Senzorické systémy a virtuální modelování pro vývoj automobilů s DCAS

New York 1900 and 1913: where are the horses?

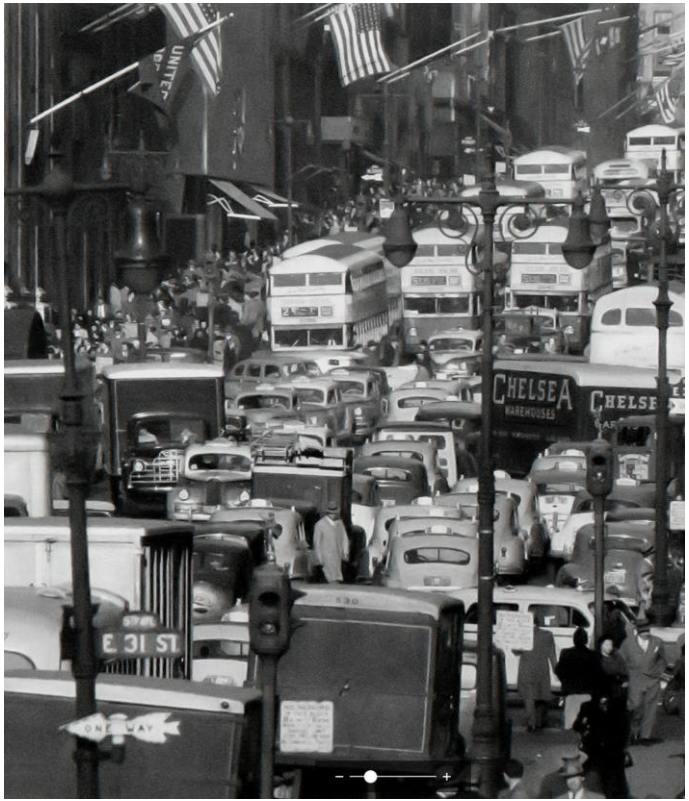
Photo: Fifth Ave NYC on Easter Morning 1900
2001-2014 by Tony Seba

Source: US National Archives from (Wikipedia)

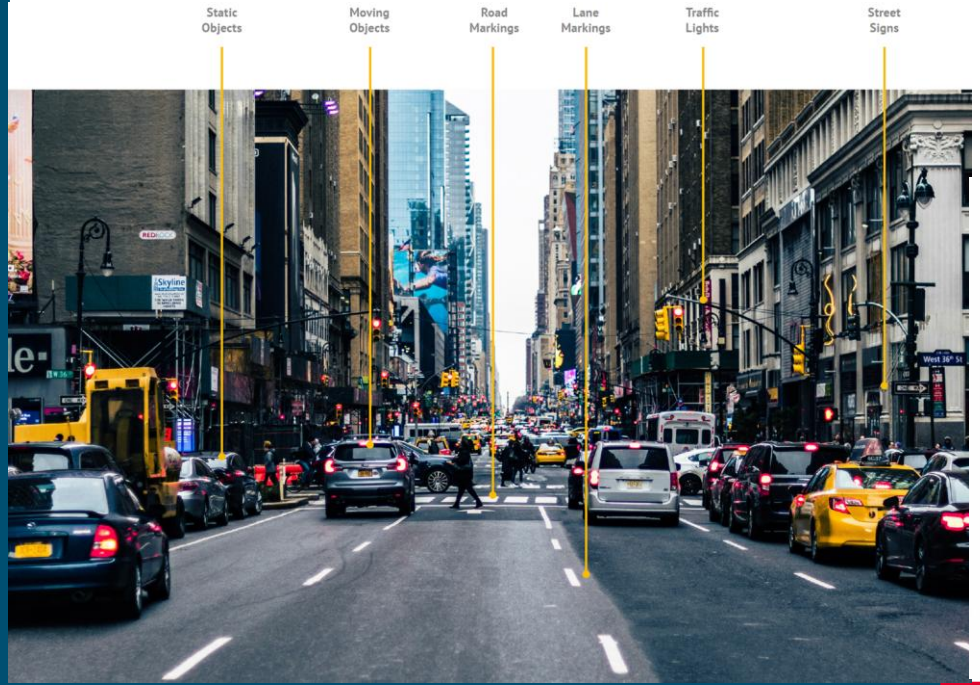
Photo: Easter 1913, New York. Fifth Avenue looking north. George Grantham Bain Collection

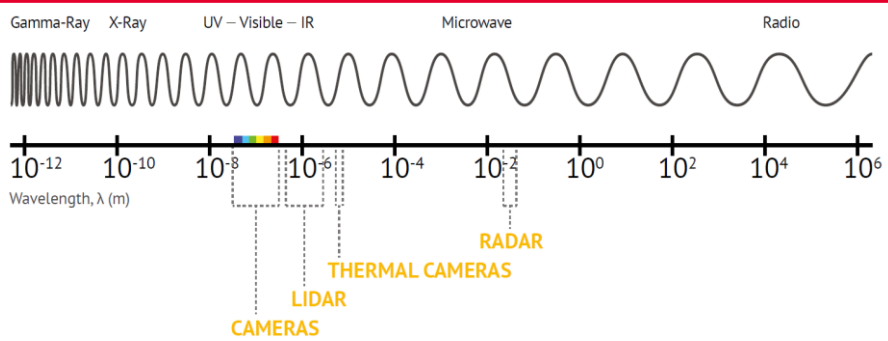
Source: shorpy.com

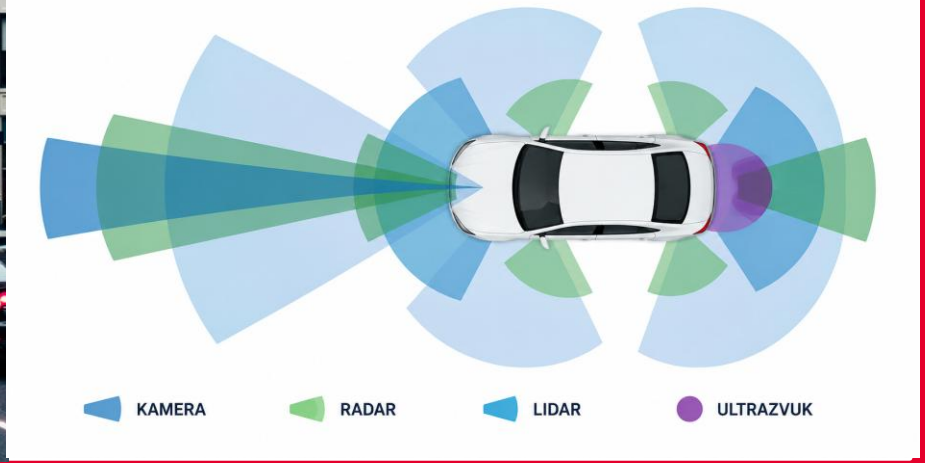
New York 1953 and 2003?



Autonomous vehicles: sensing the world







Motivation and confusion in acronyms

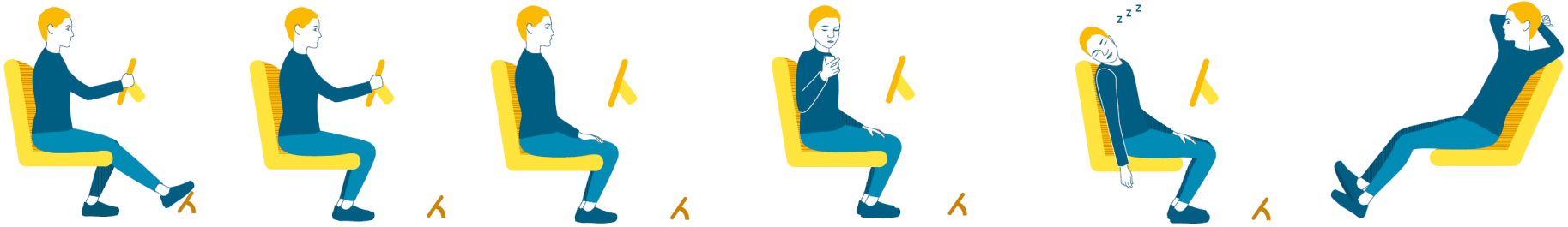
SAE J3016	Klíčová taxonomie úrovní automatizace řízení **L0–L5**.
UN R171	Předpis OSN pro Driver Control Assistance Systems, tedy **DCAS**.
UN R155	Kyberbezpečnost vozidel.
UN R156	Softwarové aktualizace a systém řízení aktualizací.
GSR	General Safety Regulation, evropský rámec povinných bezpečnostních systémů.
Euro NCAP	Evropský spotřebitelský program hodnocení bezpečnosti vozidel, včetně ADAS a Assisted Driving.
DMS	Driver Monitoring System — Systém sledování řidiče, například pozornost, únava, pohled, ruce na volantu.
OMS / IMS	Occupant / Interior Monitoring System — Sledování posádky nebo interiéru vozidla.

ADAS	Advanced Driver Assistance Systems	Pokročilé asistenční systémy řidiče. Zastřešující pojem pro ACC, AEB, LKA, ISA, BSM apod.
AD, AV	Automated Driving	Automatizované řízení. Obecný pojem pro systémy, které částečně nebo zcela přebírají část řízení.
ADS	Automated Driving System	Systém automatizovaného řízení, správně hlavně pro úrovně SAE L3–L5.
FAD	Fully Automated Driving	Plně automatizované řízení; často marketingově nebo výzkumně používaný pojem, blízký L4/L5.

From mechanics to the software-defined vehicle

The automobile has changed from a product whose value is determined mainly by hardware into a continuously evolving platform. Key features, safety functions and the user experience are defined and updated by software — often remotely over the air (OTA).

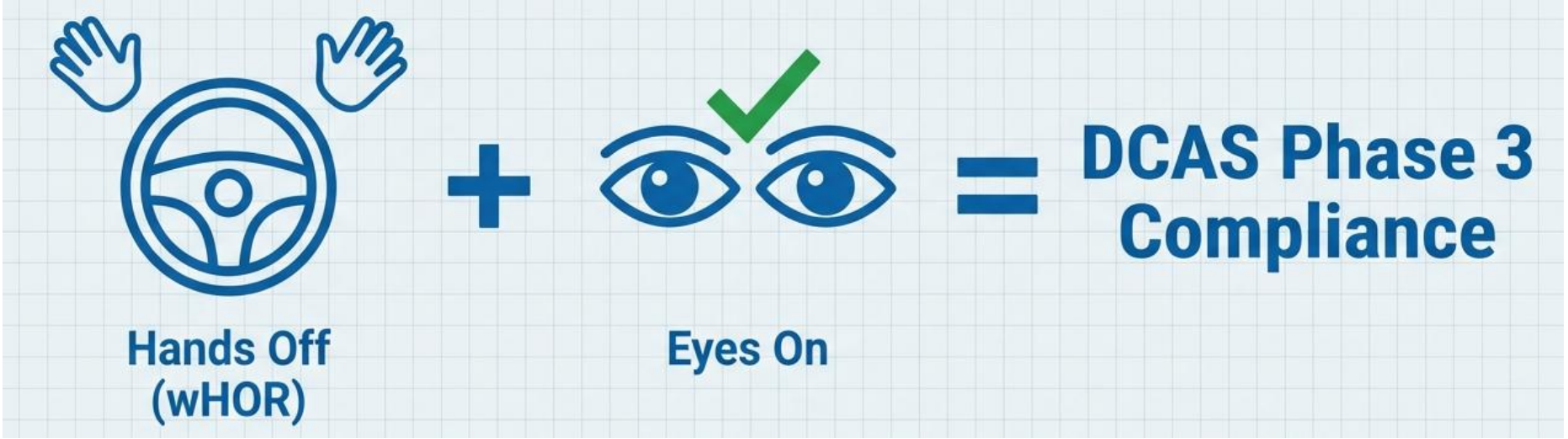
Autonomous vehicles: automation levels L0–L5



0	1	2	3	4	5
BEZ AUTOMATIZACE	ASISTENTI ŘIDIČE	ČÁSTEČNÁ AUTOMATIZACE	PODMÍNĚNÁ AUTOMATIZACE	VYSOKÁ AUTOMATIZACE	PLNÁ AUTOMATIZACE
	Sledujete prostředí. Jste řidičem, i když jsou zapnuté automatizační funkce.	Když si to systém vyžádá, musíte převzít kontrolu.		Nevyžaduje se, abyste převzali řízení	
	Systém vás podporuje při řízení	Systém pracuje, když je specifikovaný jsou splněny podmínky.			Systém funguje za všech podmínek
	Řízení NEBO rychlost jsou automatizované		**Řízení a rychlost jsou automatizované**		

Asistenční systémy nejvíce pomohou starším lidem. Babička sedne do auta a řekne: “Zavez mě ke svaté Anně a zaparkuj. “
To je skutečná mobilita.

Hands-free / wHOR and the 'eyes-on' condition



Safety criticality: the system must detect ODD limits and prompt the driver to take over control in time.

wHOR = hands-free on/off. Legal release of the steering wheel is allowed only in defined zones.

Testování nemožného: Jak ověřit bezpečnost?

Největší výzvou není auto naučit jezdit za standardních podmínek. Je to zajištění bezpečnosti v milionech nepředvídatelných, kritických situací. Fyzické testování zde selhává.

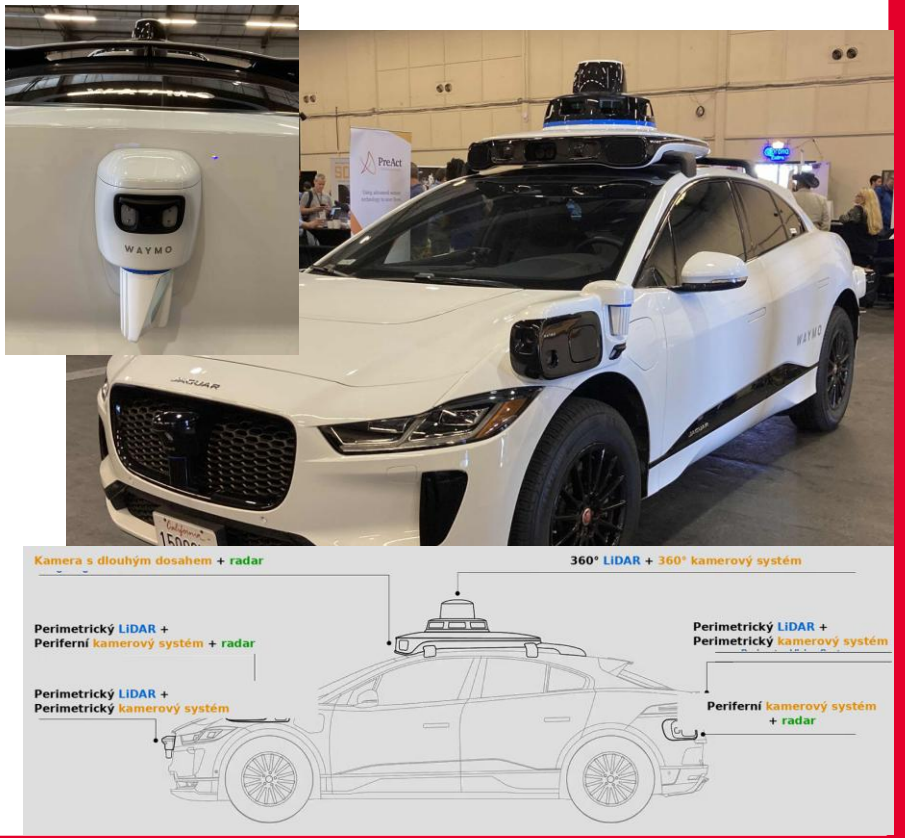
Proč je fyzické testování nedostatečné?

- **Nekonečné scénáře:** Nelze fyzicky otestovat každou nebezpečnou situaci, která může nastat.
- **Vzácné, ale kritické události („edge cases“):**
  - Dítě vybíhající zpoza autobusu.
  - Opilý cyklista kličkující v mlze.
  - Nehoda za hustého sněžení.
- **Čas a náklady:** Najet miliardy testovacích kilometrů v reálném světě by trvalo staletí a stálo by astronomické částky.

Potřebujeme testovací prostředí, kde můžeme bezpečně a rychle simulovat miliony nebezpečných scénářů.

What an autonomous vehicle typically consists of

Sensors: cameras + radars + often LiDAR
Localization: GNSS/IMU + maps (HD map)
Perception: detection of objects, lanes, traffic lights and “free space”
Prediction: estimating what other road users will do
Planning & control: trajectory generation and longitudinal/lateral control
Safety: redundancy, minimal-risk manoeuvre, driver supervision for L2/L3 and ODD limits



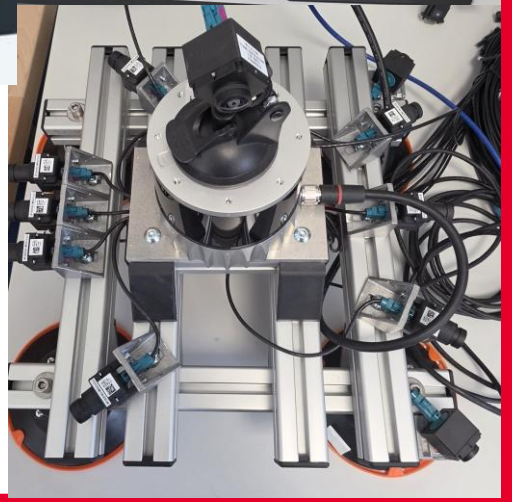
Result of intelligence: An unprecedented flood of data

CAMERAS: ~20–40 MB/s

GPS: ~50 KB/s

4000 GB

of data per day processed by an autonomous vehicle



Equivalent to 2,666 average internet users

LIDAR: ~10–70 MB/s

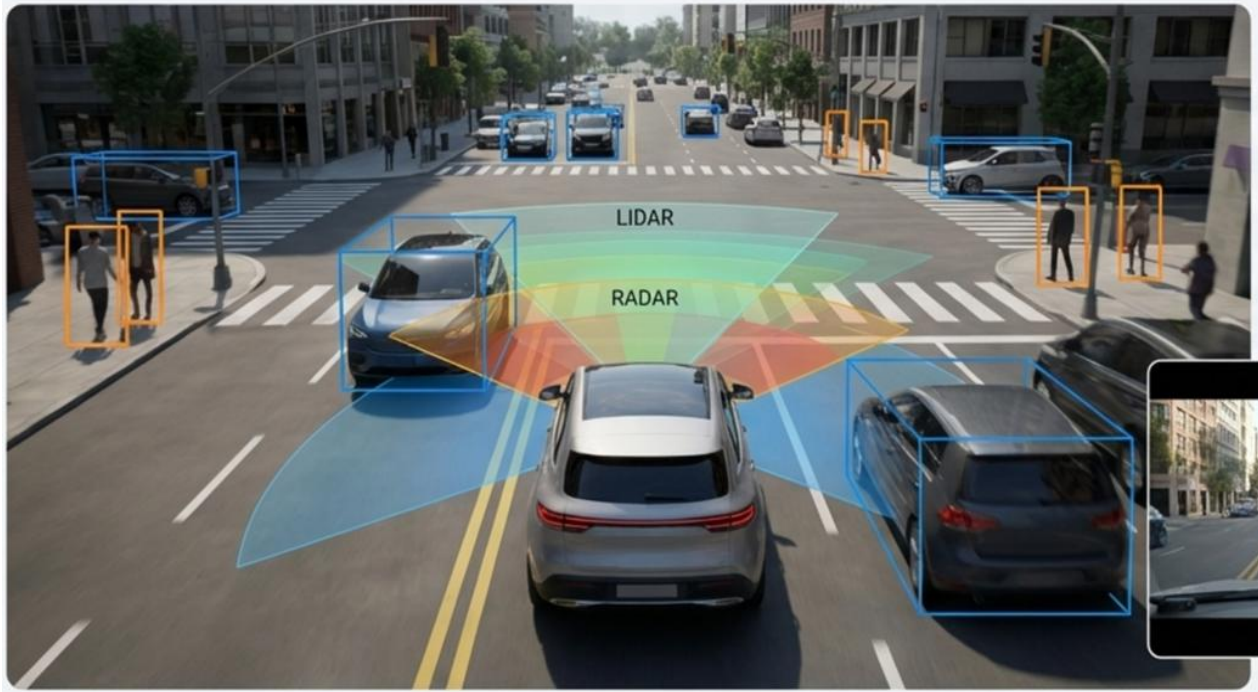
RADAR / SONAR: ~10–100 KB/s

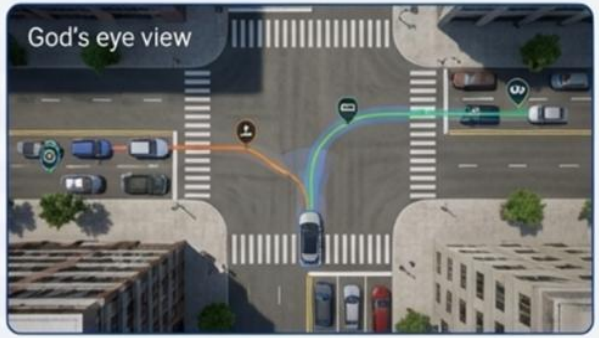
Waymo:
- **29 cameras, including infrared**
- **6 radars**
- **5 LiDARs**

Tesla:
- **6 cameras**
- **2 stereo cameras**

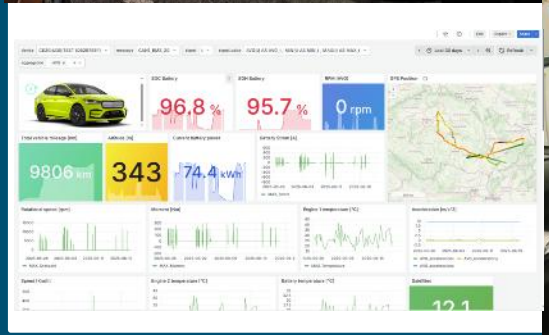
Testing the impossible: Verifying ADAS systems in realistic scenarios

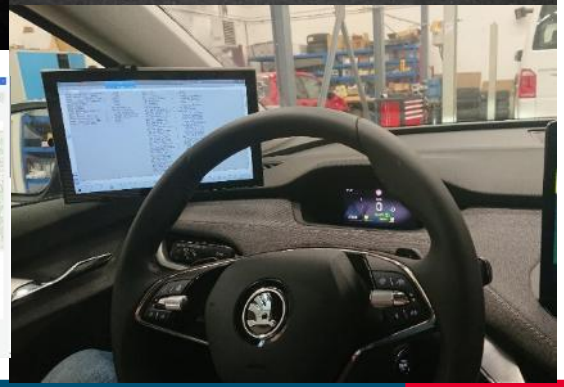
Digital twins contain integrated models of vehicle sensors / cameras, radar, lidar / and enable their behavior to be tested in complex traffic situations with intelligent traffic monitoring.





DIGITAL TWINS SKODA ENYAQ BEV RWD 132 kW





Digital Twins Software :

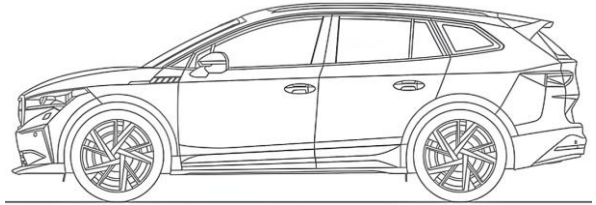
- **IPG CarMaker**
- **GT Suite**
- **Matlab/Simulink/RoadRunner**
- **Matlab Web Server – MS SQL**
- **Power Bi , Grafana**

Measuring system VECTOR + imc
Software imc STUDIO FAMOS
Signals - 25,000 variables at any time

- **EV CAN:** Electric motor torque, regenerative quantities, torque gradient
- **CAN Antrieb:** Longitudinal and lateral acceleration, rolling acceleration, ABS interventions, ESP, steering angle and gradient, accelerator position and gradient
- **Comfort CAN:** Ambient and cabin temperature, Off-air intensity, Seat and steering wheel heating, HVAC flap position
- **FAS CAN (fahrerasistenz):** Lane assist and front assist interventions, Distance from lines, Line crossing, Ambient light intensity
- **LTE modem Teltonika**

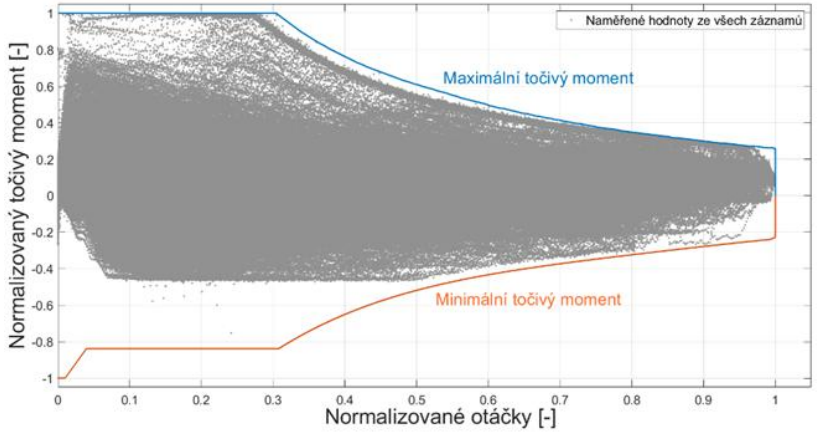
Skoda Enyaq iV 60

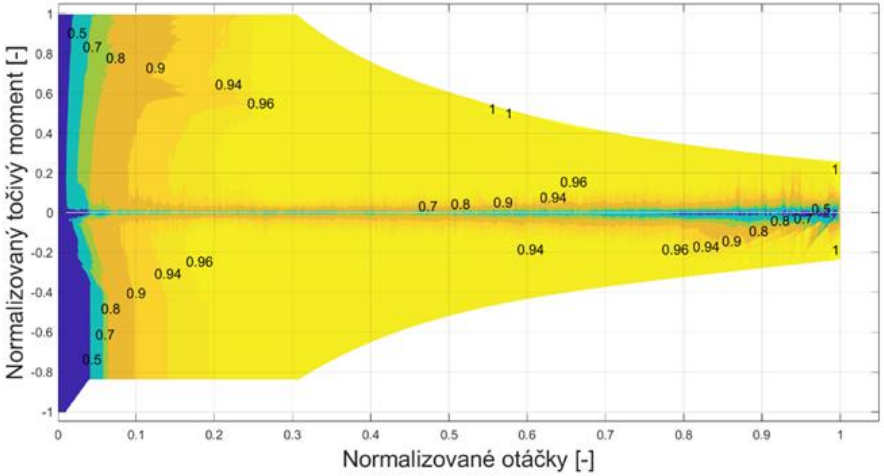
- electric motor (310 Nm, 132 kW)
- battery 62 kWh (available 58 kWh)



Signals - 25,000 variables at any time

- **CAN comfort features**
- **CAN main control unit**
- **CAN electric drive**
- **CAN driving assistants**
- **GPS**





Methodology Without Compromise: A Multi-Level Validation Pyramid

Level 3:
Real-World Driving Data

Data collection from real driving.
(Comprehensive system validation)

Level 2:
Vehicle Dynamics (K&C)

Testing the kinematics
and overall vehicle performance
on the K&C rig.
(Subsystem testing)

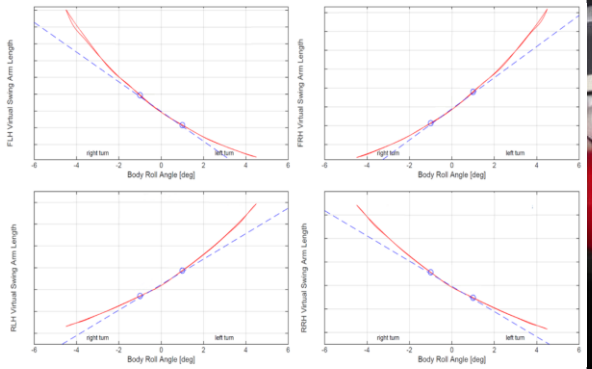
Level 1:
Powertrain (Dyno)

Isolated powertrain validation
on the dynamometer.
(Component testing)

VEHICLE DYNAMICS DATA ACQUISITON AND VALIDATION

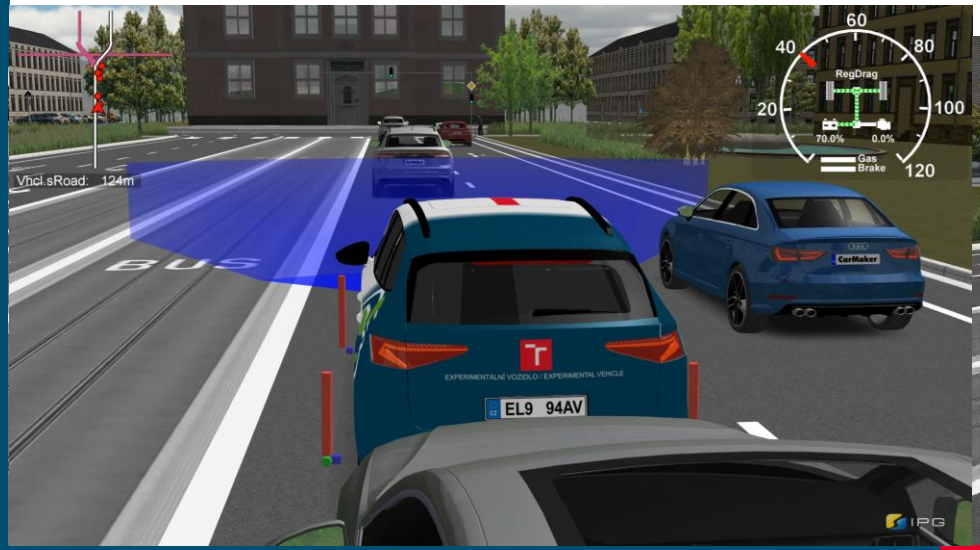
- Longitudinal Behaviour Validation
  - Acceleration tests
  - WLTP reproduction
  - Real traffic cycle comparison
  - Speed trace: Measured vs Simulated
  - High agreement across full cycle

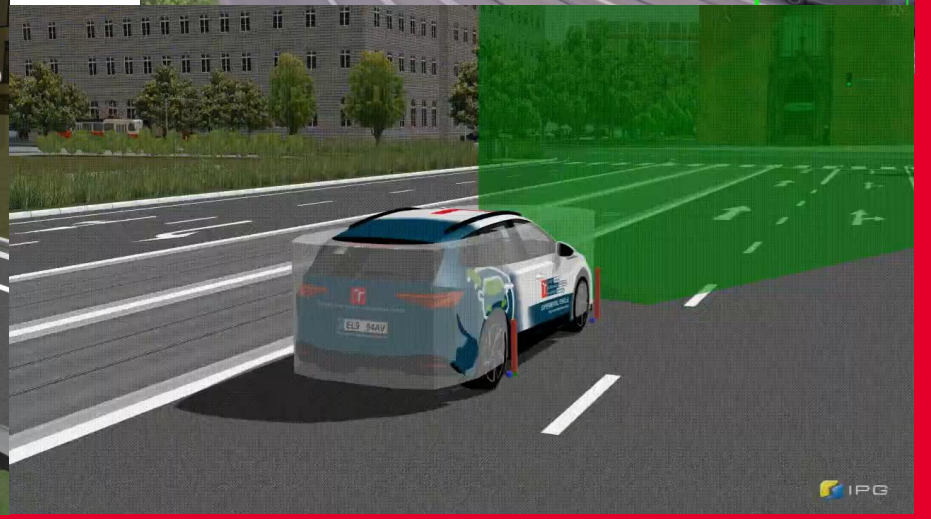
- Lateral Behaviour Validation
  - Step steer test
  - Yaw rate response
  - Lateral acceleration comparison



SCENARIO SIMULATION WITH DIGITAL TWIN

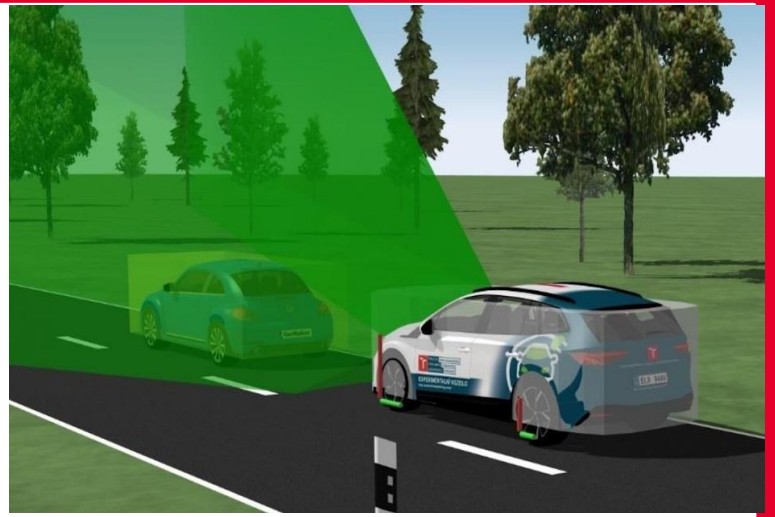
- Realistic vehicle dynamics model
- Realistic environment
- Digital twin added into scenario based on real situations
    - Intelligent traffic monitoring



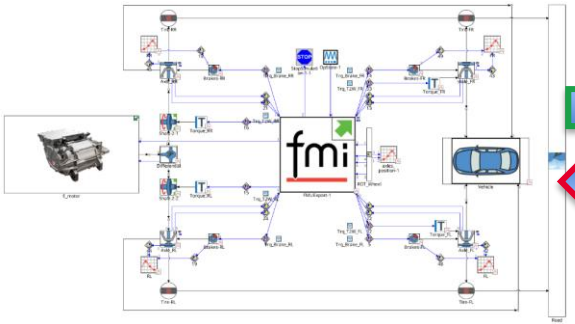


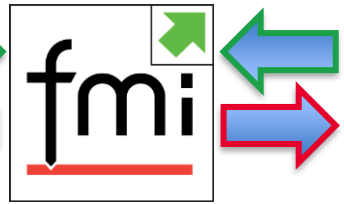
DIGITAL TWIN ARCHITECTURE OVERVIEW

- Powertrain domain → GT-SUITE
- Vehicle dynamics & environment → IPG CarMaker
- Coupling standard → Functional Mock-up Interface
- Modular FMI-based co-simulation architecture



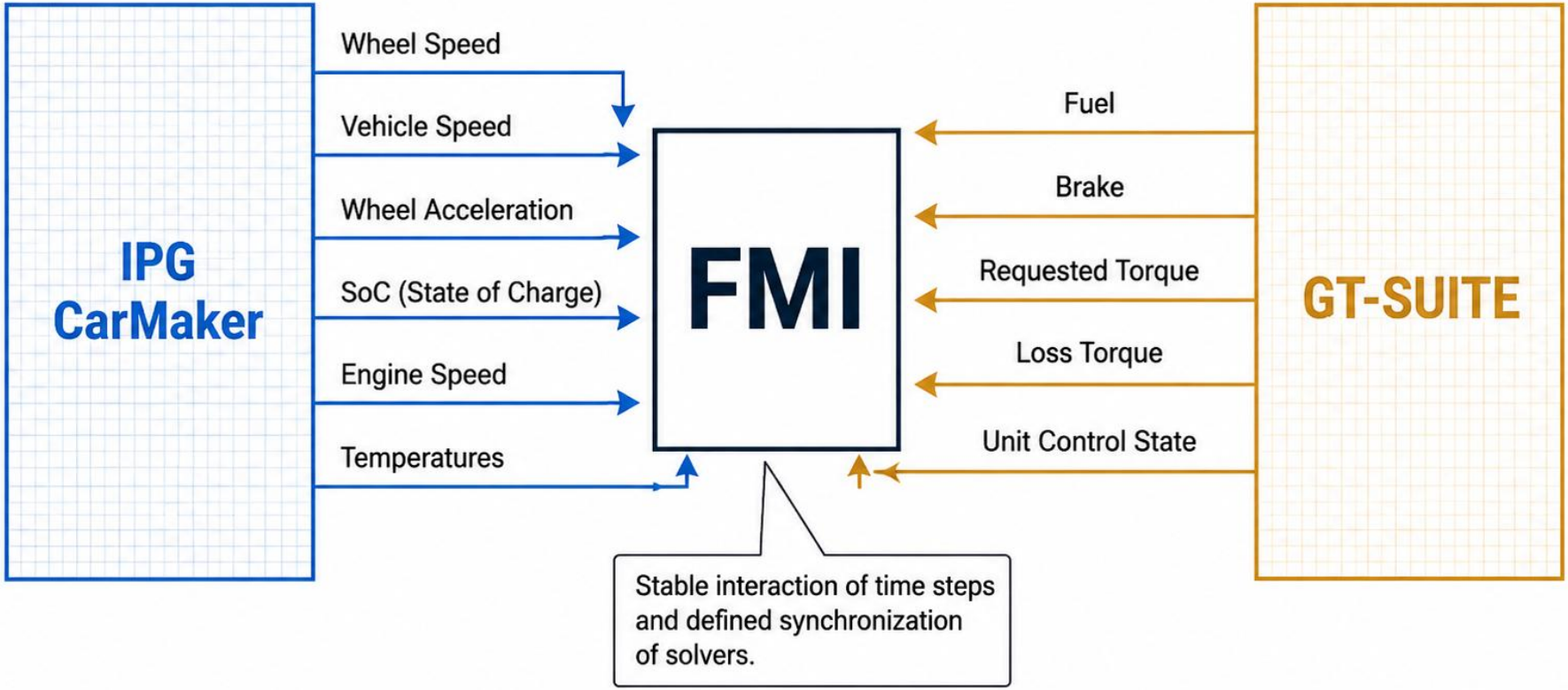
GAMMA TECHNOLOGIES





IPG AUTOMOTIVE

FMI Integration: Real-Time Bidirectional Signal Exchange

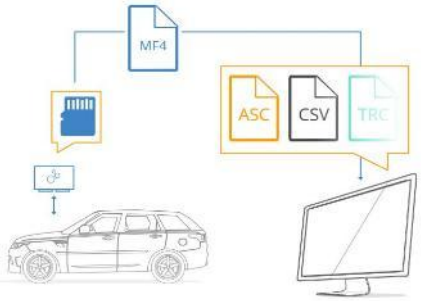


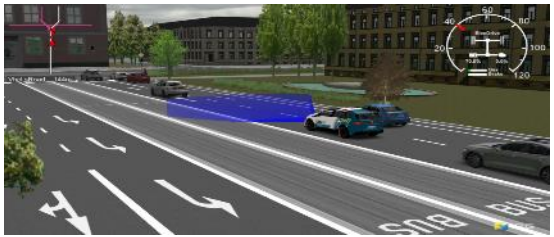
Web Portal

Real Vehicle

CANedge

S3-Compatible Object Storage





Virtual City

Real City

Cloud Storage

Virtual Vehicle

IPG AUTOMOTIVE

CM

CarMaker

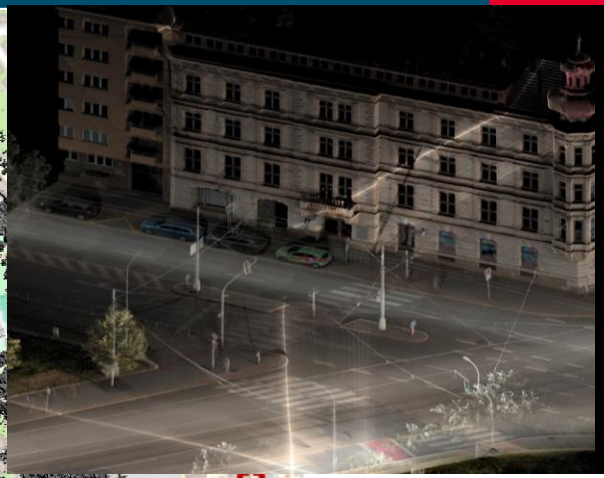
MATLAB

WorkStation

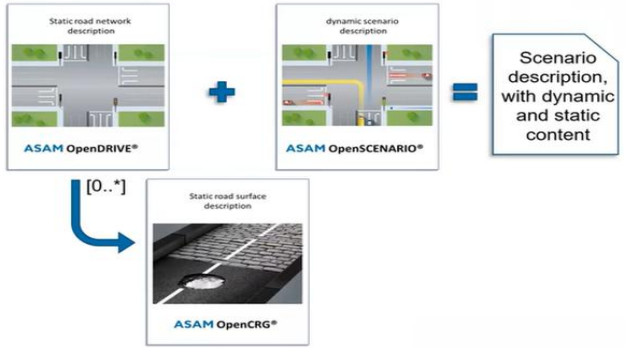
FME iae

#AutaVUT MOBILITY LAB

https://automotiveengineering.online/

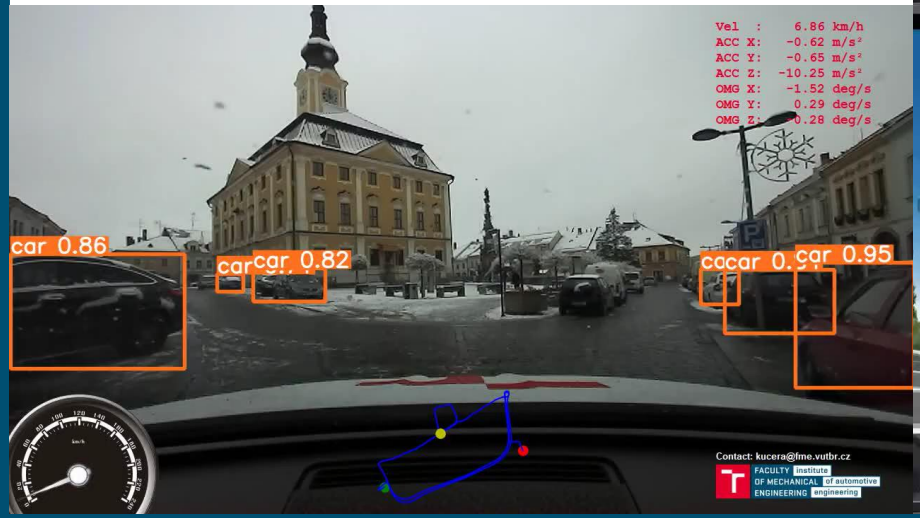


Part of the Brno Center for Testing ADAS and HD Maps

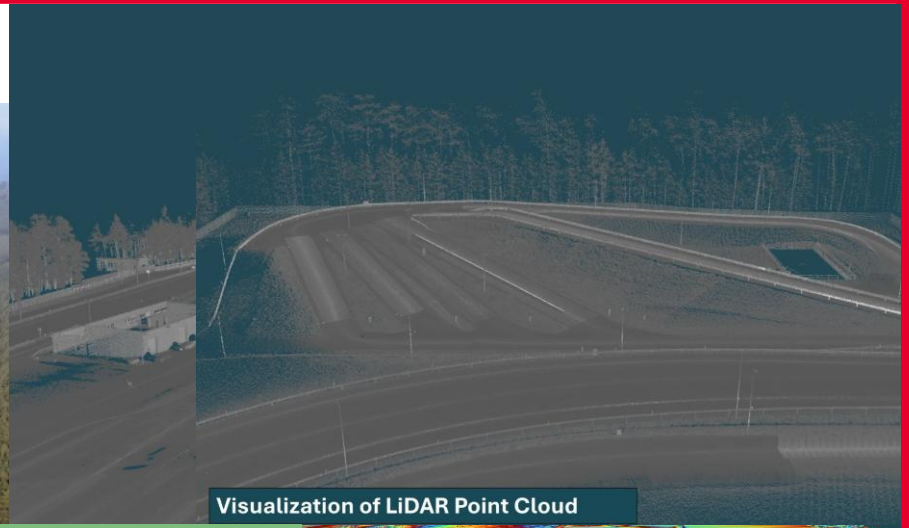


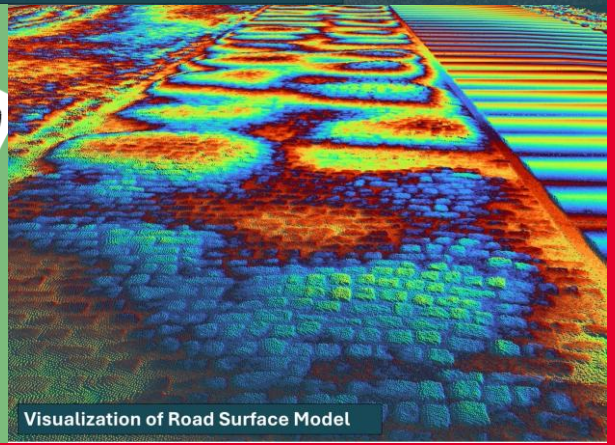
POLYGON IN BRNO CITY

- High-fidelity EV digital twin developer
- Multi-level experimental validation performer
- FMI-based architecture ensures modularity
- Strong agreement with measured data
- Suitable for advanced virtual vehicle development

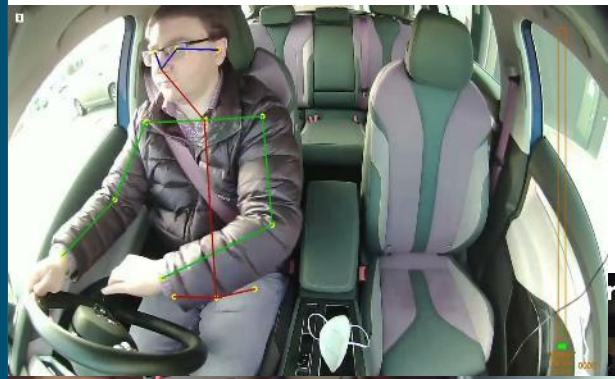


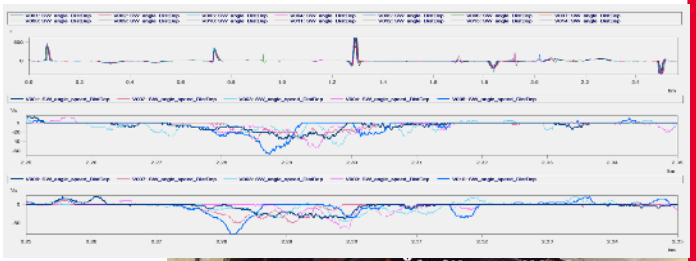
AUREL POLYGON CZ

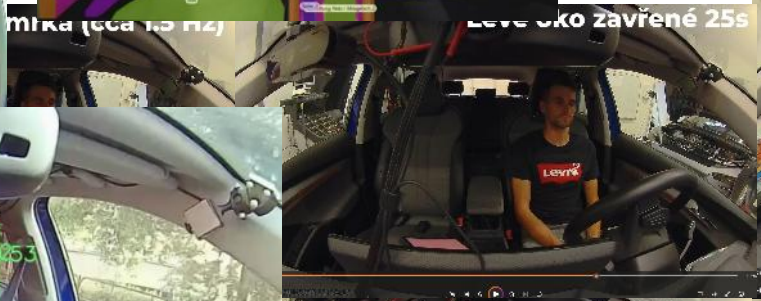


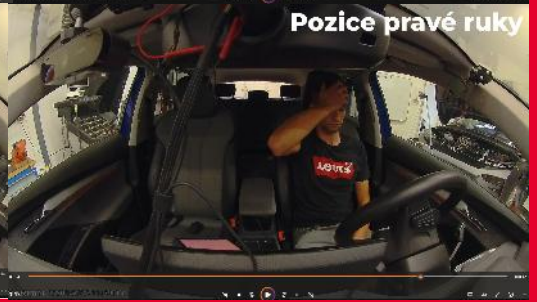


Training for recognizing different driver states

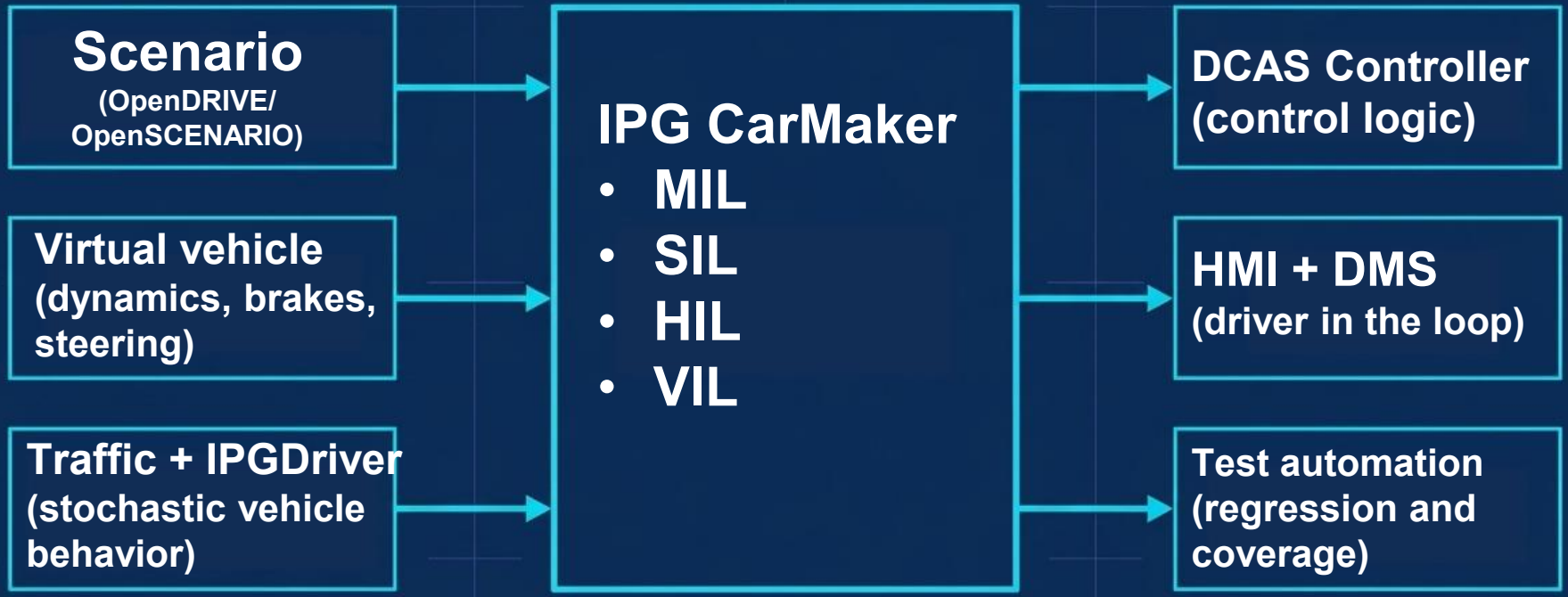








Closed loop of vehicle and traffic dynamics



CarMaker provides the deterministic and repeatable physical foundation for the entire test.

Physics-based perception simulation (Ansys AVxcelerate)

Ansys AVxcelerate

CAMERA

Effects of optics, lenses, light reflections and rain

RADAR

Doppler shift, MIMO, multipath reflections

LIDAR

Detailed point cloud dependent on material and reflectivity

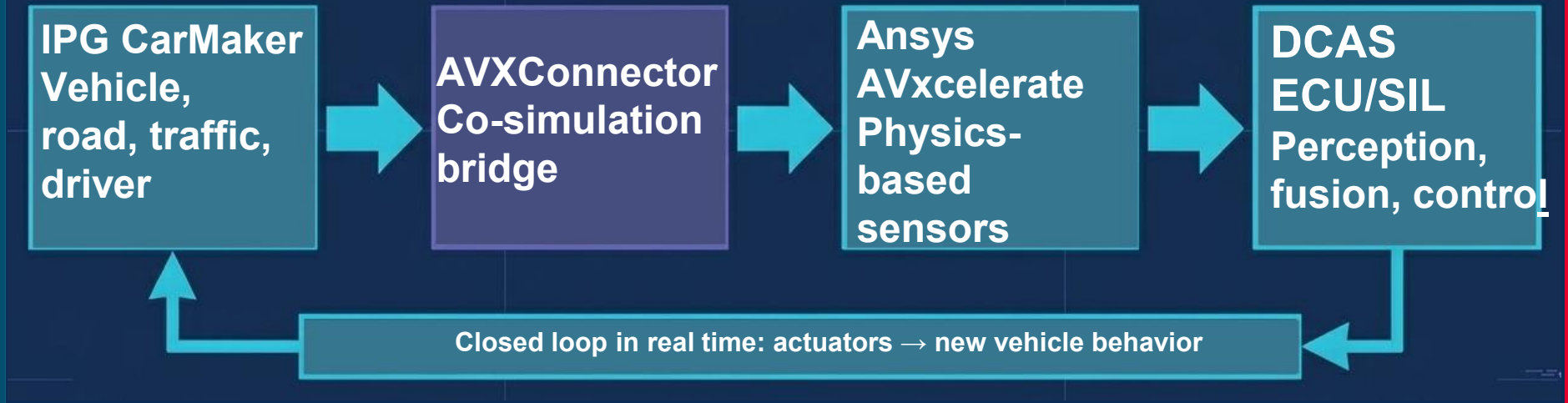
THERMAL

Thermal contrasts and night vision

Outputs correspond to raw data from real sensors in a realistic 3D environment for training and validation of AI sensor fusion.

Synergie: IPG CarMaker x Ansys AVxcelerate

CarMaker controls dynamics and scenario; AVxcelerate generates a physics-based feed.



Ansys documentation: a co-simulation project enables AVxcelerate Lighting and Sensors to be used in a dynamic environment created in CarMaker; AVxcelerate Sensors Library for CarMaker uses AVXConnector.

ASAM OpenX Standards: The language of the digital twin

OpenDRIVE
Road geometry, lanes, sign semantics

OpenSCENARIO
Dynamic maneuvers, e.g. cut-in

OSI
Common sensor interface and ground truth

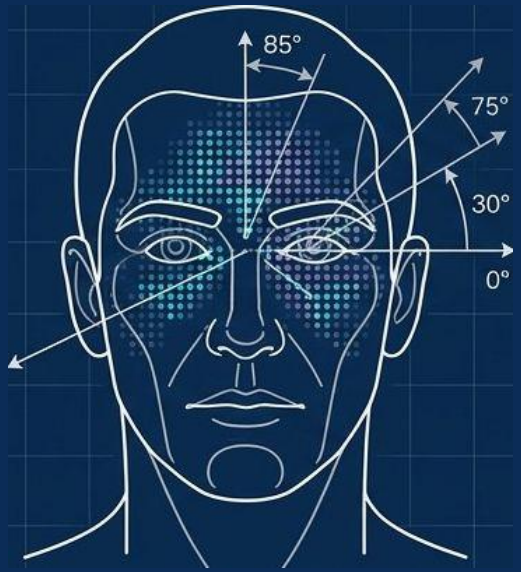
OpenLABEL
Data annotation for AI training

Real measured data (MDF, Parquet, ROS) for replay and correlation

Goal: One scenario library usable across MIL, SIL, HIL and the real vehicle.

Driver in the Loop: The human factor at the center of DCAS

MONITORING



Monitoring loss of attention (DMS). Detection of cognitive and physical disengagement.

INTERACTION

Escalation of warnings and forced takeover. Prevention of misuse: relying on fully autonomous driving.

A simulator (DIL) enables safe testing of the riskiest part of the system: the unpredictable response of a bored or overloaded driver.

Robotic Steering for Repeatable Vehicle Testing

Steering robots, pedal actuators and proving-ground automation for ADAS, vehicle dynamics and digital twin validation.

±0.5 km/h
targeted speed accuracy in robot systems

≈2 cm
targeted lateral deviation in automated tests

Repeatable input — same steering profile, speed and maneuver every time
Lower driver variability — clear comparison between vehicle setups or software versions
Safety envelope — remote stop, supervision and immediate human takeover
Traceable data — steering angle, torque, vehicle response and pass/fail criteria

CarMaker + MovieNX Driving Simulator

DRIVER-IN-THE-LOOP · VIRTUAL TEST DRIVING

A compact simulator platform for teaching, ADAS demonstrations, digital twins and repeatable vehicle dynamics scenarios.

Thank you for your attention.
Q&A

For more information and updates, please visit:

- automotiveengineering.online
- digitaltwin.science

This publication was supported by the project "Innovative Technologies for Smart Low Emission Mobilities ", funded as project No. CZ.02.01.01/00/23_020/0008528 by Programme Johannes Amos Comenius, call Intersectoral cooperation.

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