Leveraging Virtual Testing from Algorithm to Vehicle Level in Series Application Projects

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Motivation

Project Management spent most of its budget for function development and forgot about testing?

Sales promised a feature to the customer which does not yet exist?

Solution?

Fast, scalable and cost-saving way of testing to get the needed confidence for a release

Virtual Testing over all levels

Introduction

Eric Funke

Continental Engineering Services >3 years

Technical Project Lead
SW/Algorithm Testing

Virtual Workshop

Virtual Vehicle Prototypes

› Parametrization and validation
› Virtual Integration of functions and models

Virtual Test Environments

› Test cases and maneuver catalogs (e.g. Euro NCAP, UN ECE R152, …)
› Automated results evaluation and reporting
› Customized interfaces to other toolchains and middleware solutions

Test Systems

› Model/Software-in-the-Loop (MIL/SIL)
› Hardware-in-the-Loop (HIL)
› Vehicle-in-the-Loop (VIL)

Virtual Vehicle Testing

Testing

› Test maneuver execution
› Results evaluation and reporting
› "HIL Operator" for specific test request

Simulation studies

› Compliance to regulations
› Concept evaluation
› Sensitivity analysis

Development support

› Agile adaption of vehicle models and test scenarios according to changing requirements
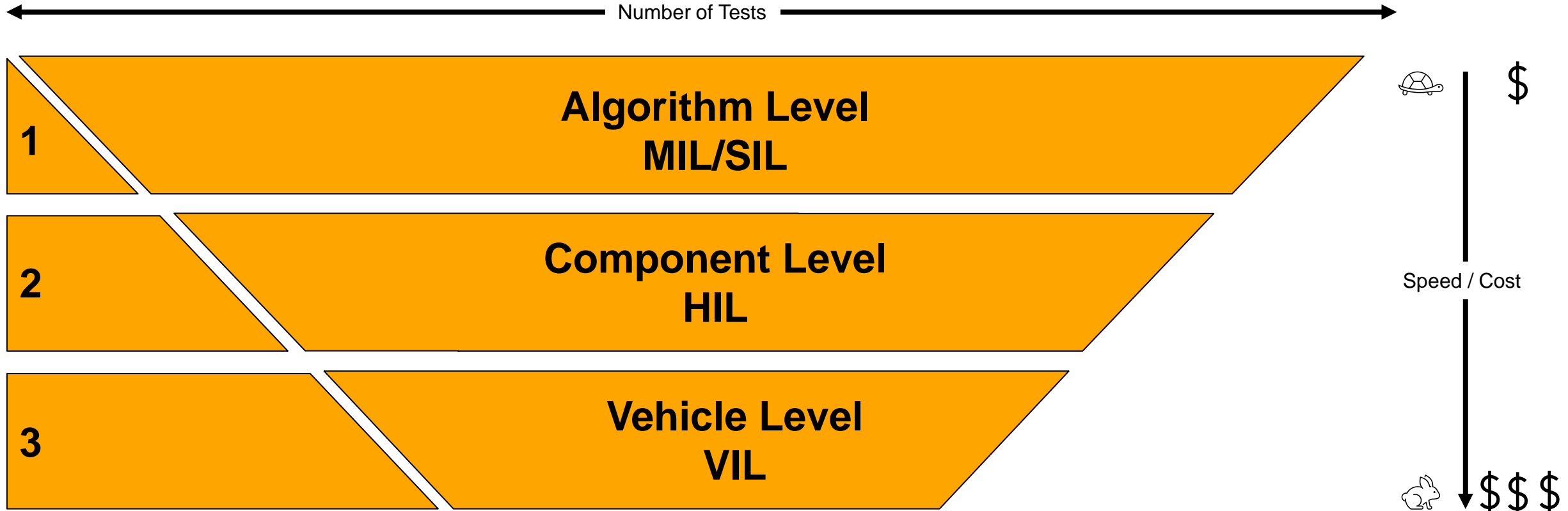› Application tasks

Simulation Engineering

Simulation Process Consulting

› Simulation as a part of virtual integration
› How to set up vehicle models
› Purpose-driven fidelity
› Efficient model validation
› Refinement of models and parameters – Why and how?
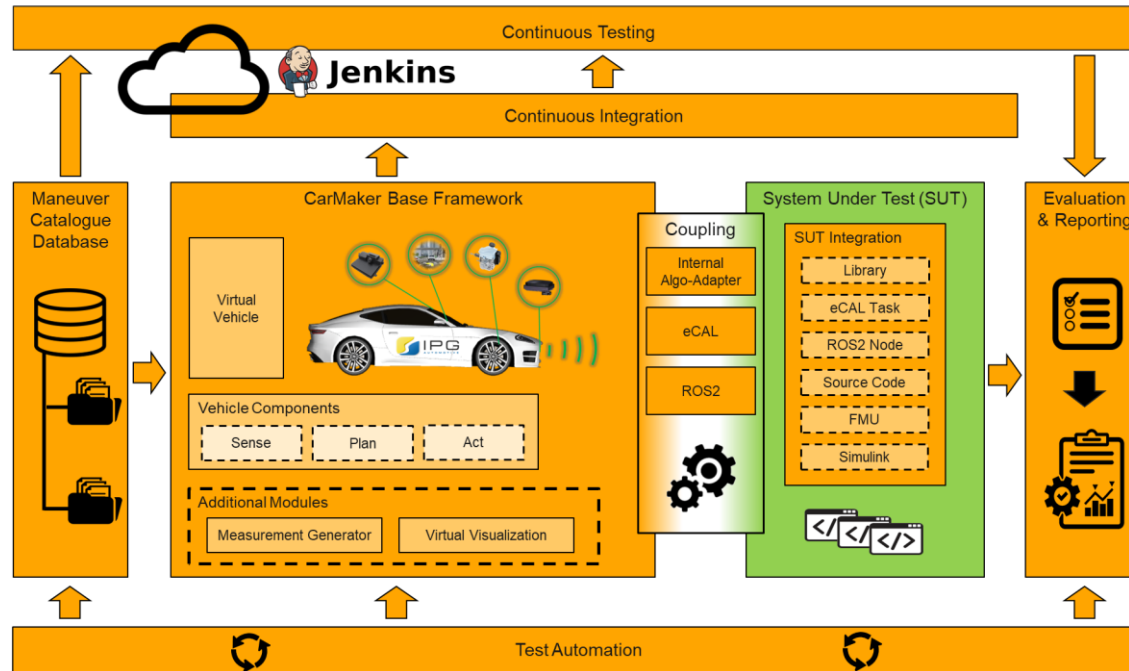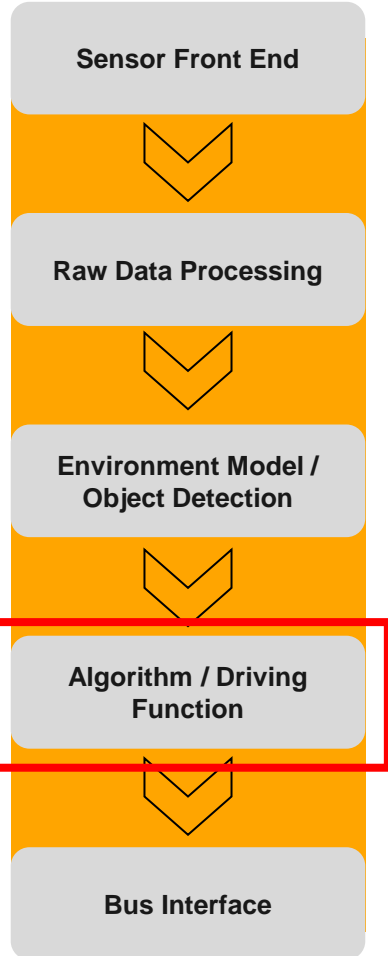› Simulation-based release testing

Test System Consulting

› Planning and realization of SIL, HIL, VIL
› Real-time computer hardware setup and I/O interface specifications

Agenda

Number of Tests

**Algorithm Level
MIL/SIL**

1

**Component Level
HIL**

2

**Vehicle Level
VIL**

3

$

Speed / Cost

$ $ $

MIL/ SIL Testing

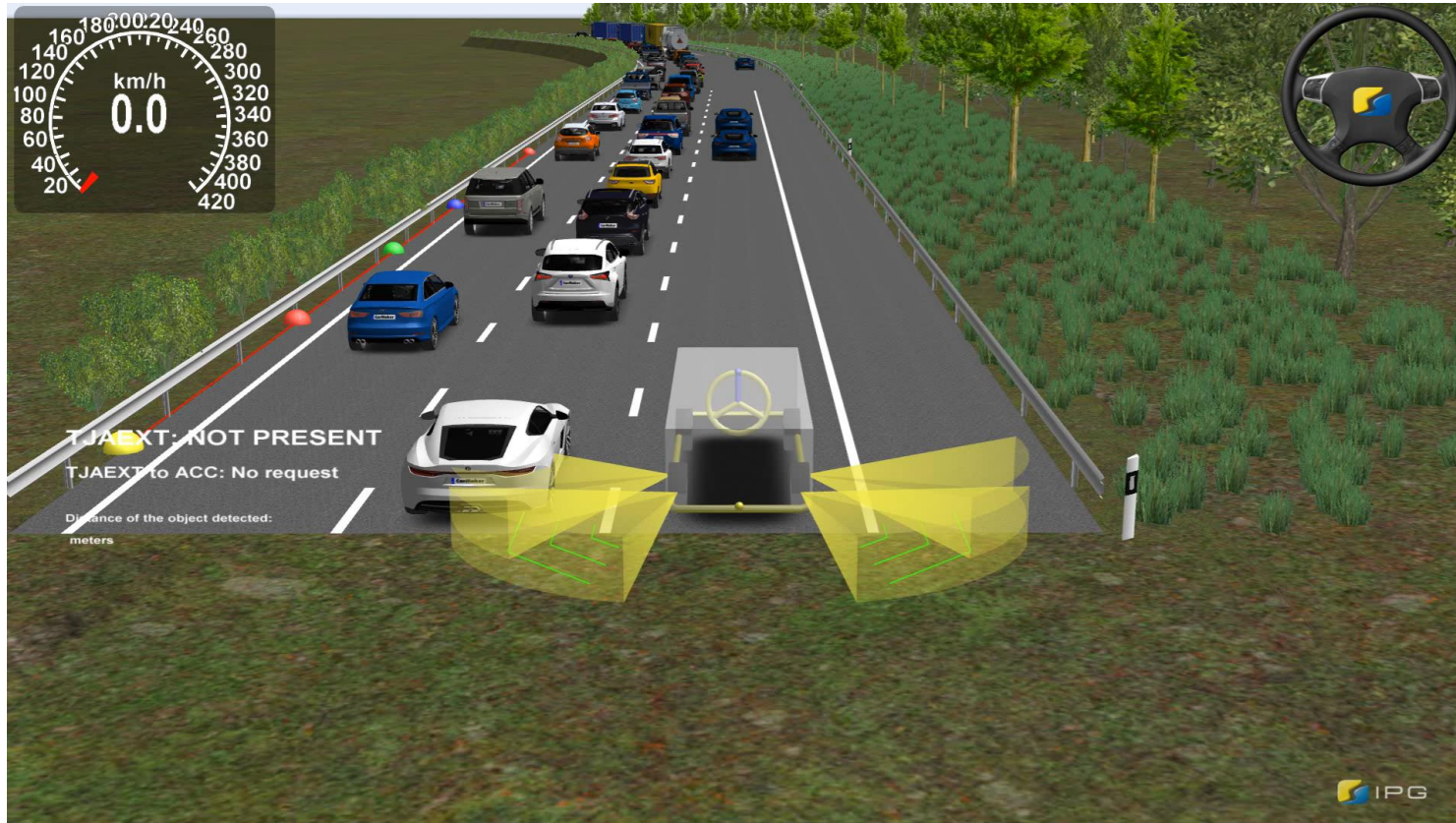**Working Principle**

› CarMaker-based (works also for Truck-/MotorcycleMaker)

› Modular architecture allows easy application to specific use cases

› Supports from early development until final validation
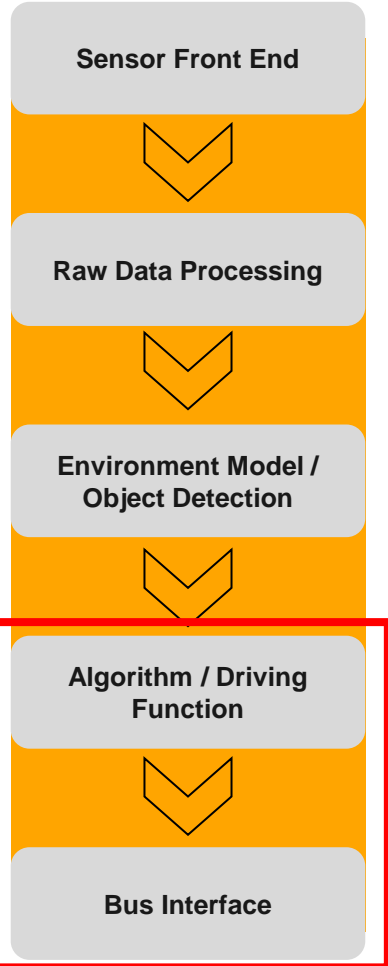
MIL/ SIL
Example and Benefits

Benefits within the Project

› **Development-/Presentation tool**
Early Hands-on for developer, good for showcasing

› **Smoke-testing**
Fast feedback for code changes and new feature development

› **SW-Release Testing**
As CI/CT capable was used as environment for automated release

HIL Testing
Radar Object HIL

SUT

- Sensor Front End
- Raw Data Processing
- Environment Model / Object Detection
- Algorithm / Driving Function
- Bus Interface

Working Principle

› Synthetic objects are injected into the physical radar via a special object HiL software interface

› The complete vehicle is simulated as restbus and the physical radar is stimulated with vehicle data

› The functional response of the radar are fed back to the simulation environment viz. CarMaker to provide the closed loop environment testing

› Around **30% of chain of effects** i.e. Plan-Act part can be tested with this setup. The Sense part of the physical radar is neglected with this setup

Technical Layout
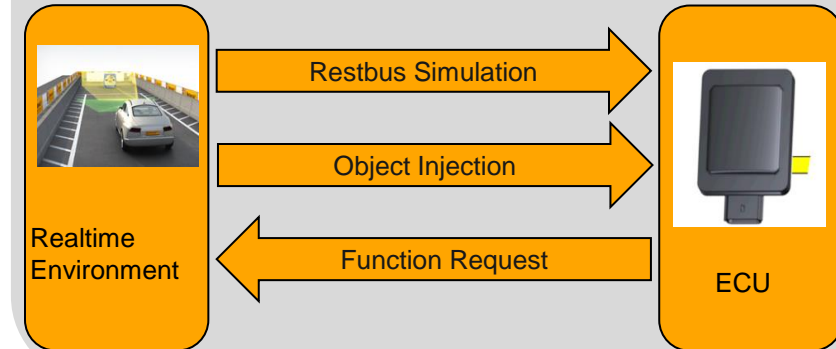
Realtime Environment

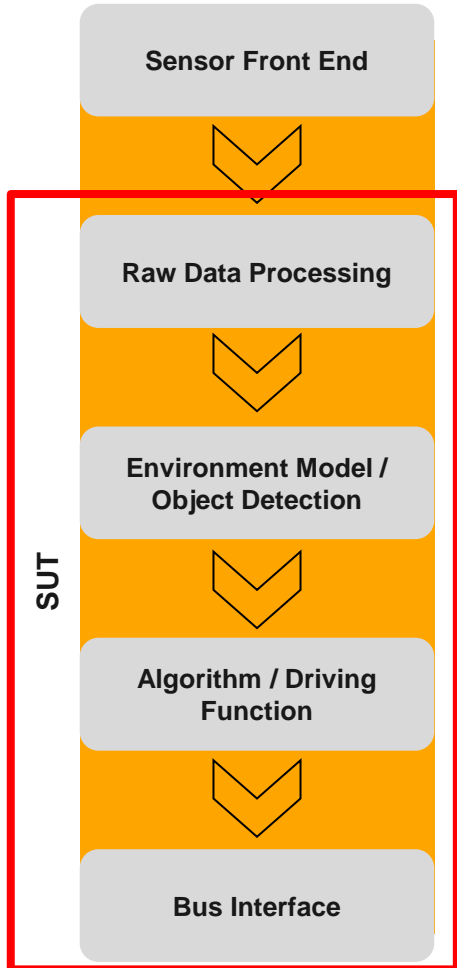Restbus Simulation →

Object Injection →

← Function Request

ECU

Benefits within the project

› **Cost efficient**
number of test vehicles and tests on proving ground can be reduced

› **Fast Feedback** for Developer and Integrators
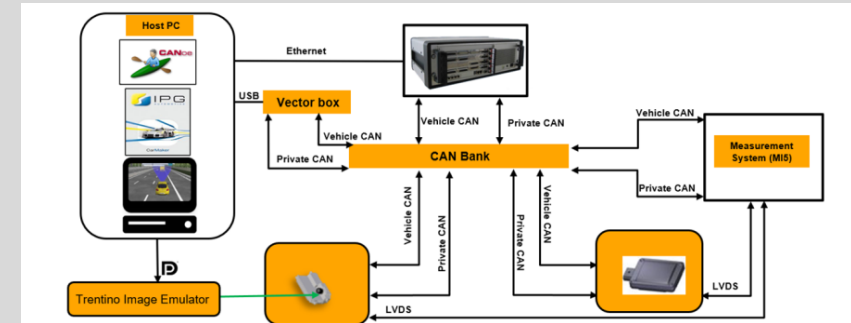early state integration- or functions tests show maturity of function

HIL Testing
Camera Raw Data Synthetic HIL

SUT

- Sensor Front End
- Raw Data Processing
- Environment Model / Object Detection
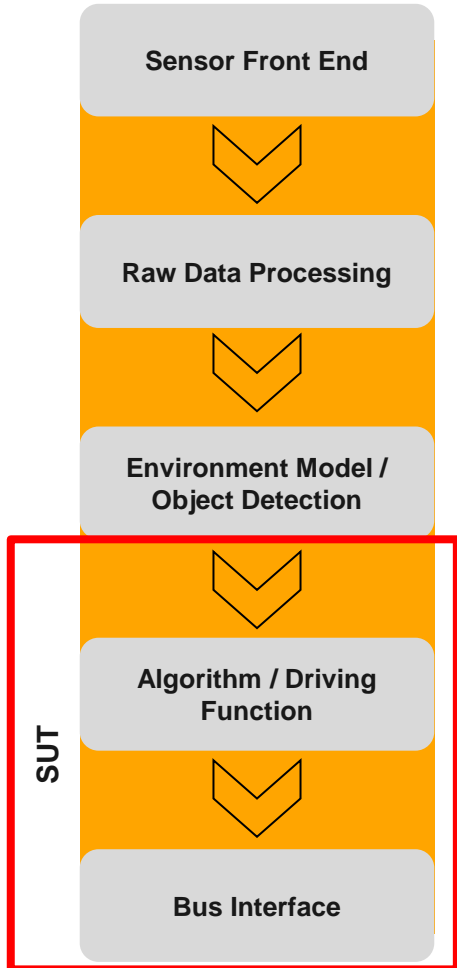- Algorithm / Driving Function
- Bus Interface

Working Principle

› The imager is in the loop just for I2C initialization, and the lens model is developed in simulation environment viz. CarMaker

› The stream of image data from simulation rendering engine viz. CarMaker Movie NX is fed by an Image Emulator viz. Trentino Box into the camera

› Vehicle bus and part of the private CAN are simulated with the help of realtime system viz. Xpack4 and transmitted to the camera

› Around **85% of chain of effects** i.e. Sense (From RDP)-Plan-Act part can be tested with this setup. Only the camera front end i.e. physical imager is in the loop for I2C synchronization with image emulator

## Technical Approach / Layout

Benefits within the project

› **Cost efficient**
number of test vehicles and tests on proving ground can be reduced

› **Fast Feedback** for Developer and Integrators
early state integration- or functions tests show maturity of function

VIL Testing

Sensor Front End

Raw Data Processing

Environment Model / Object Detection

Algorithm / Driving Function

Bus Interface

SUT

Working Principle

› Vehicle-in-the-Loop (VIL) means driving a real vehicle while being surrounded by virtual traffic infrastructure

› Real vehicle motion, provided by D-GPS, controls position, velocity and heading of virtual vehicle running in CarMaker

› Virtual vehicle is equipped with virtual sensors / modelled sensors which observe traffic and road infrastructure in virtual scenario

› Function under test works with virtual sensor input, while function output can be experienced in real vehicle i.e. Access to full chain of effects

Technical Approach / Layout
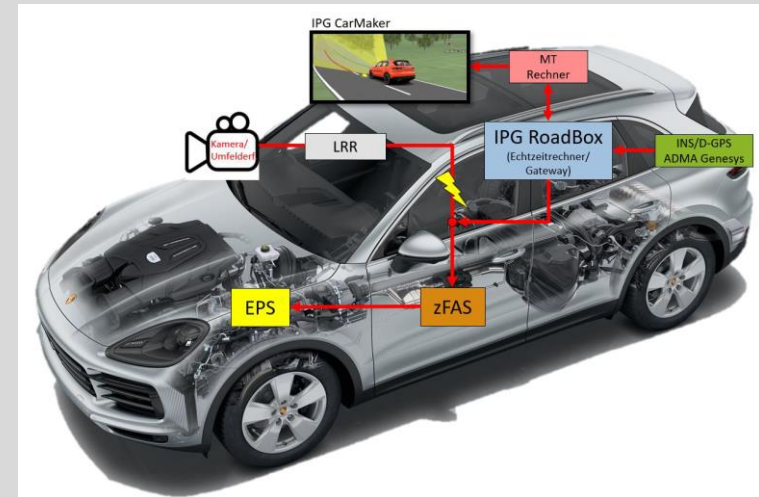
› Different injection points can be used for injecting synthetic sensor data into the sensor
› Monitor or AR glasses are used for visualization for tester immersion in the virtual environment
› Different combination of IPG HW, Image Emulators, Gateways are used for injecting synthetic data into the sensor and into the physical vehicle bus

VIL
Example and Benefits

Benefits within the Project

› **Cost efficient**
No other real traffic participants needed.
No special requirements to ground
markings and surrounding needed

› **Accurate and repeatable**
due to clinical driving situations accurate
or high-risk maneuver easy possible

› **Release Testing**
validated test-environment to be used
for homologation tests

Vision Zero
GSR – NCAP – V2X – Autonomous Driving

Tomorrow's topics are complex and challenging

with a high demand for virtual testing

We are ready.

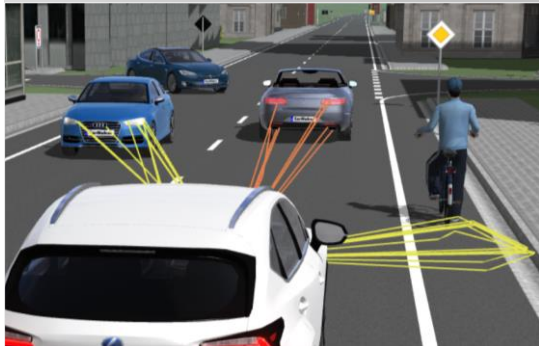# Thank you for your attention

Continental Engineering Services

CES Virtual Testing & Simulation (VTS)
Simulation Products for External and Internal Customers

Test Environments

› CarMaker Test Suite for Euro NCAP Active Safety Testing

› CarMaker Test Suite for UN ECE R152 Testing

› Creating Recordings of Virtual Scenarios for Algo Replay Tests

Vehicle-in-the-Loop

› VIL for ADAS/AD and Brake Function Test and Application

› VIL „Driving Instructor" for Interactive Visualization

› Vehicle-in-the Loop Concept Study and System Design

Models and Tools

› High-Fidelity Vehicle Models for Driving Dynamics and ADAS/AD Application

› Control Function Integration into Virtual Prototype Vehicles

› Radar Sensor Models

› Plugins for Continuous Integration and Testing (CI/CT)

› ROS2 and eCAL Interfaces
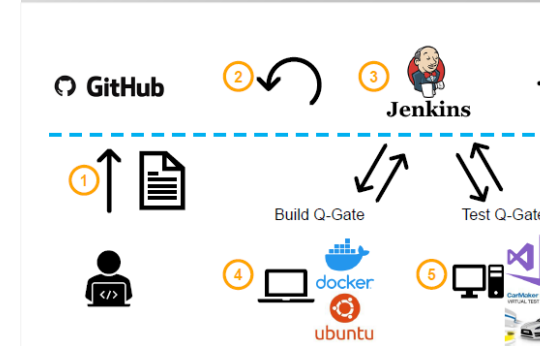
Simulation Study

› Euro NCAP Performance Prediction

› UN ECE R152 Compliance Prediction

› Virtual Benchmark for Vehicle Attribute Tuning

› Sensitivity Study for Control Function Application
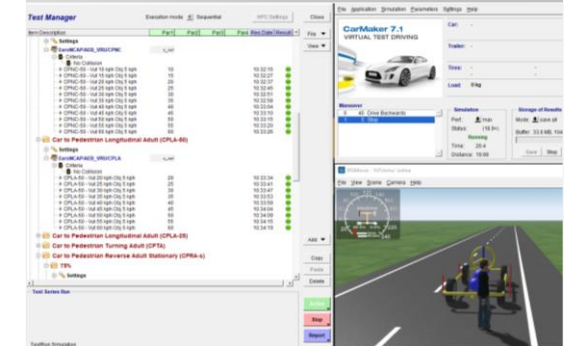
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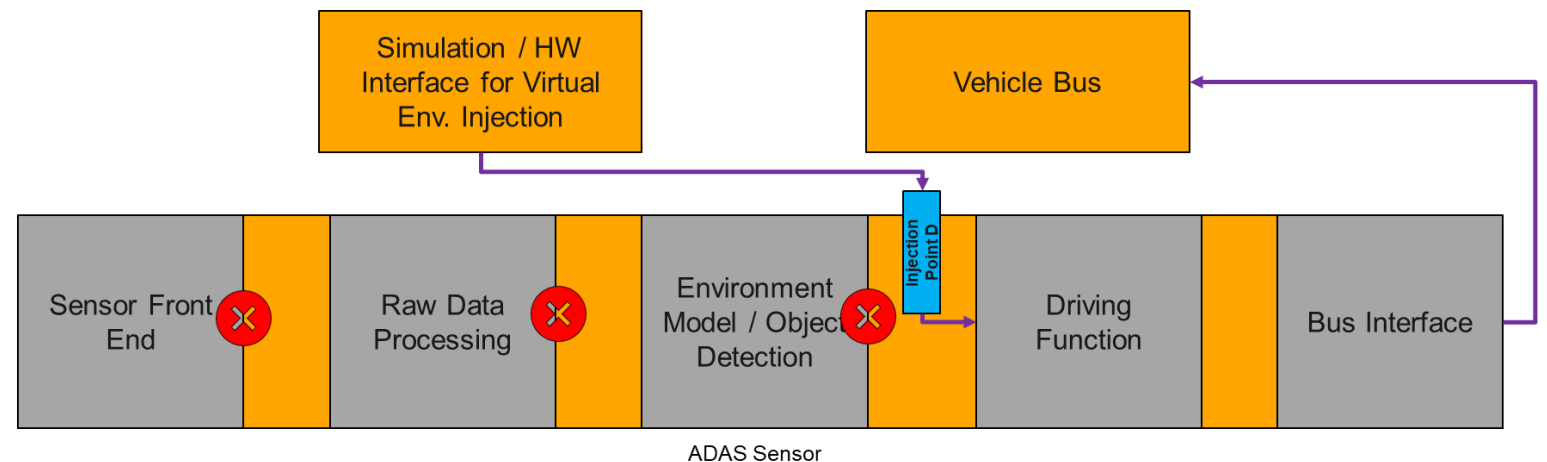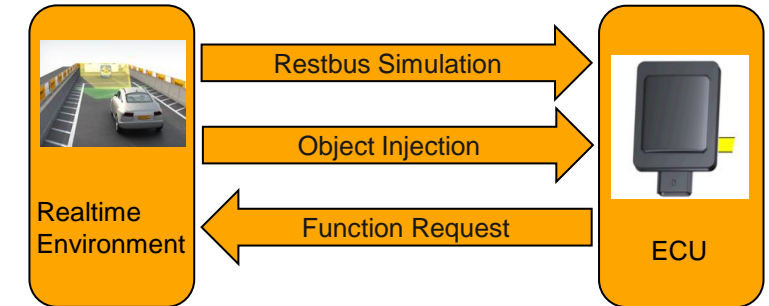
HiL Test Systems
Radar Object HiL

Working Principle

› Synthetic objects are injected into the physical radar via a special object HiL software interface

› The complete vehicle is simulated as restbus and the physical radar is stimulated with vehicle data

› The functional response of the radar are fed back to the simulation environment viz. CarMaker to provide the closed loop environment testing for control functions like EBA, ACC, BSD, RCTA, RCTB, etc.

› Around **30% of chain of effects** i.e. Plan-Act part can be tested with this setup. The Sense part of the physical radar is neglected with this setup

› Used in automotive and motorcycle applications

› **Testing Scope**

  › Smoke / Integration tests

  › Function tests

  › System release tests

HiL Architecture

Gen 4 / 5 Radars

› Synthetic Closed Loop

› Object Data

› HiL Injection SW: CarMaker

› HiL Injection HW: Xpack4

› HiL Interface: CANFD

Technical Approach / Layout

Realtime Environment — Restbus Simulation → ECU; Object Injection → ECU; Function Request ← ECU

Simulation / HW Interface for Virtual Env. Injection

Vehicle Bus

Injection Point D

Sensor Front End | Raw Data Processing | Environment Model / Object Detection | Driving Function | Bus Interface

ADAS Sensor

HiL Test Systems
Camera Raw Data Synthetic HiL

| Working Principle	HiL Architecture	Technical Approach / Layout

Working Principle

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› Around **85% of chain of effects** i.e. Sense (From RDP)-Plan-Act part can be tested with this setup. Only the camera front end i.e. physical imager is in the loop for I2C synchronization with Image emulator

› Setup can be expanded to a system level closed loop HiL comprising of camera and radar

› **Testing Scope**

  › Smoke / Stability tests

  › Perception / Functional / Release tests

HiL Architecture

Gen 5 Multifunction Cameras

› Synthetic Closed Loop

› Raw Synthetic Image Data

› HiL Injection SW: CarMaker

› HiL Injection HW: Trentino Box

› HiL Interface: MIPI-CSI2

› Bus Emulator: XPACK4

Technical Approach / Layout

ADAS Sensor
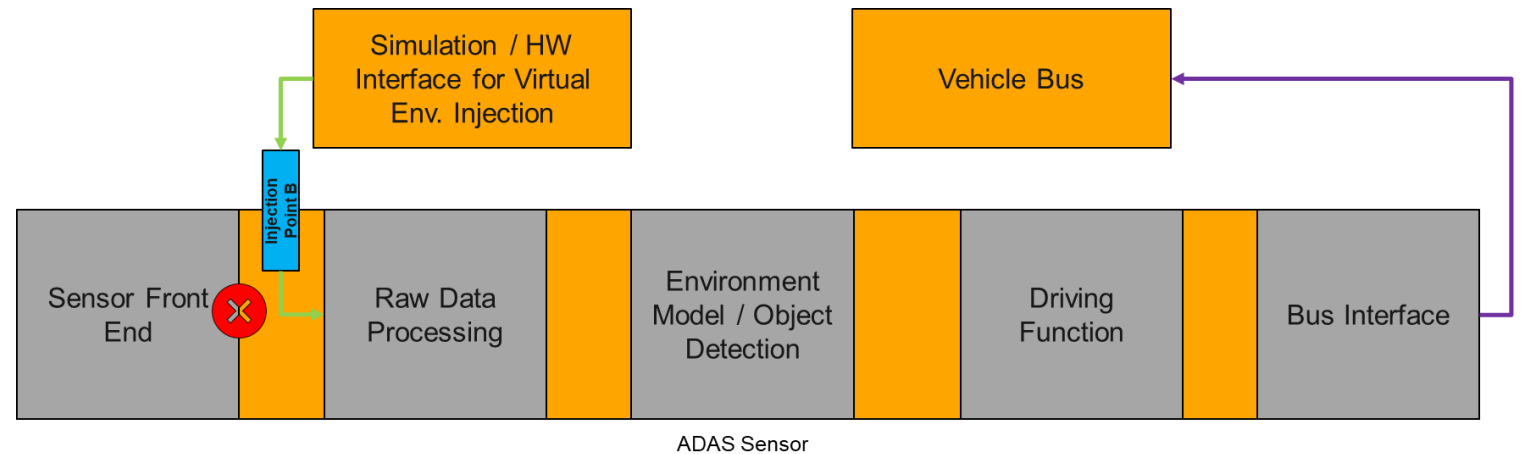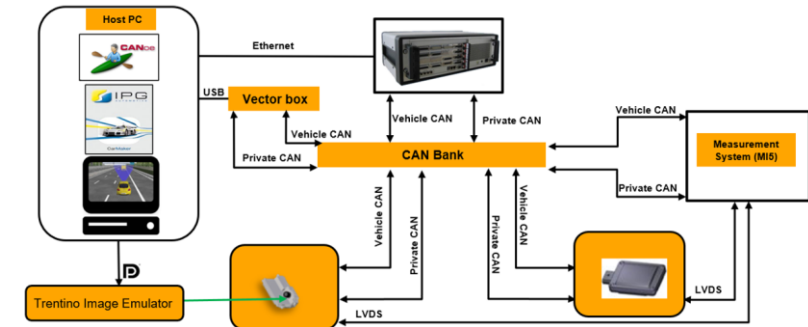
ViL Test Systems
AD/ADAS ViL

Working Principle

› Vehicle-in-the-Loop (VIL) means driving a real vehicle on a test track while being surrounded by virtual traffic and virtual infrastructure

› Real vehicle motion, provided by D-GPS, controls position, velocity and heading of virtual vehicle running in CarMaker

› Virtual vehicle is equipped with virtual sensors / modelled sensors which observe traffic and road infrastructure in virtual scenario

› Function under test works with virtual sensor input, while function output can be experienced in real vehicle i.e. Access to full chain of effects

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› Monitor or AR glasses are used for visualization for tester immersion in the virtual environment

› Depending on the project, different combination of IPG HW, Image Emulators, Gateways are used for injecting synthetic data into the sensor and into the physical vehicle bus

Testing Scope

EBA / FCW · ACC Stop&Go · Traffic Jam Assist · Lane Support Functions · Parking · Cross Traffic Alert

Technical Approach / Layout