VMAD Integration
    - Functional Requirements for Automated and Autonomous Vehicles (FRAV)
    - Validation Method for Automated Driving (VMAD)
    - Electro-Mechanical Braking (EMB)
    - SIG on UN Regulation No. 157
    - Automatically Commanded Steering Function (ACSF)
    - Automatic Emergency Braking and Lane Departure Warning Systems (AEBS/L
    - Modular Vehicle Combinations (MVC)
    - GRVA - WebEx (2019 Q1)

UNECE VMAD Scenario based Validation

- The UNECE VMAD framework emphasizes
  - ✓ physical road testing alone is insufficient to demonstrate the safety of automated driving systems.
- Instead, it promotes
  - ✓ **a combination of Scenario-based Validation, Virtual Validation, and real-world testing** to achieve comprehensive safety assurance.
- SiLS and ViLS provide practical platforms for executing large numbers of representative and edge-case scenarios across the entire Operational Design Domain (ODD).

Figure 3

Relationship between VMAD Pillars, Scenarios and FRAV Safety Requirements



Transmitted by IWG on VMAD

Informal document **GRVA-15-26**
15th GRVA, 23-27 January 2023
Provisional agenda item 4(b)

(based on WP.29-187-08)

New Assessment/Test Method for Automated Driving (NATM) Guidelines for Validating Automated Driving System (ADS) – amendments to ECE/TRANS/WP.29/2022/58

I. Background

1. At the 178th (June 2019) session of the United Nations Economic Commission for Europe (UNECE)'s World Forum for Harmonization of Vehicle Regulations (WP.29), Terms of Reference (ToRs) (WP.29/1147/Annex VI) for the Informal Working Group on Validation Methods for Automated Driving (VMAD) were developed. VMAD's mandate under these ToRs is to develop assessment methods, including scenarios, to validate the safety of automated systems based on a multi-pillar approach including audit, simulation/virtual testing, test track, and real-world testing. Throughout this document, safety encompasses the safe performance of automated driving systems and System Safety.

2. Also at the 178th session, WP29 adopted the Framework document on automated/autonomous vehicles (WP.29/2019/34/Rev.2) herein referred to as the Framework document. The Framework document instructed VMAD to develop a 'new assessment/test method for automated driving' (NATM) for consideration during the 183rd (March 2021) session of WP.29.

3. To inform this work, VMAD developed the NATM master document which outlines a conceptual framework for validating the safety of automated driving systems. The first version of this document was adopted at the 184th session (June 2021) of WP29 (ECE/TRANS/WP.29/1159). The second version was submitted to the 12th session (January 2022) of GRVA (ECE-TRANS-WP29-GRVA-2022-02e).

4. Building on this conceptual work, VMAD was instructed by WP29 (ECE/TRANS/WP.29/1159) to undertake the development of NATM guidelines that could provide direction to developers and contracting parties of the 1958 and the 1998 UN vehicle regulations agreements on recommended procedures for validating the safety of automated driving systems (ADS).

II. Purpose and scope

5. This guidelines document represents current best practices identified by the Informal Working Group on Validation Methods for Automated Driving (VMAD) for validating the safety of automated driving systems (ADS) using the NATM. These guidelines aim to provide clear direction for validating the safety of an ADS in a manner that is repeatable, objective and evidence-based, while remaining technology neutral and flexible enough to foster ongoing innovation by the automotive industry. The intended audience for these guidelines includes both developers of ADS technologies as well as contracting parties to both the 1958 and the 1998 UN vehicle regulations agreements.

6. Validating ADS safety is a highly complex task which cannot be done comprehensively nor effectively through one validation methodology alone. As a result, it is recommended to adopt a multi-pillar approach for the validation of ADS, composed of a scenarios catalogue and five validation methodologies (pillars):

(a) Simulation/virtual testing,

(b) Track testing

(c) Real world testing

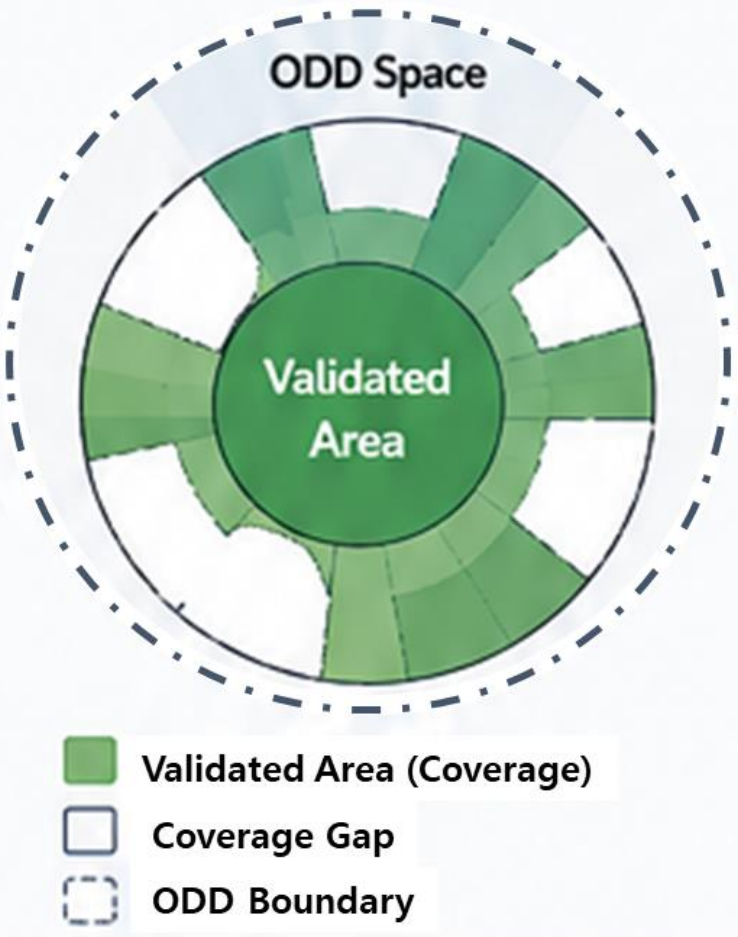
(d) Audit/assessment

Quantitative ODD Coverage Evaluation by SiLS and ViLS

- Safety assurance of autonomous driving systems requires verification
  - ✓ the system operates reliably throughout its intended Operational Design Domain (ODD).

- SiLS and ViLS enable systematic execution of large-scale scenario sets
  - ✓ under varying environmental, traffic, and road conditions
  - ✓ supporting quantitative evaluation of:
    - ODD Coverage
    - Coverage Gap
    - ODD Boundary Conditions
    - Scenario Completeness

- These metrics provide objective evidence for safety assurance and are key indicators for future validation.



Digital Twin enabled safe and Repeatable Evaluation of Rare and Hazardous Scenarios

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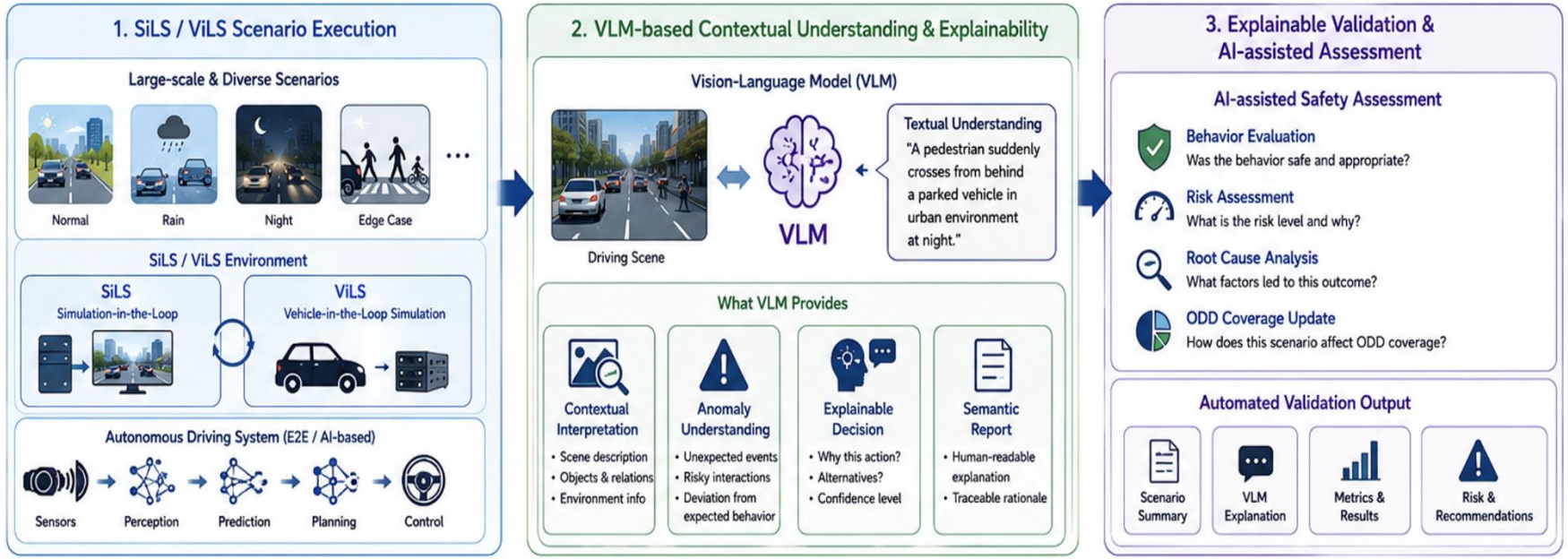
- Many critical driving situations are difficult, expensive, or unsafe to reproduce on public roads.

- Digital Twin-based SILS and ViLS environments
  - ✓ enable safe, repeatable, and scalable validation of these rare and hazardous scenarios
  - ✓ significantly reducing development cost and testing time.

VLM for Explainable an AI driven ADS Validation

- As AI-based autonomous driving systems become more complex,
  - validation must evolve beyond conventional pass/fail metrics **toward understanding why a driving decision was made and under which operational context it occurred.**

- By integrating Vision-Language Models (VLMs) with SiLS and ViLS, it enables
  - ✓ semantic scene understanding, contextual reasoning, anomaly interpretation, and explainable validation of autonomous driving behaviors
  - ✓ contextual interpretation of driving scenes, anomaly understanding, and explainable validation become possible.



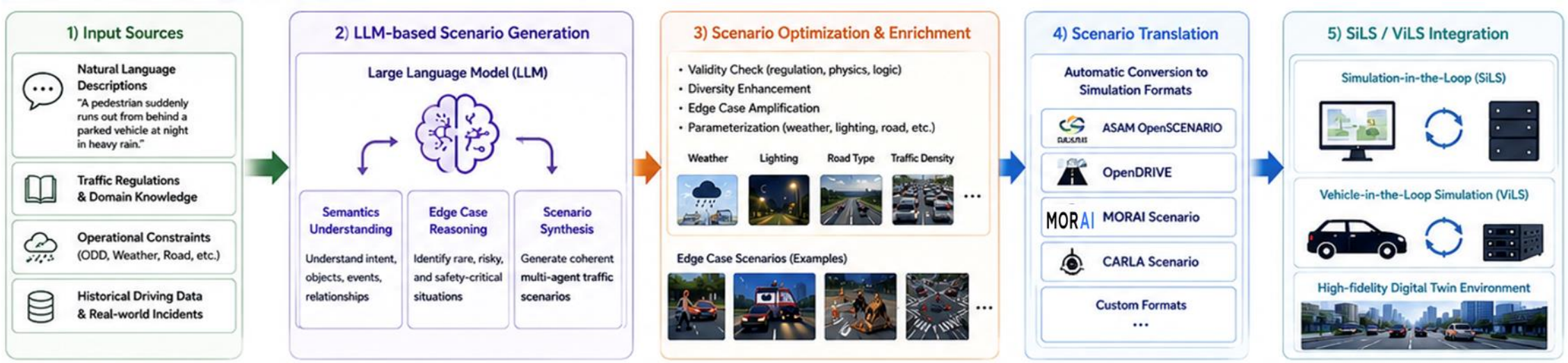
LLM-enabled Edge Scenario Generation for ViLS and SiLS-based Validation

- Ensuring the safety of autonomous driving systems requires
  - ✓ validation under a wide range of rare, hazardous, and previously unseen driving situations (Edge Cases).

- However, manually designing such scenarios is
  - ✓ labor-intensive, difficult to scale, and often fails to capture the diversity of real-world traffic conditions.

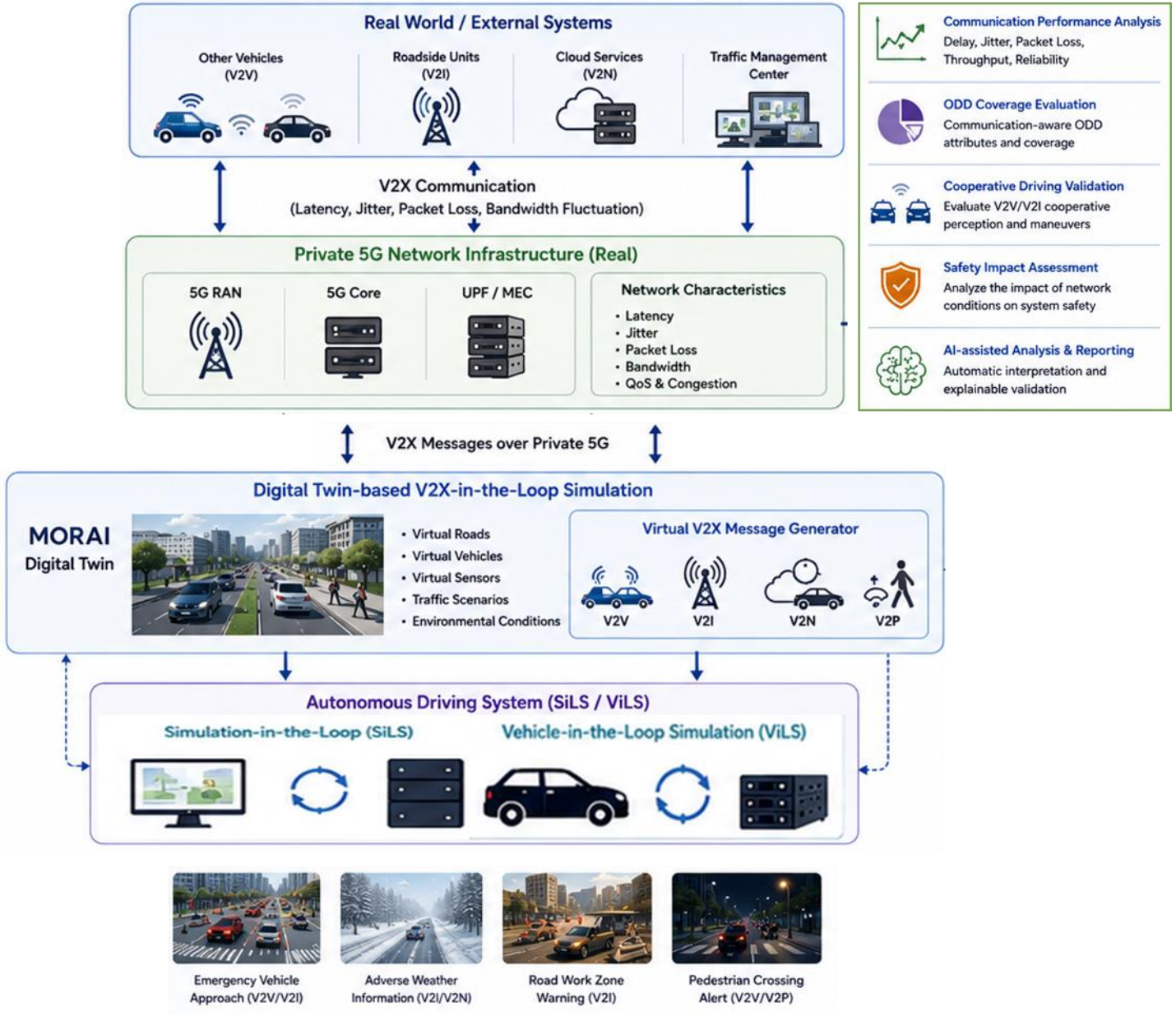
- To address this challenge, LLM-enabled Scenario Generation Framework
  - ✓ automatically generates semantically meaningful driving scenarios from natural language descriptions, traffic regulations, operational constraints, and historical driving data.

- The generated scenarios are then integrated into SiLS and ViLS environments
  - ✓ for large-scale autonomous driving validation.



Private 5G-enabled V2X-in-the-Loop Simulation Framework

- Real Private 5G Integration
  - ✓ Integrates a Digital Twin simulator with a real Private 5G network to evaluate autonomous driving systems under realistic communication conditions.
- Network-aware Safety Assessment
  - ✓ Reflects latency, jitter, packet loss, bandwidth limitations, and QoS variations in the validation process.
- Communication-aware ODD Evaluation
  - ✓ Extends conventional ODD evaluation by incorporating V2X communication quality as an additional ODD attribute.
- Scalable and Flexible Validation Framework for Cooperative Automated Driving
  - ✓ Enables validation of V2V, V2I, V2N, and V2P applications under realistic wireless communication environments.



AI native Virtual Validation Framework

Integration of Key Technologies for Next-Generation Validation

Digital Twin
High-fidelity Environment

+

SiLS / ViLS / V2XiLS
Large-scale Simulation and Vehicle-in-the-Loop

+

LLM-based
Scenario Generation (Edge & Rare Cases)

+

VLM-based
Contextual Analysis & Explainability

+

ODD Coverage & Risk Assessment

Toward AI-native Virtual Validation Framework

Scenario Generation (LLM-based)
- Generate diverse & edge scenarios
- Target uncovered ODD regions

→

Scenario Execution
SiLS / ViLS / V2XiLS

→

Data Collection
- Logs
- Sensor Data
- Behavior Data
- V2X Data

→

VLM Analysis & Interpretation
VLM
Understand context, anomalies, and decisions

→

Evaluation & Reporting
Compute metrics
Generate reports
Assess safety

→

Feedback & Improvement
Update models
Improve scenarios
Enhance coverage

Continuous Learning & Improvement

Horizon Europe Project "AutoTrust"

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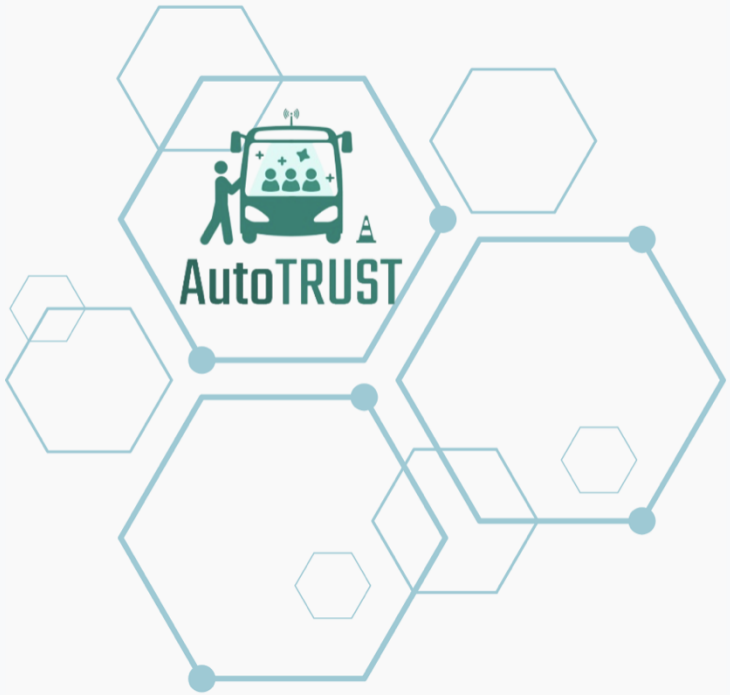


About AutoTRUST

AutoTRUST is an innovative project focused on creating *AI-powered, self-adaptive vehicle technologies* to enhance the safety, accessibility, and overall experience of automated mobility.

Funded by the **EU's Horizon Europe program**, it aims to make transportation more inclusive and resilient, driving the transition to fully automated vehicles.

Project Highlights

10 DIFFERENT COUNTRIES

14 PARTNERS

4 PILOTS

CERTH
MORAI
AVISENSE
SIEMENS
alkè ELECTRIC VEHICLES
UiA University of Agder
University of Cyprus
waveye
CYPRUS PUBLIC TRANSPORT
Cáritas Diocesana de COIMBRA
UNIVERSITÉ DE GENÈVE
tpg
beti MOBILITE AUTOMATE
KATECH

Pilot 1: Connected and Autonomous Vehicles

Location: Greece (AviSense.AI) and Italy (ALKE)

Pilot 2: Adaptive Bus Public Services

Location: Cyprus (NPT, UCY)

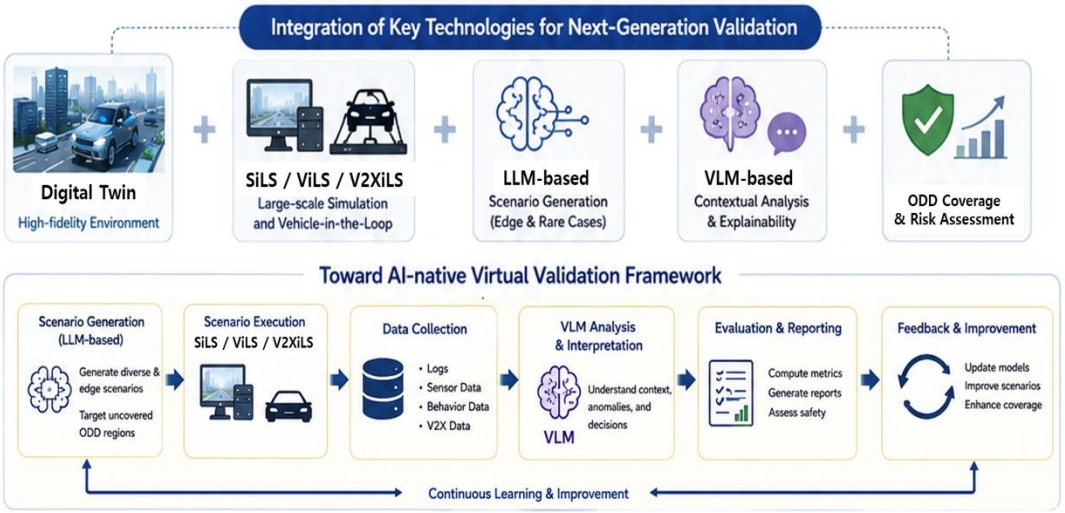
Pilot 3: Adaptive Mini Buses

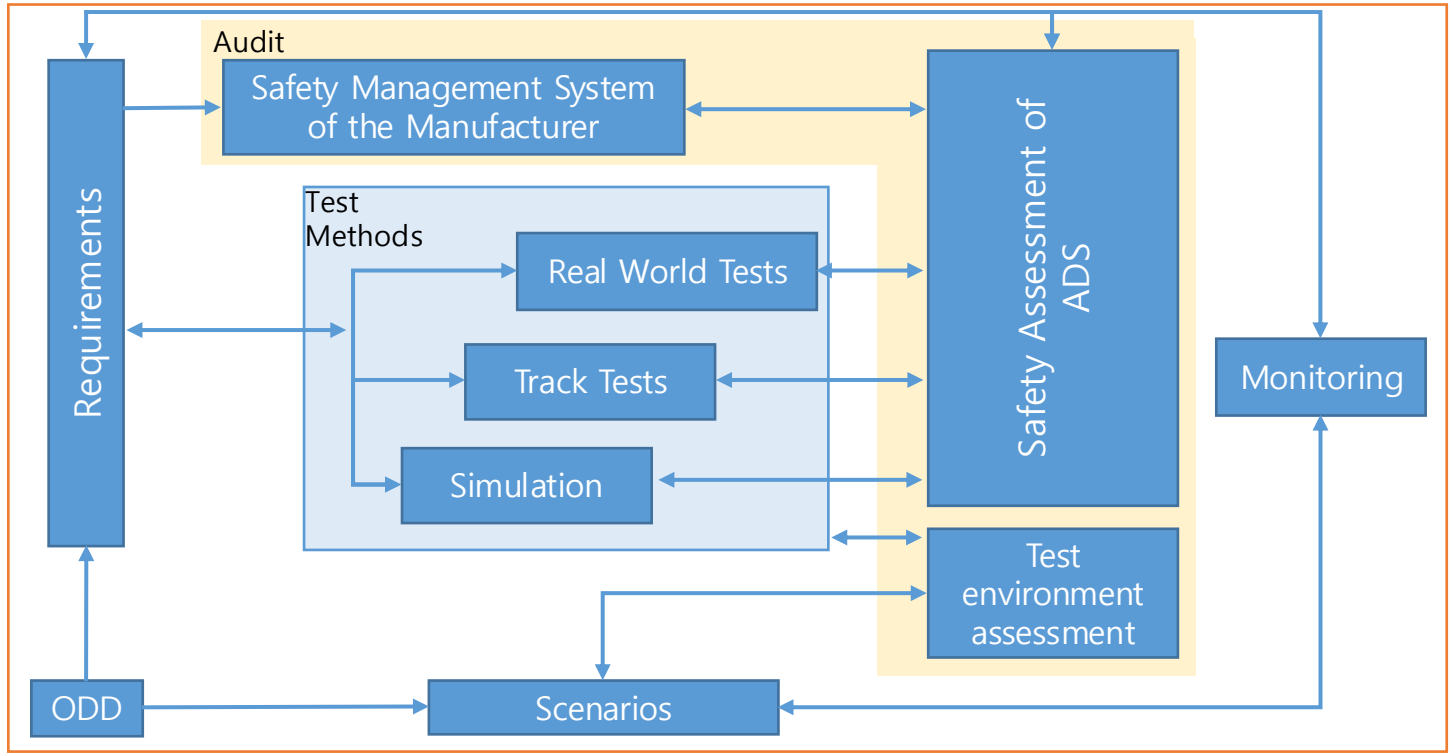
Location: Switzerland (TPG, UNIGE)

Pilot 4: Adaptive Autonomous Taxi

Location: Crest, France (BETI)

AutoTrust Validation Framework (Compared to UNECE/GRAV/VMAD Framework)





AutoTRUST

Pilot 1: Connected and Autonomous Vehicles

Pilot 2: Adaptive Bus Public Services

Pilot 3: Adaptive Mini Buses

Pilot 4: Adaptive Autonomous Taxi

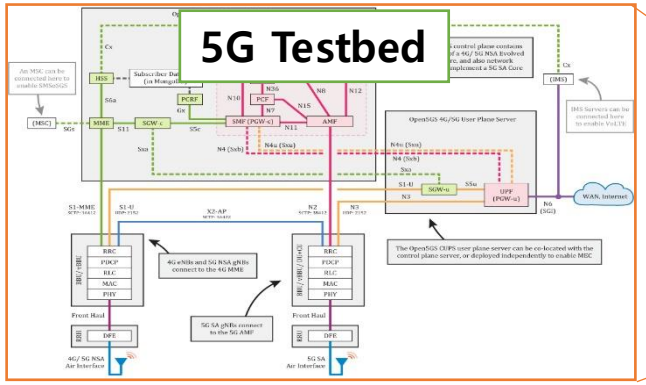
Test scenarios (Corner cases)

User Requirement Definition → Test setup based on test scenario (User Defined, LLM Based) → Simulation/ Virtual Test → Evaluation/ Validation

Simulator and Validation Solution

Advanced Monitoring System and Data Processing
Intelligent Personalization, Adaptation and Virtual Assistant System

AutoTrust Validation Framework

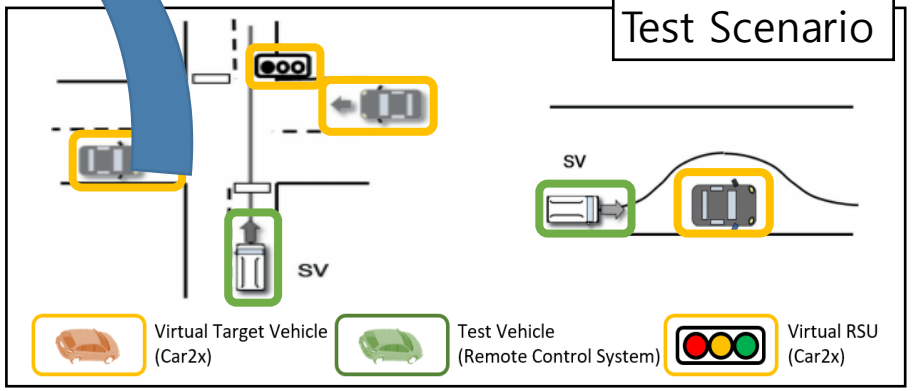


5G testbed w/ network slicing

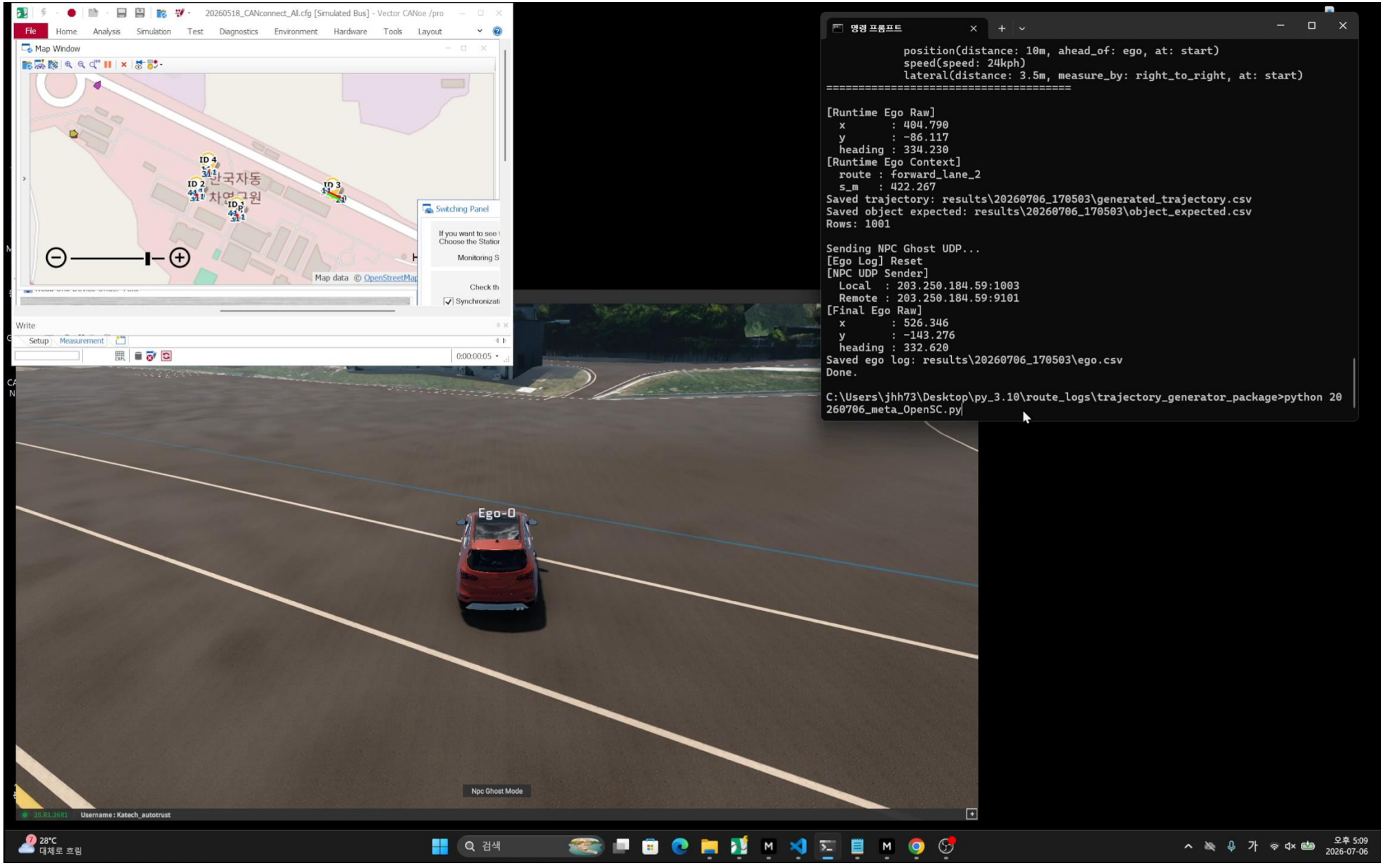
V2X in the loop

(Digital Twin)

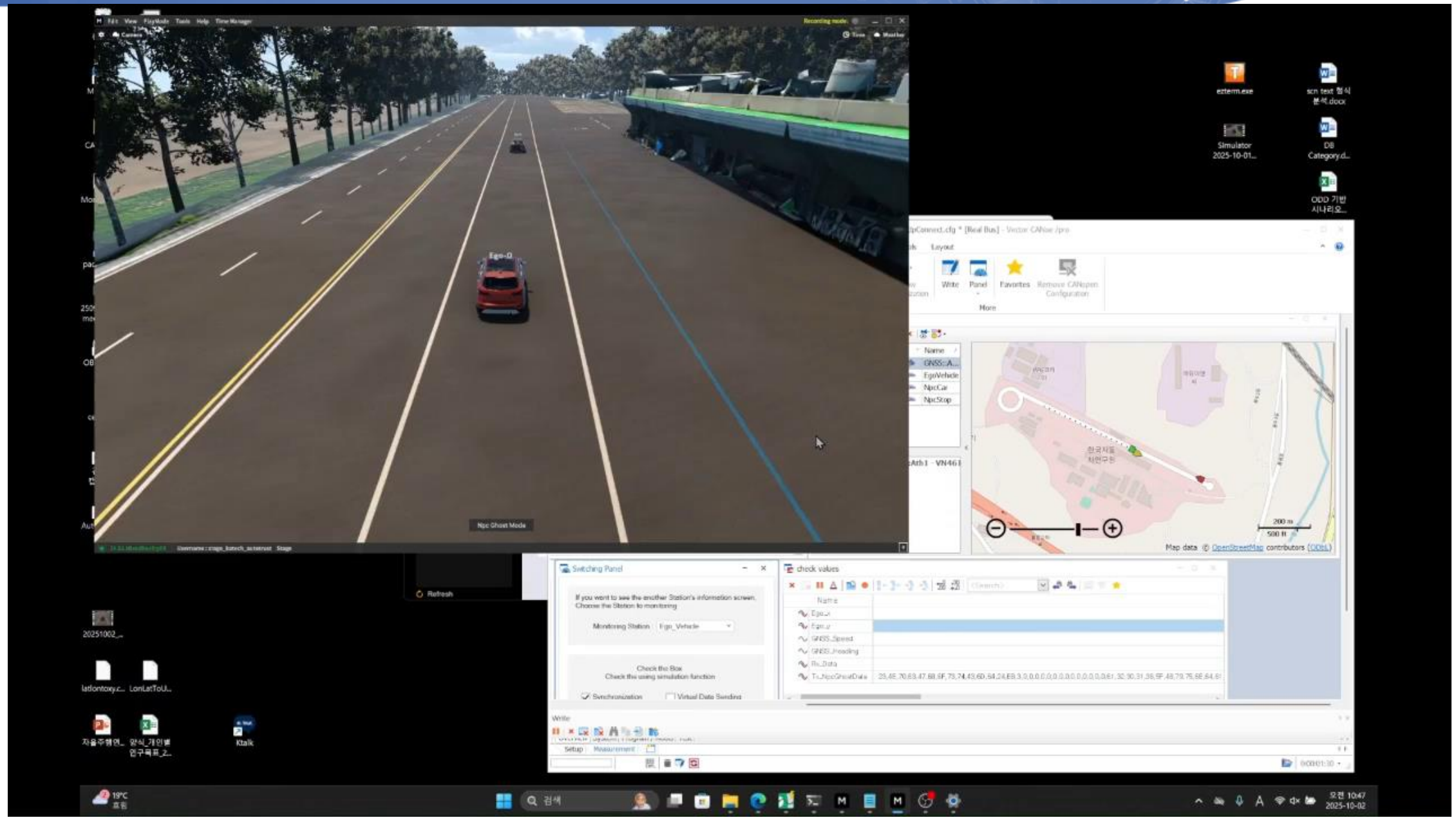
Test Scenario Deployment (LLM or User Defined)



LLM based Test Scenario Generation and SiLS Integration



V2X-SW in the Loop Simulation (V2X-SiLS) based Validation



V2X-Vehicle in the Loop Simulation (V2X-ViLS) based Validation

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Key Benefits of Digital Twin-enabled SiL, ViL and V2X-in-the-Loop Validation Framework

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- **Comprehensive Scenario-based Validation**
- **Safe, Repeatable and Scalable Testing**
- **Network-aware Connected Vehicle Validation**
- **Quantitative ODD Coverage Assessment**
- **AI-powered Context-aware Validation (VLM)**
- **Intelligent Edge Scenario Generation (LLM)**
- **Closed-loop Validation and Continuous Improvement**
- **International Standard Compliance**

Challenges in Next-generation Autonomous Driving Validation

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- **Increasing Complexity of AI-based Autonomous Driving Systems**
- **Limited Coverage of Real-world Testing**
- **Insufficient ODD Coverage Evaluation**
- **Lack of Repeatable and Scalable Validation**
- **Limited Consideration of Connected Vehicle Communications**
- **Manual Scenario Generation**
- **Limited Explainability of Validation Results**
- **Fragmented Validation Workflow**

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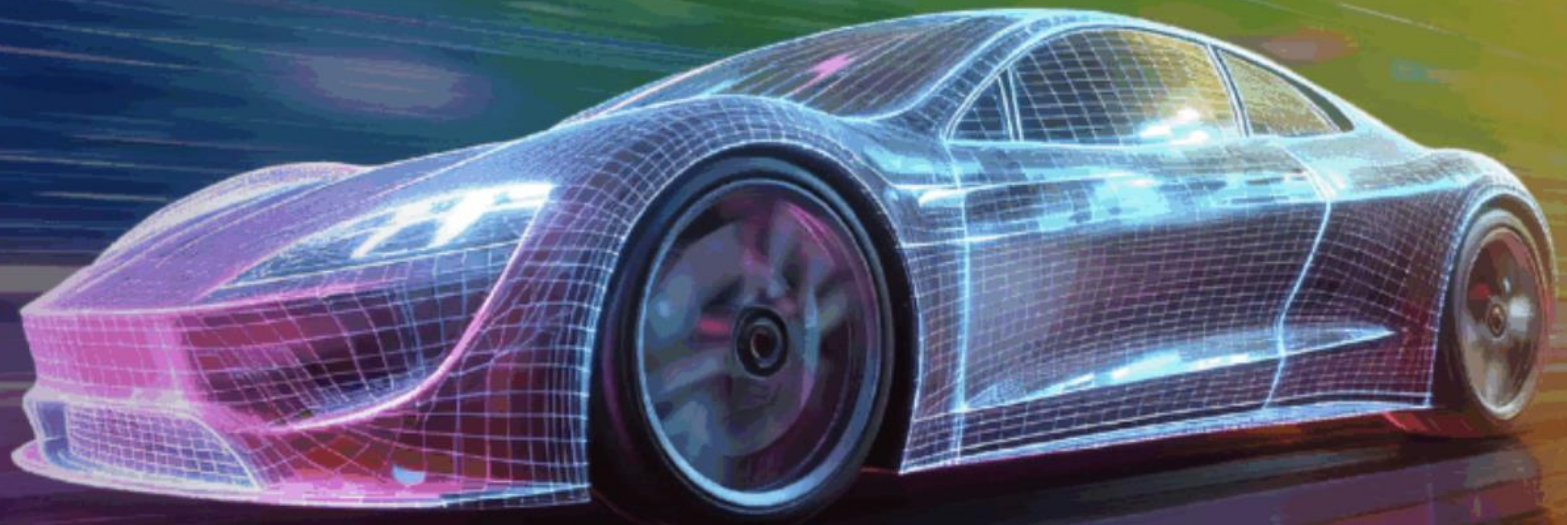
#ConnectedCar

Thank you !



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