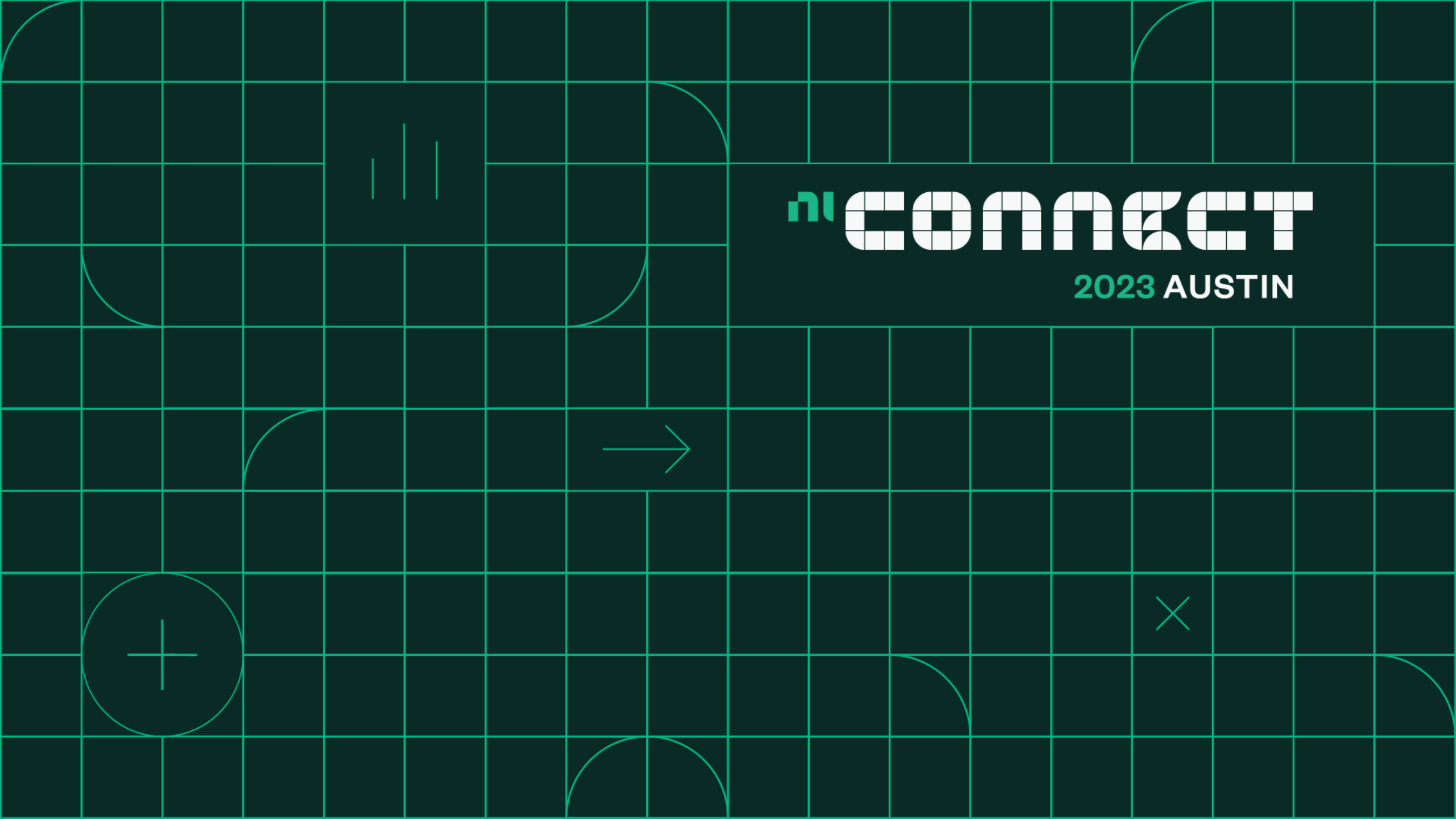

WELCOME TO AUSTIN


NI CONNECT
2023 AUSTIN

ADAS/AD Workflow: Evolution Advancements in Data-Driven Software Validation

Vidya Ramadoss

NI

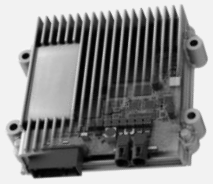
Electrification and Autonomy Adoption Accelerating

Safety and Performance Drive Innovation, Create Opportunity, and Challenge Traditional Process

Traditional Supply Chain

OEM

TIER 1



COMPONENT

BY 2030

30%
ELECTRIC

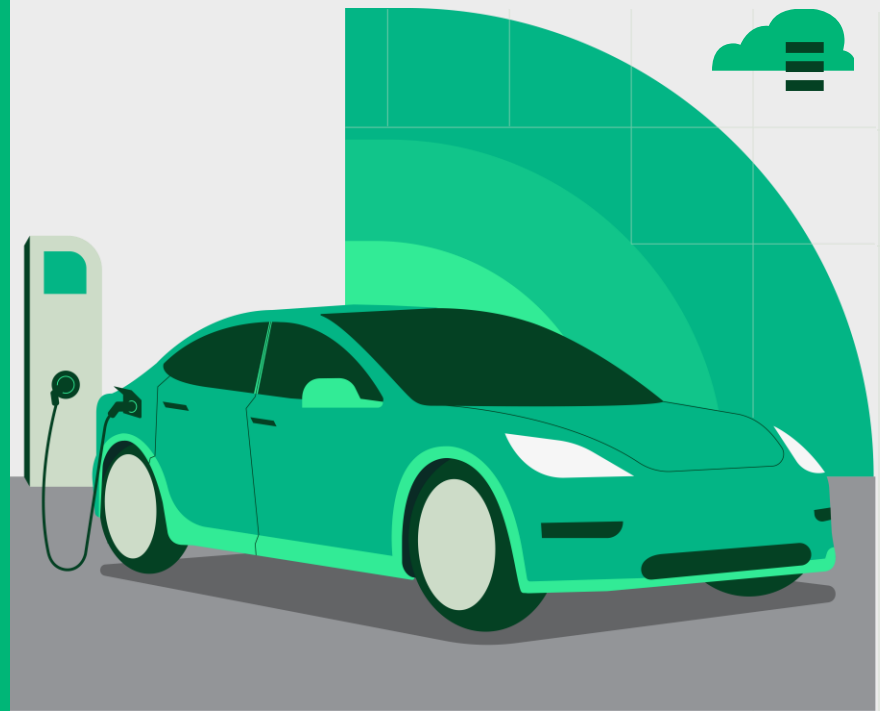
50%
>L2 AUTONOMY

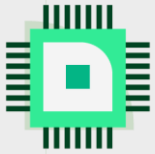
New Automotive Ecosystem

New Technology

New Suppliers

New Opportunity





The Road to the Future is Paved with Software

Acceleration of EV and ADAS Roadmaps will Require New Tools and Process to Meet Demand

	2020	2030
Vehicle Production	77M New Vehicles	~100M New Vehicles (1.3x Increase)
Electrification	<5% Battery Electric	>30% Battery Electric (7x Increase)
Autonomy	<15% L2 Autonomy or Above	>50% L2 Autonomy or Above (5x Increase)

Automotive companies plan to spend

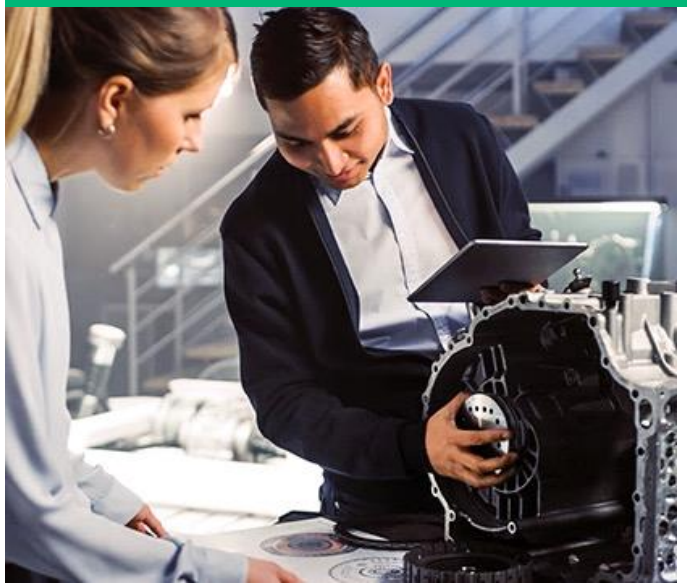
45% of 2021 R&D budget on software

– IHS SURVEY

NI in Transportation

We Accelerate the Future of Transportation by Transforming Test into an Enabler of Product Performance

Growth Areas



ELECTRIFICATION

ADAS AND AUTONOMY

DIGITAL TRANSFORMATION

NI in Transportation

We Accelerate the Future of Transportation by Transforming Test into an Enabler of Product Performance

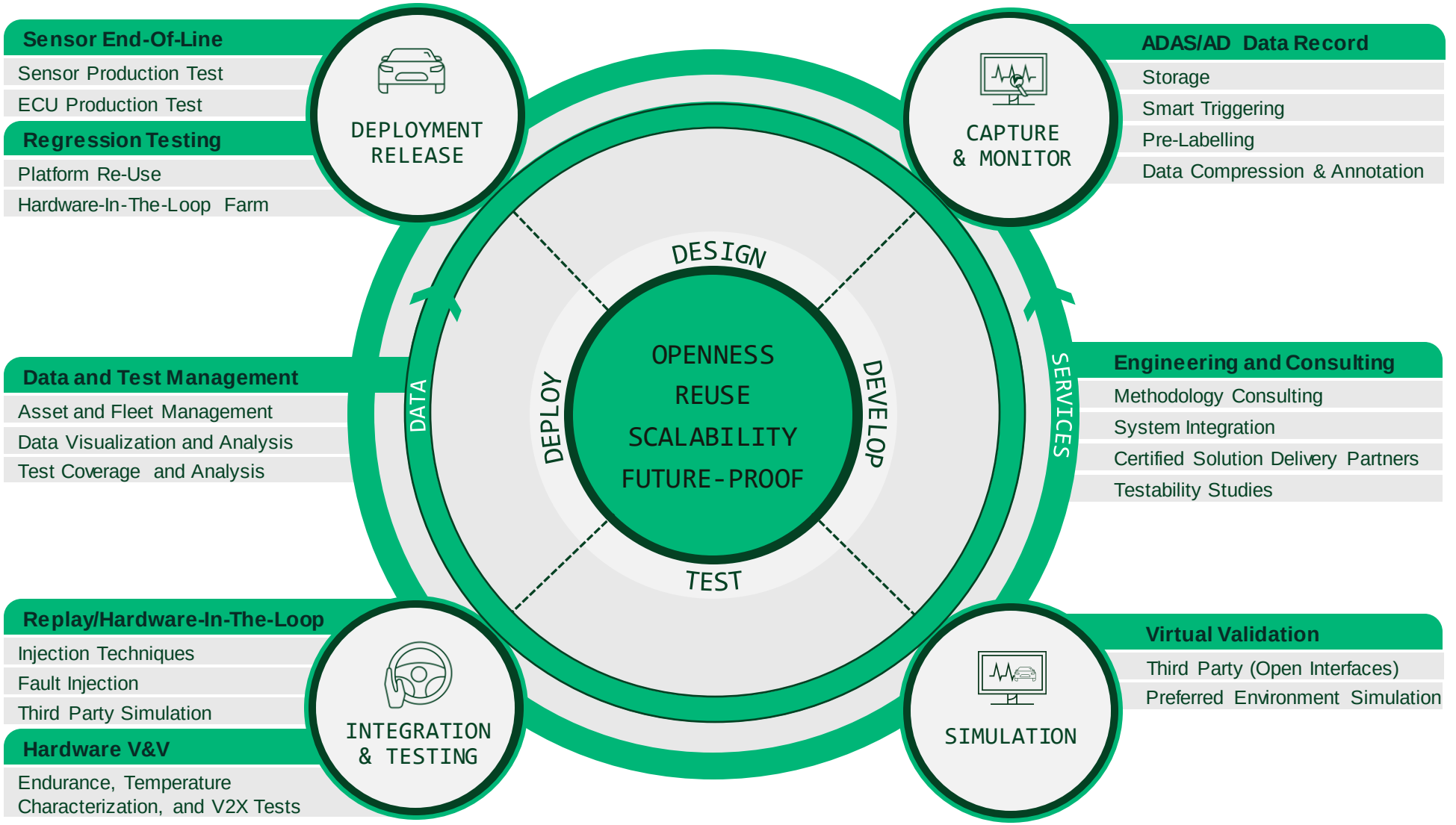
Growth Areas

ELECTRIFICATION

ADAS AND AUTONOMY

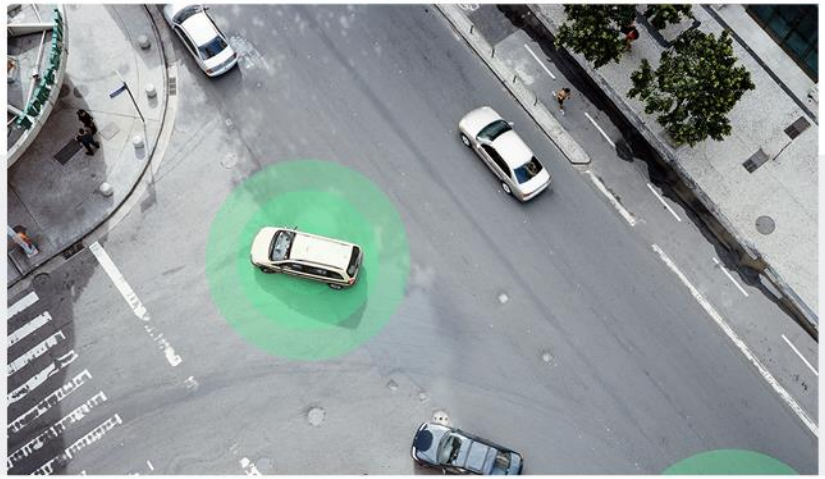
DIGITAL TRANSFORMATION

ADAS/AD Across the whole Product Life Cycle



Have You Tested Automated Driving Functions Enough to Trust Your Loved Ones with Them?

Replacing the human driver promises more productivity, comfort, and safety, but uneasiness remains as failure puts lives and reputations at risk. This complex challenge requires testing against infinite real-world scenarios that you need to master.



1.3M TRAFFIC FATALITIES WORLDWIDE IN 2021[1]

~90% AUTOMOBILE CRASHES CAUSED BY HUMAN ERROR[2]

∞ NUMBER OF SCENARIOS TO BE CONSIDERED LEADING TO TESTING AGAINST THE UNKNOWN

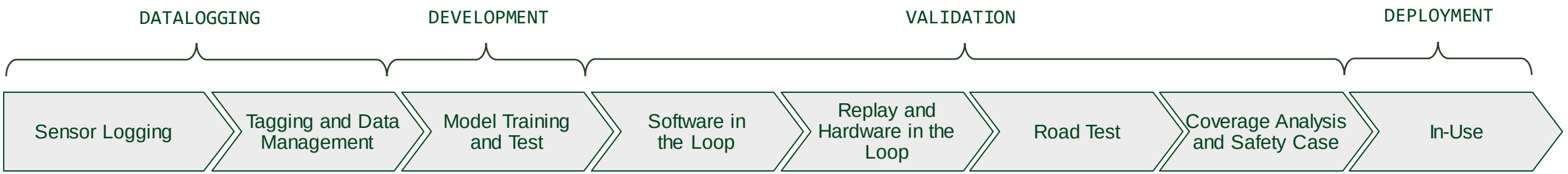
$27B ADAS MARKET WORLDWIDE IN 2021[3]

$75B ADAS MARKET WORLDWIDE BY 2030[3]

~30% FUTURE IMPACT OF DATA SCIENCE AND AI/AV SOFTWARE JOBS TO THE AUTOMOTIVE BUSINESS[4]

[1]SOURCE: UN NEWS [2]SOURCE: NHTSA [3]SOURCE: RESEARCH AND MARKETS [4]SOURCE: KPMG

Workflow for ADAS/AD Throughout Development

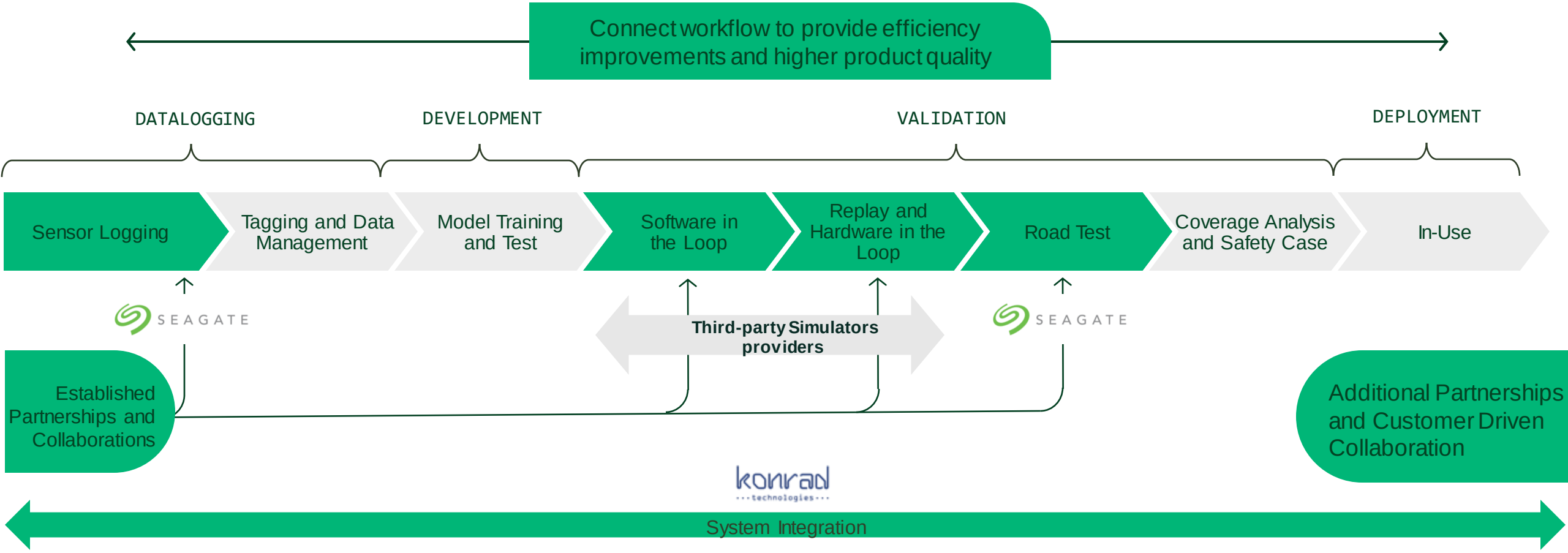


Serving ADAS/AD | Software Connected Workflow

A cohesive toolchain that combines the best-in-class components needed to test ADAS/AD software.

Shows both the “art of the possible” and serves a starting point that already works for customers along with projected market-leading solutions.

Modular and can be changed out to match a customers existing tools/workflows (with work)



Valeo's ADAS

PHYSICAL VALIDATION

worldwide network of
9 TEST TRACKS
with on-site facilities
running **250+ vehicles**

40
PETABYTES

VIRTUAL VALIDATION

large scale simulation capability
with **8 HIL & SIL FARMS**
on sites and in the cloud
running **250+ test benches**





ADAS/AD Workflow:
Data-Driven and Software-Connected Architecture

Martin Zmrhal

Valeo R&D Center Prague, Czech Republic

SMART TECHNOLOGY
FOR SMARTER MOBILITY

Valeo Group Introduction

Tier 1 Automotive Supplier and Partner to Automakers Worldwide

#1 IN ADAS

1 vehicle out of 3 on roads worldwide

EQUIPPED WITH VALEO ADAS SOLUTIONS

#1 IN ELECTRIFICATION

1 vehicle out of 3 on roads worldwide

EQUIPPED WITH VALEO THERMAL & ELECTRIC SOLUTIONS

Valeo DVS

Test Tools & Infrastructure

Valeo DVS Products





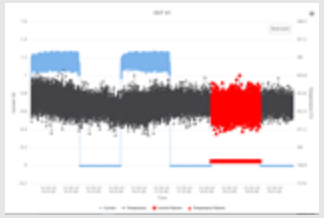






Test Infrastructure & Tools

HW / SW R&D → Design Validation (DV / PV) → In Vehicle Recording & Test → System Validation (HIL + Automation) → Production Test



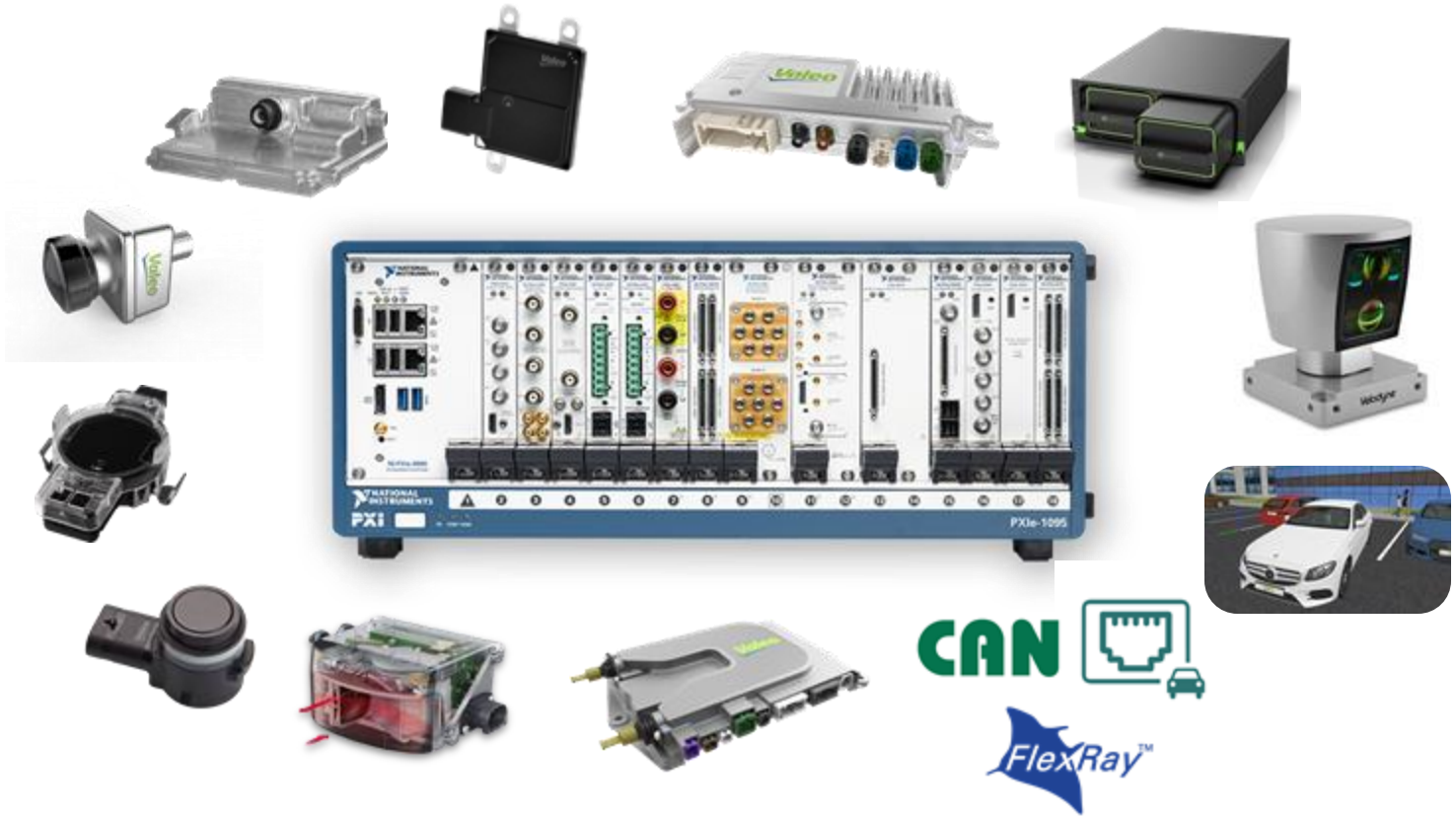

LabVIEW Center of Excellence





The Key Enabler: NI PXI Platform

Reused Across All Areas of Valeo DVS Validation



- ✓ Reusable Hardware
- ✓ Robust and Reliable
- ✓ Scalable & Modular
- ✓ High Throughput
- ✓ HW Triggering & Sync
- ✓ Short Development Time
- ✓ Automotive Compatibility

Valeo Automated Parking

HIL System Validation

Automated Parking and Surround View System Validation

Requirements & Challenges

- Valeo DVS typical delivery to OEM: Automated Parking or Surround View System
- Sensor data fusion ⇒ environment map ⇒ parking maneuver
- Extensive system validation campaign
- Thousands of test cases with each parking SW release
- Target vehicle is often not available

Automated Parking ECU Architecture

Input & Output Interfaces

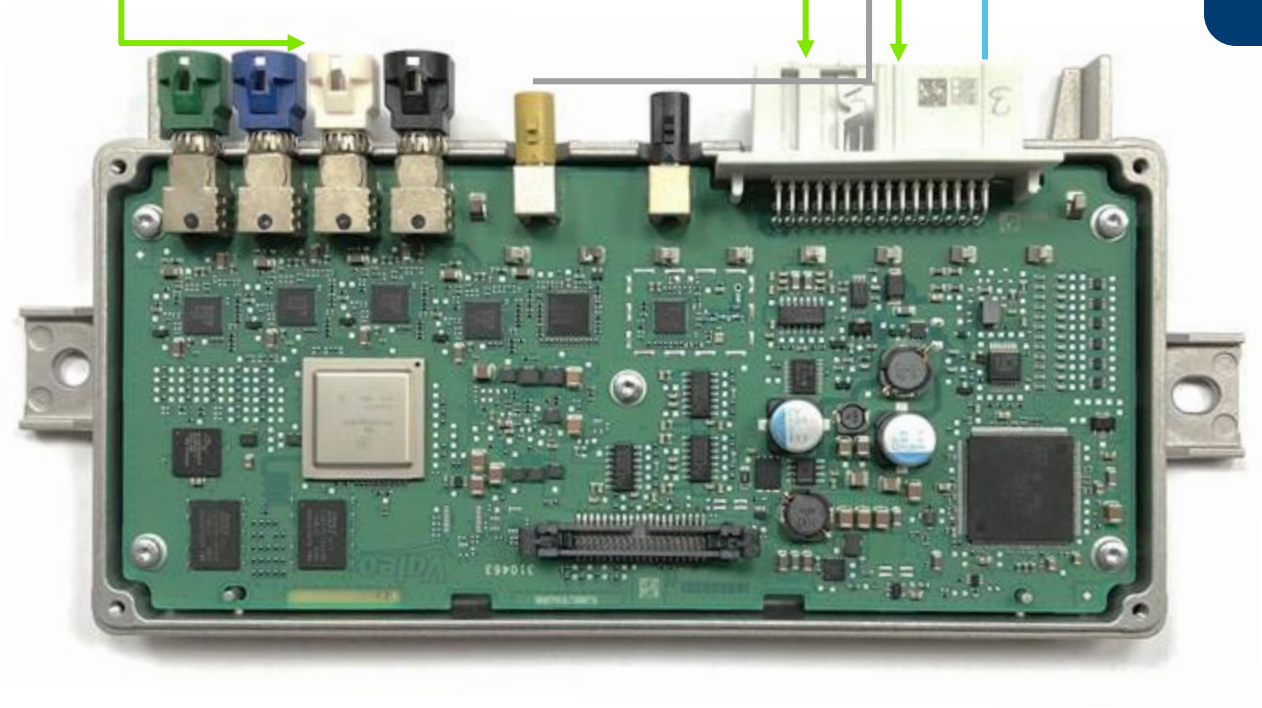
Ultrasonic Sensors
- 12 sensors
- 20ms cycle

Vehicle Odometry
- Wheel speed
- Steering angle
- Current gear

Control Signals
- Requested Steering angle
- Requested gear

4x Camera stream
- 1-8 Mpx @ 30FPS
- RAW / YUV video format

Video Out
- Full HD @ 25FPS
- Driver's display



ECU Sensor Input

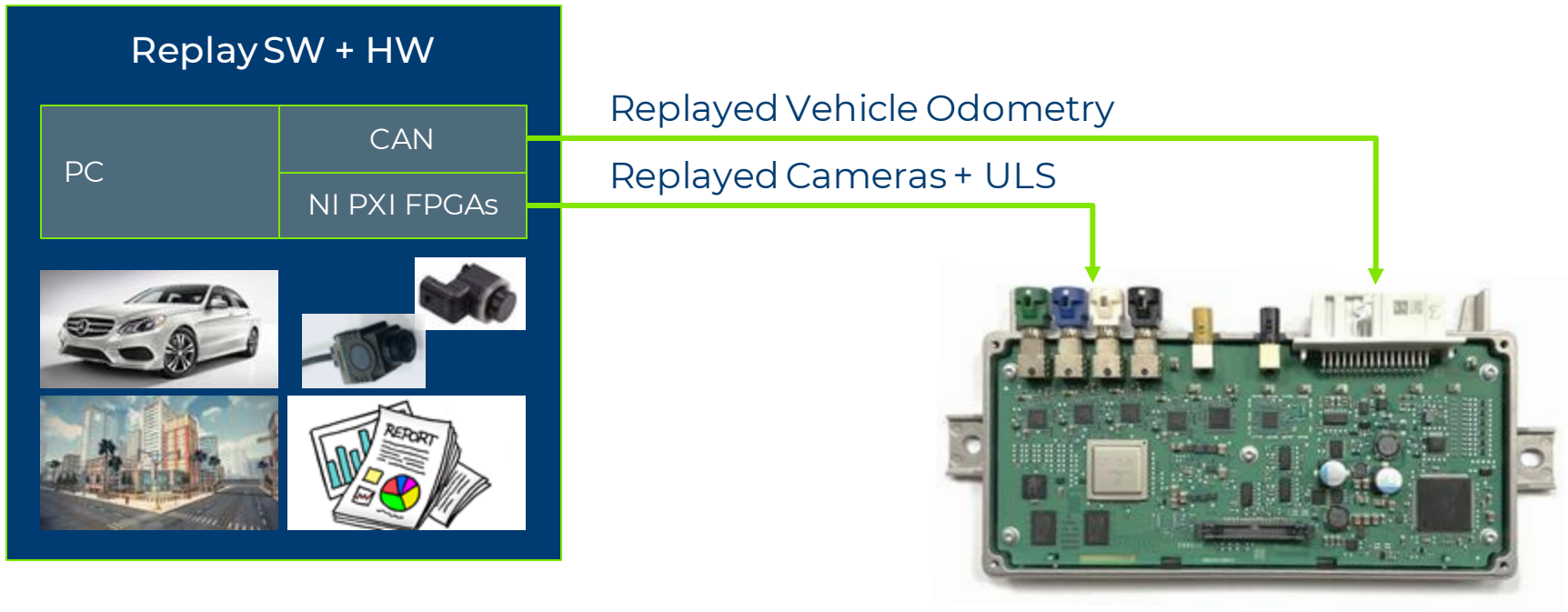
ECU Display Output

ECU Requested Control Signals

Open Loop Replay HIL Testing

Recorded Data Replay

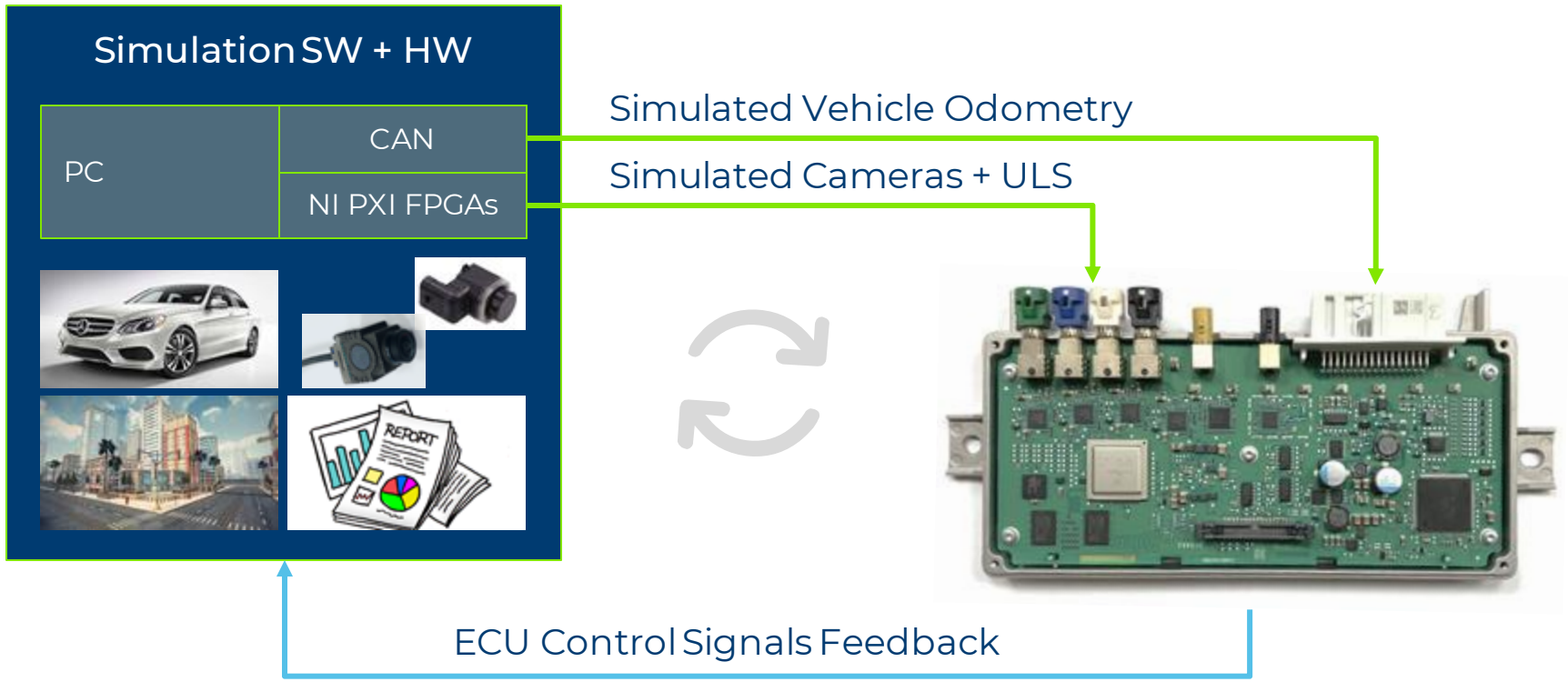
- Reinjection of real captured sensor data to the real ECU (i.e. HiL)
- Open loop ~ ECU output cannot be reflected in the replayed scene
- Useful for detection algorithm KPI / performance testing



Closed Loop Virtual HIL Testing

Sensor Data Simulation + ECU Feedback to Simulation

- Closed loop HIL system required to test AP ECU, feeding the ECU vehicle control requests back into the simulation
- End user function testing + negative scenarios testing possible!



Closed Loop Virtual HIL / Vehicle Testing

Pro's and Con's Comparison

In-Vehicle Testing

- ⊕ Real vehicle system
- ⊕ Real environment
- ⊖ Expensive
- ⊖ Time consuming
- ⊖ Location, weather constraints
- ⊖ Target vehicle availability
- ⊖ Minimum 2 drivers
- ⊖ Negative scenarios

Virtual HIL Testing

- ⊕ Any car variant
- ⊕ Fully automated
- ⊕ 24/7 unattended operation
- ⊕ Tooling costs
- ⊕ Bench reuse
- ⊖ Simulation only
- ⊖ Performance testing
- ⊖ Complex test system

Shift from Vehicle to Virtual Validation

Virtual Validation is a Must Nowadays!

- Increasing ADAS system complexity, new detection algorithms
- Number of test cases grows with every project
- Not feasible to test everything in the real car
- Not possible to test negative scenarios in the vehicle
- Industry trend to move to virtual validation and model based design
- Many suppliers offering simulation / virtual validation tools

Validating High-ASIL Systems via Testing Is Challenging

Need to test for at least ~3x crash rate to validate safety

- Hypothetical fleet deployment: New York Medallion Taxi Fleet
  - 13,437 vehicles, average 70,000 miles/yr = 941M miles/year
    - 7 critical crashes in 2015 [2014 NYC Taxi Fact Book]
    - ➔ 134M miles/critical crash (death or serious injury) [Fatal and Critical Injury data / Local Law 31 of 2014]
- Assume testing representative; faults are random independent
  - $R(t) = e^{-lamba*t}$ is the probability of not seeing a crash during testing
- Illustrative: How much testing to ensure critical crash rate is at least as good as human drivers? ➔ (At least 3x crash rate)
  - These are optimistic test lengths…
    - Assumes random independent arrivals
    - Is simulated driving accurate enough?

Testing Miles	Confidence if NO critical crash seen
122.8M	60%
308.5M	90%
401.4M	**95%**
617.1M	99%

Using chi-square test from: http://reliabilityanalyticstoolkit.appspot.com/mtbf_test_calculator

* Koopman, P., "Challenges in Autonomous Vehicle Validation," April 2017.

Valeo Open / Closed Loop HIL Architecture

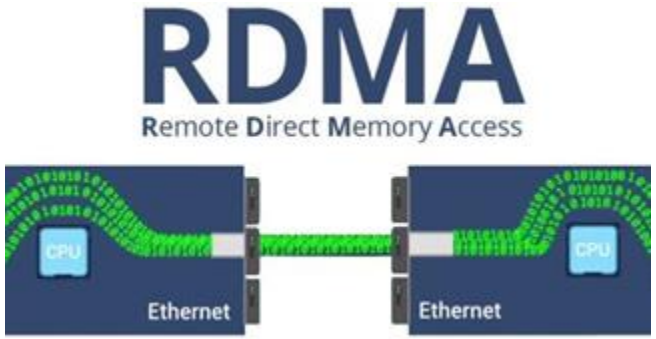
Three Main HIL Designs

MXI Based HIL

Host PC ⇔ MXI ⇔ NI PXI

HDMI Based HIL

GPU ⇔ HDMI ⇔ NI PXI



RDMA Based HIL

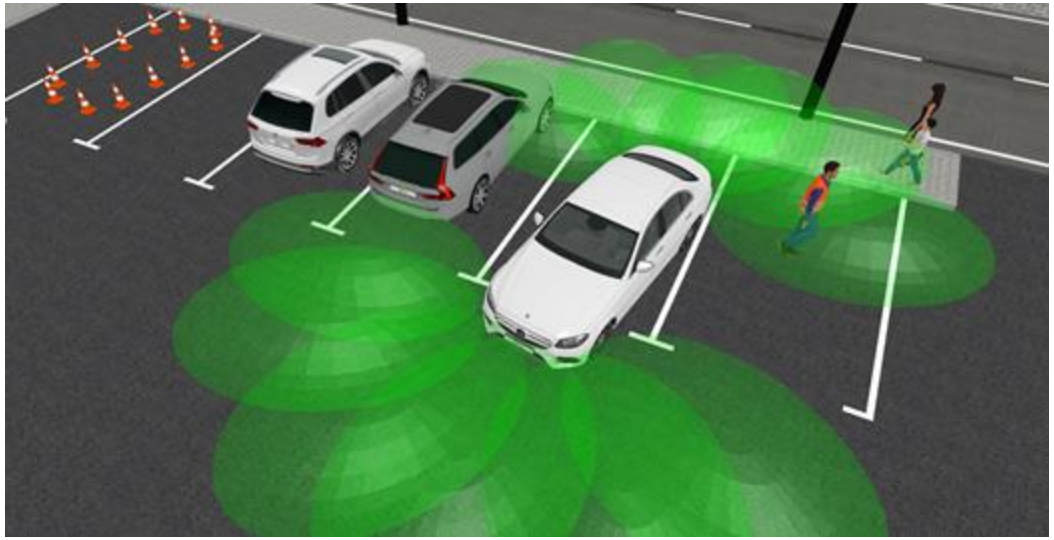
Host PC ⇔ RDMA ⇔ NI PXI

Valeo DVS Virtual Validation

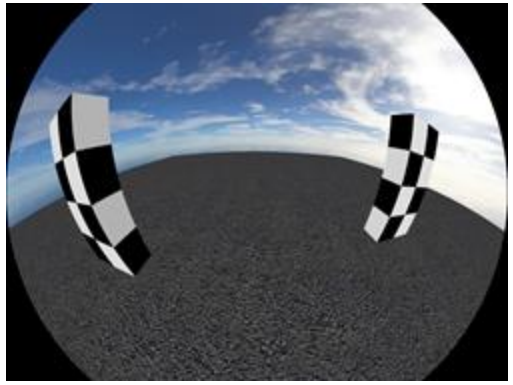
MXI Based Closed Loop HIL

Vosstrex Simulation Engine

Valeo In-House Simulation Platform

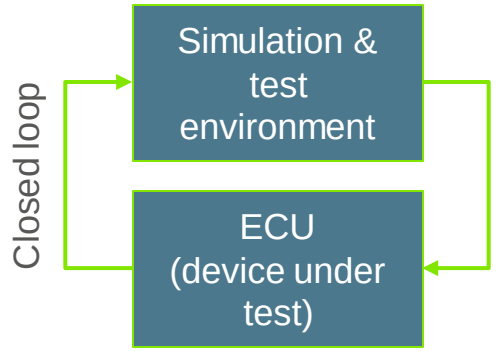


Real image



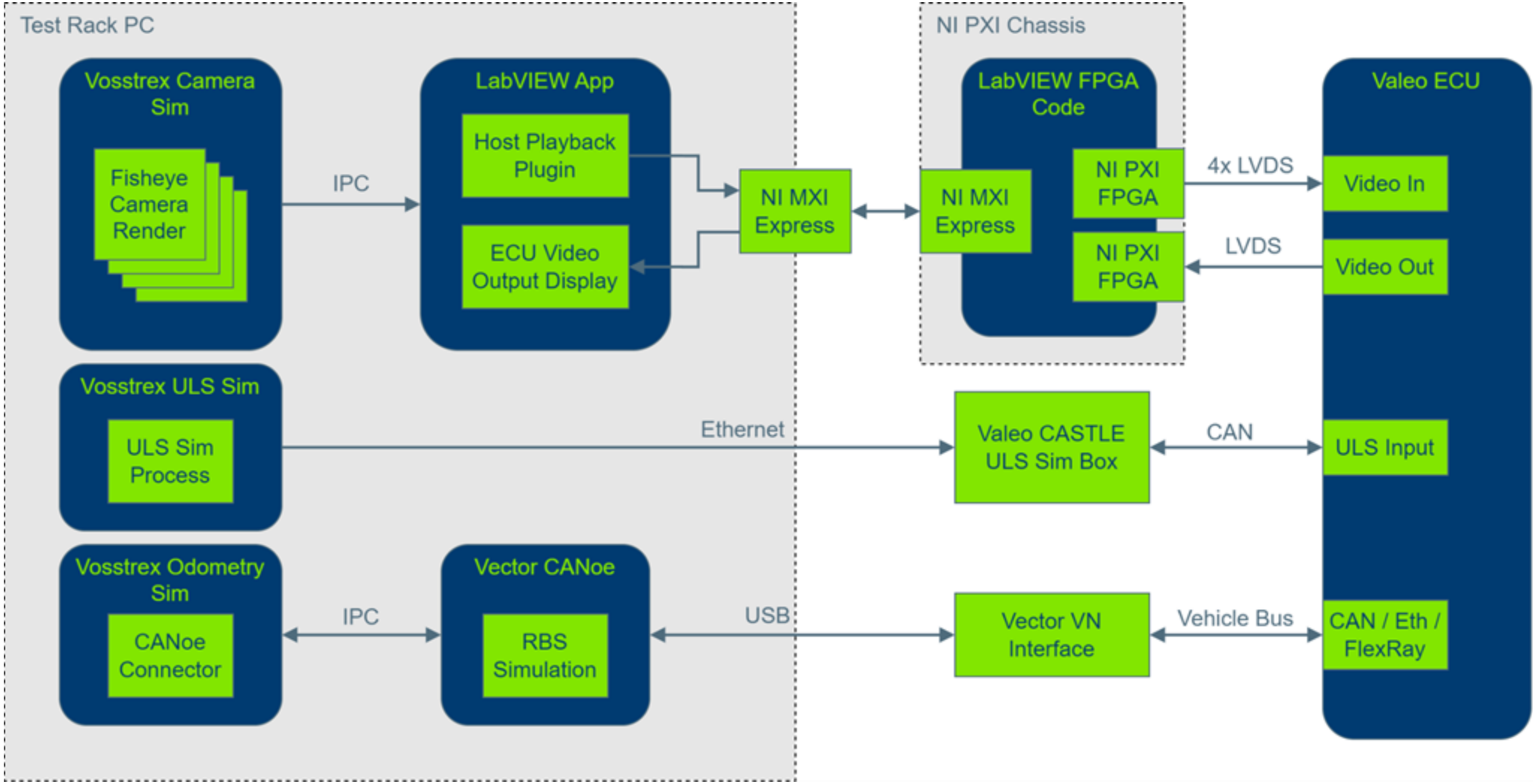
Simulated image

- Valeo in-house development
- Accurate fisheye camera and ultrasonic sensor models
- End user functions testing:
  - Automated Parking, Reverse Parking (Emergency) Braking, …
- Comes with a scene editor and dynamic ego vehicle model
- Integration with Vector CANoe



Vosstrex Closed Loop HIL

Architecture Diagram



Vosstrex Closed Loop HIL

Summary & Highlights

- ~ 50 Vosstrex HILs running worldwide on multiple OEM projects
- Initial validation setup early in the project (before vehicle integration available)
- Full source code ownership
- Validated latency of 1 - 2 frames in the video pipeline
- Limitations:
  - No synchronization between camera / ULS / vehicle bus
  - Depends on IPC integration with the simulation engine
  - Potential throughput limitations
  - Visual fidelity for deep learning algorithms

~ 50 Vosstrex HILs
on 9 Valeo sites worldwide
testing on **12+ OEM projects**

Valeo DVS Virtual Validation

HDMI Based Camera Sensor Simulation HIL

HDMI Based Camera Sensor Simulation

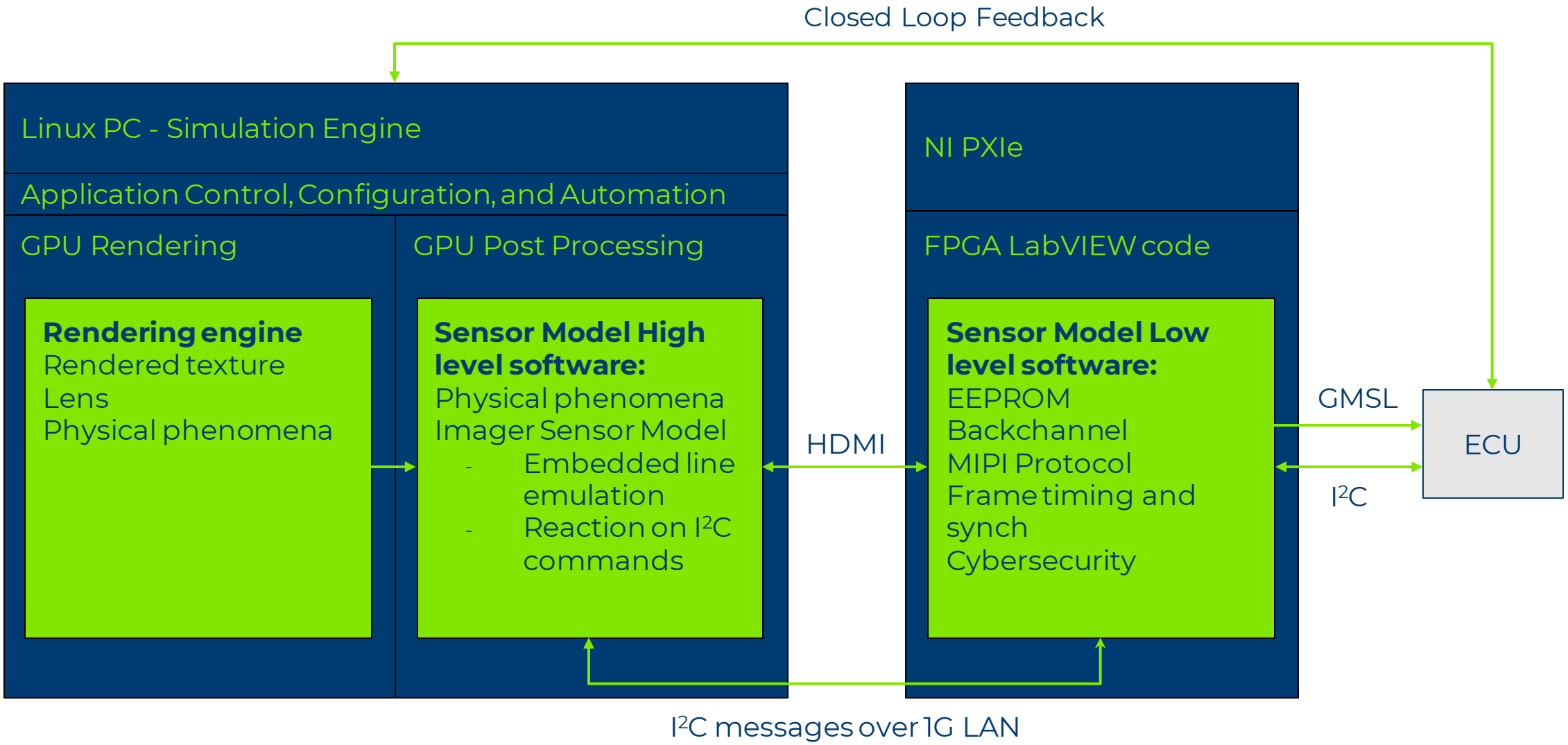
Project Requirements & Challenges

- Architecture based on a premium EU OEM requirements
- 8x 8Mpx AD + 4x 3MPx SVS cameras simulation
- 2 different simulation engines running on Linux OS
- Rendering: 4 PCs running 12 GPUs
- 4x the bandwidth of the highest throughput Valeo HIL to date!
- Developed together with NI
- The HIL architecture designed by NI

PC1	GPU1	8 MPx AD	3840x2160@30, 16bpp	1118 MB/s
	GPU2	8 MPx AD	3840x2160@30, 16bpp	
	GPU3	3 MPx SVS	1920x1536@30, 16bpp	
PC2	GPU4	8 MPx AD	3840x2160@30, 16bpp	1118 MB/s
	GPU5	8 MPx AD	3840x2160@30, 16bpp	
	GPU6	3 MPx SVS	1920x1536@30, 16bpp	
PC3	GPU7	8 MPx AD	3840x2160@30, 16bpp	1118 MB/s
	GPU8	8 MPx AD	3840x2160@30, 16bpp	
	GPU9	3 MPx SVS	1920x1536@30, 16bpp	
PC4	GPU10	8 MPx AD	3840x2160@30, 16bpp	1118 MB/s
	GPU11	8 MPx AD	3840x2160@30, 16bpp	
	GPU12	3 MPx SVS	1920x1536@30, 16bpp	

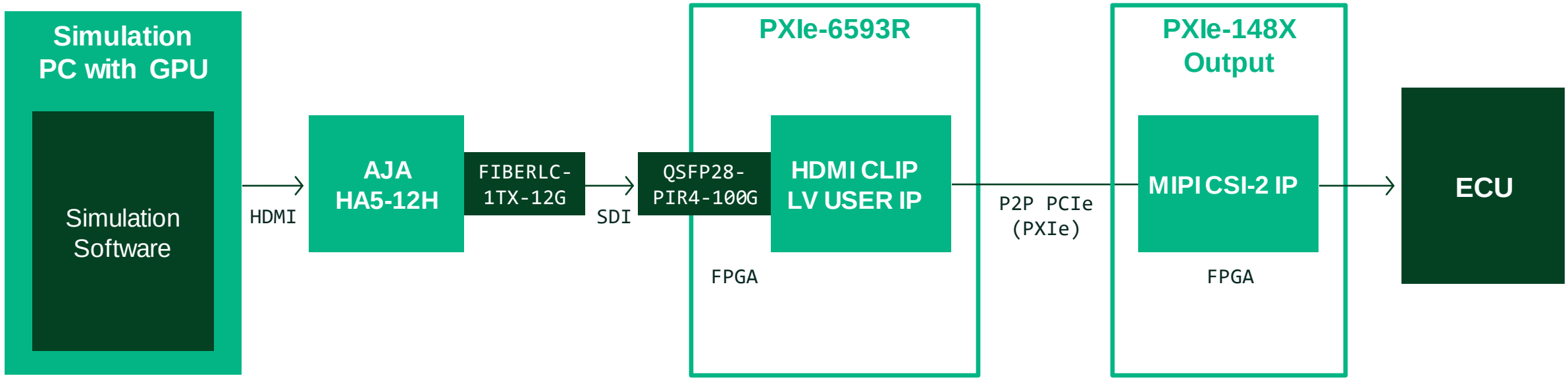
HDMI Based Camera Sensor Simulation

High Level Architecture



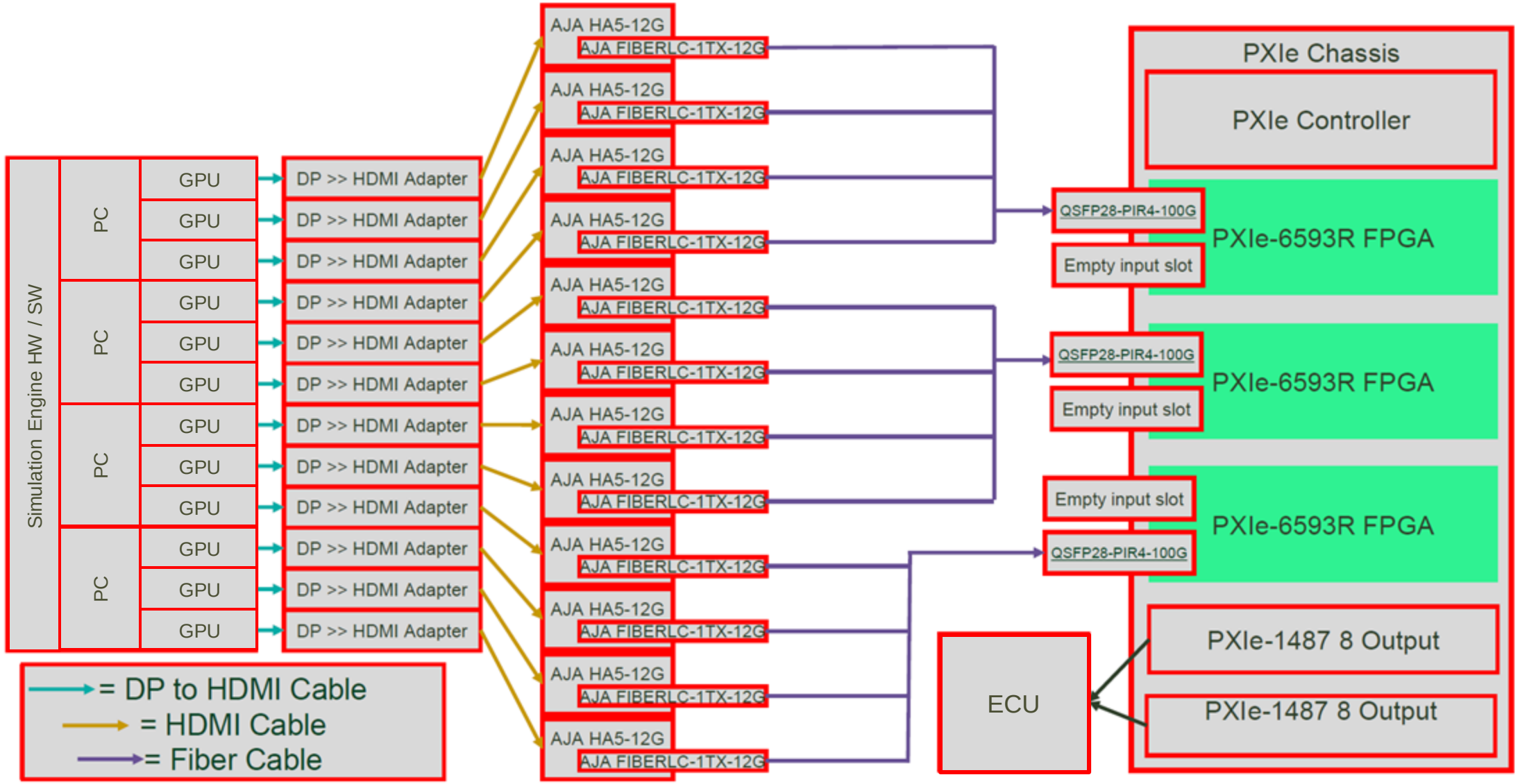
HDMI Based Camera Sensor Simulation

Video Injection Pipeline Architecture



HDMI Based Camera Sensor Simulation

12 Cameras Simulation Architecture



HDMI Based Camera Sensor Simulation

Summary & Highlights

- 4,5 GB/s of video data rendered & injected to the ECU
- Simulation agnostic solution
- Extra FPGAs can do extra processing (cybersecurity, I2C backchannel emulation)
- Kick of in 2021, first HILs delivered to customer in 2022
- Limitations:
  - HDMI interface not ideal
  - Complicated conversion toolchain
  - No synchronization between camera / ULS / vehicle bus
  - Cannot be reused as open loop replay HIL

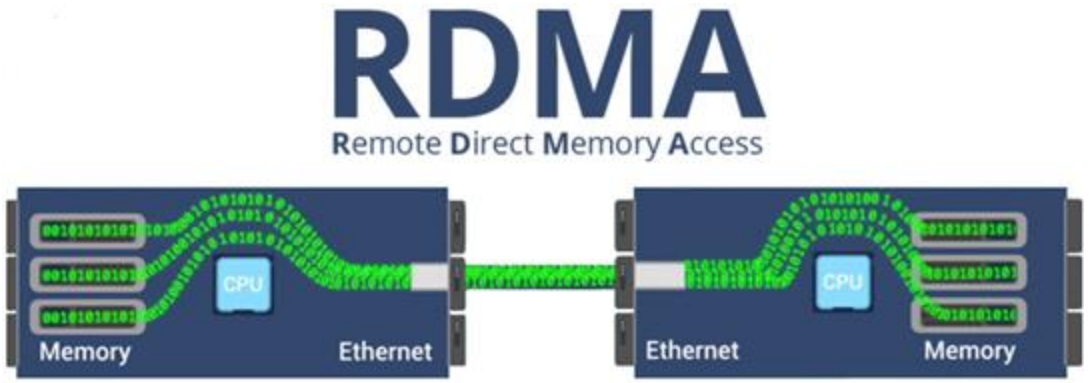
NI RDMA Based HIL

Open / Closed Loop RDMA HIL

Remote Direct Memory Access (RDMA)

One Computer Memory to Another With Low Latency

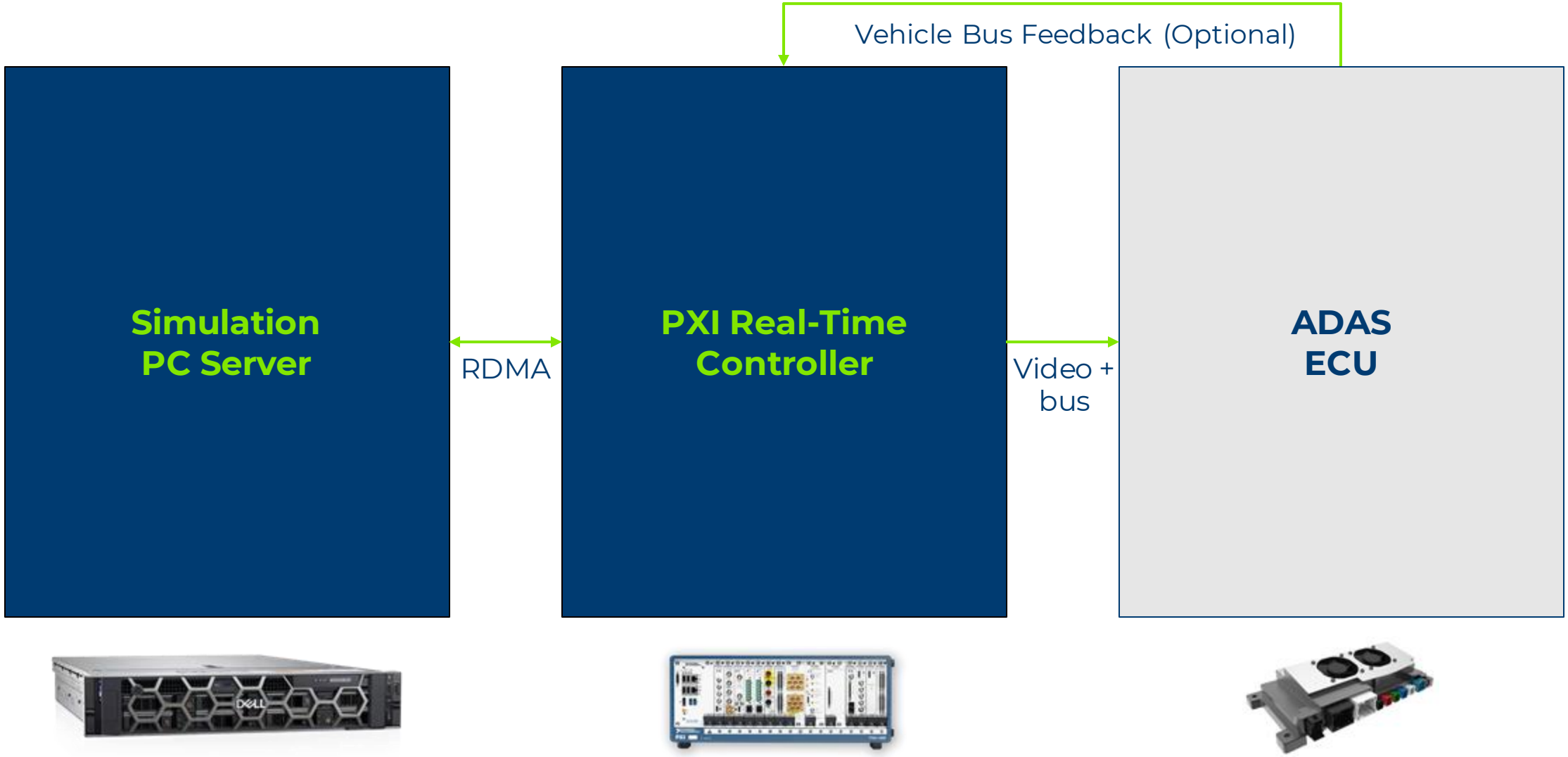
- RDMA: Remote Direct Memory Access
- Data movement over ethernet network
- Zero memory copy, low-latency, high bandwidth



NI PXIe-8285
RDMA Ethernet Interface Module

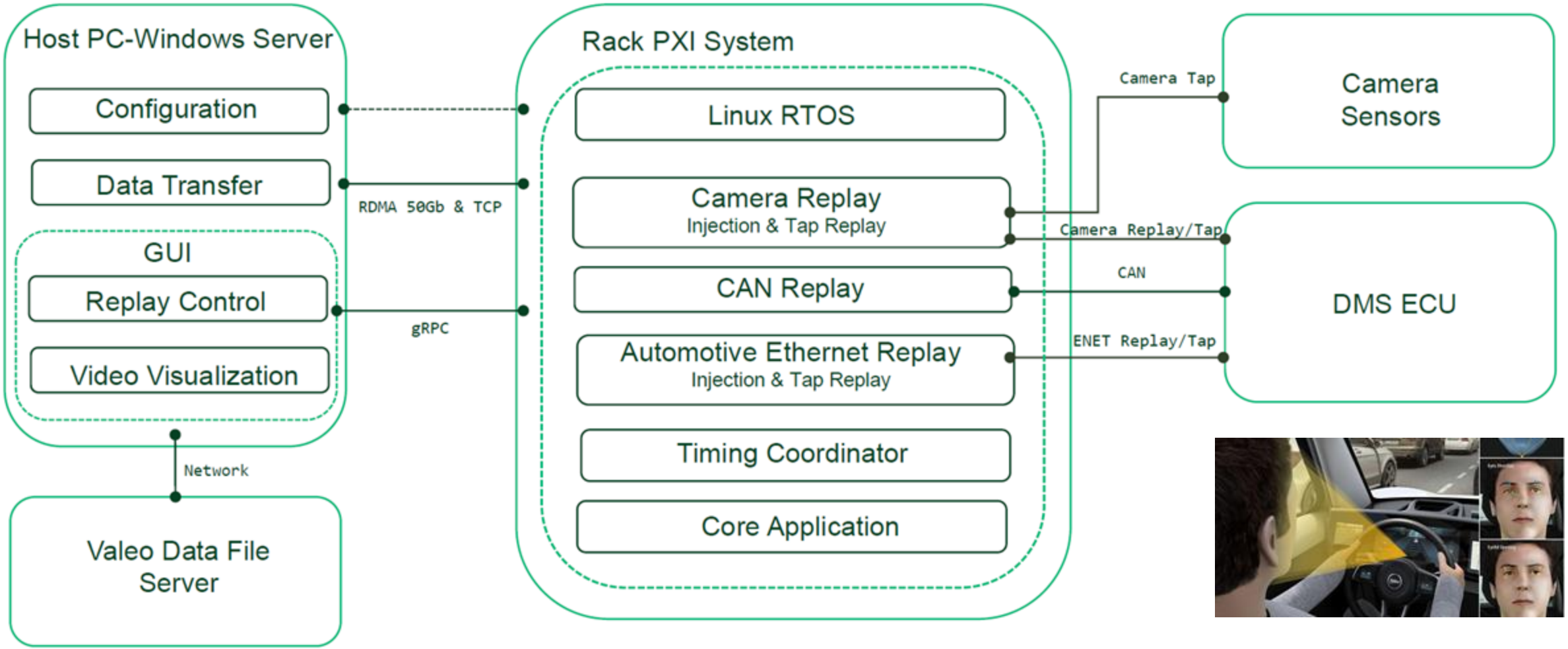
Open / Closed Loop RDMA HIL

High Level Architecture



Valeo DMS Open Loop Replay HIL

Driver Monitoring System



Open / Closed Loop RDMA HIL

Summary & Highlights

- 50 Gbit/s throughput (~ 6.25 GB/s) per RDMA module
- Common architecture for virtual simulation HIL (closed loop) and replay HIL (open loop) ⇒ cost savings
- Accurate synchronization between emulated sensor data and vehicle bus simulation
- Likely to become a Valeo standard solution (DMS, DFC, DVS to evaluate soon)
- Considerations:
  - Simulation engine has to support external DLL integration (RDMA client)
  - Can be overcome by HDMI to RDMA converters
  - Slightly more expensive than the MXI based HIL (an extra PXI RT controller)

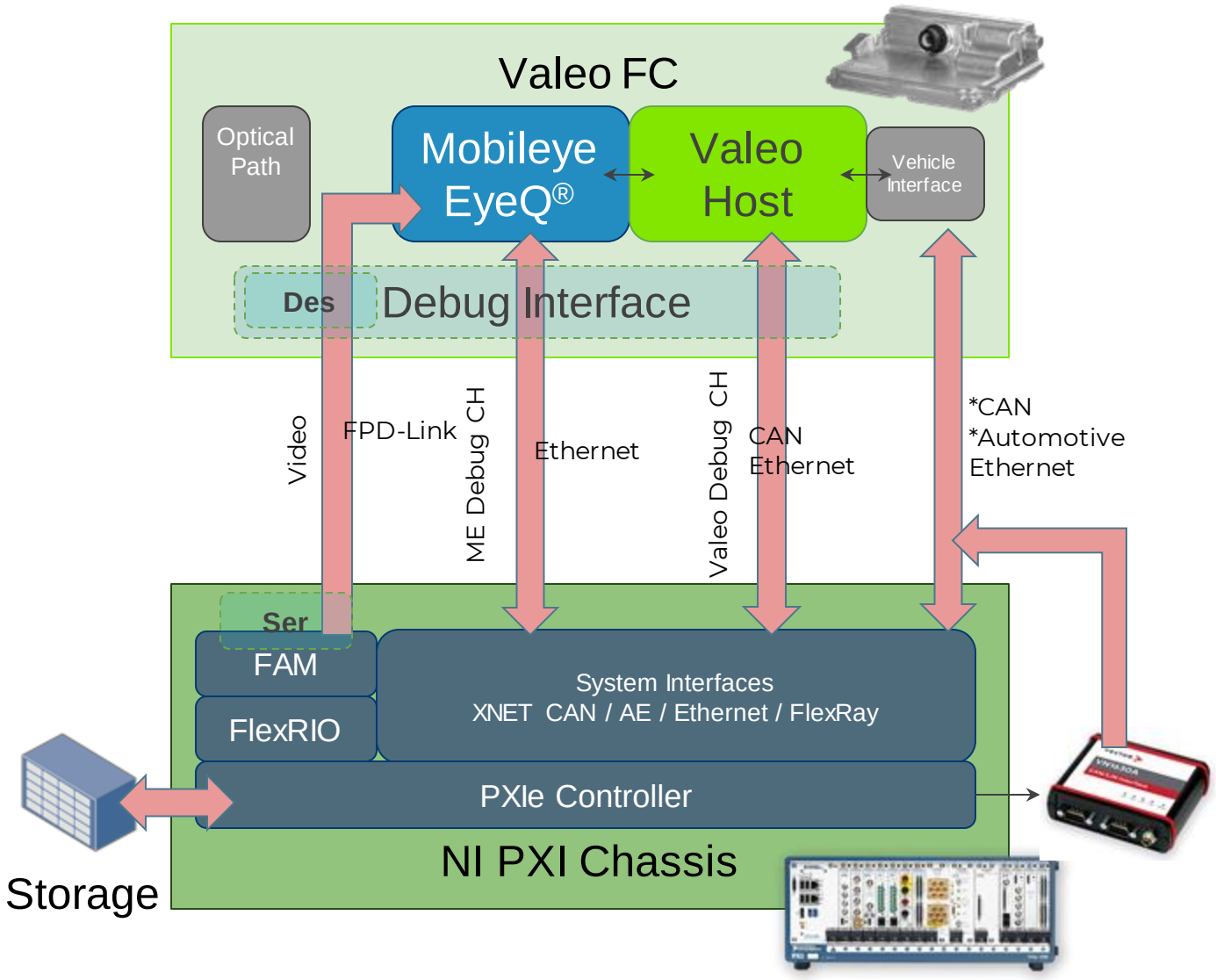
ADAS/AD Workflow:
Iterative Innovation Valeo's Smart Front Camera

Vít Neruda

Valeo R&D Center Prague, Czech Republic

VALEO DFC : Evolution of Smart Front Camera HIL system

Initial version of **open loop replay HIL (obsolete)**



SW Stack Logging / HiL

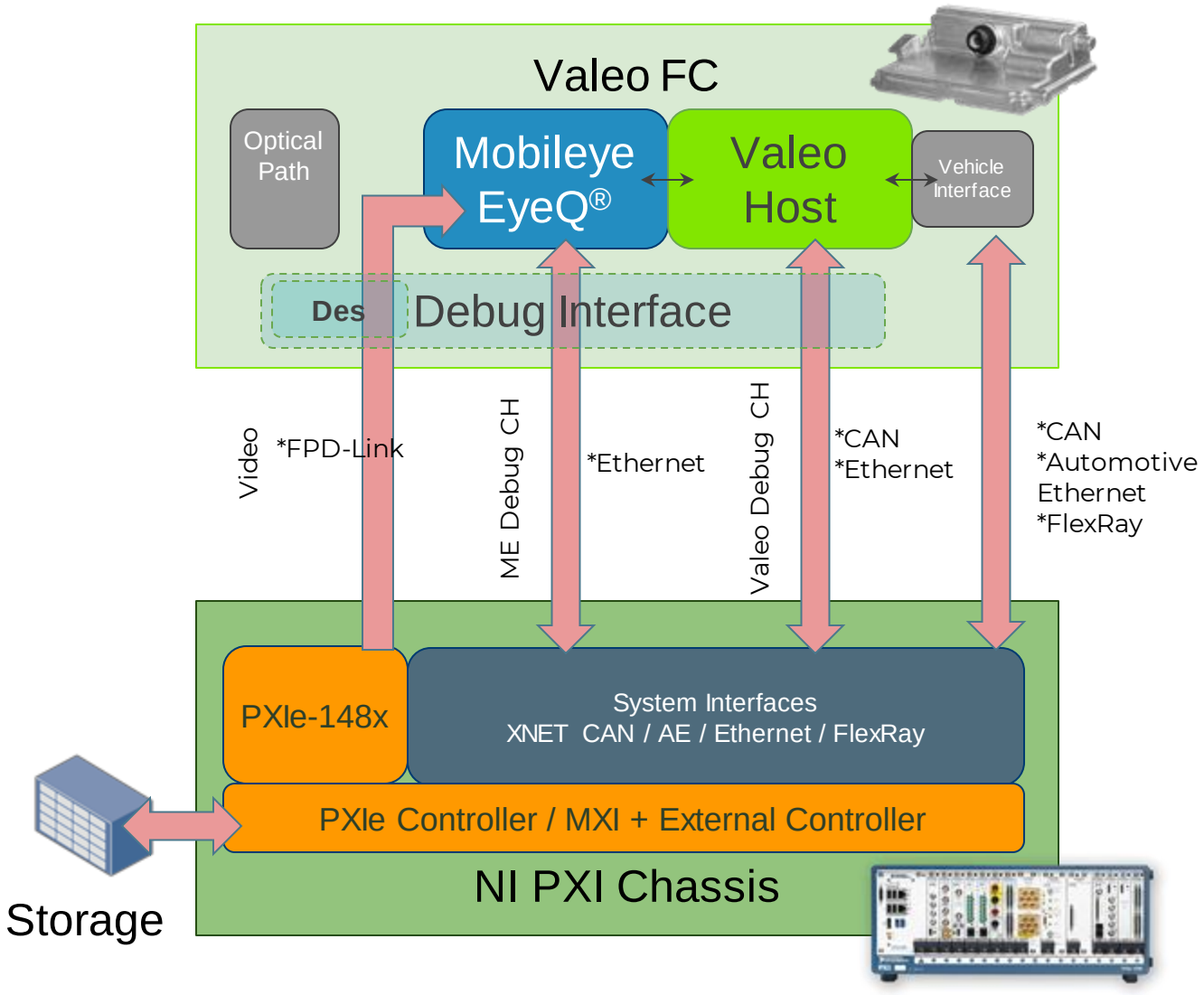
LabVIEW · RA CONSULTING · VECTOR · ECU-TEST · Elektrobit

Initial State: Complex cocktail of platforms

- Unnecessarily complex: two different SW stacks for each use case:
  - ADTF + LabVIEW in Logging
  - ECU TEST + DiagRA + LabVIEW in Replay HiL
- Not stable: complex integration between components
- Not cost effective: several licenses required
- Not expandable: Impossible to extend to multi-camera setup in any case
- Limited: constrained environment for automation, limited synchronization between interfaces

VALEO DFC : Evolution of Smart Front Camera HIL system

Actual version of **open loop replay HIL**



SW Stack Logging / HiL

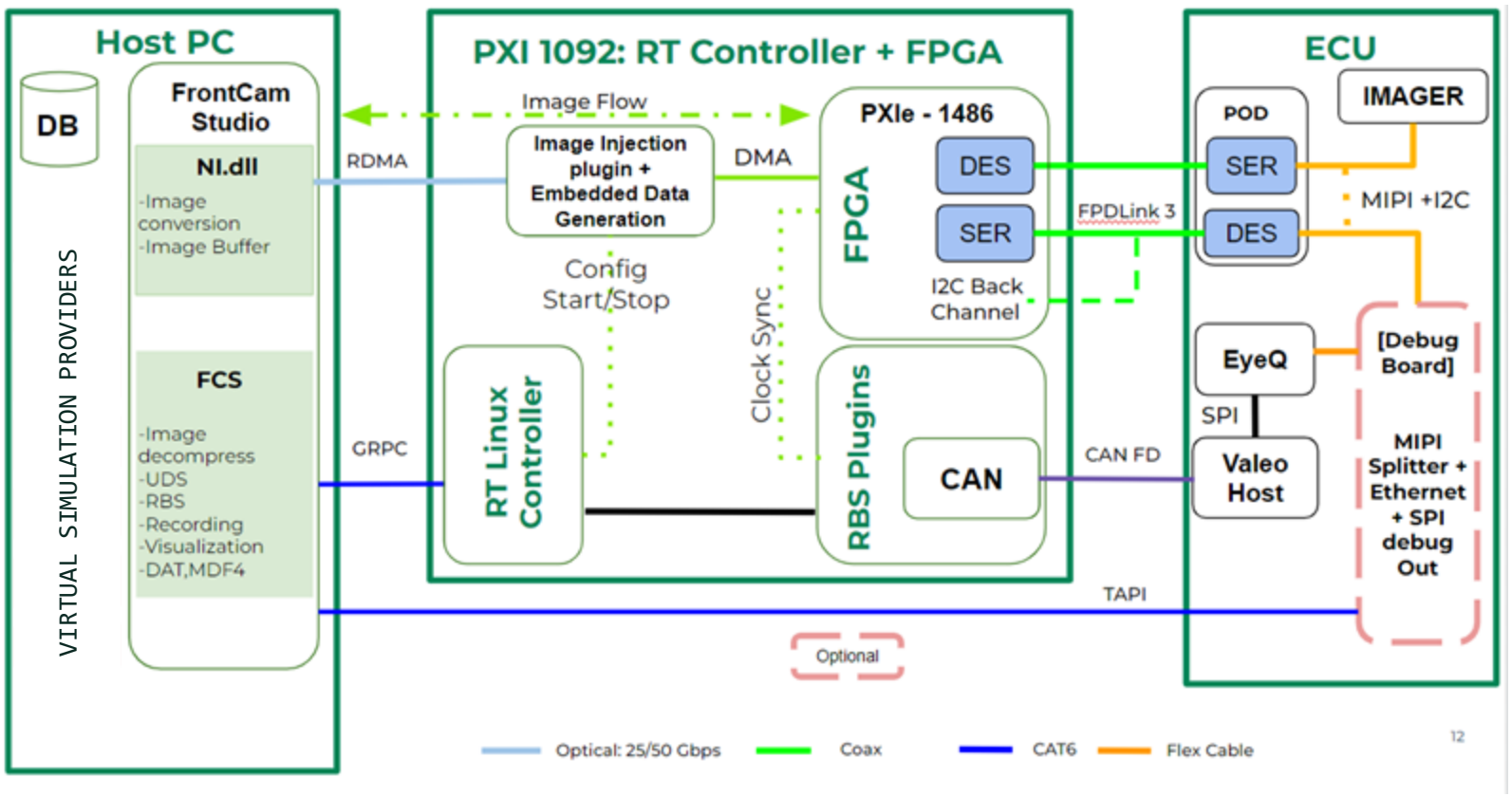
LabVIEW Valeo FrontCam Studio

Evolution: Unified solution in FrontCam

- In-house tool **FrontCam Studio**: Unified solution for all FC needs:
  - Strongly integrated with NI Architecture (PXI, XNET, LabVIEW)
  - Developed in-house: no licenses needed
- Robust solution for both logging and Replay HiL:
  - Optimized use of resources
  - Data synchronization for all interfaces
  - Integrated environment
- Reusable platform for several environments

VALEO DFC : Evolution of Smart Front Camera HIL system

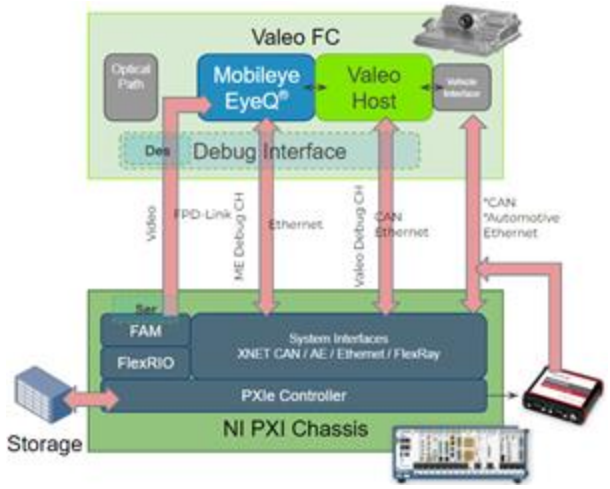
Direct Video Injection



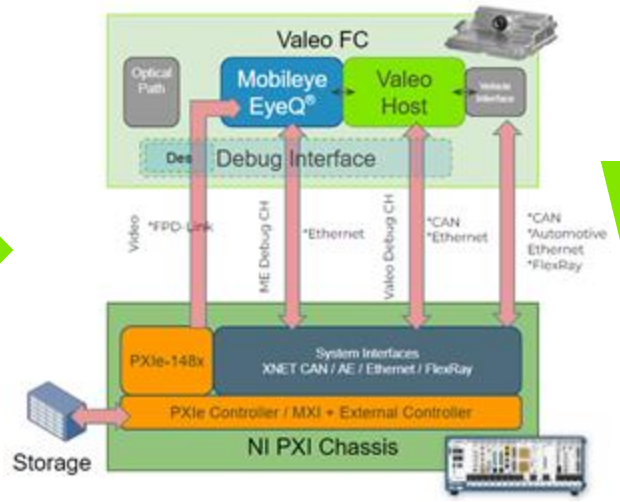
New generation: All in one

- Remove the need of **“HiL Mode”**.
- Replay of ***pre-recorded*** clips or **synthetic** generated video with RBS
- Compatibility with multiple simulation environments
- RT operating system provides High accuracy of trace reprocessing
- **Functional, performance and robustness testing of HW/SW without debug boards**
- Reusable platform for several environments

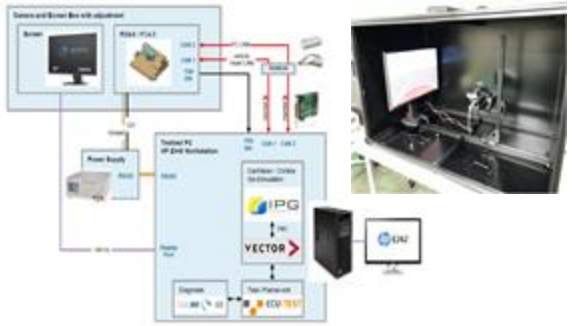
Evolution of Smart Front Camera HIL system



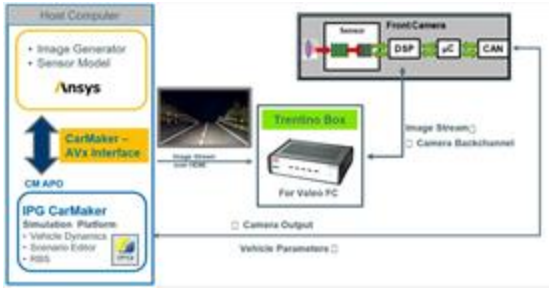
Initial version of **open loop rHIL**



Actual version of **open loop rHIL**

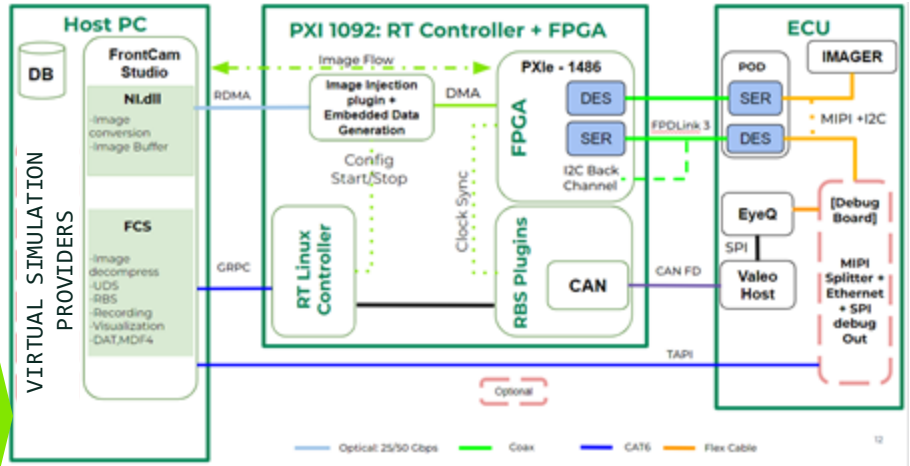


Initial version of **synt close loop HIL - OTA**



Actual version of
synt close loop HIL - Trentino

Direct Video Injection - all in one



- ⊕ One NI based Platform
- ⊕ High reusability and quick adoption for new projects
- ⊕ Ease of data re-use
- ⊕ Plugin architecture allows scalability
- ⊕ Sensor data & vehicle bus synch

Direct Video Injection is a single solution for several application

ADAS HIL Validation

Conclusions

Open / Closed Loop HIL Comparison

Three Different Architectures Compared

MXI Based HIL

- ⊕ Proven (50 HILs)
- ⊕ Simple architecture
- ⊕ Open & Closed Loop
- ⊖ No synchronization between camera / ULS / vehicle bus
- ⊖ IPC integration with the simulation engine

HDMI Based HIL

- ⊕ Simulation SW agnostic
- ⊖ Complex HDMI conversion
- ⊖ No synchronization between camera / ULS / vehicle bus
- ⊖ Cannot be reused as open loop replay HIL

RDMA Based HIL

- ⊕ NI latest architecture
- ⊕ NI support
- ⊕ Sensor data & vehicle bus synch
- ⊕ Open & Closed Loop
- ⊖ RDMA DLL integration in the simulation engine

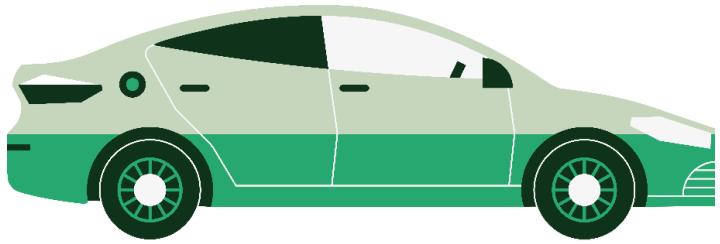
Valeo & NI Partnership: Center of Excellence

Pushing the Automotive Testing Boundaries Together

- Joint development of ADAS validation toolchain and customer deliverables for almost a decade
- Various modes of cooperation:
  - Collaborative research & development
  - Early Access Programme
  - NI engineering services
  - Turnkey validation system developed by NI
- Skills / SW / HW alignment and platform consistency are key to cover the challenging ADAS validation requirements
  - ✓ Valeo are confident that NI and NI PXI platform will allow us to keep the pace with the industry challenges and our customer's expectations in the future

Accelerating ADAS/AD Product Performance

One Single Platform for Record, Replay and Closed-Loop HIL



DATA RECORD SYSTEM AD

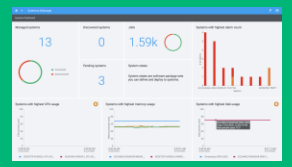
SIMULATION/MODELING

DATA CENTER
OR CLOUD

REPLAY/HIL SYSTEM

Accelerating ADAS Product Performance | Software Connected Workflow

Data and System Management

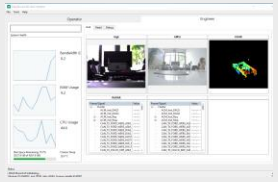


SystemLink™

DataLogging

SENSORS

Record



Data Record AD

LabVIEW™

PRE-PROCESS ROAD DATA

NI and Partners end-to-end solution

(KONRAD TECHNOLOGIES, SEAGATE, THIRD-PARTY SIMULATORS PROVIDERS)

ADAS ECU

Replay

TestStand™

Data Replay and HIL AD

VeriStand™

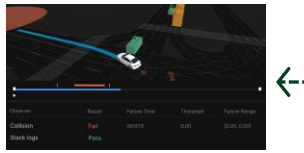
Validation

ADAS ECU

HIL

LabVIEW™

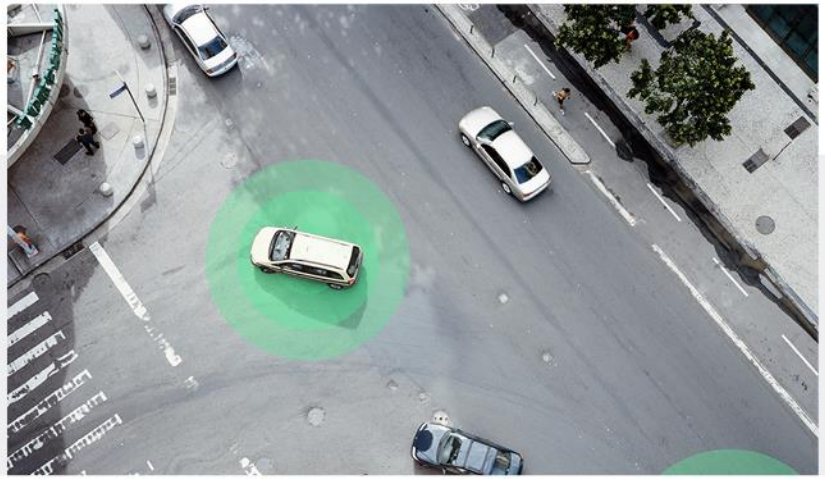
Third-party Simulators



WORLD SIMULATION

Have You Tested Automated Driving Functions Enough to Trust Your Loved Ones with Them?

Replacing the human driver promises more productivity, comfort, and safety, but uneasiness remains as failure puts lives and reputations at risk. This complex challenge requires testing against infinite real-world scenarios that you need to master.



1.3M TRAFFIC FATALITIES WORLDWIDE IN 2021[1]

~90% AUTOMOBILE CRASHES CAUSED BY HUMAN ERROR[2]

∞ NUMBER OF SCENARIOS TO BE CONSIDERED LEADING TO TESTING AGAINST THE UNKNOWN

$27B ADAS MARKET WORLDWIDE IN 2021[3]

$75B ADAS MARKET WORLDWIDE BY 2030[3]

~30% FUTURE IMPACT OF DATA SCIENCE AND AI/AV SOFTWARE JOBS TO THE AUTOMOTIVE BUSINESS[4]

NI Advantage for ADAS/AD Test: With an open, data-driven, and software-connected workflow powered by an ecosystem of experts, you can bring new and safer products to market faster and achieve the ultimate: saving lives.

The Right Partner to Get to Vision Zero, Faster.

NI is transforming test through software and helping customers turn data and analytics into actionable insights. The result: better product performance.

500% INCREASED ADAS SENSOR VALIDATION THROUGHPUT

~95% ALL DATA ANALYZED

50% REDUCED DELIVERY SCHEDULES

20% FASTER DEVELOPMENT CYCLES THROUGH DIGITAL TESTING

~96% ACCURACY IN PREEMPTIVELY DETECTING FAULT SENSORS

[1]SOURCE: UN NEWS [2]SOURCE: NHTSA [3]SOURCE: RESEARCH AND MARKETS [4]SOURCE: KPMG

NI Innovation Centers Around the Globe