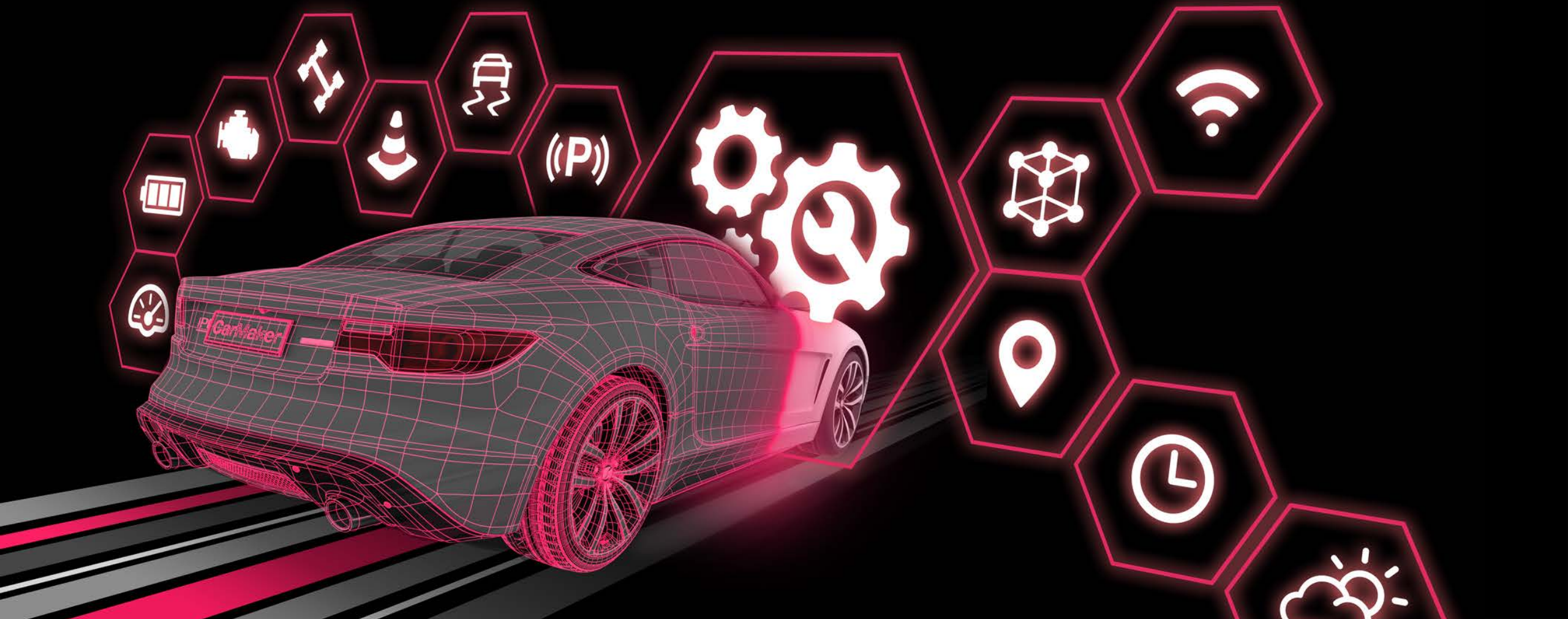
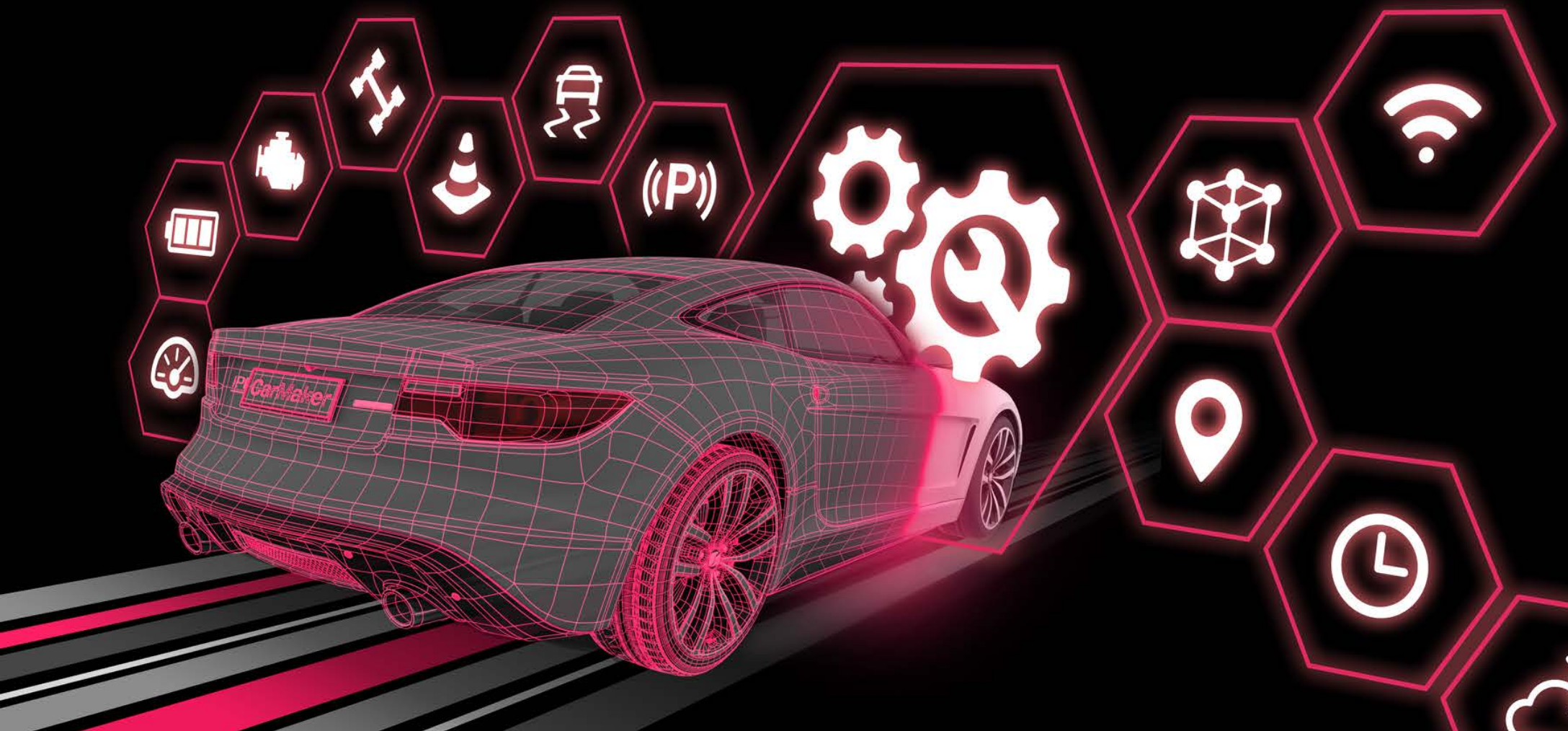
Virtual Test Driving in the Development Process – New Methods and Tools for Current Challenges



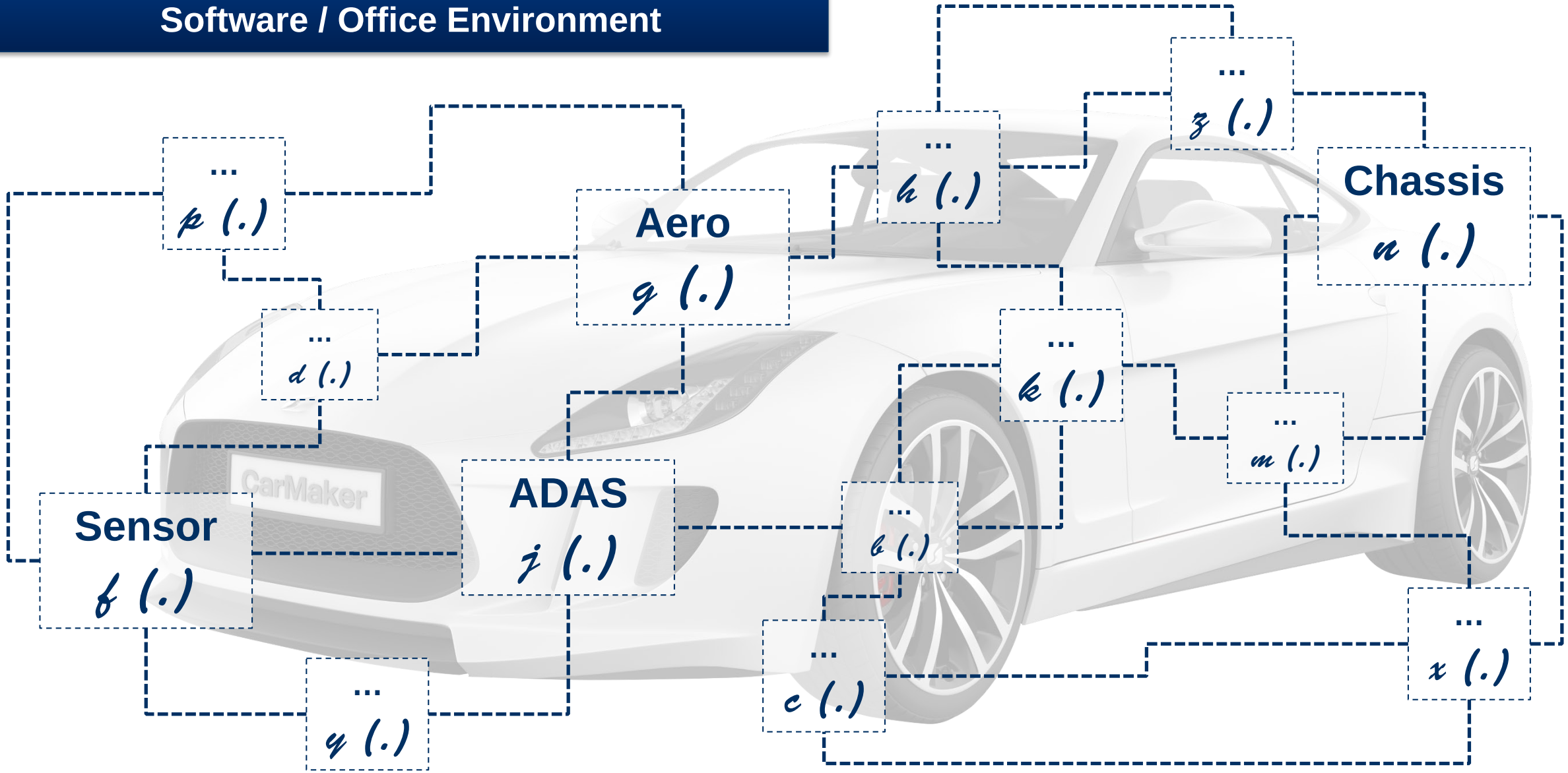
Episode 1: Hardware-in-the-Loop



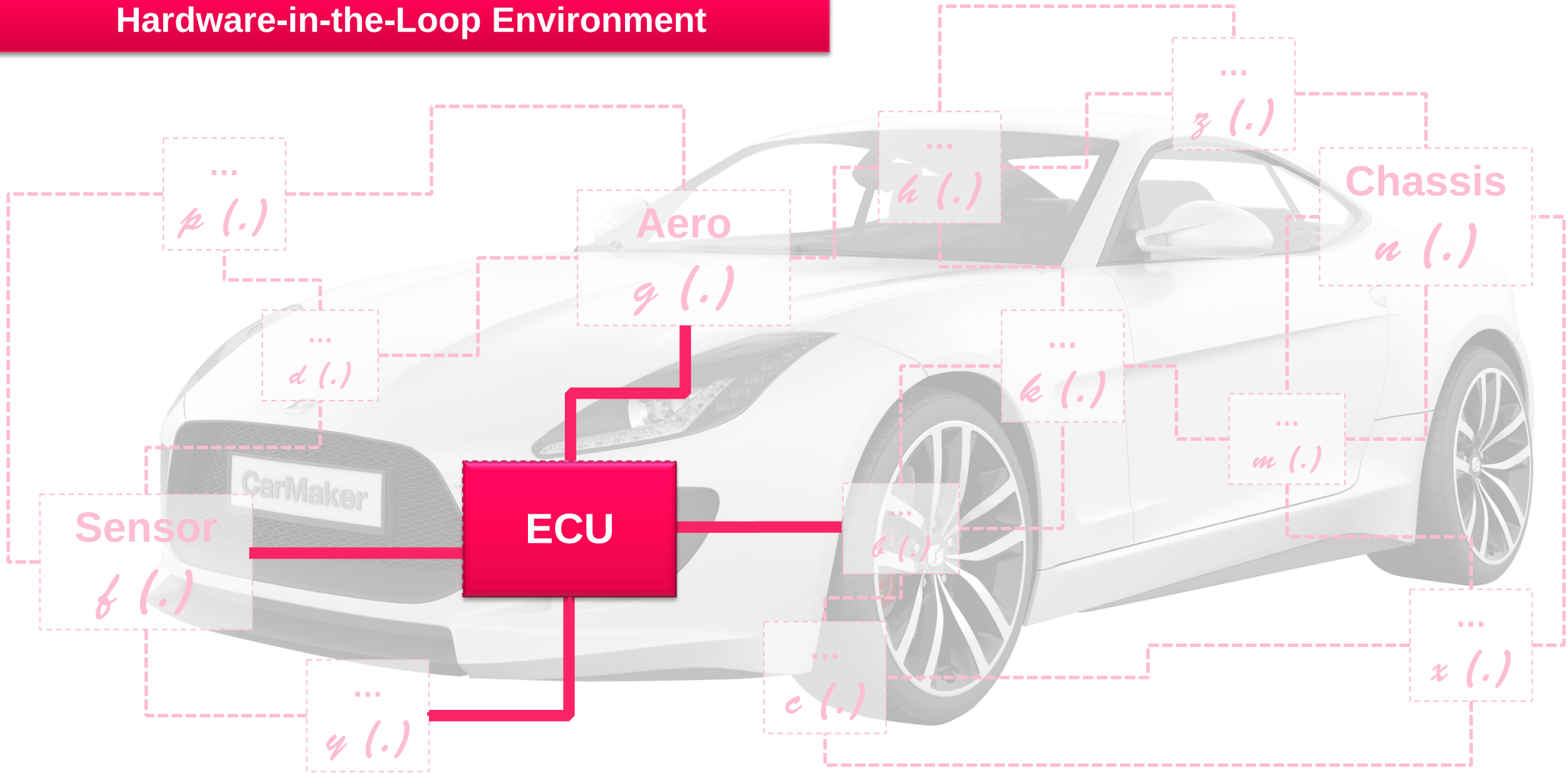
Current and Future Challenges for Function Verification with HIL

- Highly networked functions
- Platform ECUs/ „Super ECUs“
- Sensor data fusion
- Neural networks Artificial intelligence
- Automated Driving

Software / Office Environment



Hardware-in-the-Loop Environment



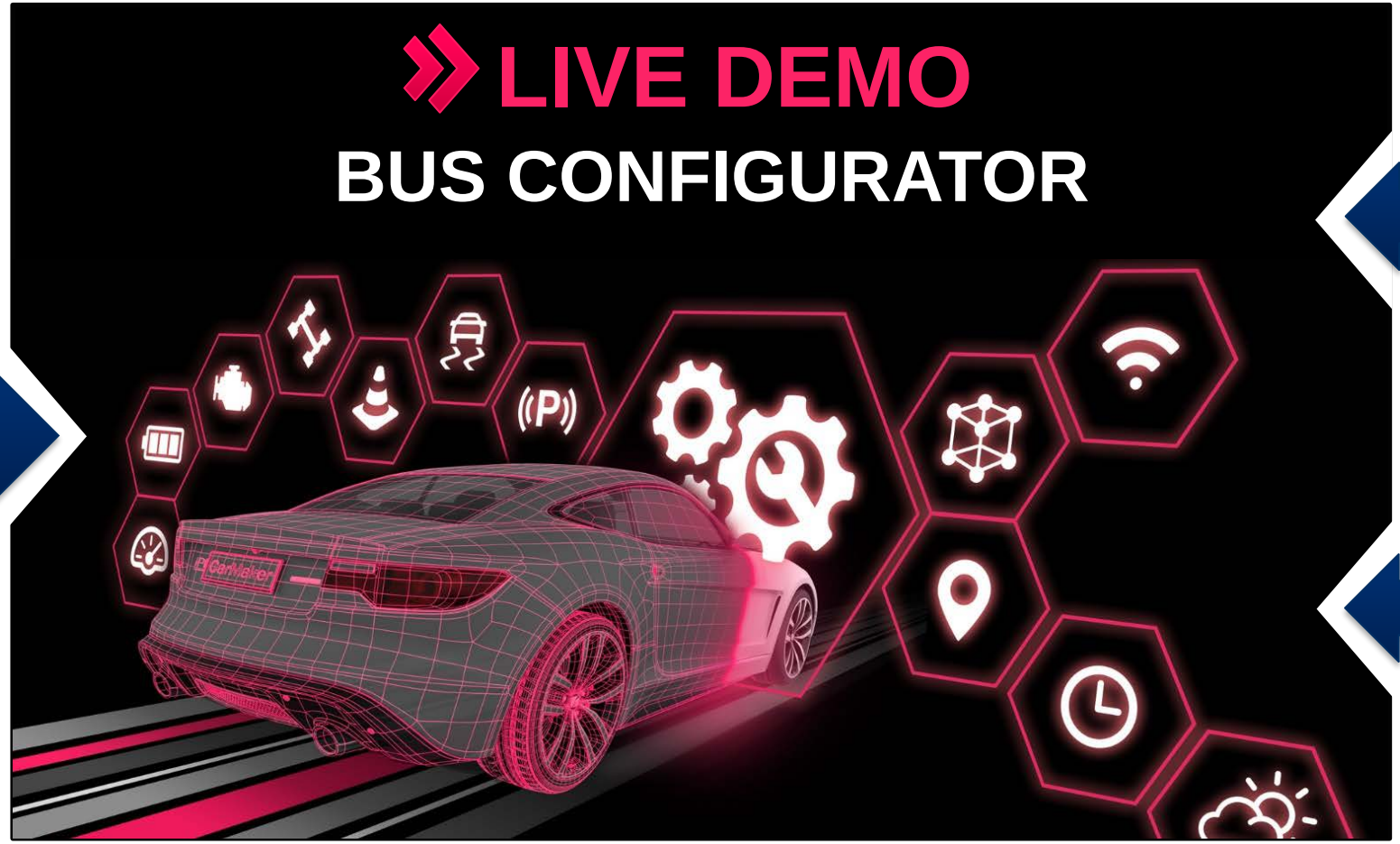
Existing Implementation with CarMaker

Bus Configurator

For rest bus simulation

Databases

- .dbc
- .xml
- .arxml



Infofiles
- FlexRayParameters
- RBSParameters
- FlexCardParameters

Infofiles
- CANParameters
- RBSParameters

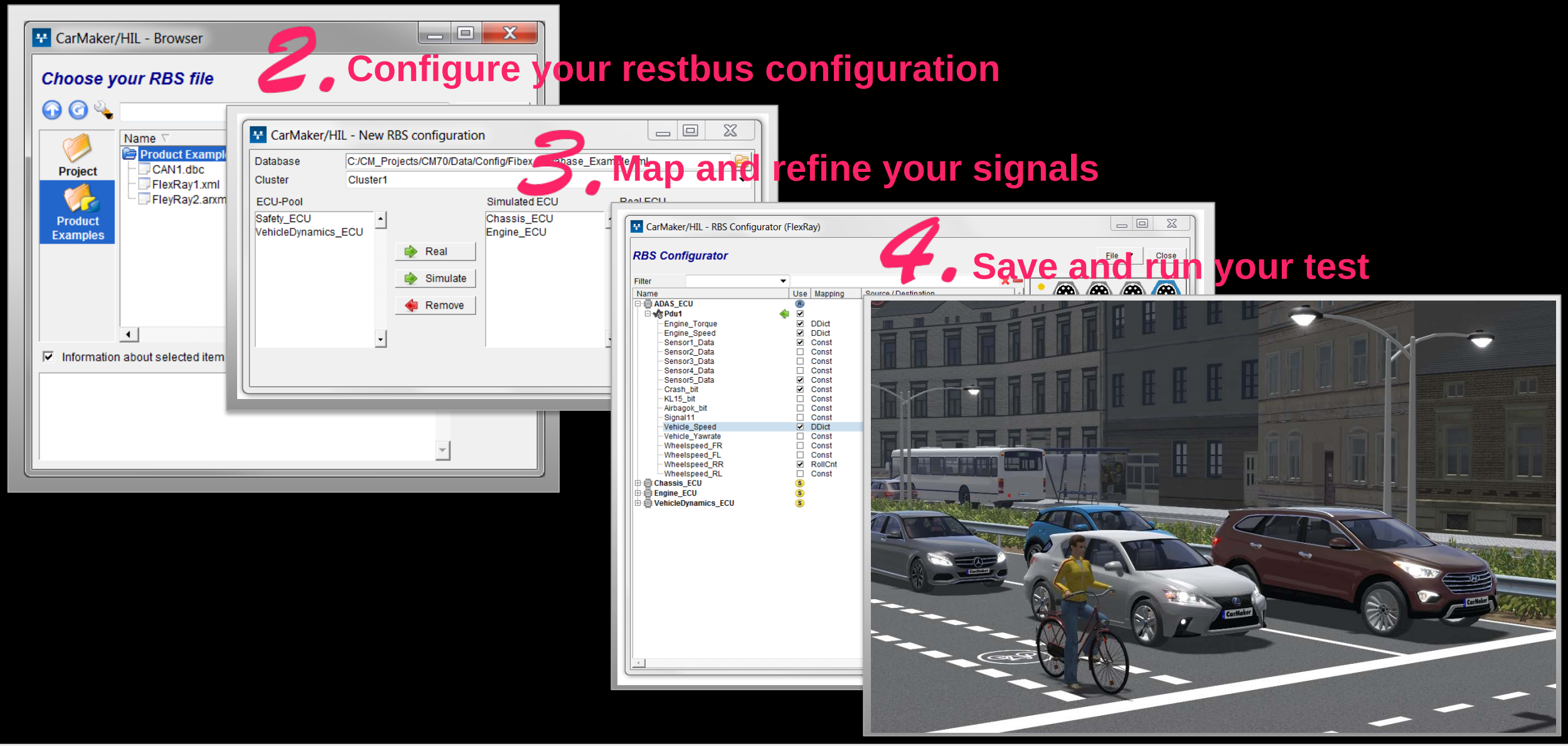
BUS CONFIGURATOR

1. Choose your database

2. Configure your restbus configuration

3. Map and refine your signals

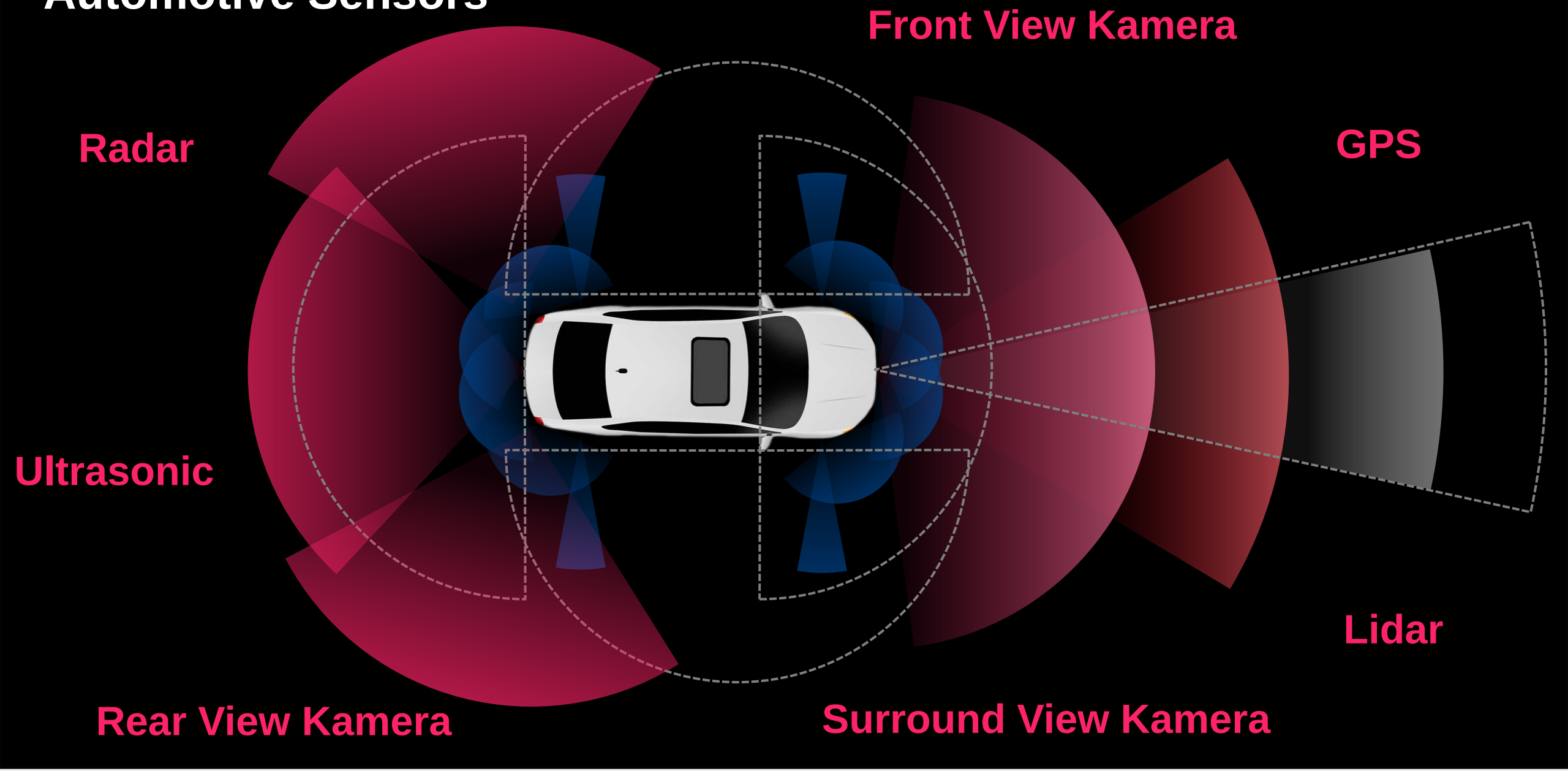
4. Save and run your test



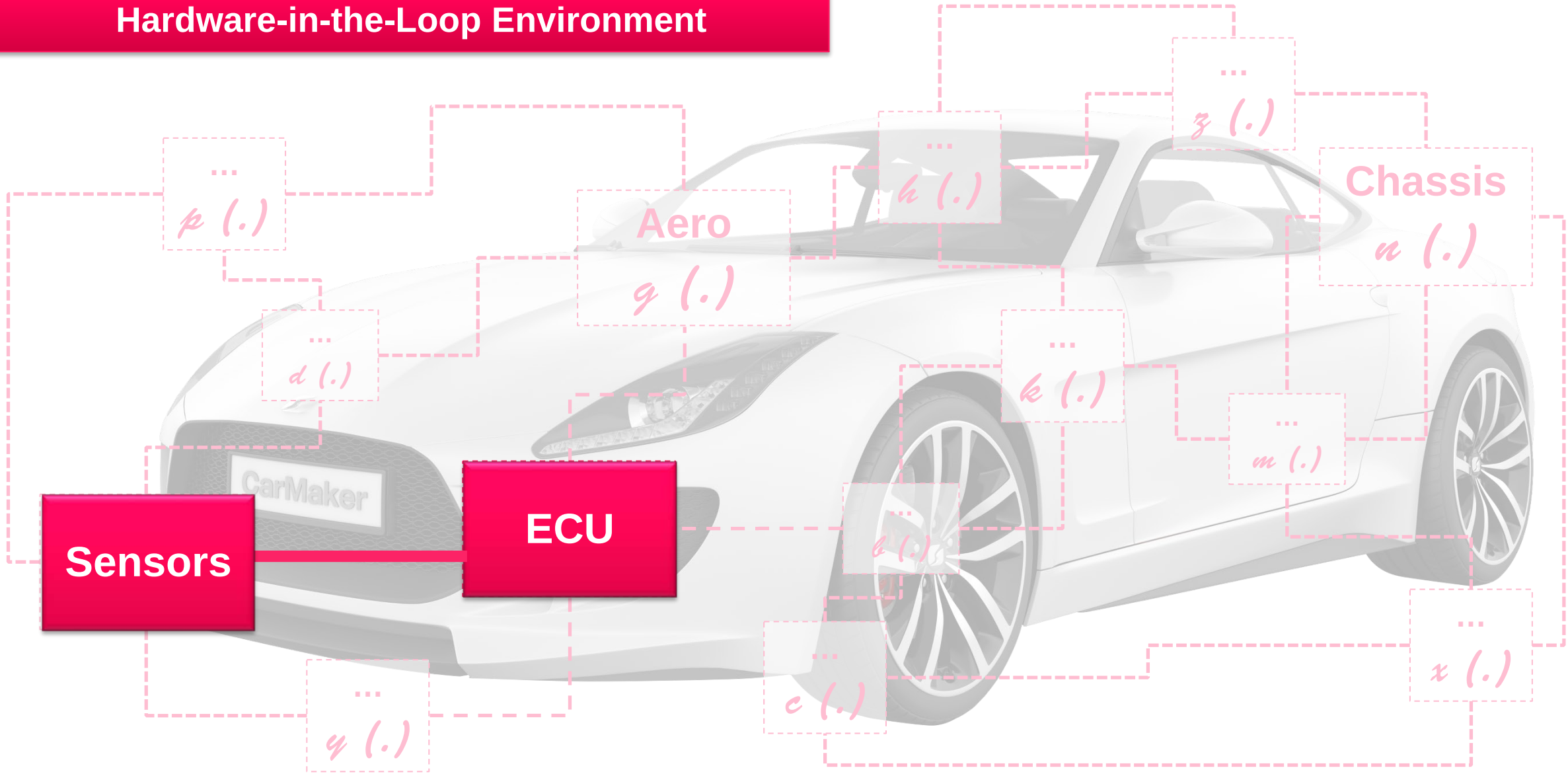
Features at a glance

- ✓ Full FlexRay support (FIBEX, AUTOSAR)
- ✓ Full CAN support (FIBEX, AUTOSAR, Vector DBC)
- ✓ Automatic detection of database type
- ✓ Automatic generation of frames, PDUs and signals
- ✓ GUI-based mapping of signals to Data Dictionary, Constants, RollingCount, E2E_P2, CRC
- ✓ Additional functions for usability (e.g. filter, hooks, trigger…)
- ✓ Infofile approach enables simulation start on-the-fly

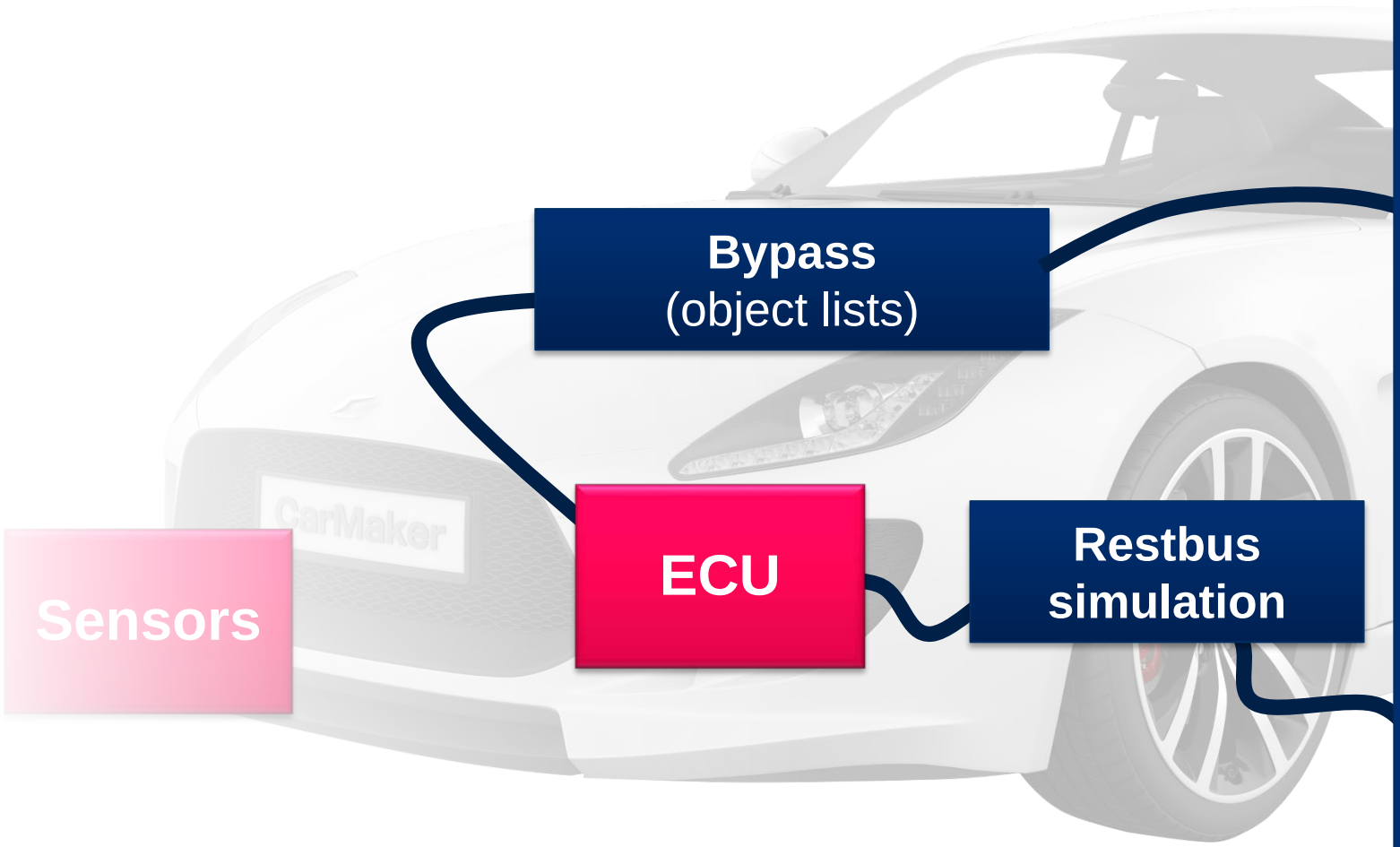
Automotive Sensors



Hardware-in-the-Loop Environment



Object List Based Injection

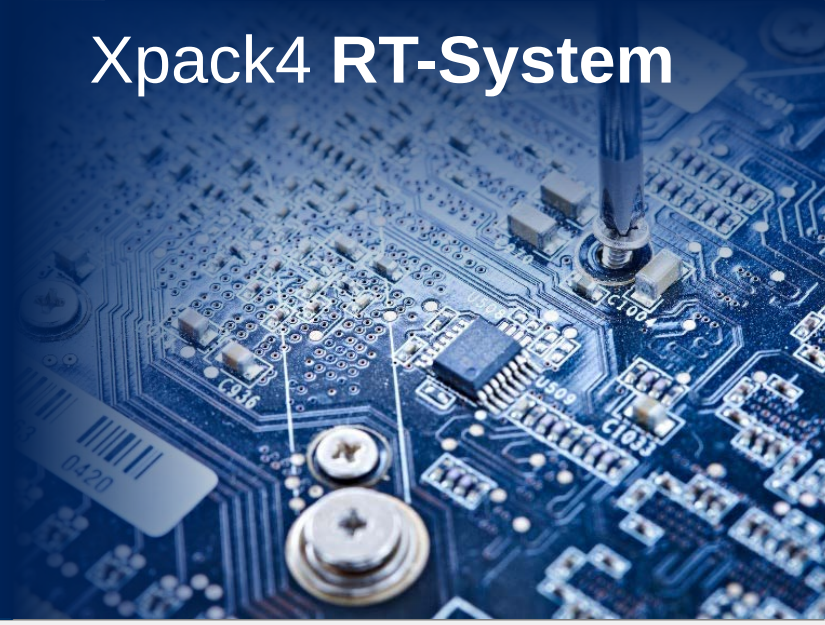


Device under test

HIL TEST SYSTEM

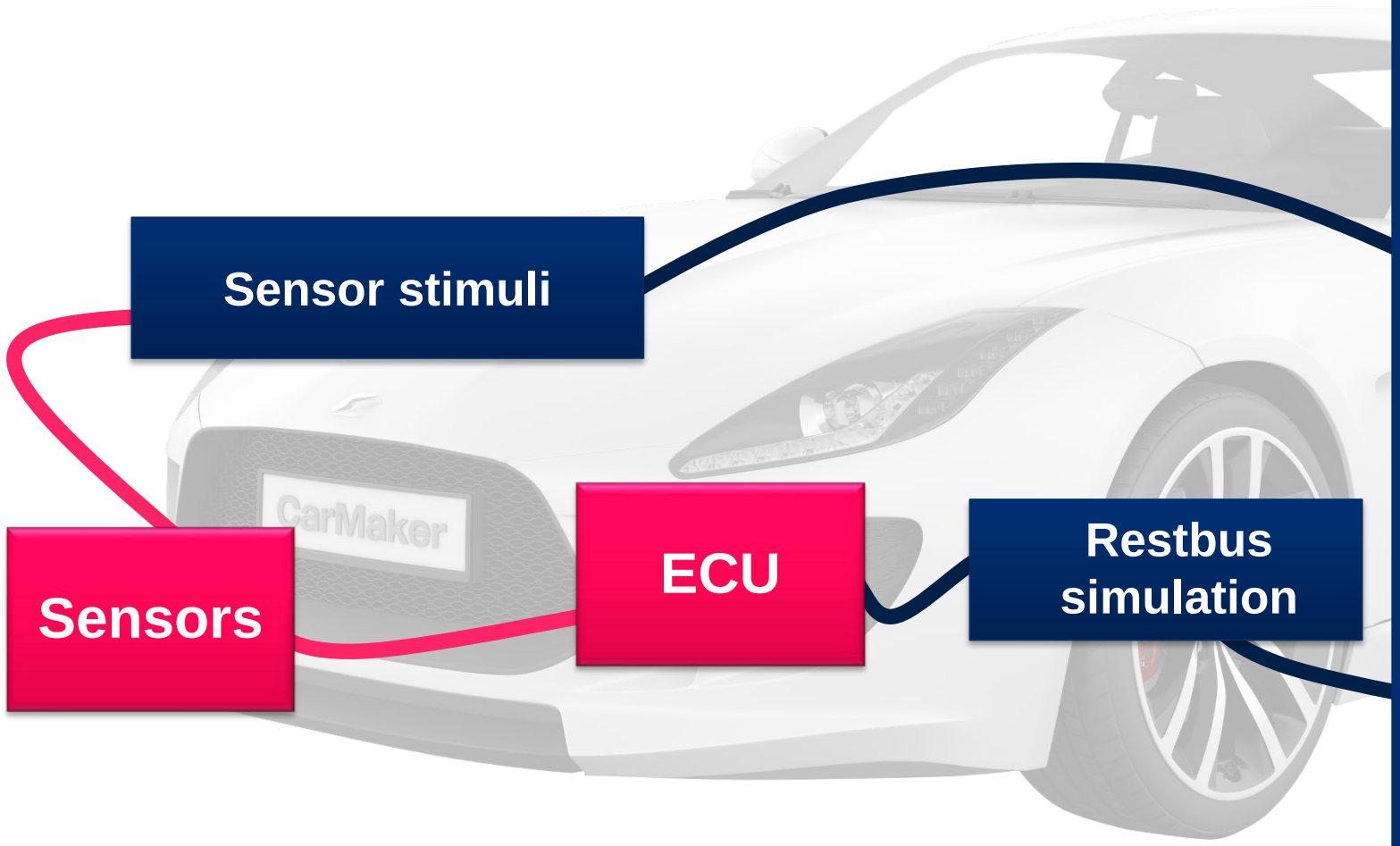
CarMaker

Xpack4 **RT-System**



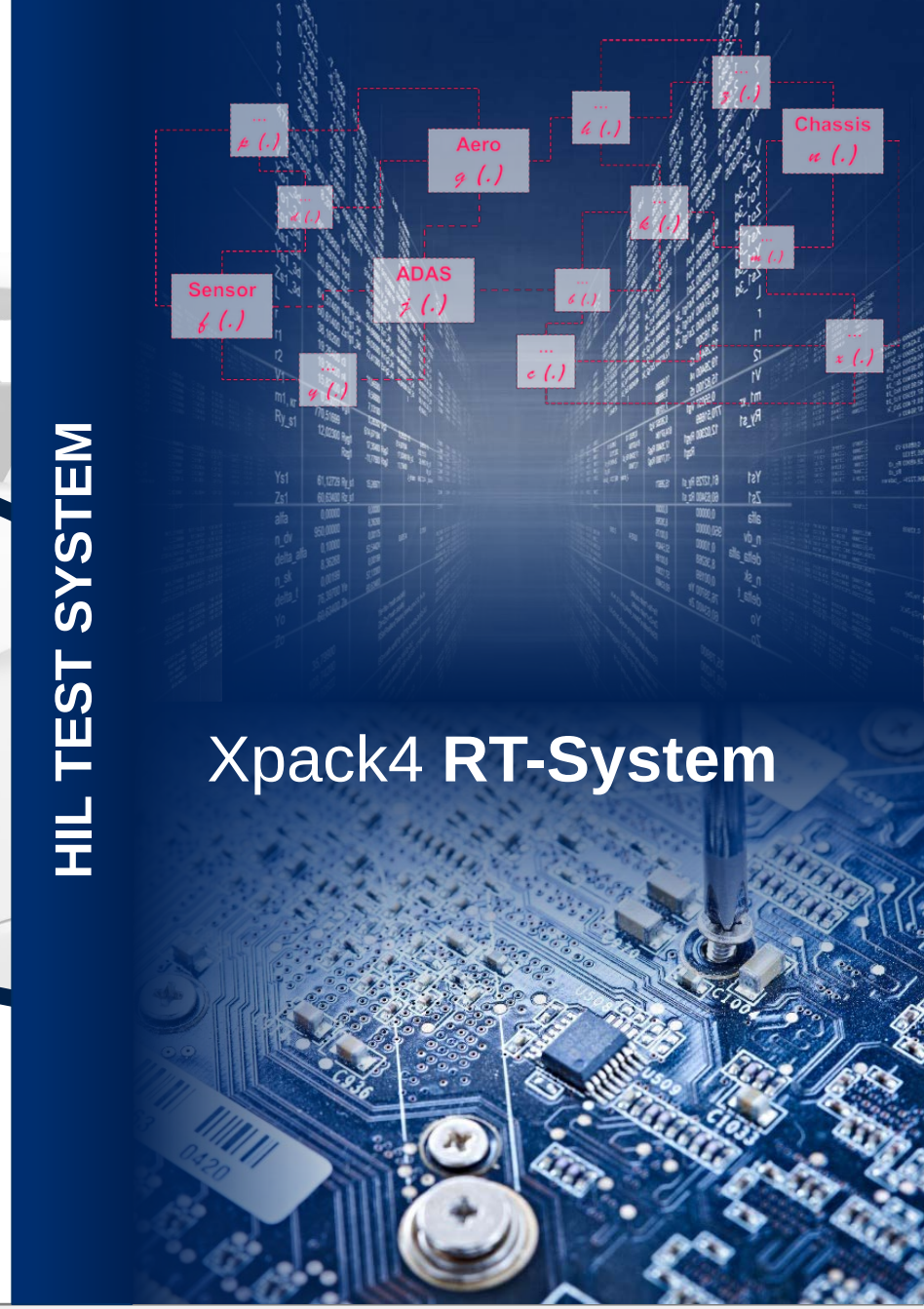
Radar Sensor

Physical Sensor Integration



Device under test

HIL TEST SYSTEM



Example: Ultrasonic Sensor Box

Restbus simulation

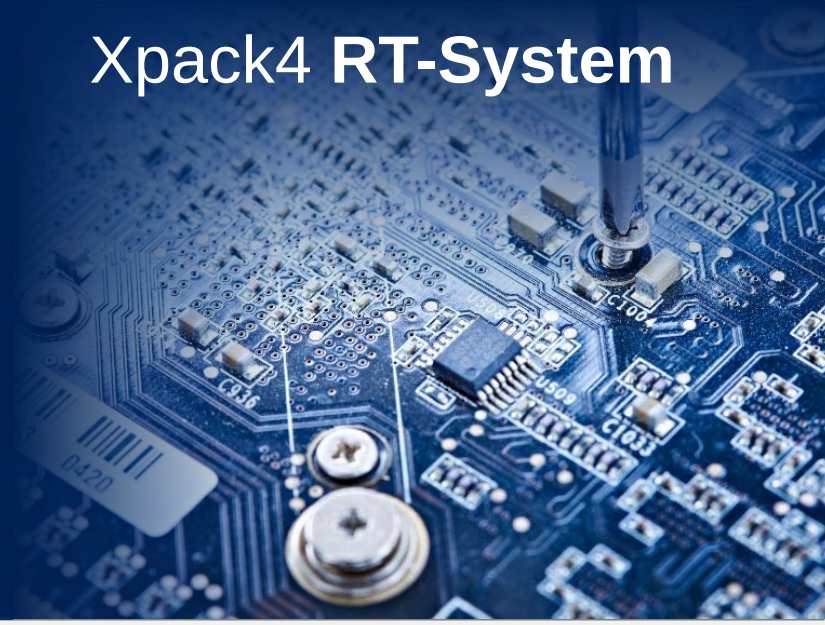
ECU

Device under test

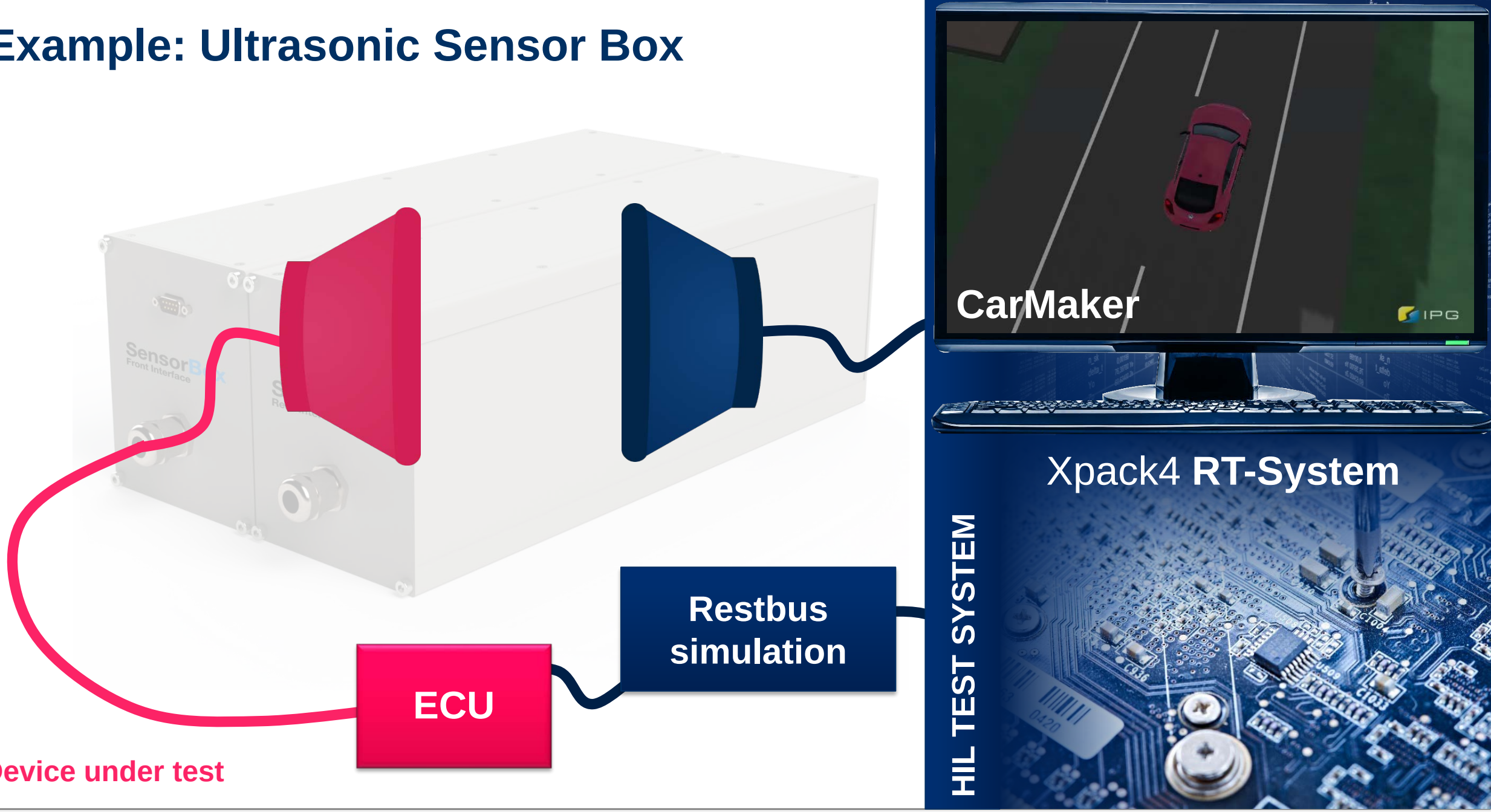
HIL TEST SYSTEM

CarMaker

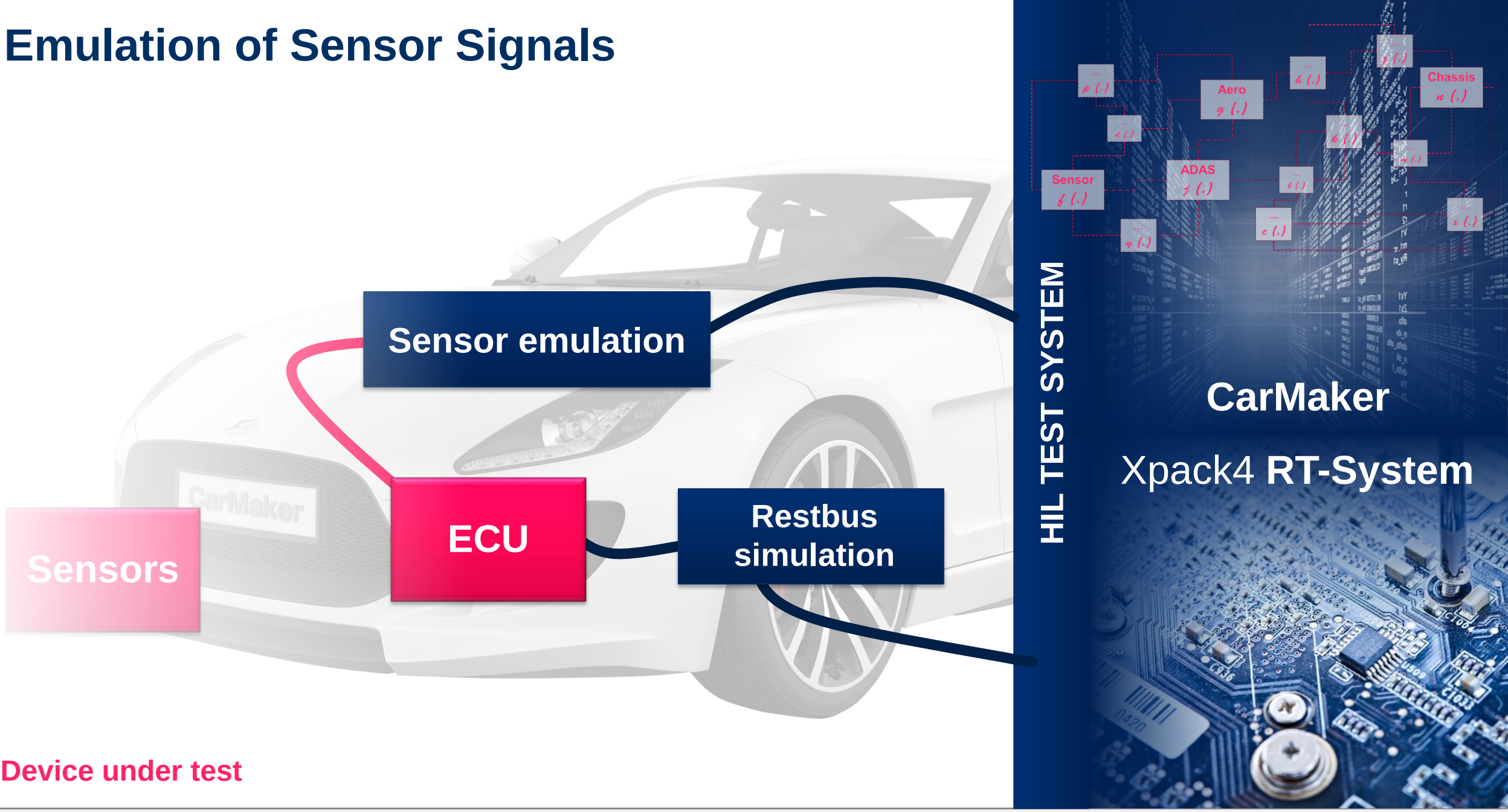
Xpack4 **RT-System**



Example: Ultrasonic Sensor Box



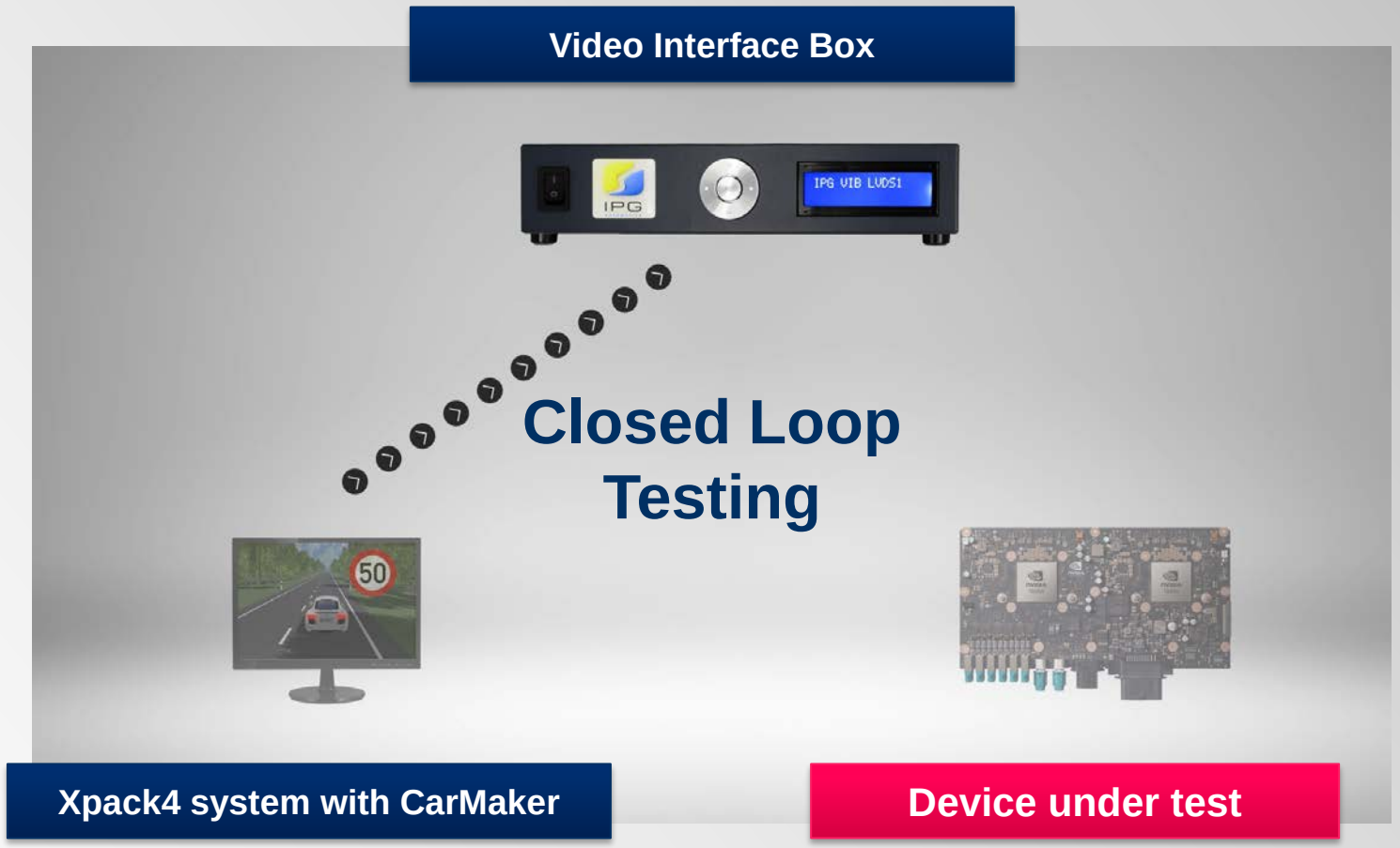
Emulation of Sensor Signals



Device under test

Example: Video Interface Box

1. Sending the virtual scenario
2. Sending the data to device under test
3. Sending back information to CarMaker
4. System reaction in CarMaker



ADAS Sensor Interfaces

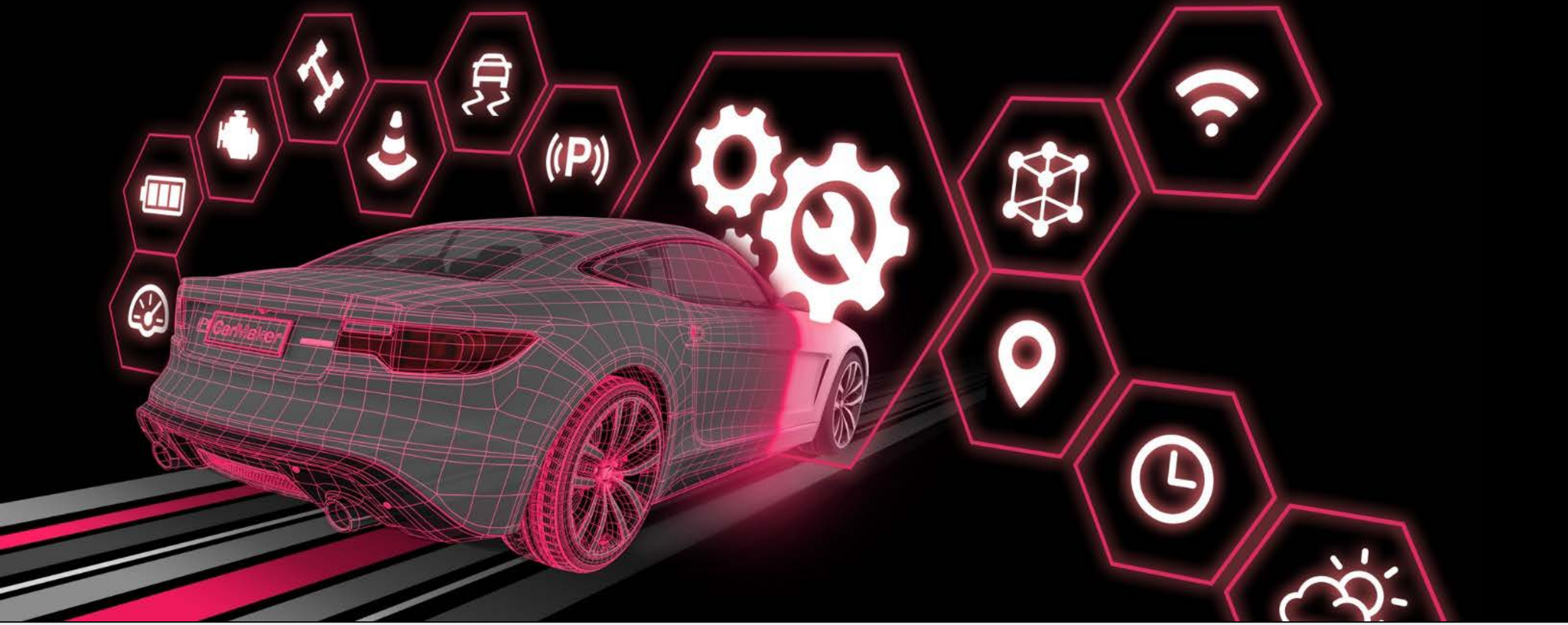
Overview

Sensors	Technology: Physical (sensor-in-the-loop)	Technology: Emulation	Technology: Object list based approach
Camera	**Screen capturing = Monitor-HIL**	**Camera RSI**	Object Sensor / Line Sensor / Traffic Sign Sensor
Ultrasonic	Ultrasonic sensor box	Ultrasonic RSI	Object Sensor
Lidar	Lidar target simulator with partners of IPG Automotive	Free Space Sensor / (Lidar RSI – coming soon)	Object Sensor
Radar	Radar target simulator with partners of IPG Automotive	**Radar RSI**	Object Sensor / Radar HiFi Sensor

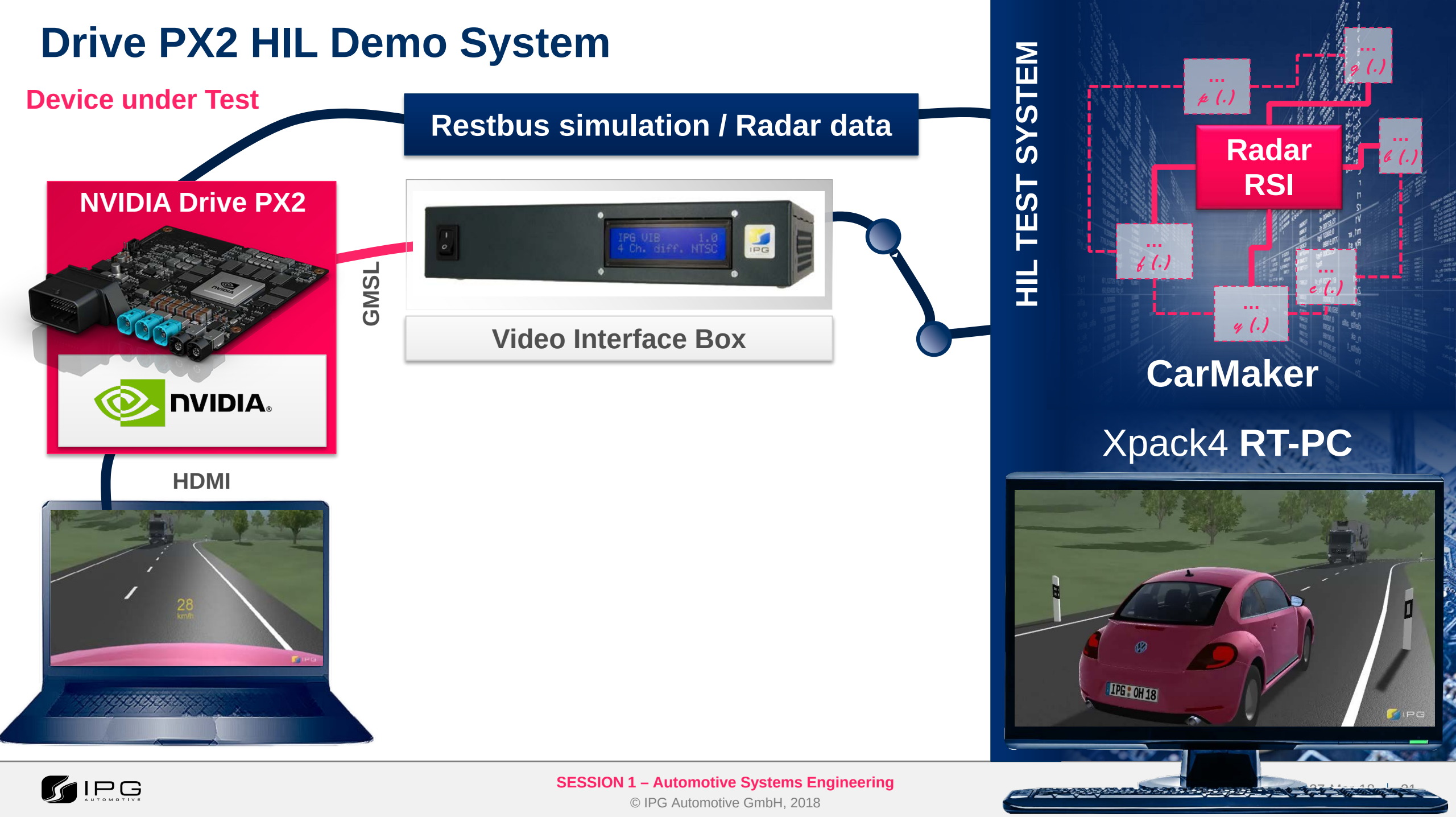
Every sensor type matches at least one HIL solution

Solution depends on requirements and available information

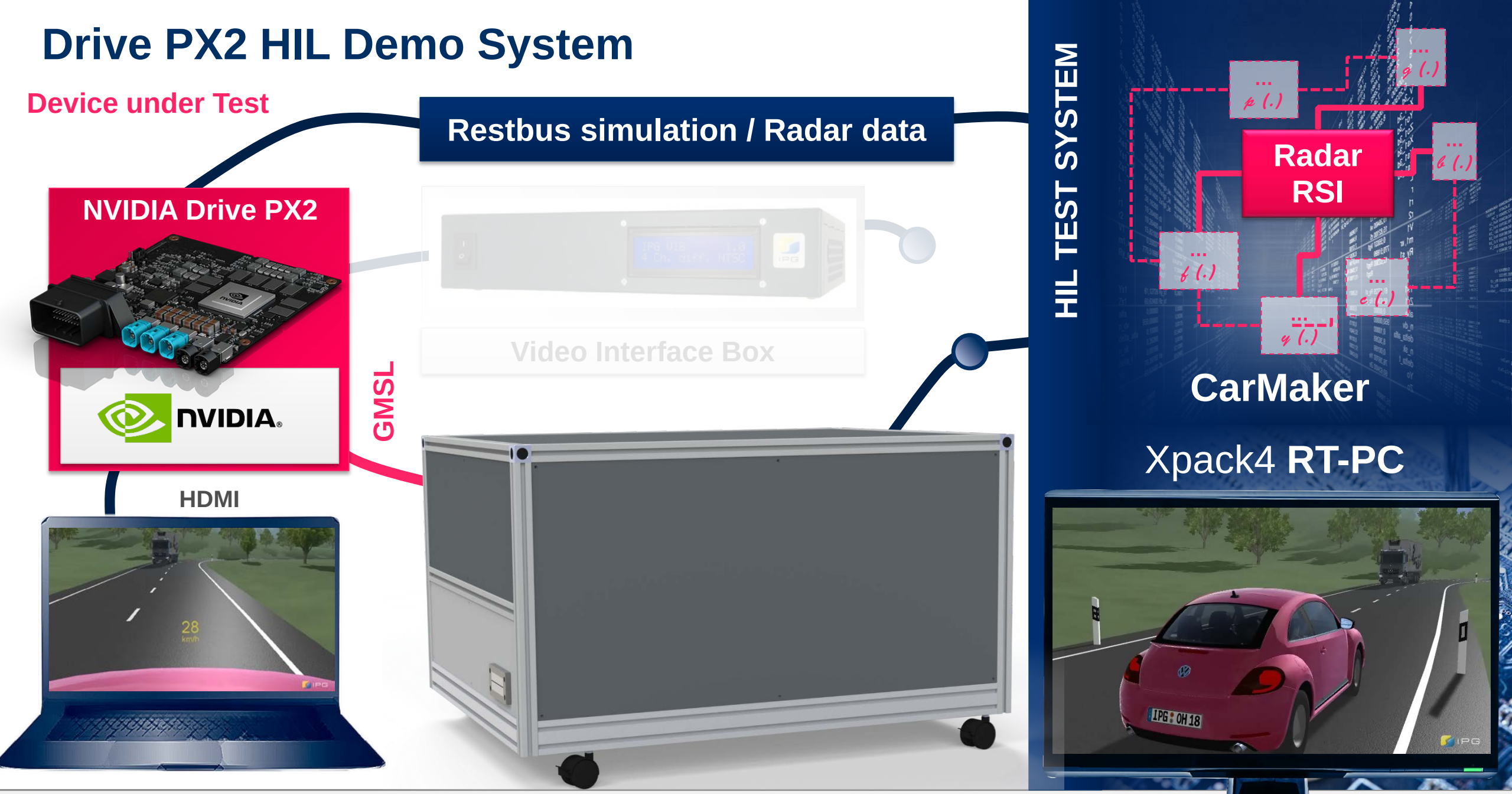
LIVE DEMO HARDWARE-IN-THE-LOOP



Drive PX2 HIL Demo System



Drive PX2 HIL Demo System



CarMaker Runs on Different Hardware Platforms

Function under test

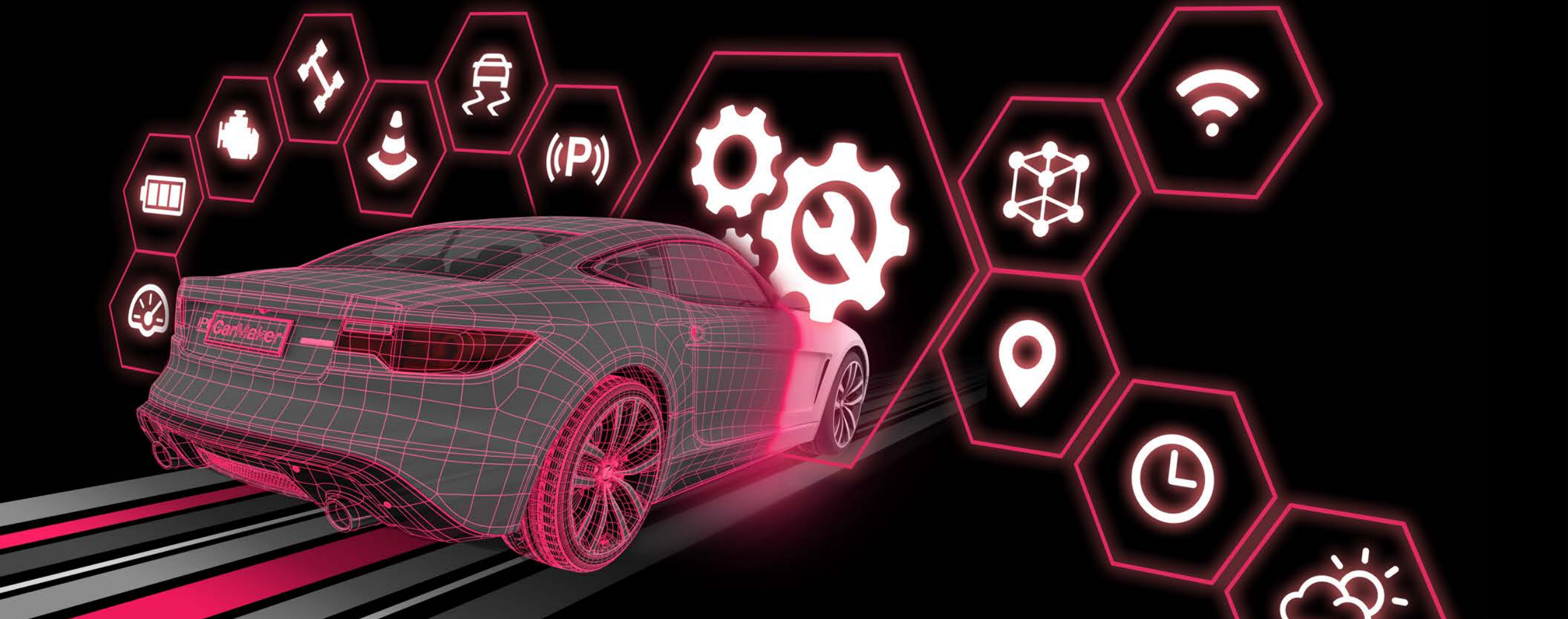
integrated in

CarMaker HIL software as middleware

running on

Hardware platform (i.e. Xpack4, National Instruments PXI, dSPACE Scalexio & DS1006, ETAS Labcar)

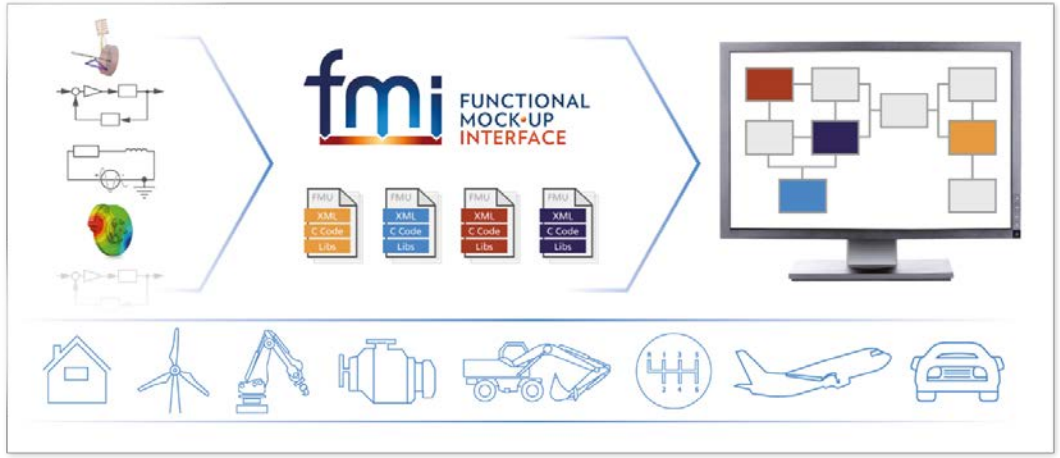
Episode 2: Virtual ECUs

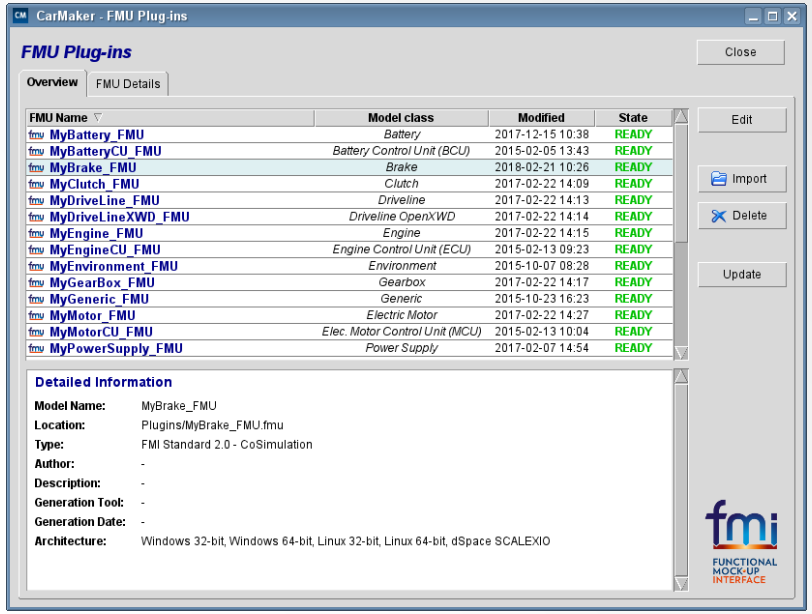


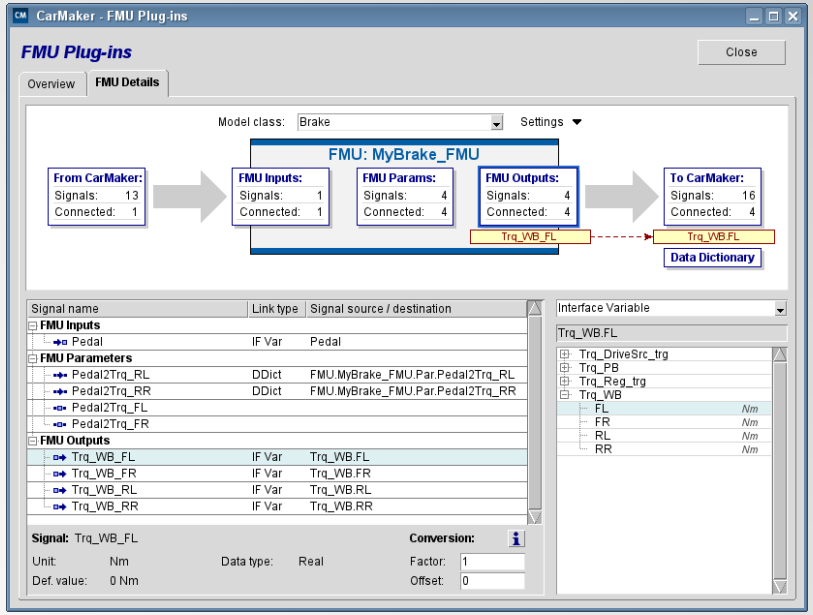
fmi 2.0

FUNCTIONAL MOCK-UP INTERFACE

- FMUs allow a seamless and easy integration of own or third-party models into CarMaker
- Automatic conversion of physical units between connected signals
  - GUI proposes factor and offset for conversion automatically based on given units
- Tunable parameters allow a runtime influencing of the FMU







Silver Virtual ECUs

Front-loading validation and testing during automotive software development

What is a virtual ECU? – Runs on a PC „like the ECU in the car“

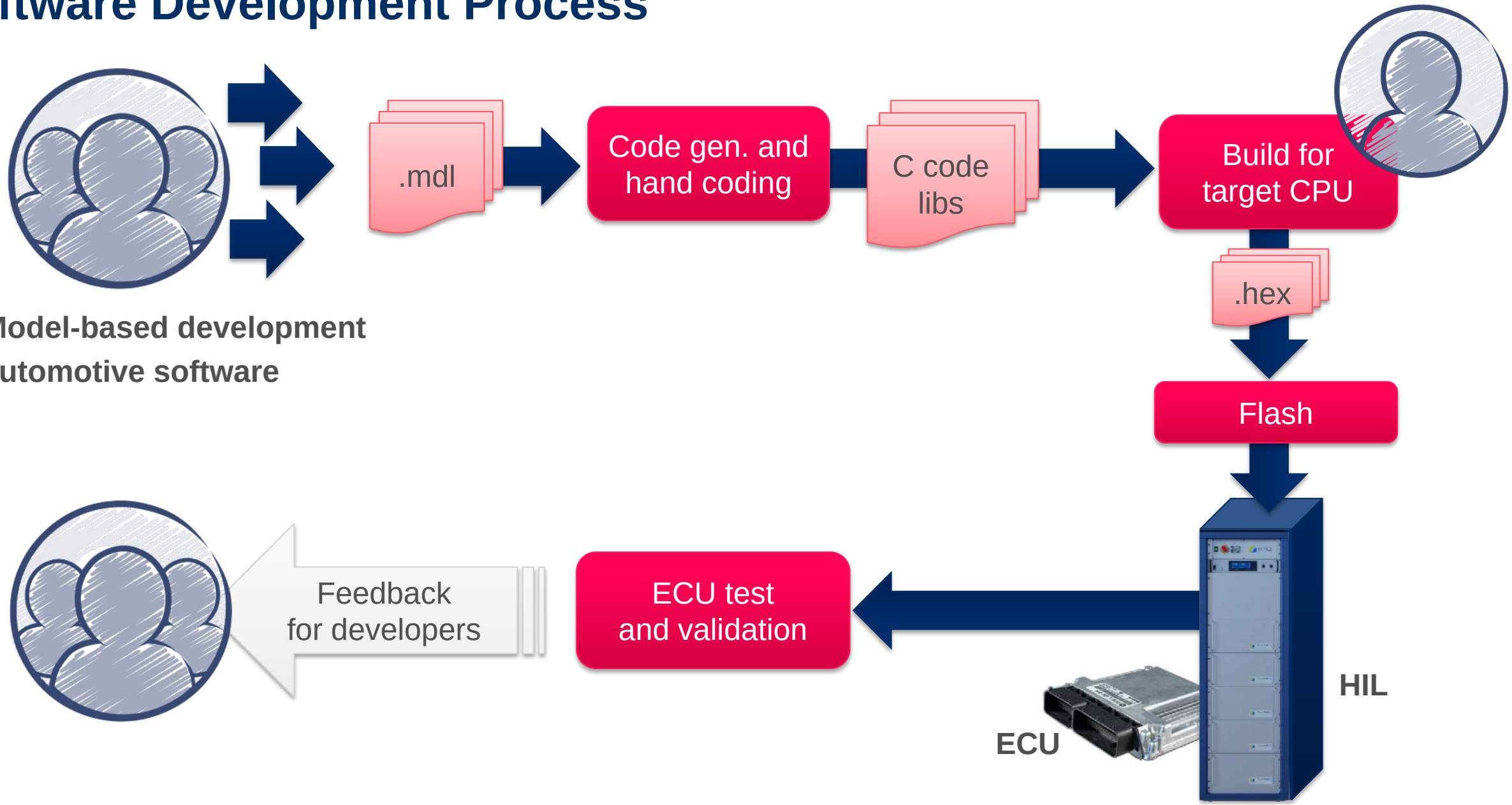
vECU and ECU share the same code

- C sources or
- Target HEX code

vECU and ECU have same interfaces

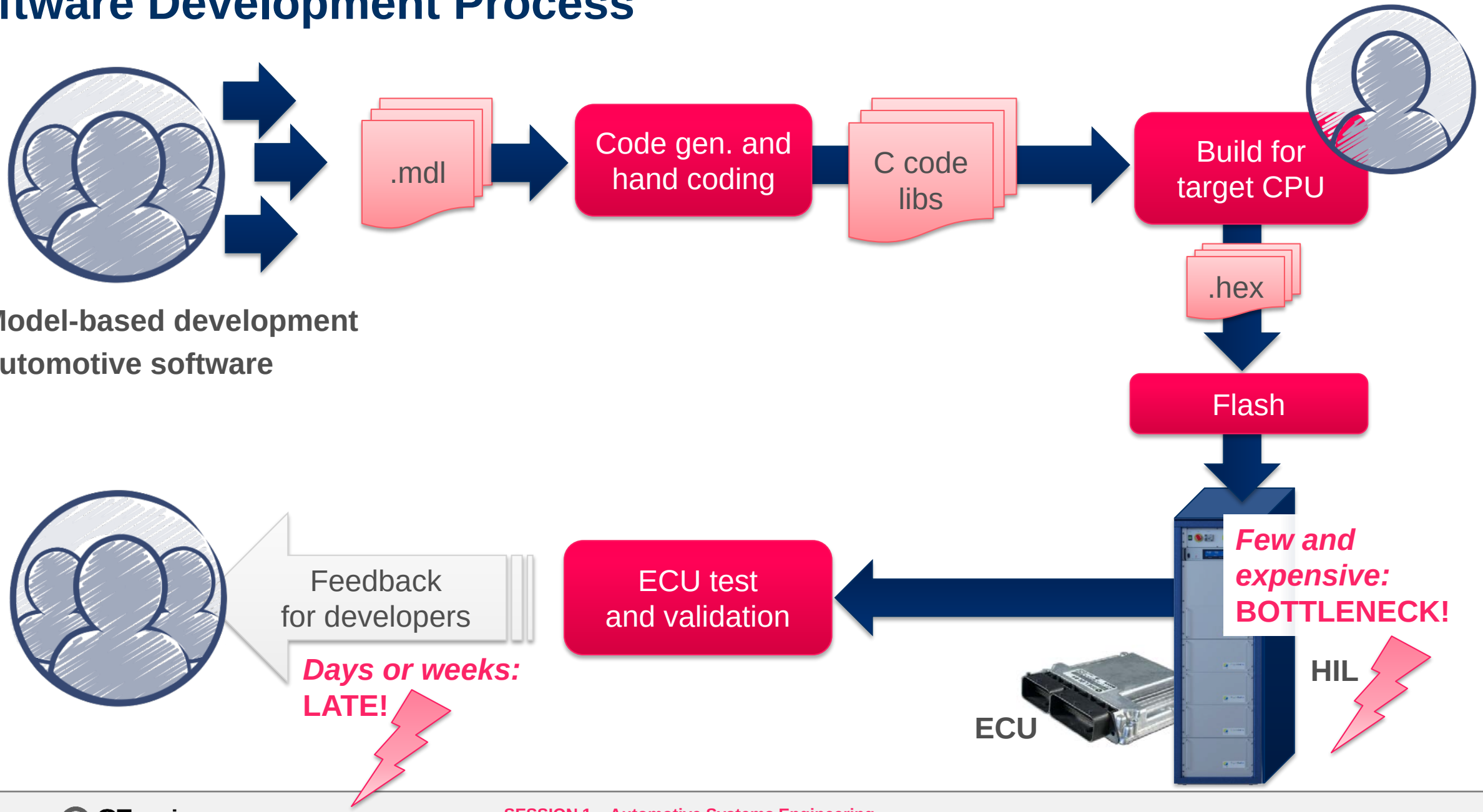
- Calibration – CANape, INCA
- Configuration files – PAR, DCM
- Networking – CAN, LIN, FlexRay

Software Development Process

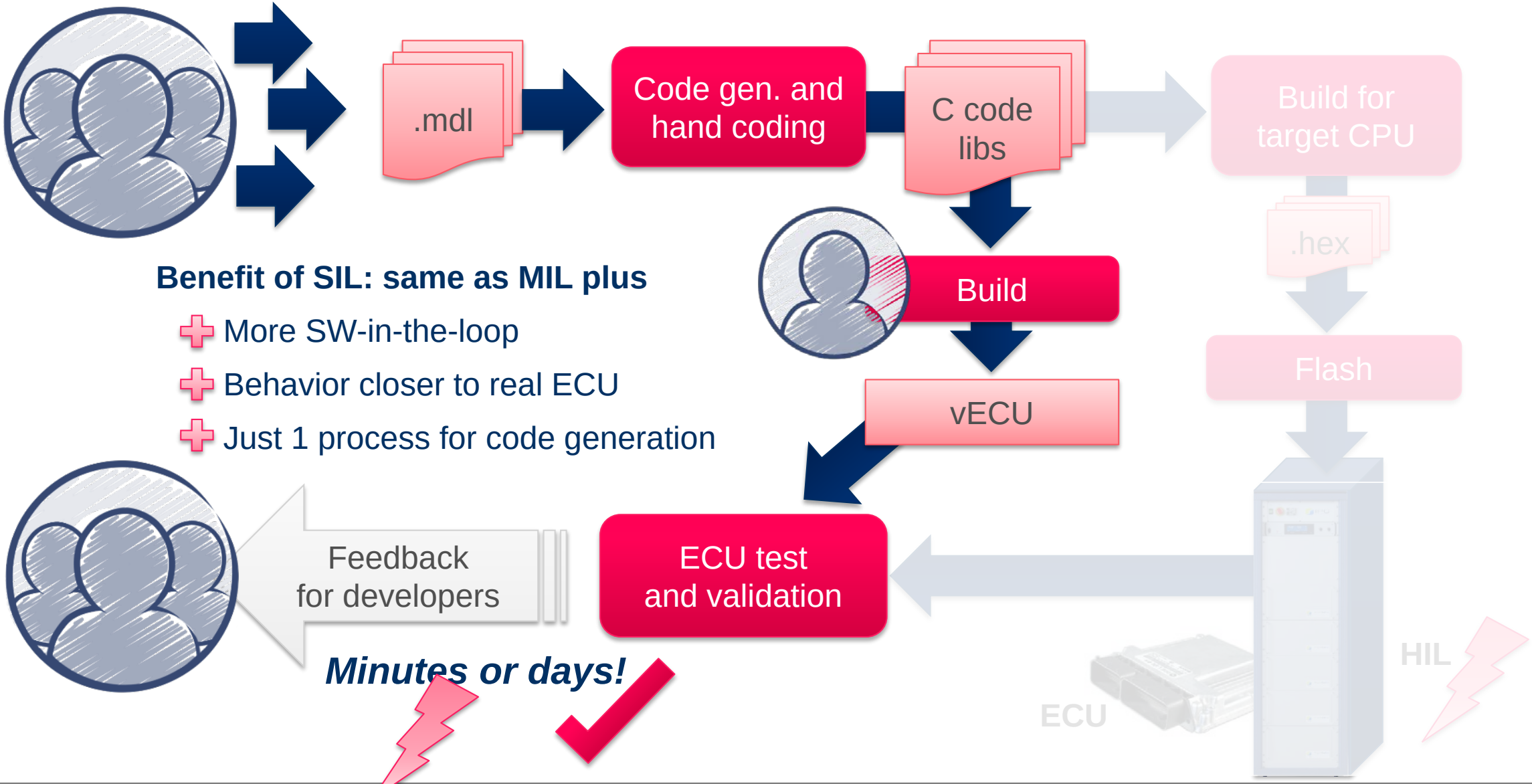


Model-based development automotive software

Software Development Process



Silver Virtual ECUs – Software-in-the-Loop

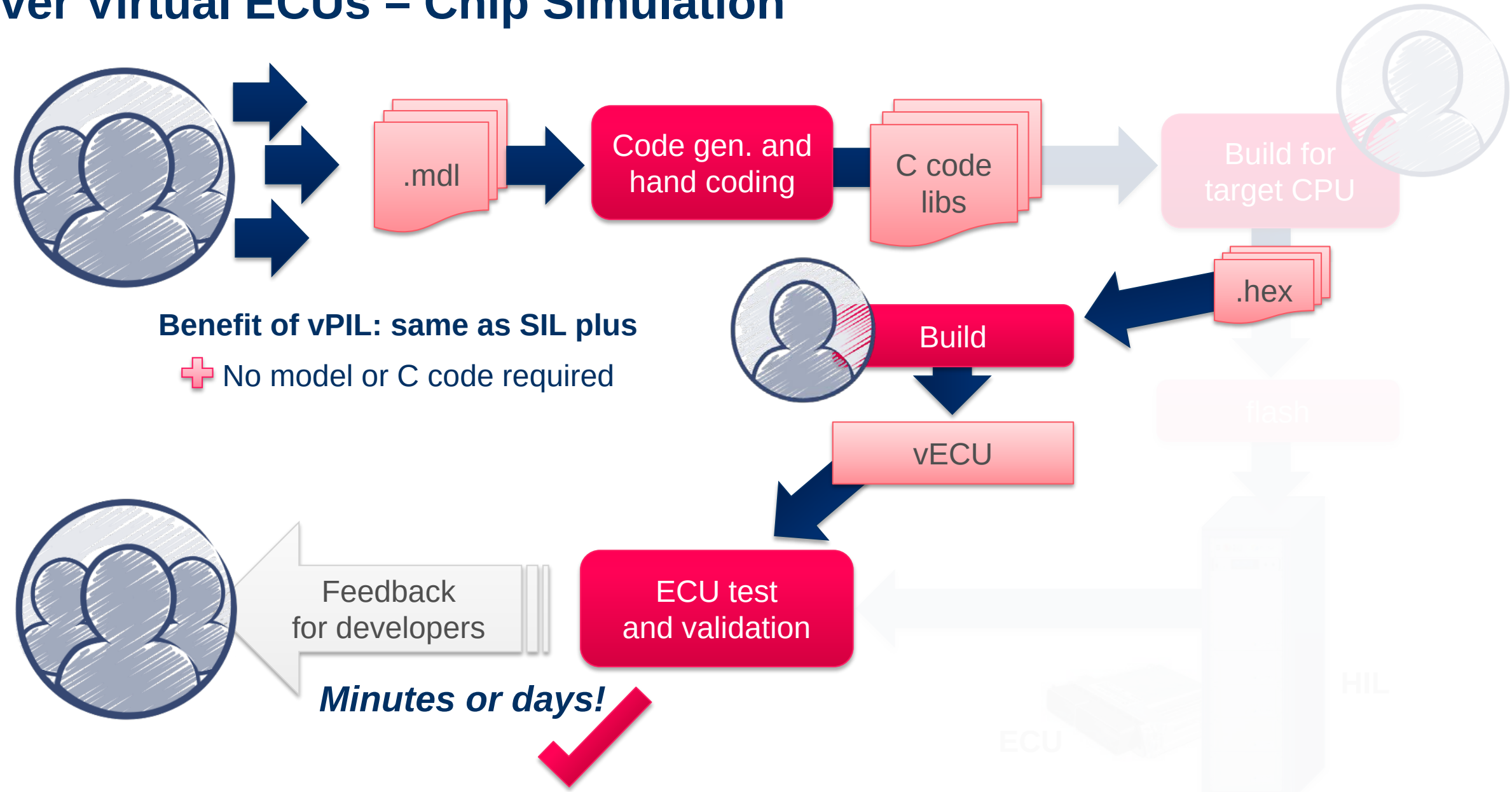


Benefit of SIL: same as MIL plus

- More SW-in-the-loop
- Behavior closer to real ECU
- Just 1 process for code generation

Minutes or days!

Silver Virtual ECUs – Chip Simulation



Benefit of vPIL: same as SIL plus

+ No model or C code required

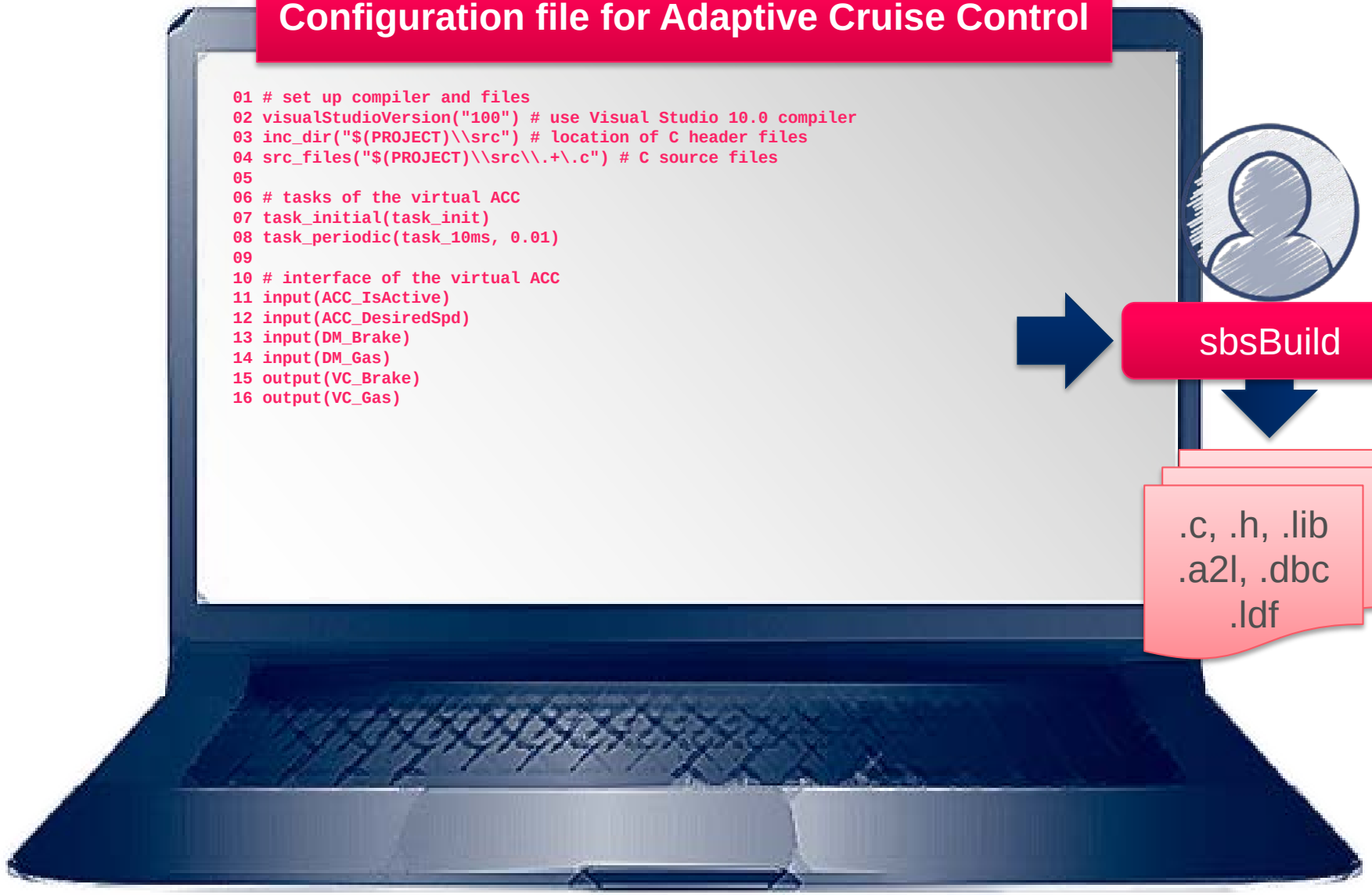
1. Build a Silver Virtual ECU

Configuration file for Adaptive Cruise Control

```
# set up compiler and files
visualStudioVersion("100") # use Visual Studio 10.0 compiler
inc_dir("$(PROJECT)\\src") # location of C header files
src_files("$(PROJECT)\\src\\.+\.c") # C source files

# tasks of the virtual ACC
task_initial(task_init)
task_periodic(task_10ms, 0.01)

# interface of the virtual ACC
input(ACC_IsActive)
input(ACC_DesiredSpd)
input(DM_Brake)
input(DM_Gas)
output(VC_Brake)
output(VC_Gas)
```



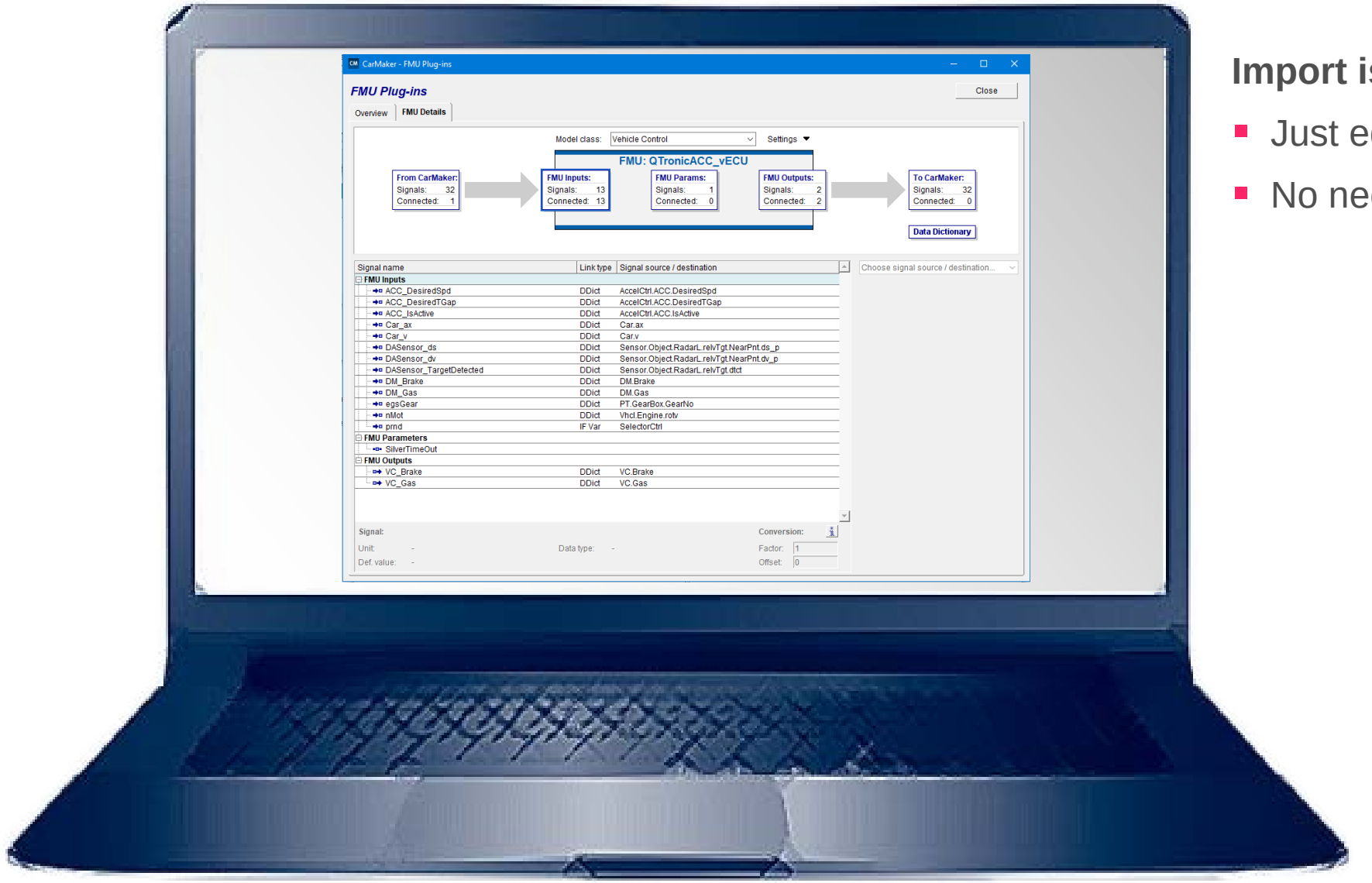
sbsBuild

.c, .h, .lib
.a2l, .dbc
.ldf

Virtual ACC

- ECU functions
- RTOS emulation
- 4 GB virtual memory
- A2L conversion
- XCP
- flash

2. Import Silver FMU into CarMaker 7.0



Import is straightforward

- Just edit the configuration
- No need to rebuild CarMaker.exe

3. Virtual Test Driving: CarMaker & Silver Virtual ECU

Entire Silver setup acts as FMU

- One or many networked vECUs
- User interface
- Optional plant models

Validation and test

- Use TestWeaver or any other test automation solution available for CarMaker and/or Silver

QTronic Silver – Summary

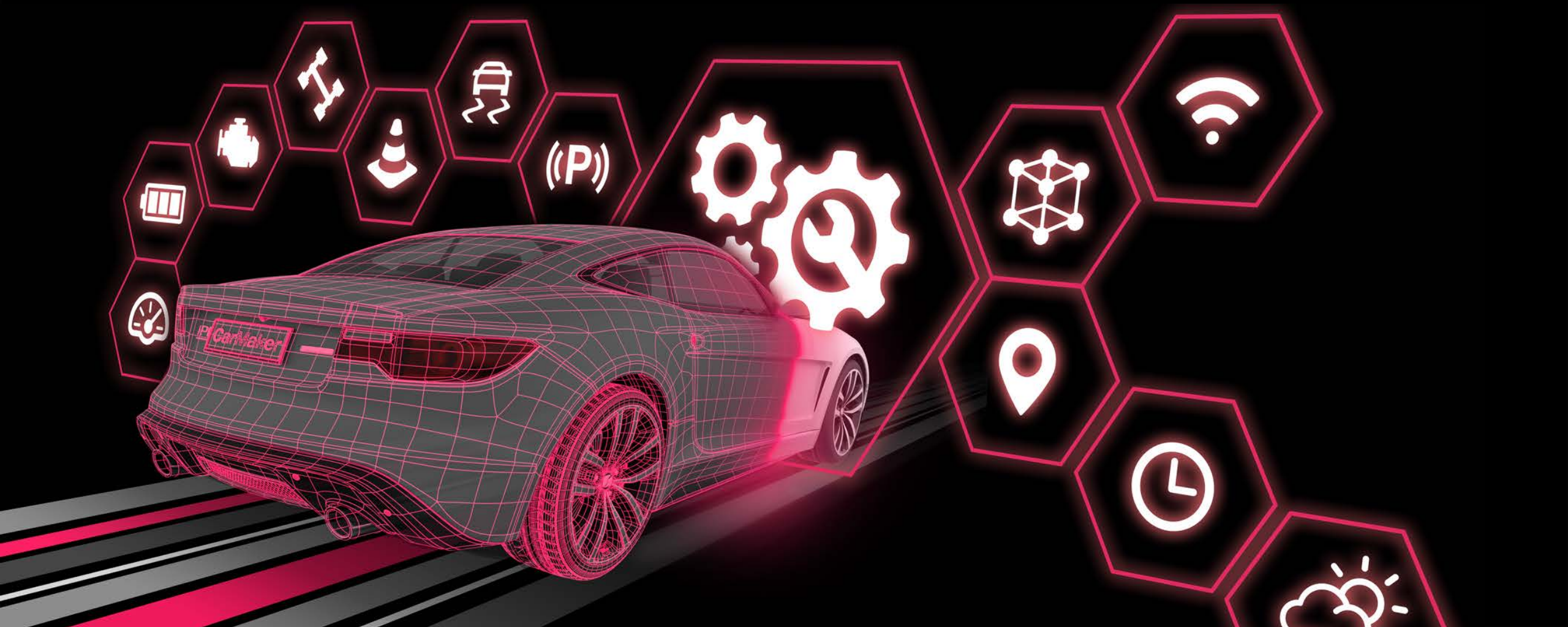
Silver offers

- ✓ PC execution platform for virtual ECUs
- ✓ Proven build process for virtual ECUs
- ✓ Co-simulation with CarMaker 6.0.4 and later

Benefit

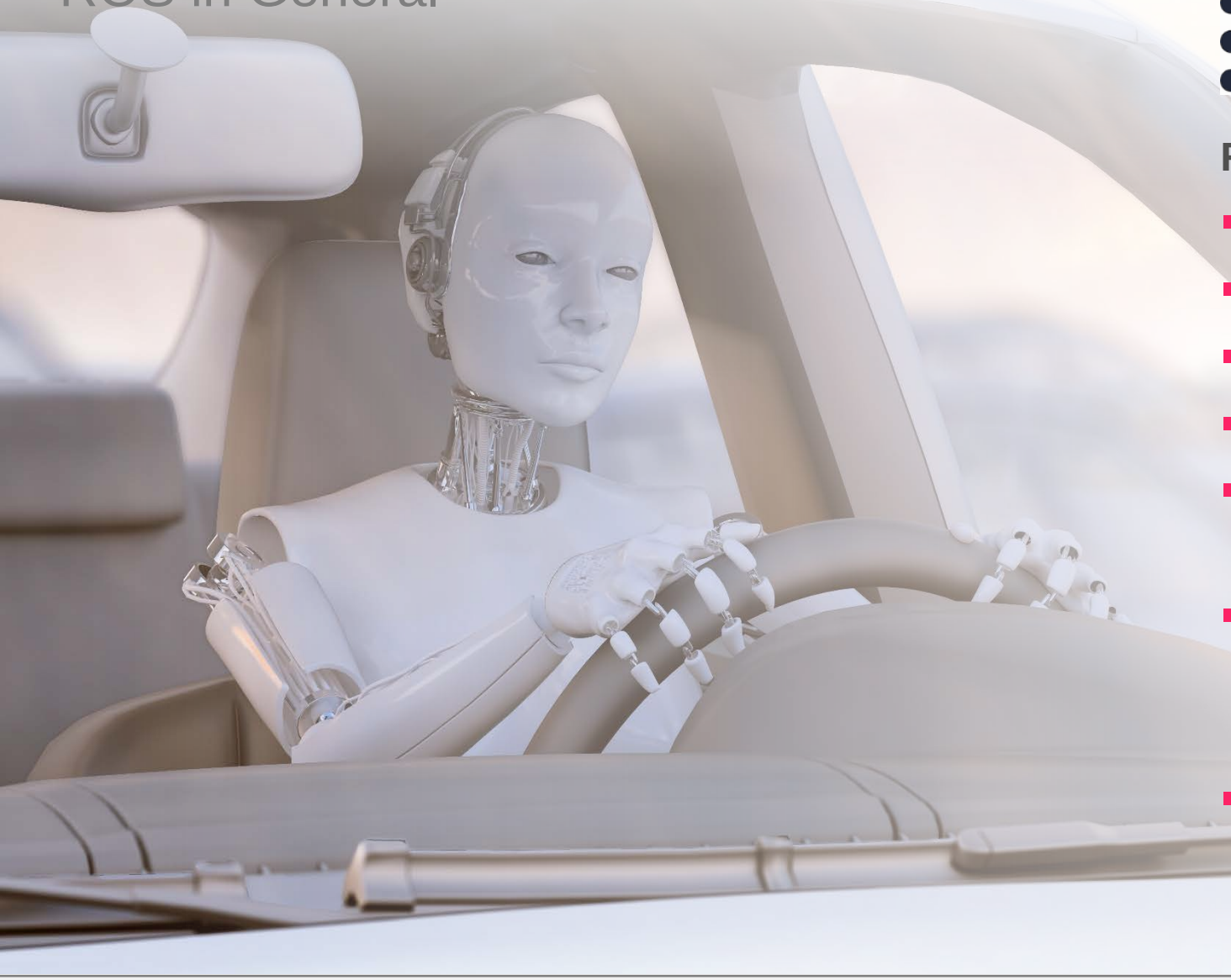
- ✓ Extremely short edit/run cycle for agile development
- ✓ Source-level debugger on PC
- ✓ Used to front-load validation and testing

Episode 3: Automated Driving



Searching for Future Solutions in Automated Driving

ROS in General



Robot Operating System (ROS)

- Open-source software framework
- Background in robotics
- Rising interest in the ADAS and AD community
- Autonomous software stack available
- Flexible architecture, very useful especially for big, complex systems
- Supports message-based inter-process communication even across hardware boundaries
- Hardware abstraction, device control and package management available

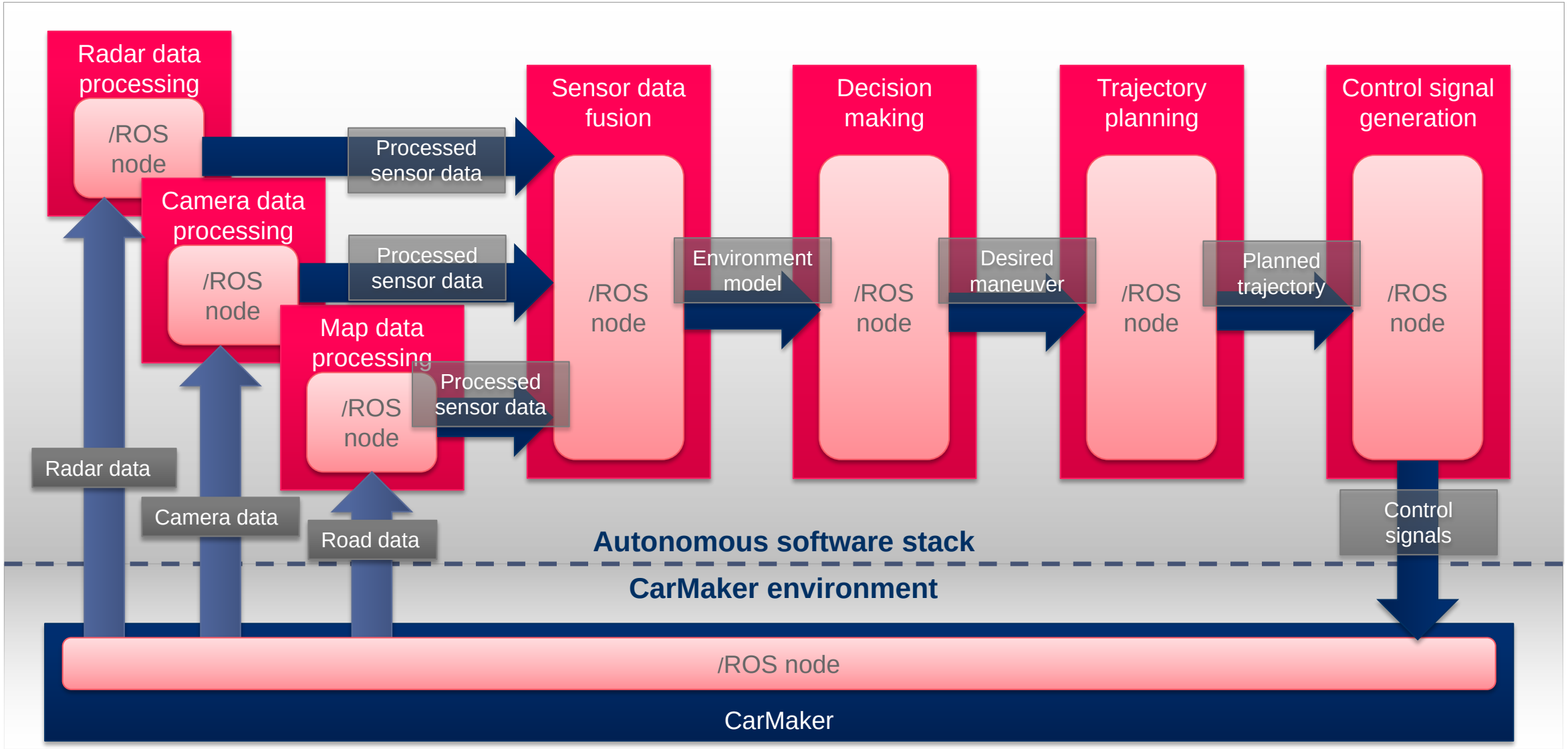
CarMaker / TruckMaker

ROS (Robot Operating System) support

- There are numerous trade-offs in creating a ROS AD architecture in combination with the simulation environment
- ROS node as plugin in CarMaker gives you a fast start
- CarMaker builds the perfect completion for a ROS-based virtual vehicle development
  - Simulates the missing environment
  - Provides the required flexibility for typical system and test designs
  - Straightforward data exchange between CarMaker and ROS

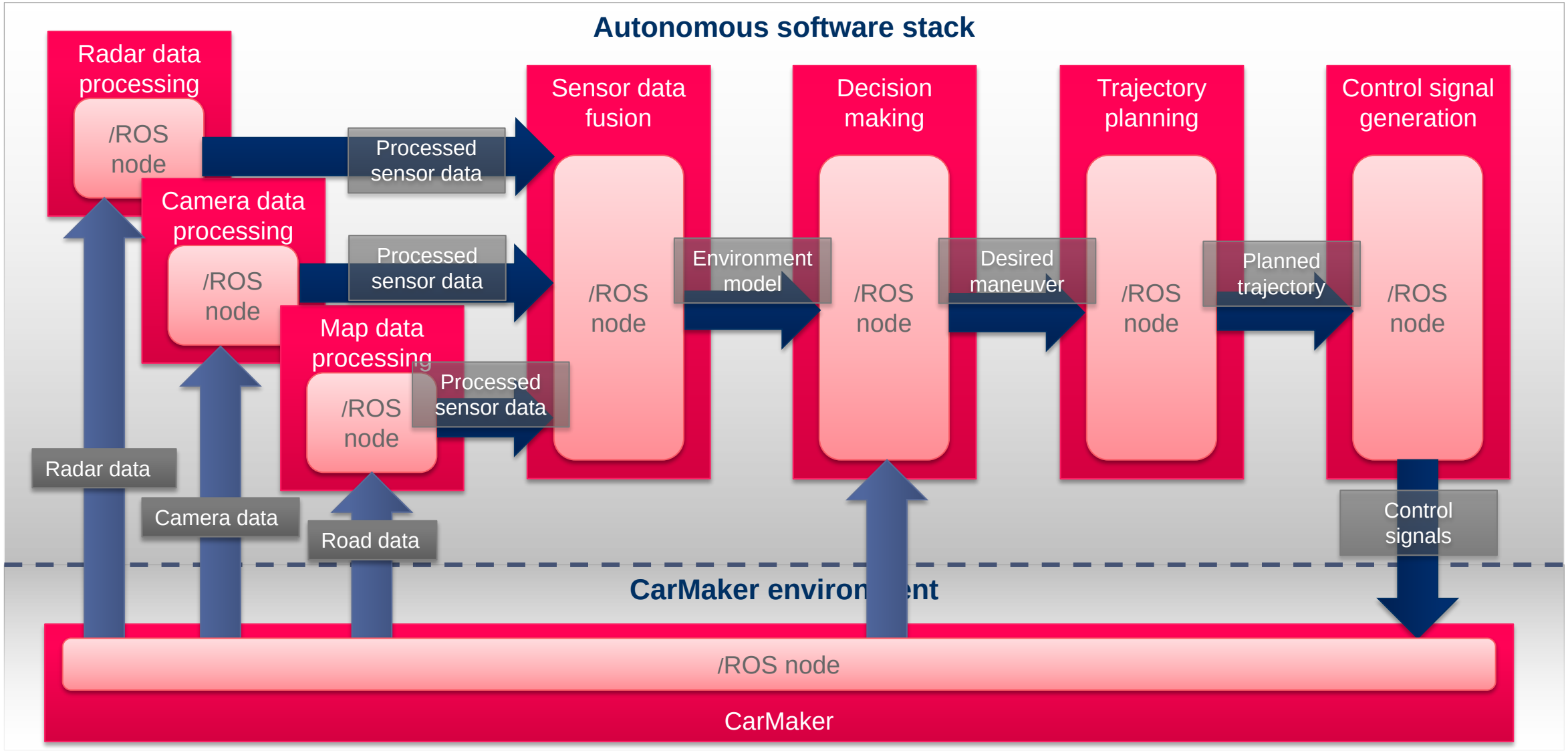
Possible Architecture for Automated Driving

Closed loop for automated driving function testing



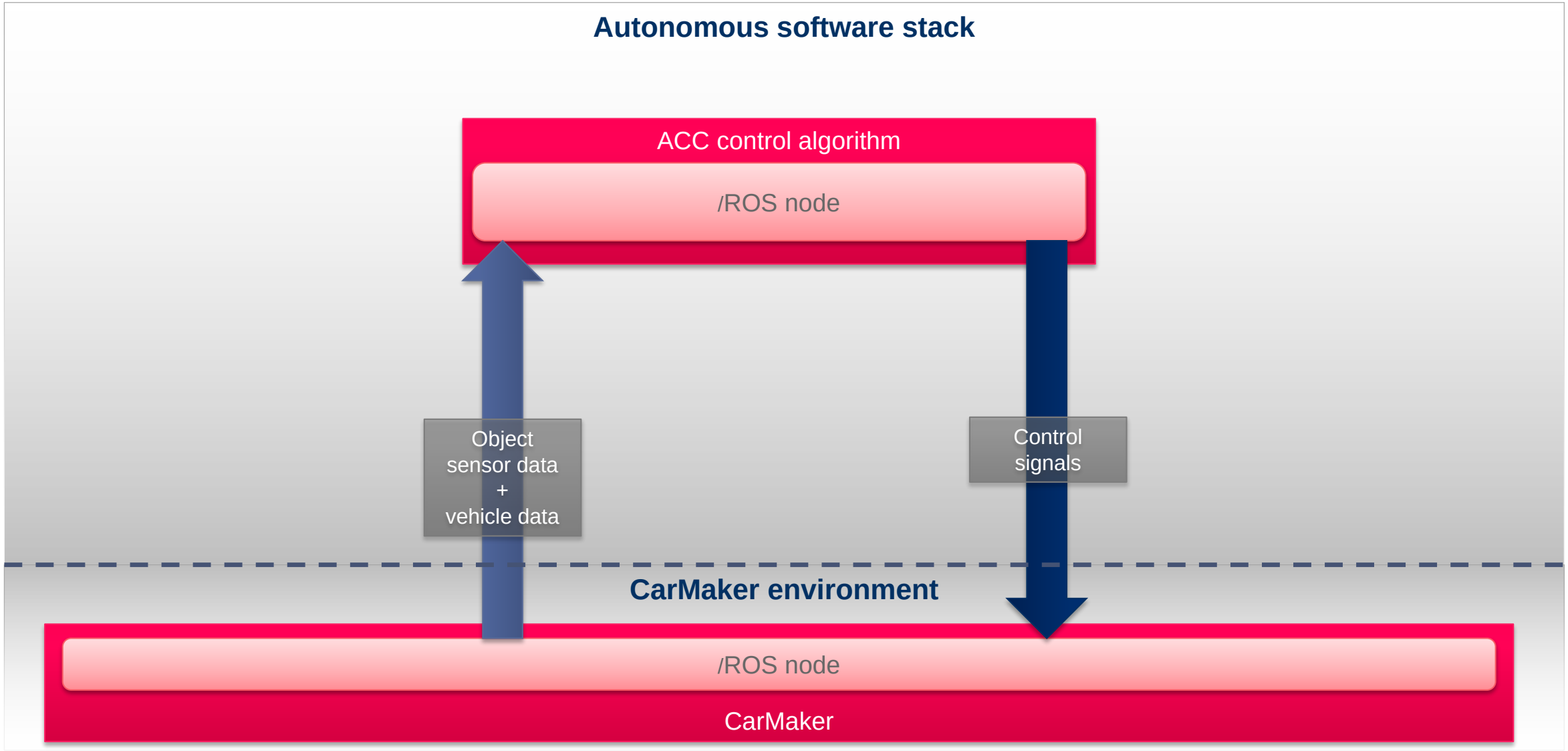
Possible Architecture for Automated Driving

Closed loop for automated driving function testing



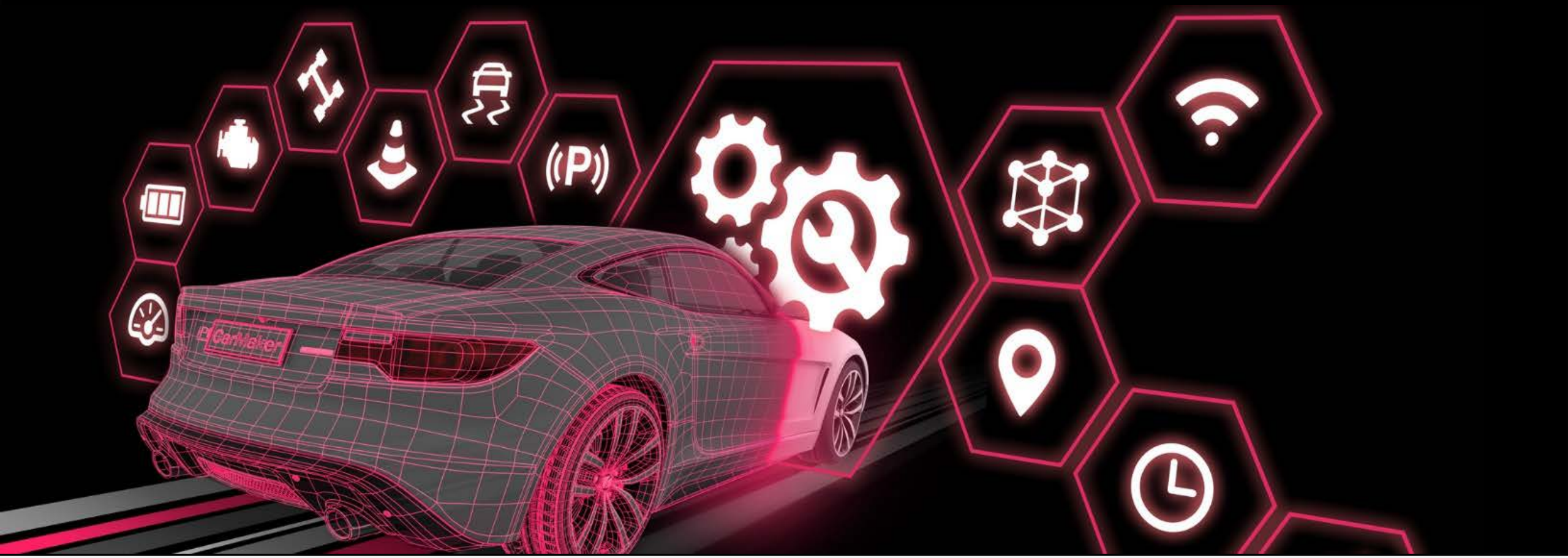
Demo Architecture for ACC Control

Closed loop for ADAS function testing

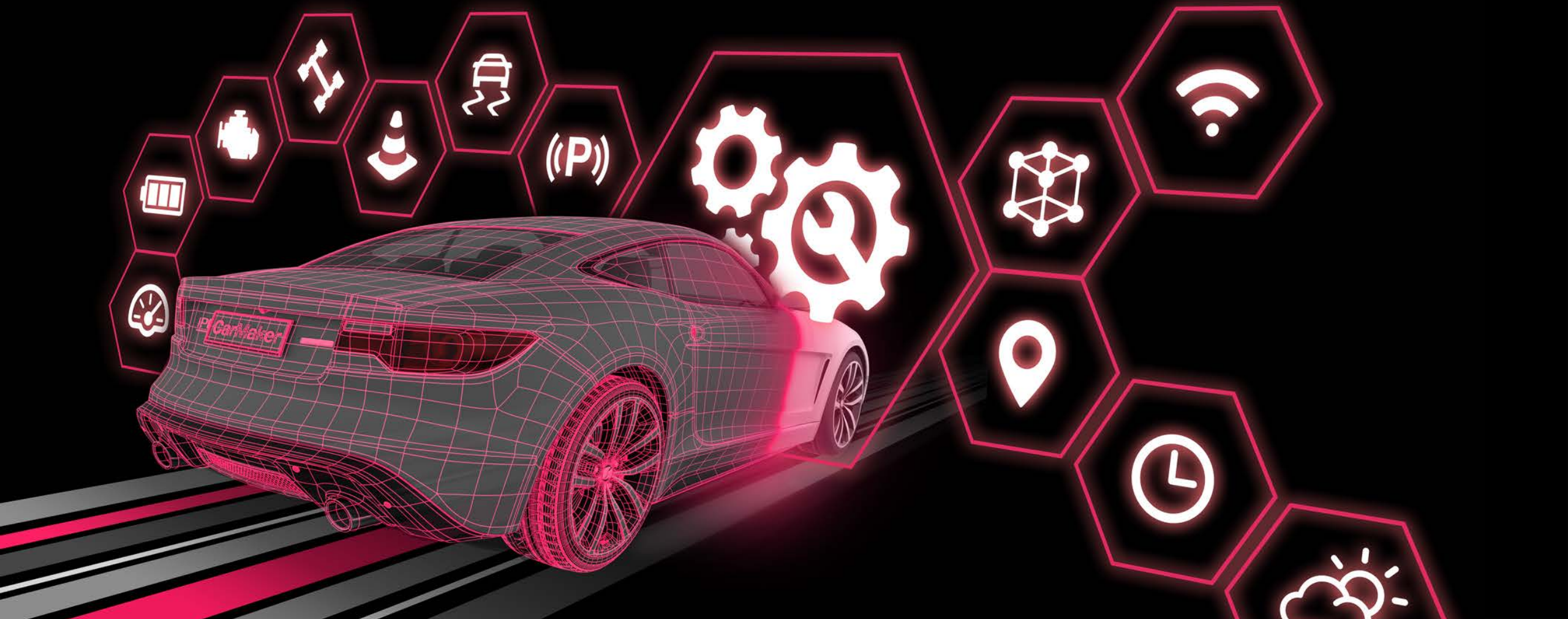


» LIVE DEMO CarMaker & ROS

Proof of Concept



Episode 4: High-Performance Computing



Parallelization Analysis

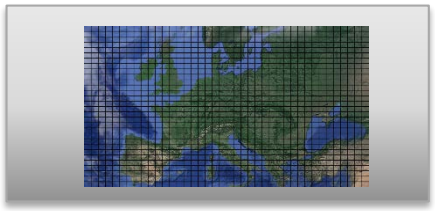
Single-domain

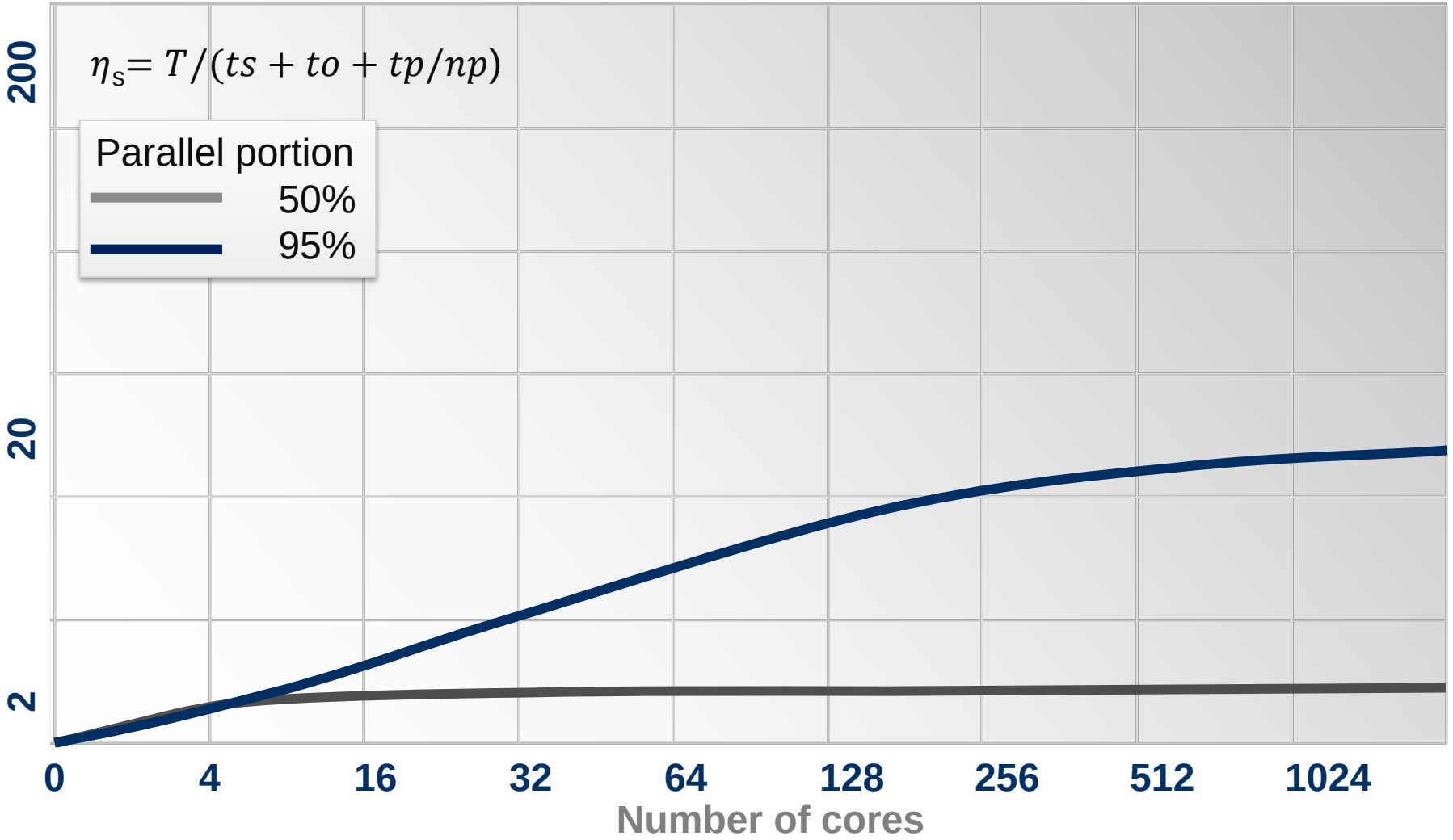
Multi-domain

Evenly distributed atomic units	Uneven model split
Constant model complexity	Purpose driven fidelity – variable model complexity
Medium serialization share	High serialization share

The Challenge of Speeding Up the Simulation

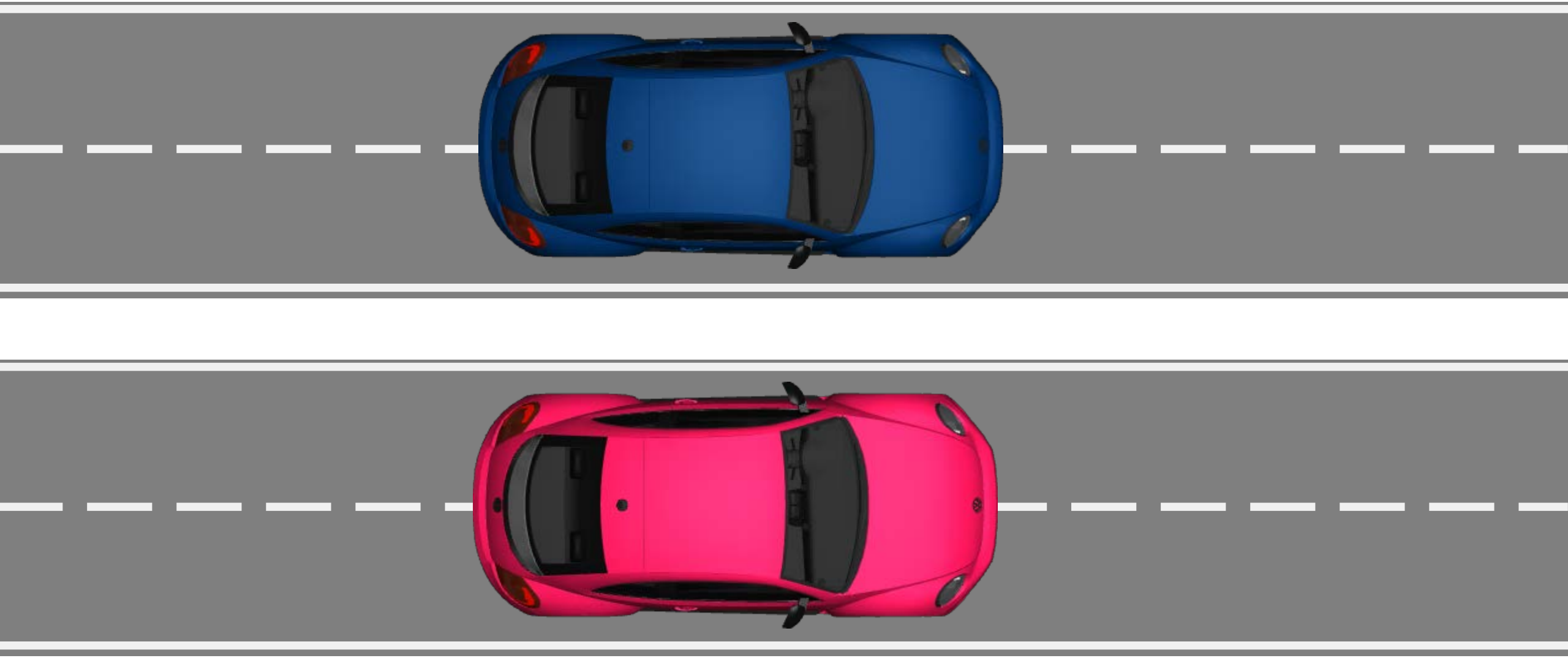
According to Amdahl's law





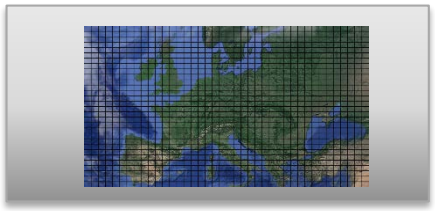
Parallelization on TestRun Level

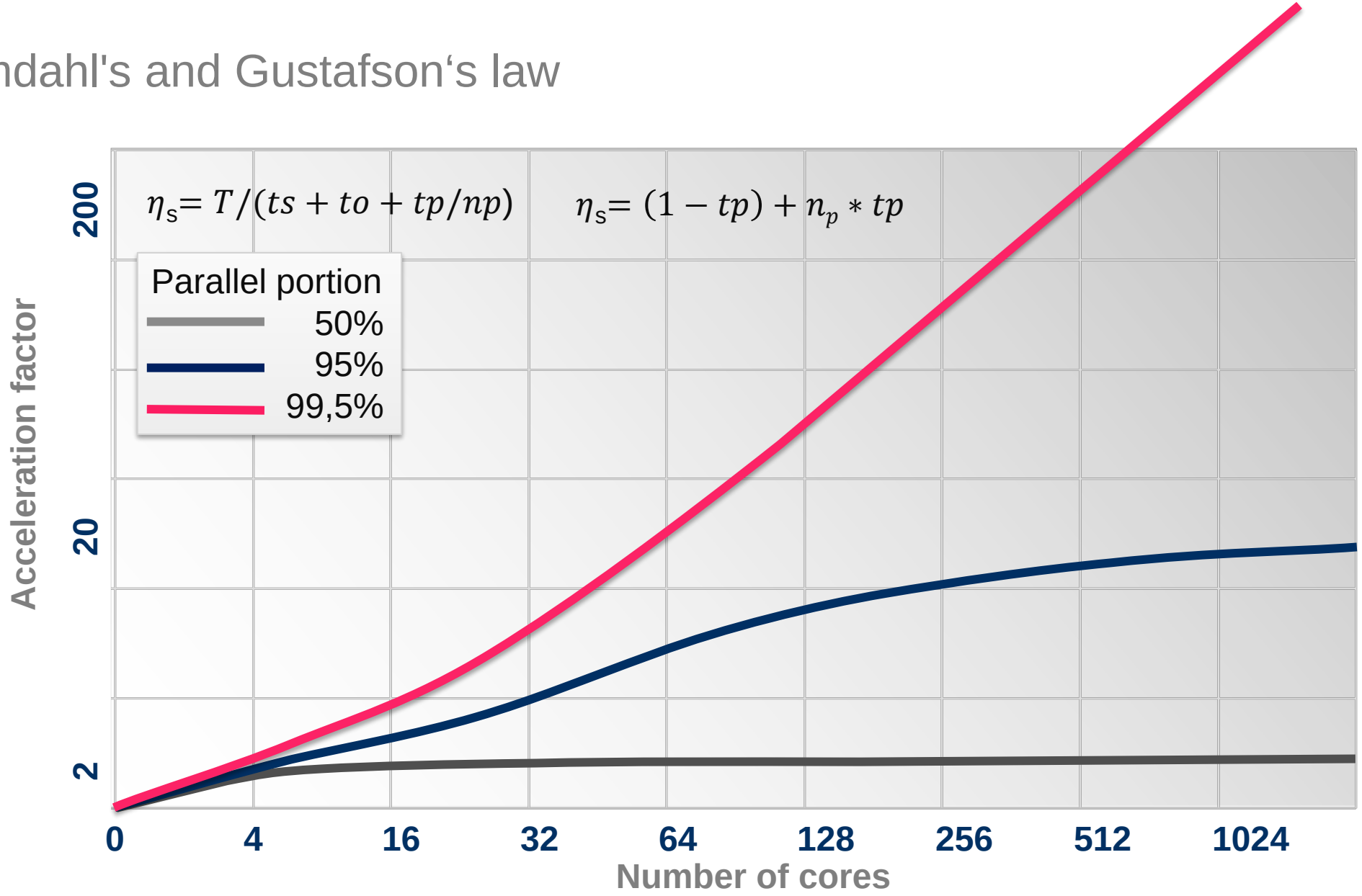
Parallelization on TestRun Level



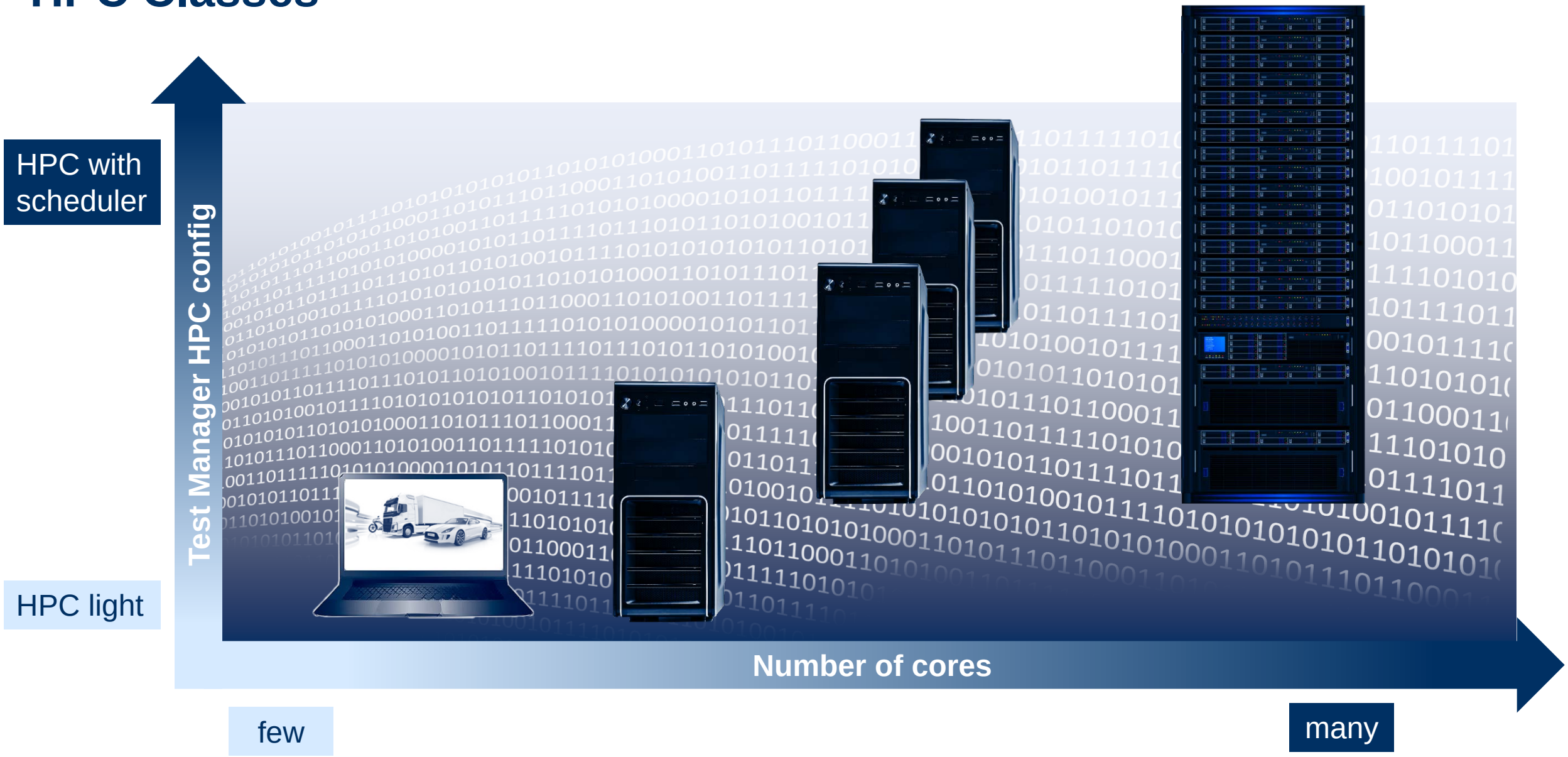
The Solution

According to Amdahl's and Gustafson's law





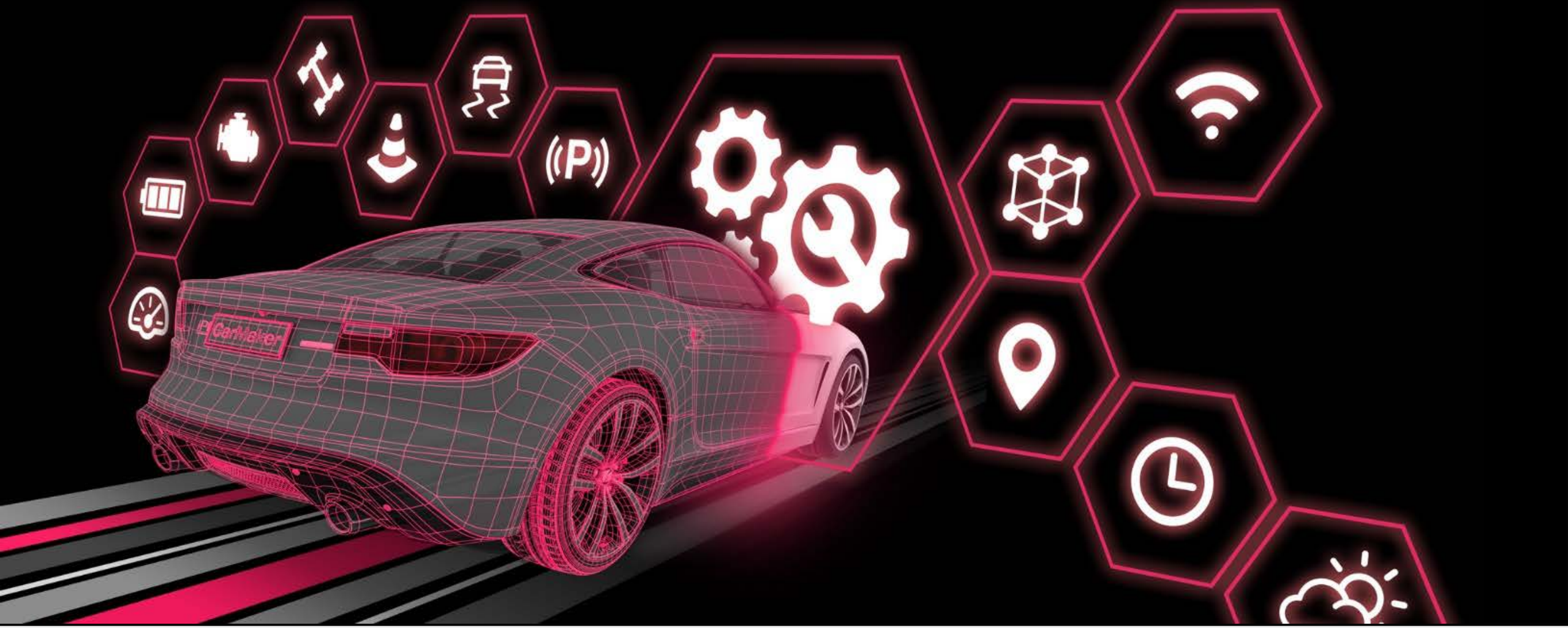
HPC Classes



HPC Light

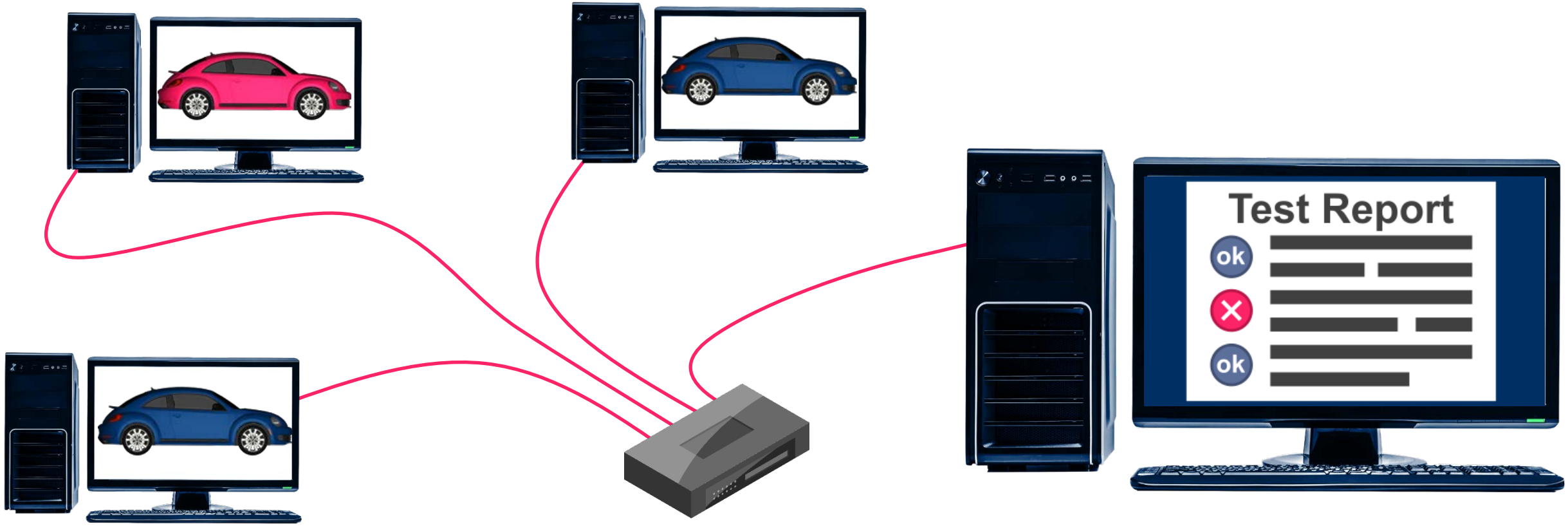
Specifications	HPC Light
Scheduler	Embedded in CarMaker Test Manager
HPC Scalability	1 node < 100 cores
Dedicated Hardware	Single PC, multi-core
Scheduling	Limitation of parallel processes
Resiliency	No special implementation
Health Checks	Process monitoring (tbi)

» LIVE DEMO HPC Light



Re-Use Your Company Infrastructure

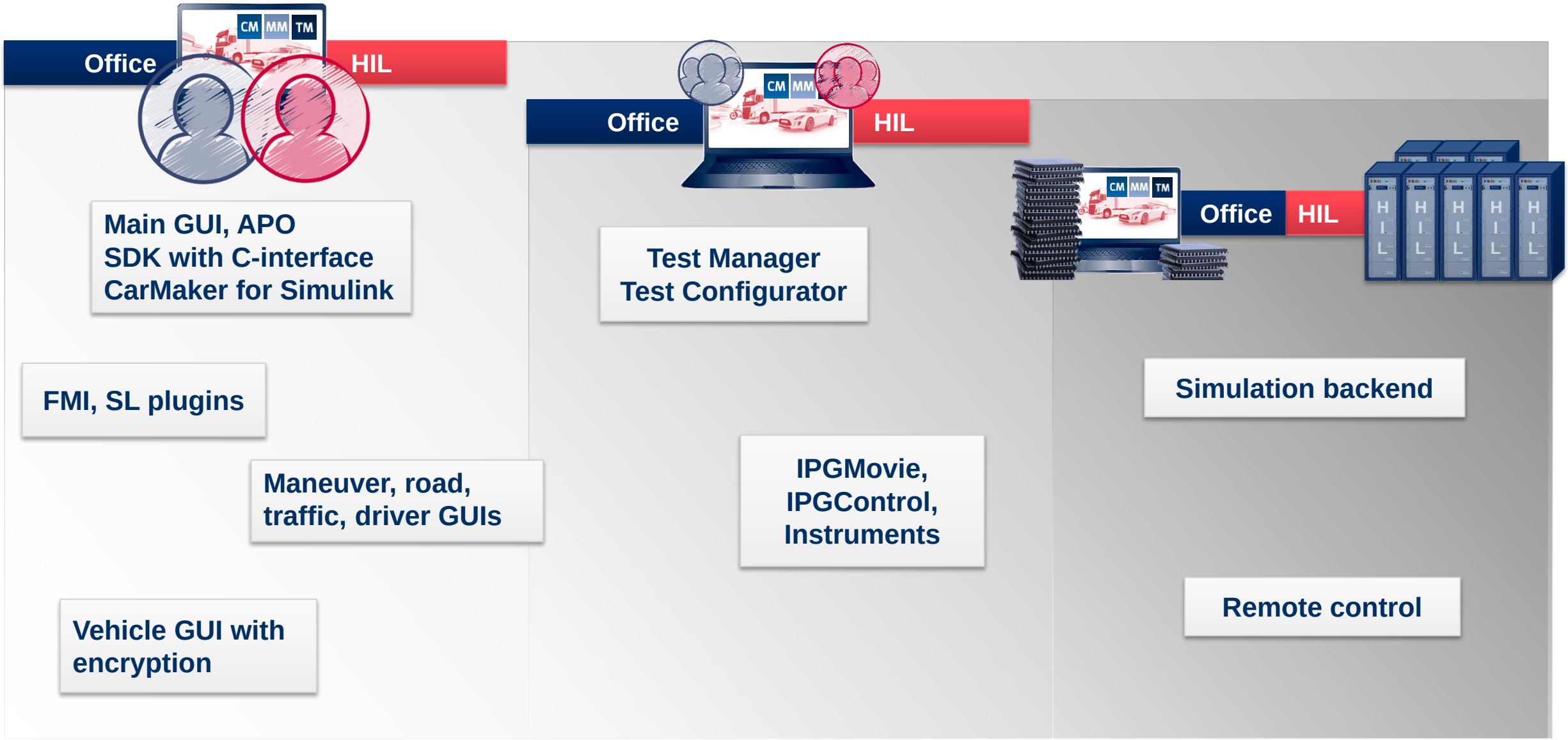
HPC with scheduler



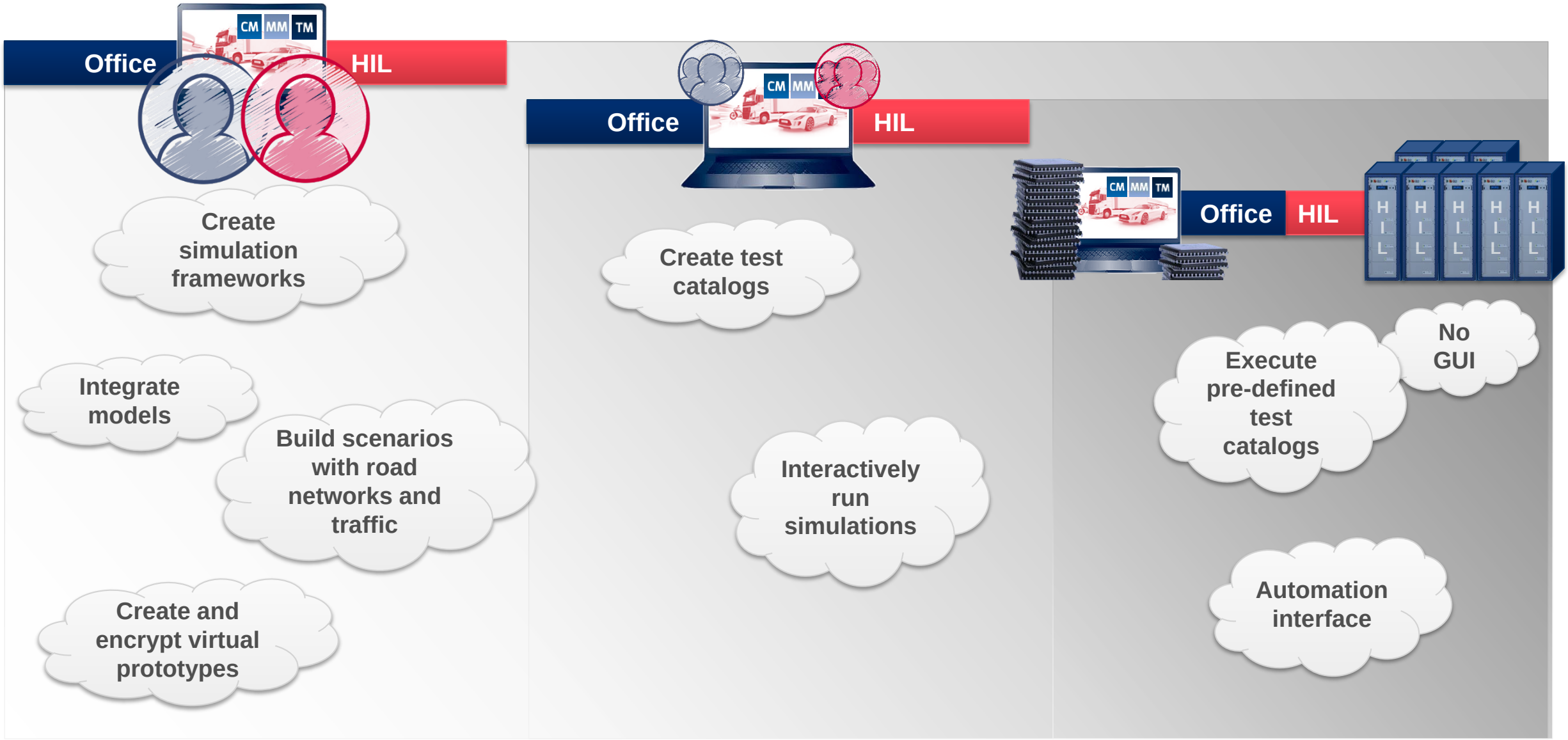
HPC with Scheduler

Specifications	HPC
Scheduler	With external scheduler (e.g. PBS professional)
HPC Scalability	beyond 50,000 nodes millions of cores
Dedicated Hardware	Clusters, clouds, and supercomputers
Scheduling	Balancing job turnaround time and utilization with optimal job placement
Resiliency	Includes automatic fail-over architecture with no single point of failure
Health Checks	Monitors and automatically mitigates faults with a comprehensive health check framework

Runtime Licenses



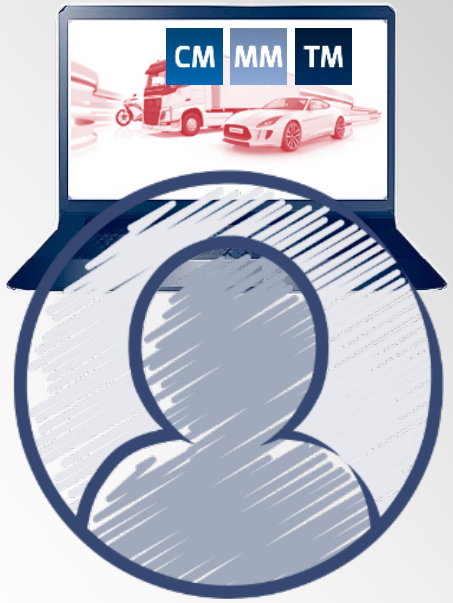
Runtime Licenses



Use Case Scenarios

Office simulations

CarMaker/Office
Full functionality



Simulation framework established

CarMaker/Office Operate
For interactive operation by humans

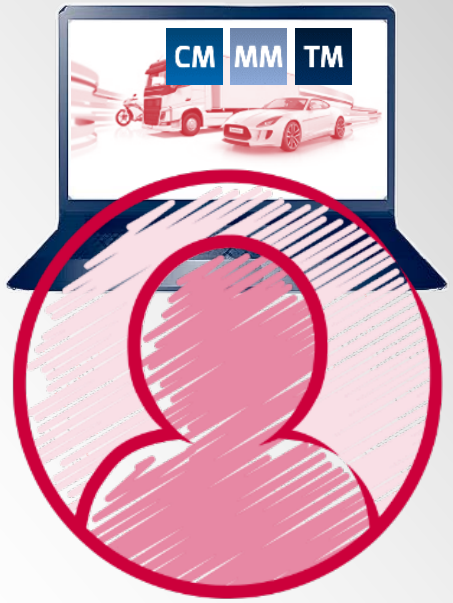
CarMaker/Office Runtime
For automatic execution

Third-Party Software

Use Case Scenarios

HIL simulations

CarMaker/HIL
Full functionality



Simulation framework established

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HPC Applications

Just the first ideas

ADAS & AD

- Use HPC to test millions of test kilometers in simulation using test automation
- Continuous integration - Robustness checks of daily builds
- Stochastic vs. deterministic traffic simulation - Simulate the unexpected
- Generate simulation data to train neural networks

Other Domains

- Identify the best vehicle dynamics setup
- Calibrate and analyze emissions and energy consumption with design of experiments (DoE)

IPGDriver – Lane Change Optimization

IPGDriver is now able to identify a driving strategy for the fastest ride in double lane change and soon in slalom maneuvers

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