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The Evolution of ADAS – Testing Systems that Include Cameras, Radar, and Sensor Fusion

Smarter Test for Smart Vehicles

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CEO, Konrad GmbH

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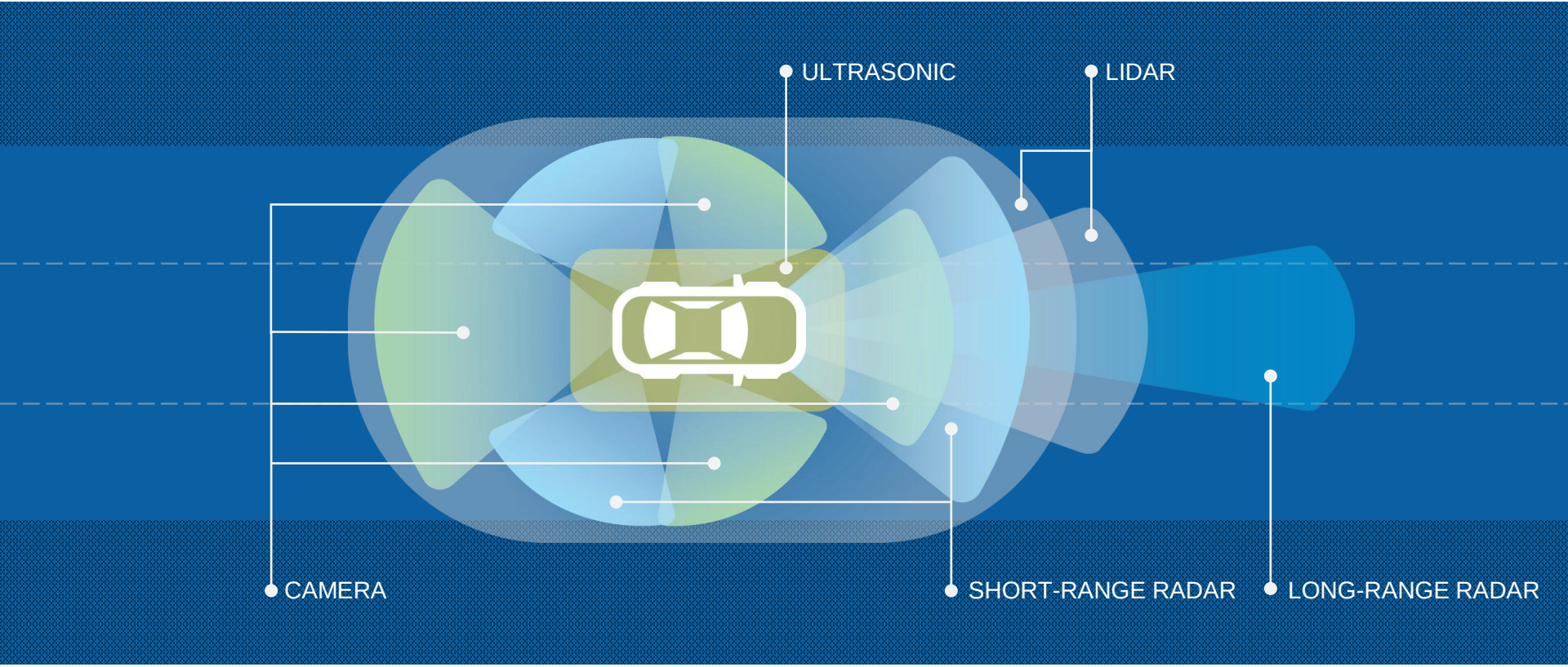
Account Manager, National Instruments

Major ADAS Sensor Types and Applications



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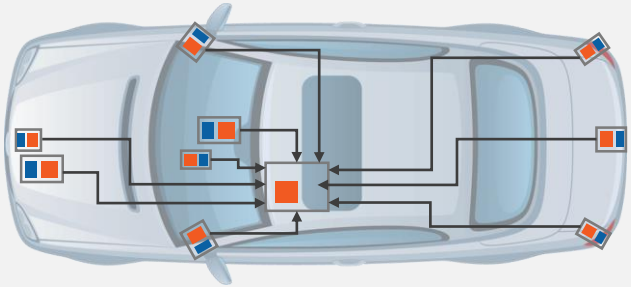
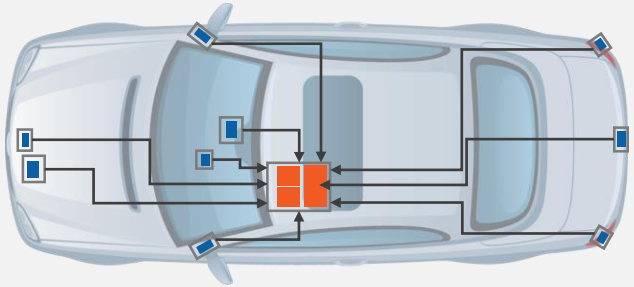
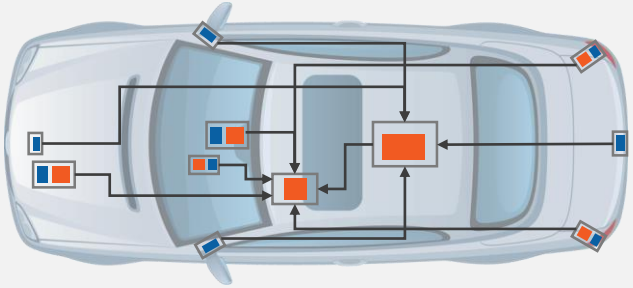
ADAS Architectures Continue to Evolve



SMART SENSORS/DECENTRALIZED PROCESSING



RAW SENSOR DATA/CENTRALIZED PROCESSING



HYBRID SENSOR/PROCESSING

Sensor

Electronic Control Module (ECM)

Source: electronics-eetimes

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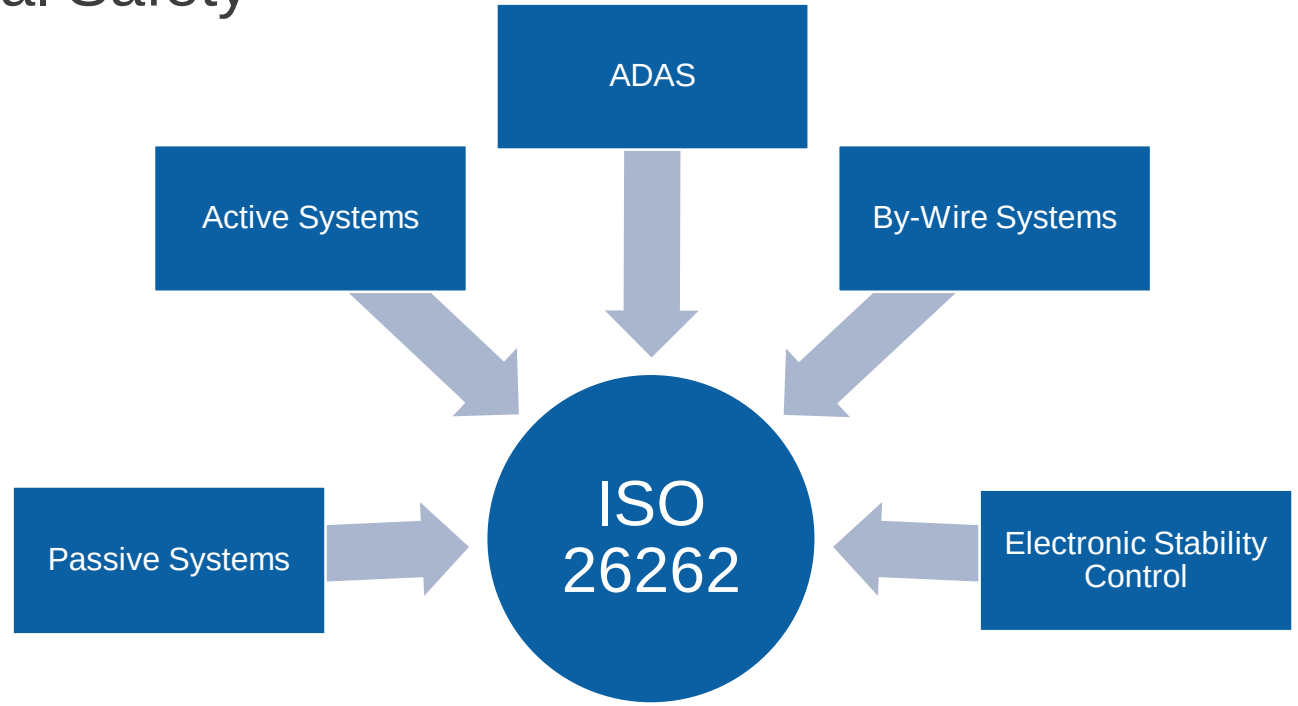
Functional Safety

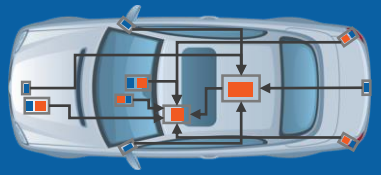
ISO 26262



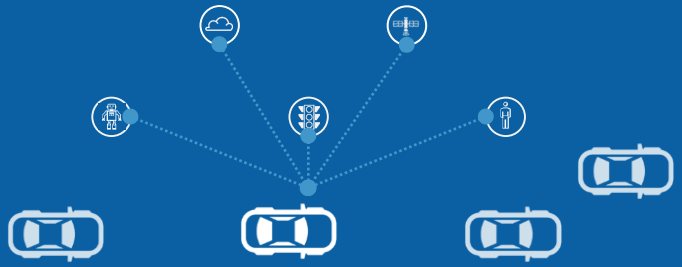
All interactions between systems of systems must be known and tested to determine how errors propagate across system and subsystem boundaries.

Testing ADAS and the Autonomous Vehicle

SENSOR



CAR



CONNECTED CAR WORLD

Characterization

Validation

Software (HIL)

Track and Road

Production

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Approaches to Test and Measurement

CLOSED

- “Vendor knows best”
- Fixed functionality
- Closed ecosystem
- Customer pays

PLATFORM

- “Customer knows best”
- Customizable solution
- Open, vibrant ecosystem
- Customer designs

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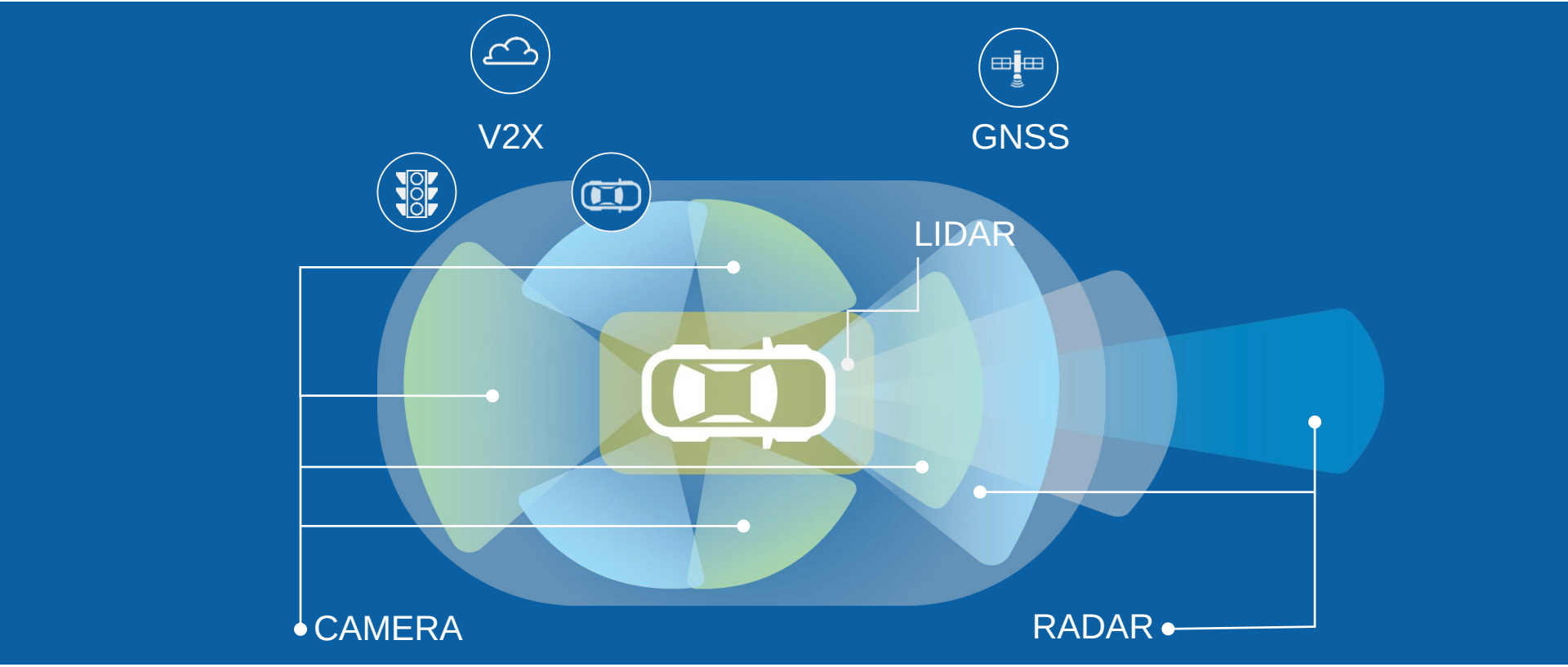
ADAS iiT Consortium of Partners

Major ADAS Technologies



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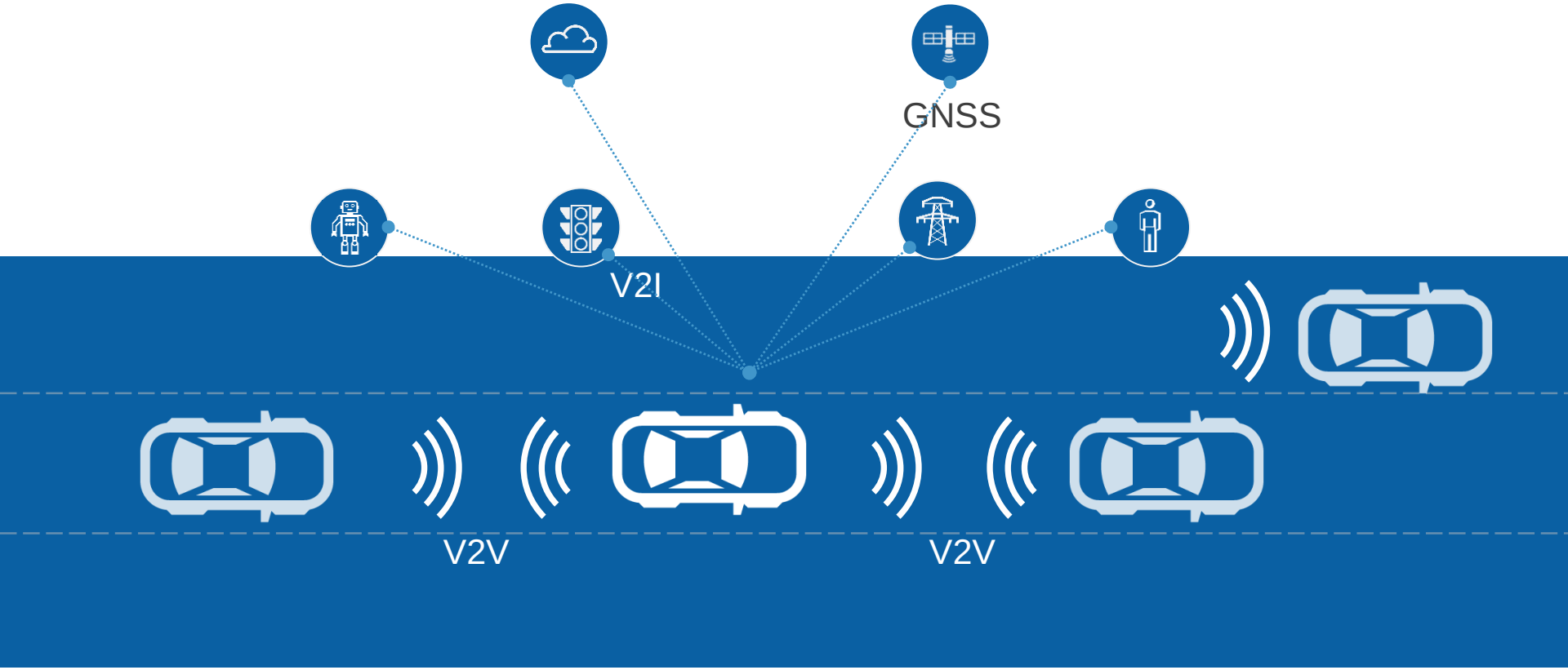
Communications and Positioning

V2X and GNSS

The Connected Car



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V2V and V2I Communications With 802.11p and LTE

IEEE 802.11p (DSRC)

- Referred to as Direct Short-Range Communication (DSRC)
- Uses unlicensed spectrum in 5.9 GHz band
- Based on half-clocked IEEE 802.11a/g with 10 MHz channel bandwidth
- Effective Tx-Rx velocity differences of up to 200 km/hr
- Supports only V2V communication

LTE V2X (Cellular V2X)

- Part of 3GPP Release 14; targeted for 2017
- Uses existing licensed LTE spectrum and infrastructure
- Bandwidth configurations up to 10 MHz
- GNSS-based symbol synchronization
- Supports both V2V (PC5) and V2I (Uu) modes

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NI's Approach for Integrating Other Standards

Flexible measurement IP from GSM to Wi-Fi

Partner IP	
WLAN (802.11a/b/g/n/ac)	GSM/EDGE
Bluetooth	WCDMA/HSPA+
GPS Generation	CDMA2k
FM/RDS Generation	LTE/LTE-A (TDD & FDD)

Wireless measurement algorithms execute on PXI controllers and reconfigurable FPGAs.

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Current V2X Solutions

ECU Test Platform

S.E.A.

RF Quality Testing

Danlaw Mx-DSRC

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StellaNGC

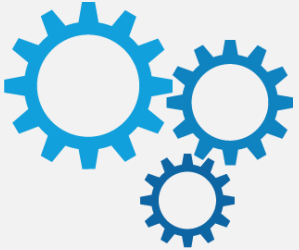
Hardware

Includes NI PXI instruments for flexible and scalable solutions;
exact configuration is determined based on customer needs

Software

Supports multiconstellation and multifrequency simulations
- GPS
- GLONASS
- GALILEO
- (Optional) QZSS, BEIDOU

Support and Services



Provides system integration to deliver complete end-to-end solutions

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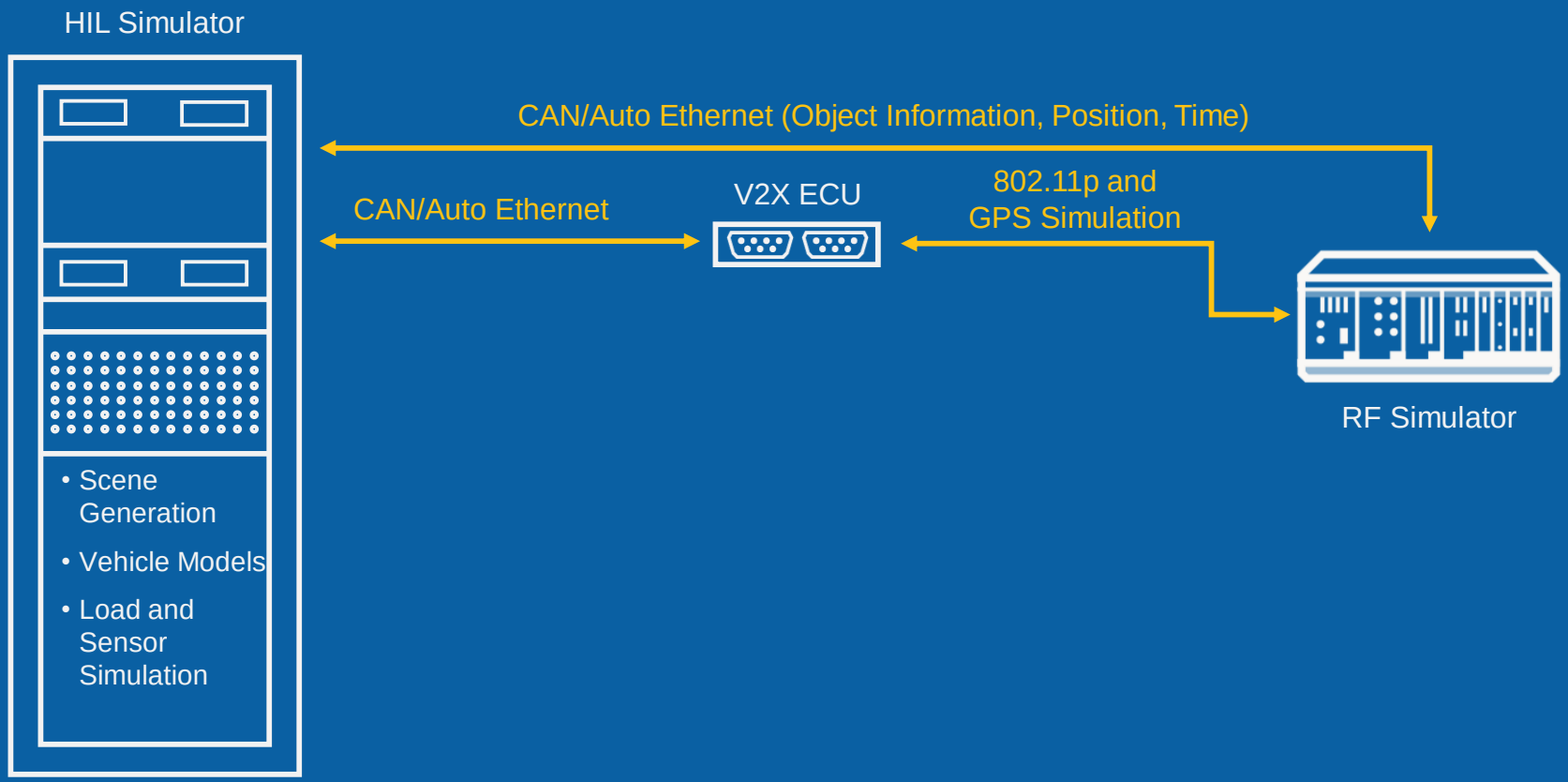
HIL Simulator
CAN/Auto Ethernet (Object Information, Position, Time)
CAN/Auto Ethernet
V2X ECU
802.11p and
GPS Simulation
RF Simulator
• Scene Generation
• Vehicle Models
• Load and Sensor Simulation

Radar

Trends in Automotive Radar

Focus on Safety

- Object identification/distinction
- Rear-end crash avoidance
- CAR2X (Car 2 Car and Car 2 Infrastructure Communication)
- 360 degrees vehicle surveillance

Adoption of 77–81 GHz

- More reliability and more accuracy
- Greater capability of distinguishing objects with high bandwidth
- Smaller footprint (multimode, multirange)

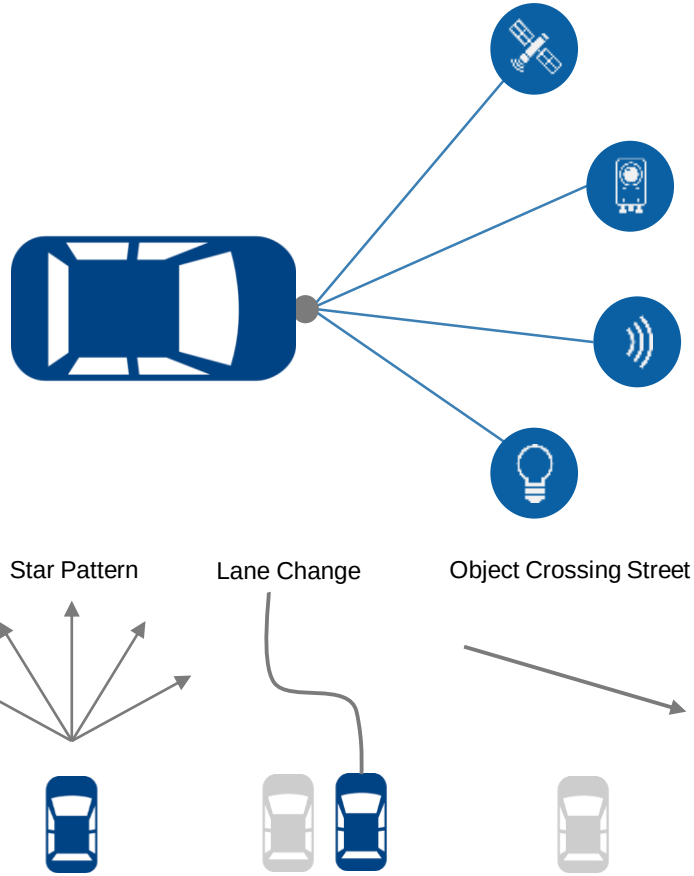

Image from http://www.wykop.pl/link/2349196//

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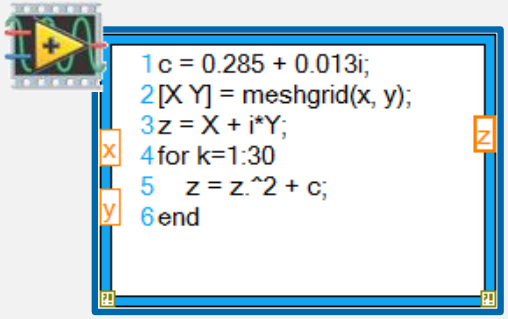
Benefits and Trade-Offs of Each Approach

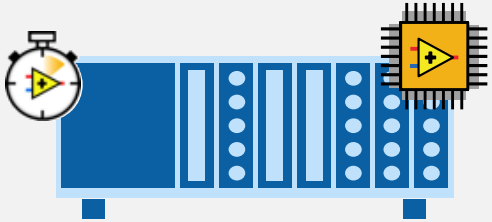
Simulation

- Uses software-only techniques
- Lowers setup complexity
- Does not truly emulate real-world behavior



Emulation

- Uses hardware-in-the-loop (HIL) techniques
- Allows the emulation of real-world scenarios
- Scales for future applications
- Requires knowledge of both hardware and software



Field Test

- Offers true real-world test
- Is difficult to set up and scale
- Limits test case coverage due to time and space complexity

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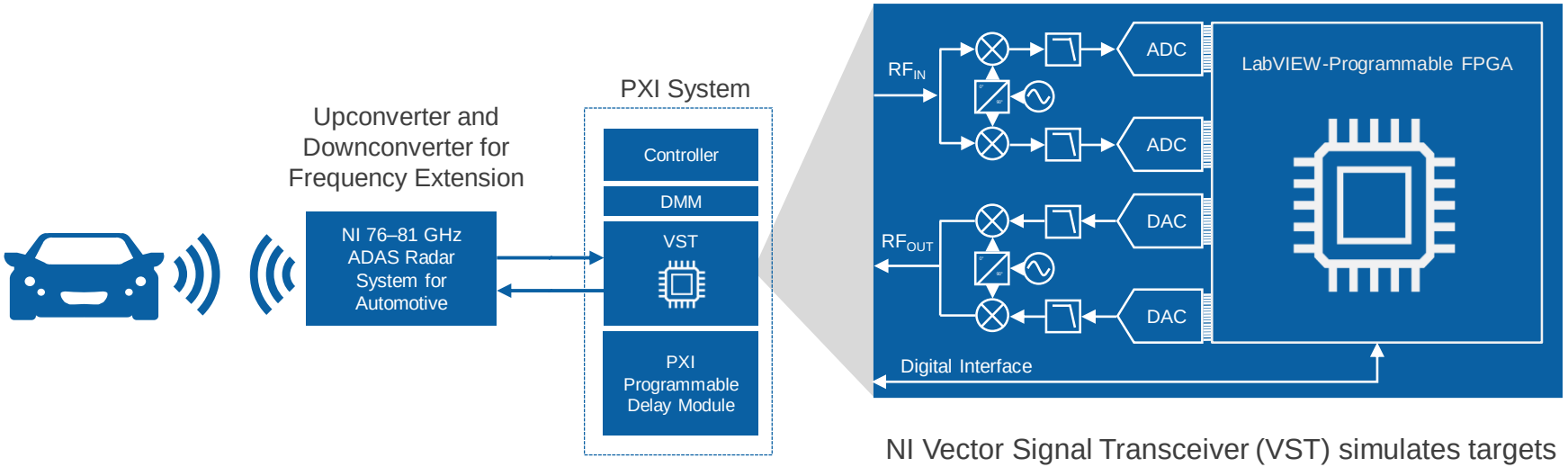
Block Diagram of Active Radar Target Simulator



NI Vector Signal Transceiver (VST) simulates targets using LabVIEW FPGA-based signal processing

- Doppler shift via Tx-to-Rx frequency offset
- Distance to target via delay
- Multiple targets

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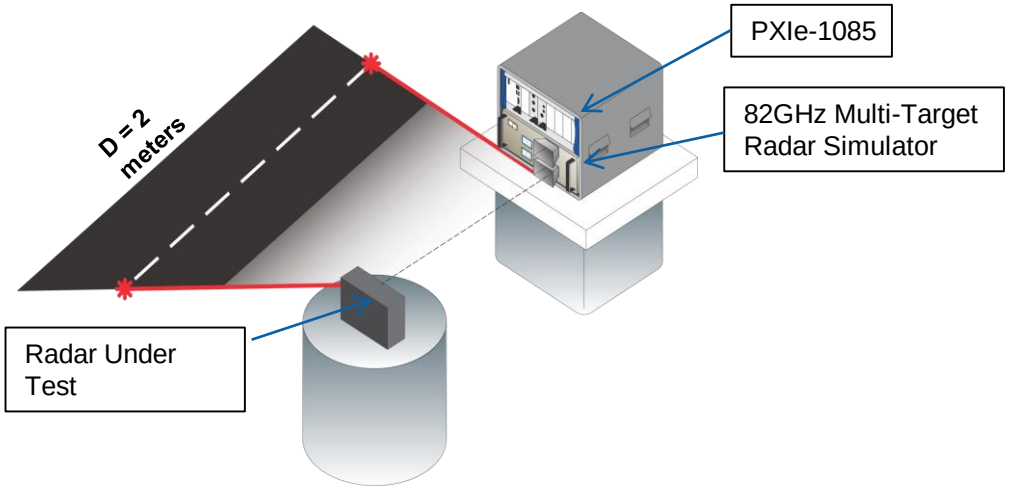
NI Vehicle Radar Test System (VRTS)

Key Features

- RF Measurements for sensor performance verification
  - Signal Analysis: EIRP, noise, beam width, frequency
  - Chirp Analysis: linearity, overshoot, recording, tagging
- RADAR Target simulator for sensor functional verification
  - Single and multiple targets
  - Fixed and variable distance
  - Multiple object scenarios (distance, velocity, size and angle of arrival)
- Customizable target scenarios



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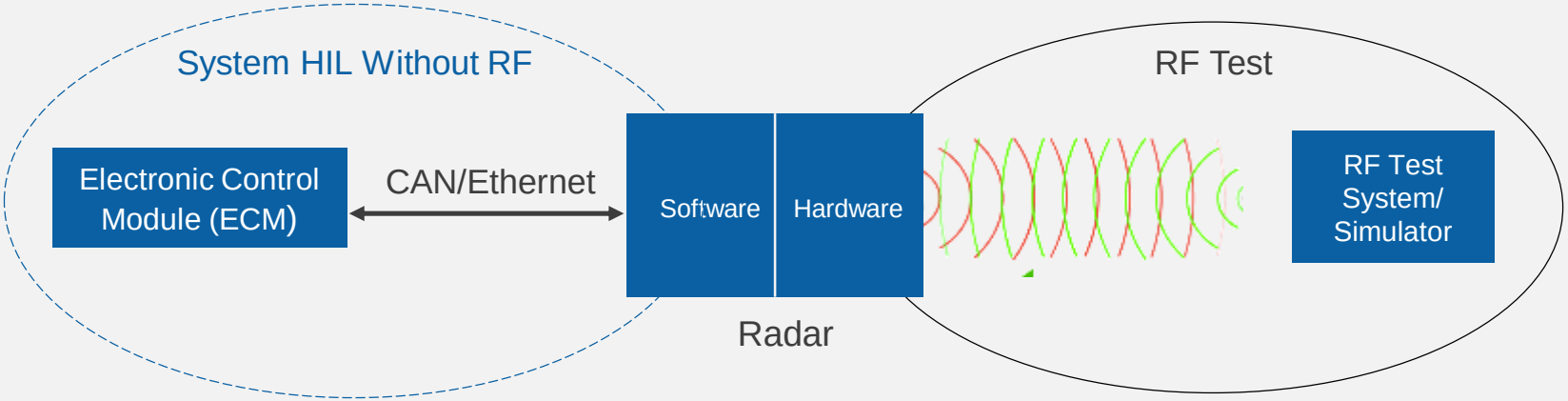
Automotive Subsystem Test Cases



“With the PXI Vector Signal Transceiver, the combination of the industry’s widest bandwidth and low latency software has allowed us to discover our automotive radar sensors as never before.”

—Niels Koch, Audi

Audi

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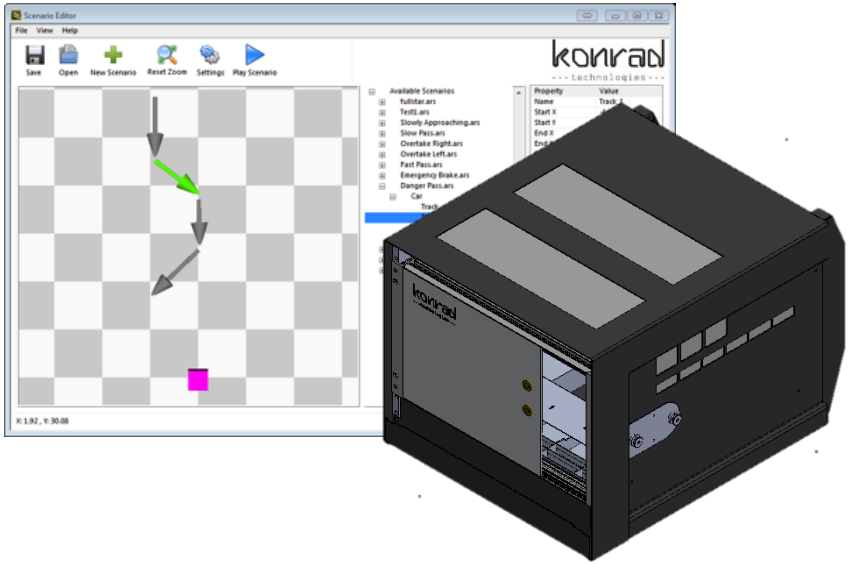
ni.com/smarter-test

Konrad

77 GHz Radar Target Simulator



System Features

- Konrad ABex Production System uses NI ADAS Test System
- 19 in. 6HE rack, all electronics, and RF components integrated in one box
- Antenna blind mate connectors for remote antenna connection

Scenario Editor Software

- Supports creation of custom scenario generation and tracks
- Simulates various radar environments with sequence tracks

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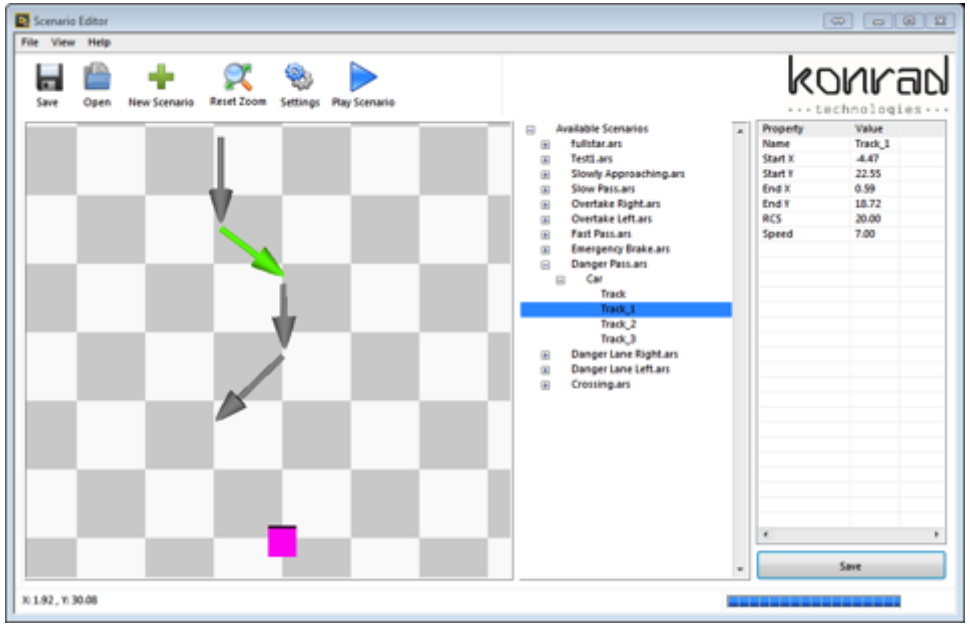
konrad technologies

ni.com

Automotive Radar - Target Simulator

76GHz to 82GHz KT VRTS (Virtual Radar Target Simulator) with KT GUI and motion controller.



Verification of Hard- and Software for new Radar Sensors.

Verification of location in the car.

Based on National Instruments RF Hardware. The Konrad Technologies editor allows the user to develop complex scenarios which can be automatically replayed.

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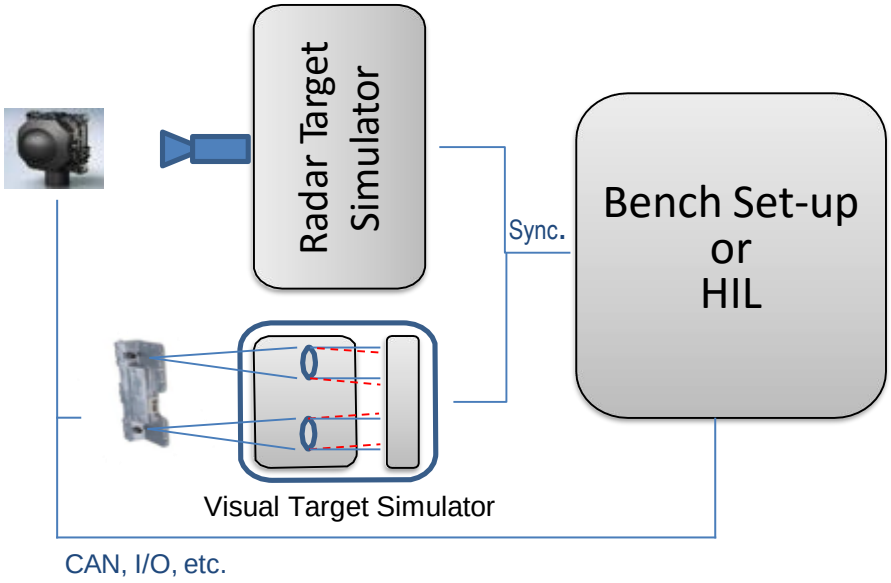
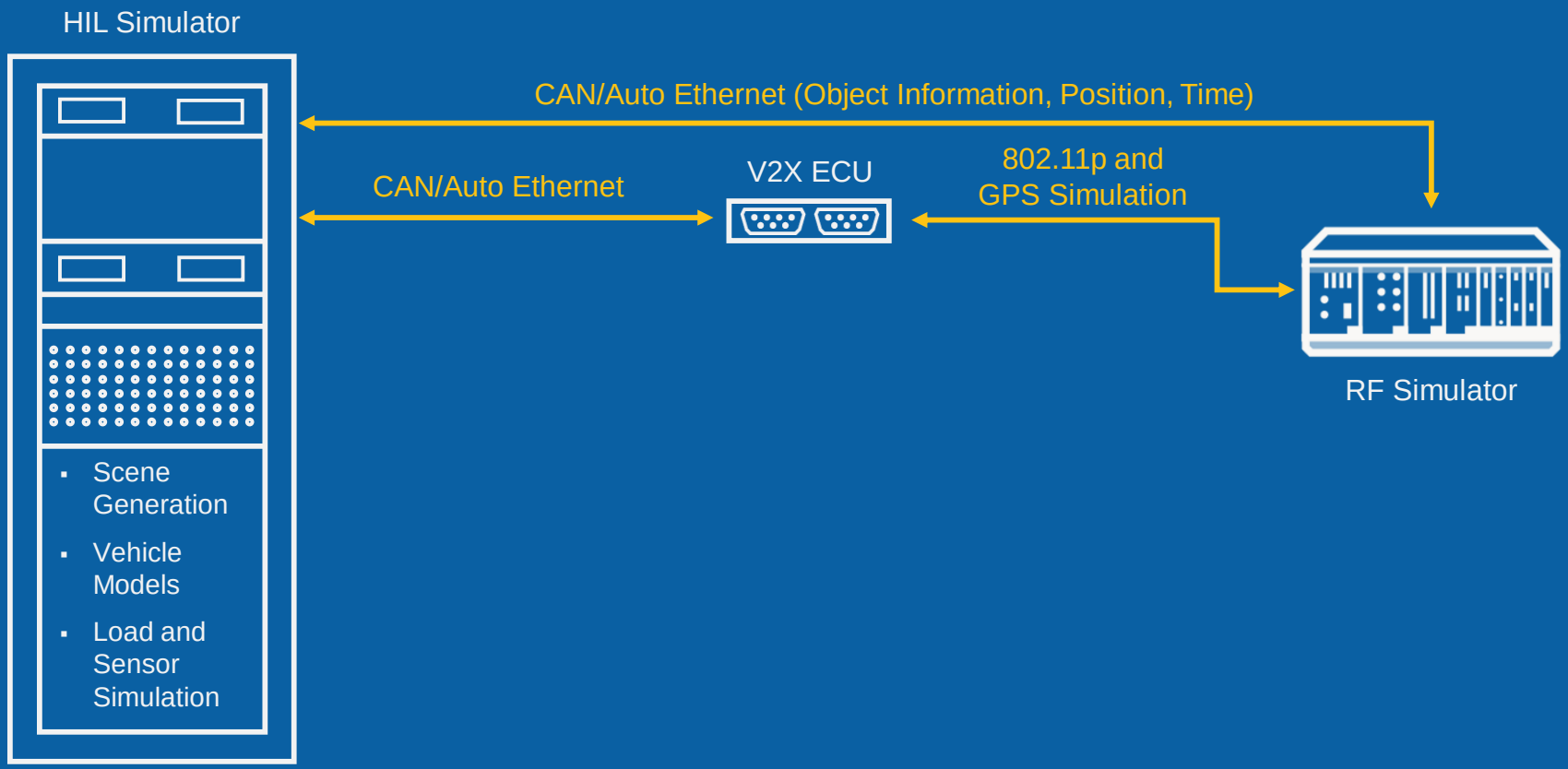
ADAS Target Simulator

- Synchronized Target Generation
- Synchronized CAN
- Synchronized additional I/Os

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RF Simulator
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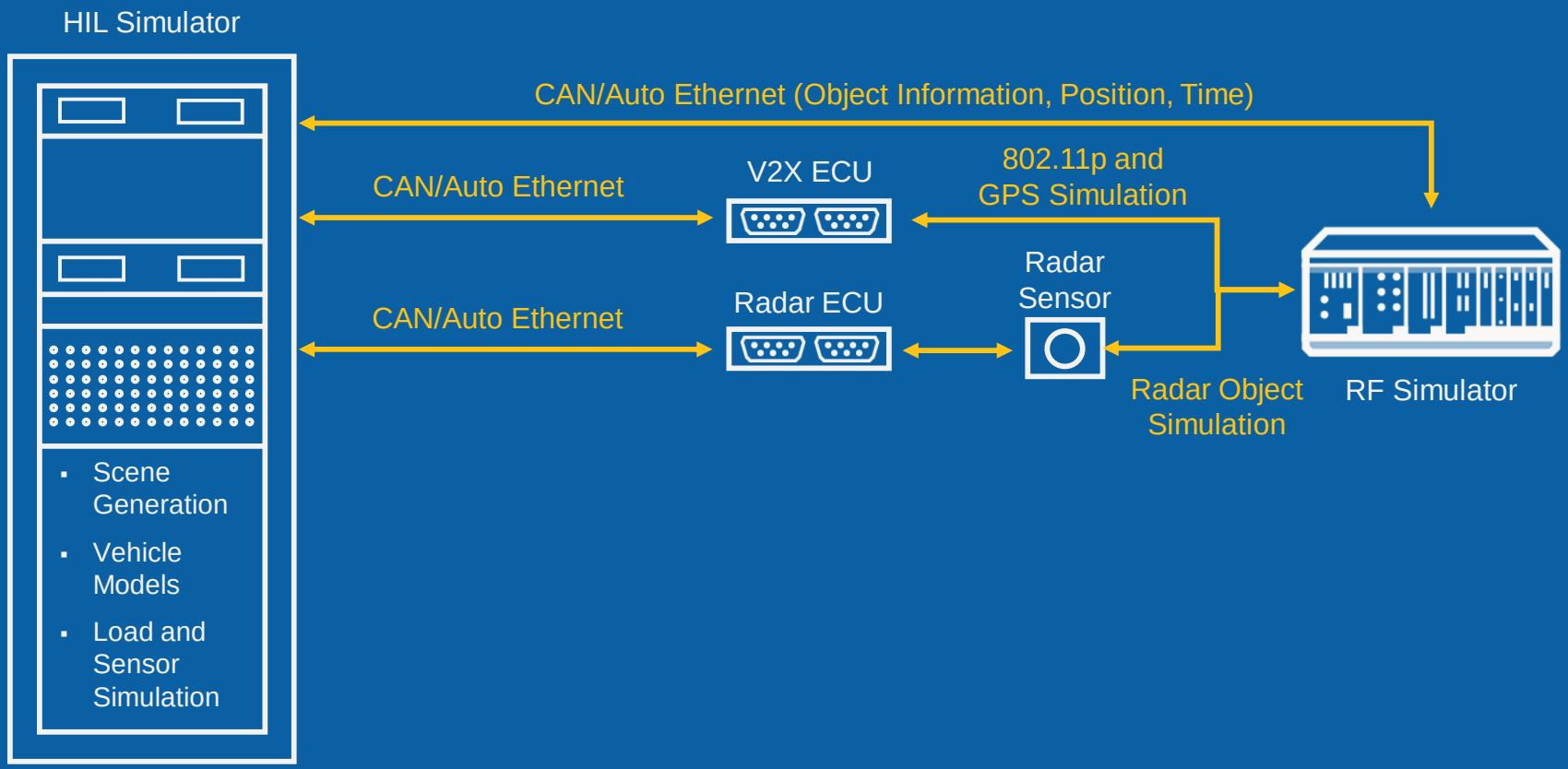
Vehicle Models
Load and Sensor Simulation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Radar
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Radar Object
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Camera

Challenges of Camera Test

Increasing Number of Cameras

Properly Simulating Conditions

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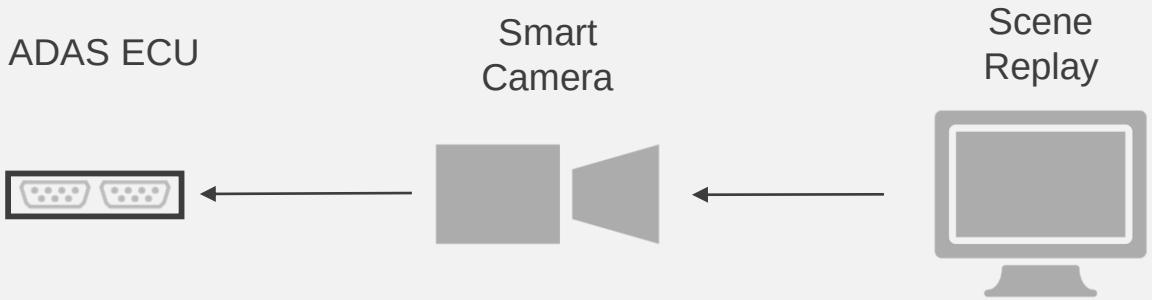
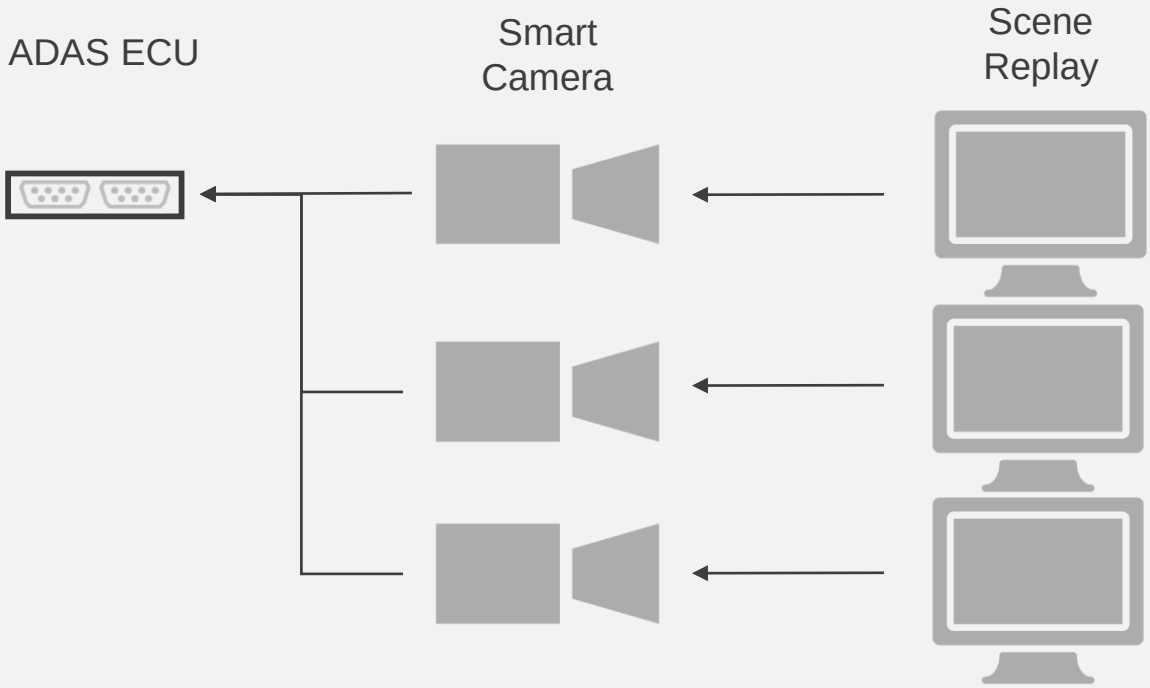
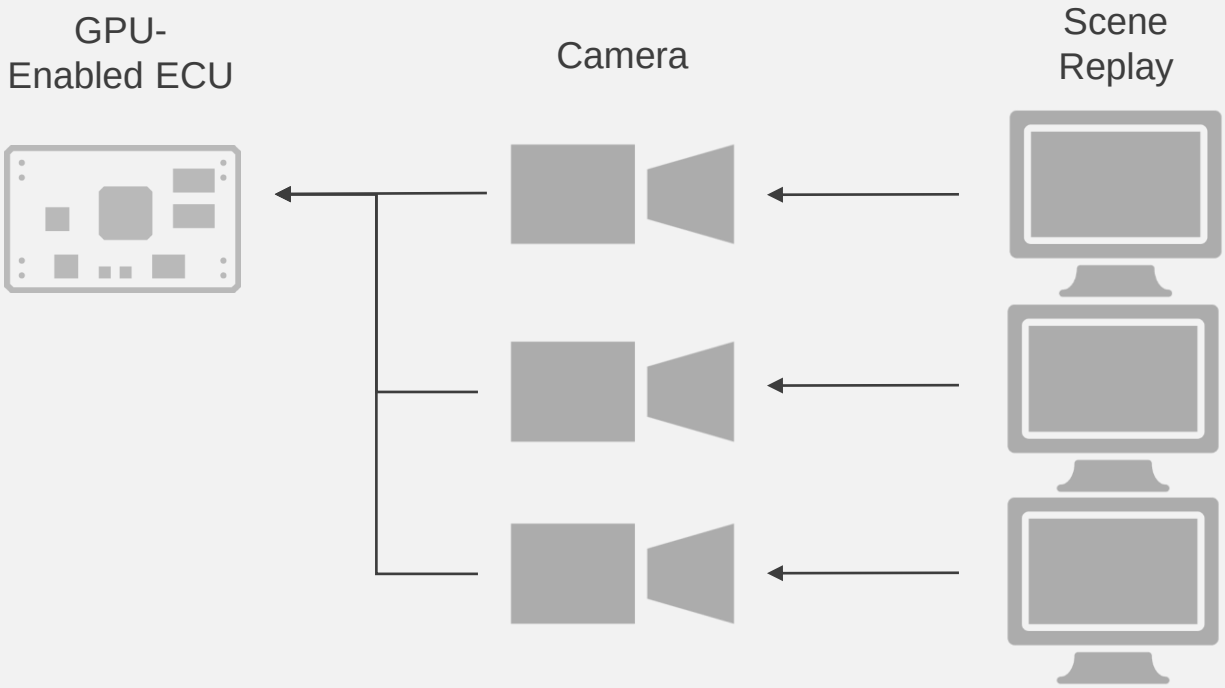
Approaches to Camera Test



Approaches to Camera Test



Approaches to Camera Test



Approaches to Camera Test

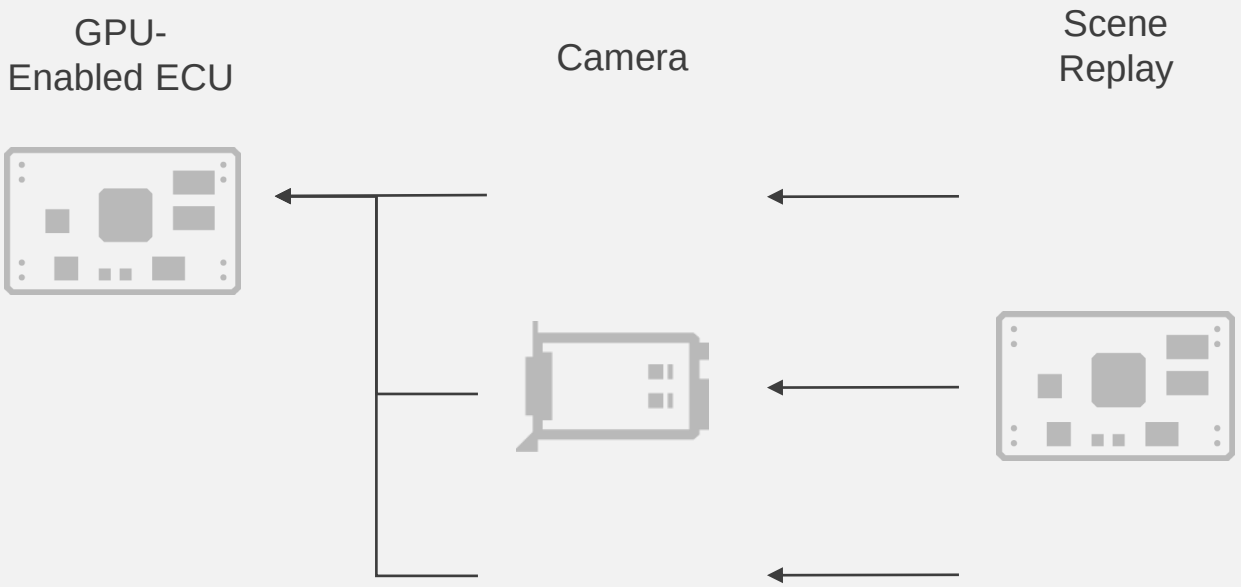


Image Manipulation With FPGA

Dropped Frames or Frame Delay

Noise and Error Injection

Bitstream Manipulation

Custom Protocols

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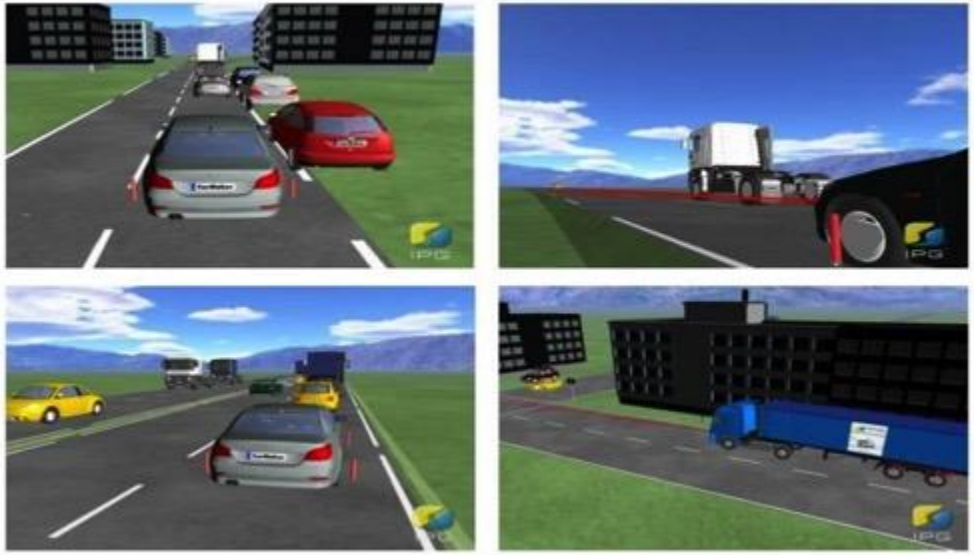
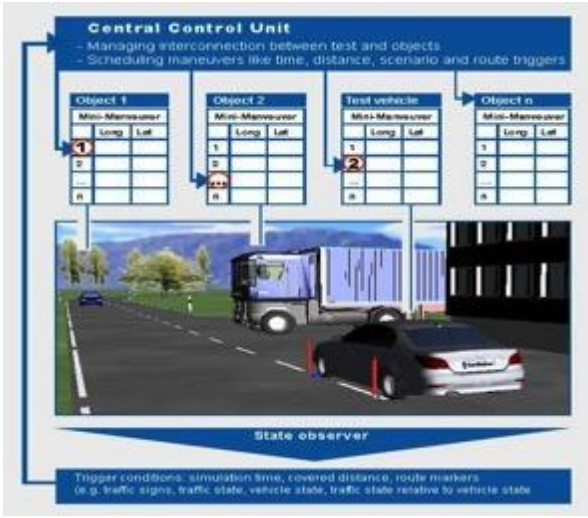
ADAS - How does Simulation SW help us





Simulation software provides camera target simulation on software level

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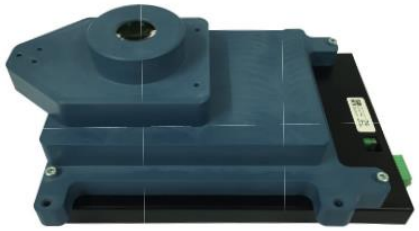
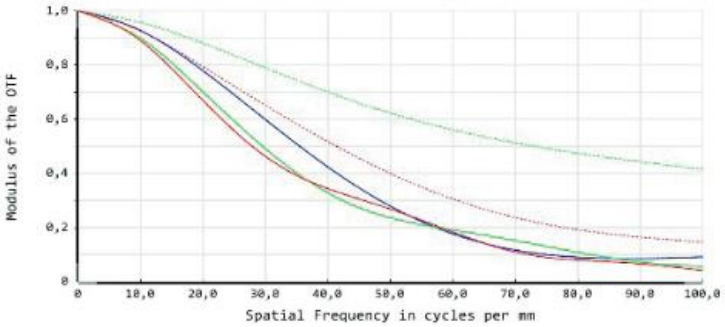
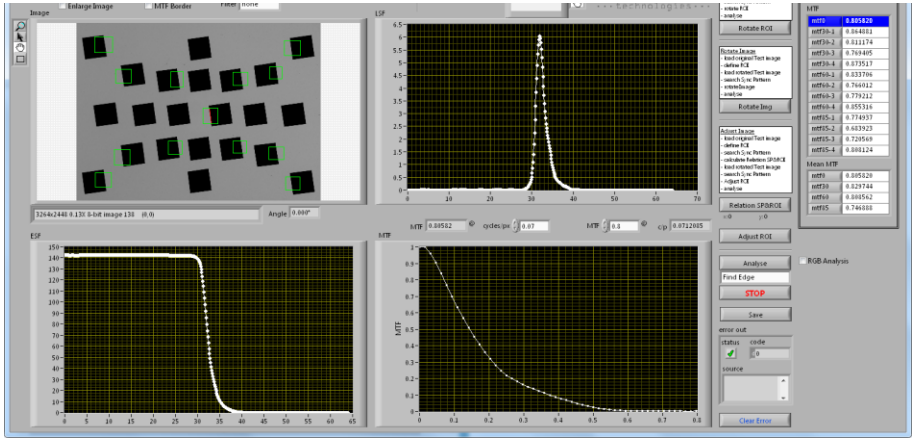
Camera Target Simulator

- Finite-Infinite MTF test
- Short DUT – Target distance
- Controlled LED back light
- Rotation
- XY
- Low distortion lens package







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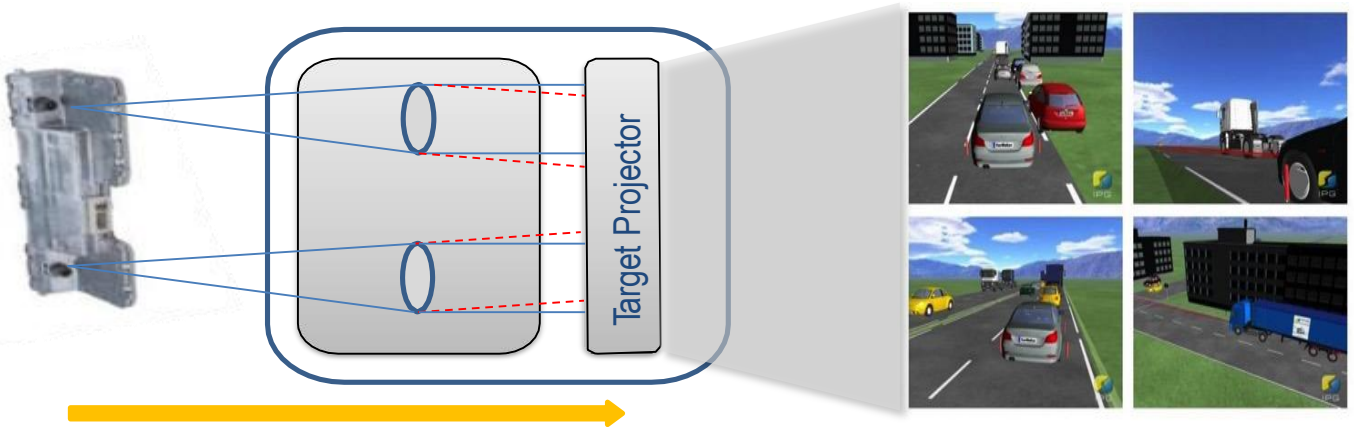
INNOVATION IN TEST

SET konrad technologies s·e·a measX Measurement System Experts

Camera Target simulator

Target Generator



Distance range adjustable (3D)

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Camera Target Simulator

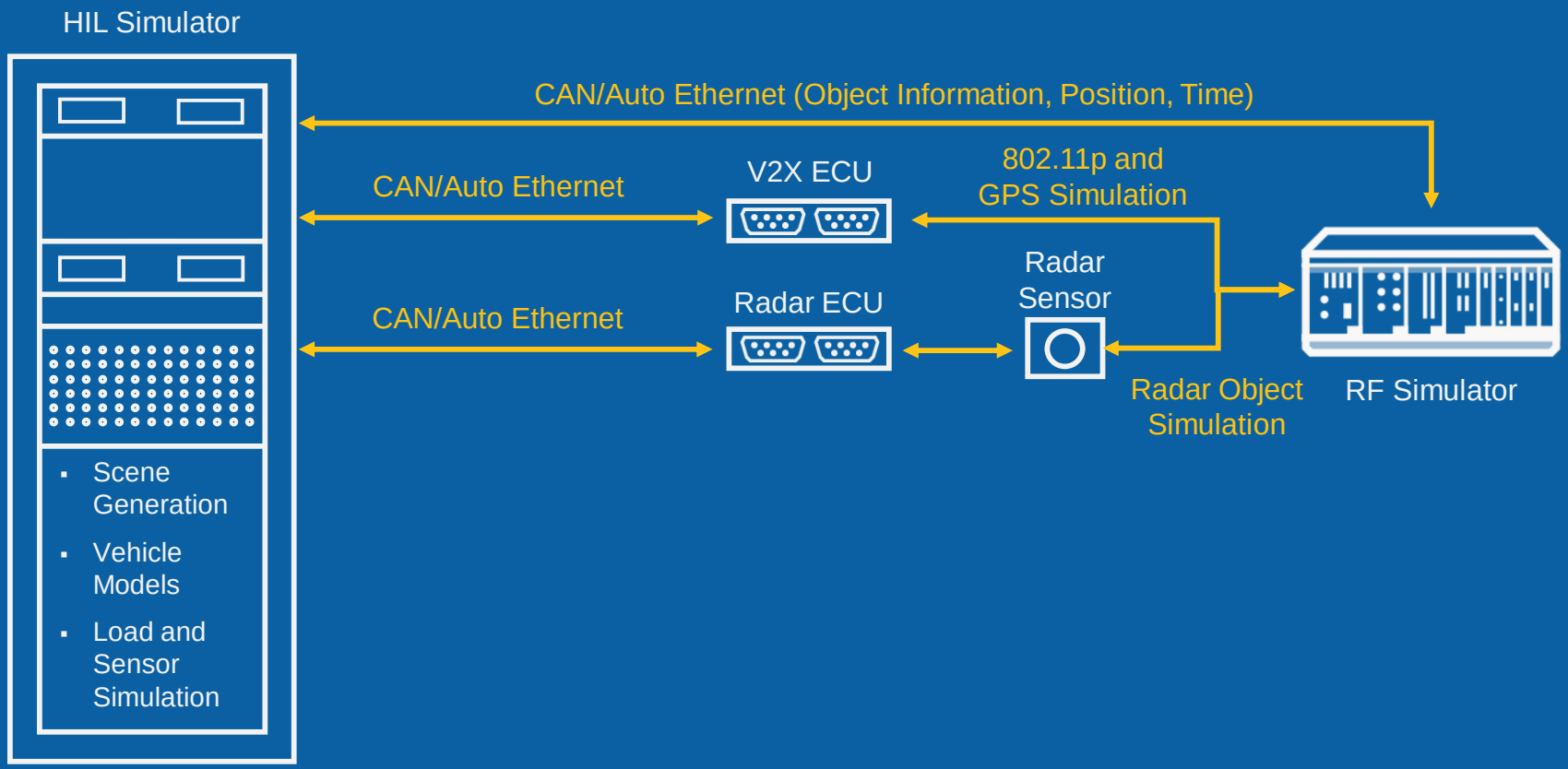
Advantages

- Optical design inside of target

  projector transfers the image focus

  into infinite range
- Camera distance to projector minimized

  to 5 cm
- System can be used on engineering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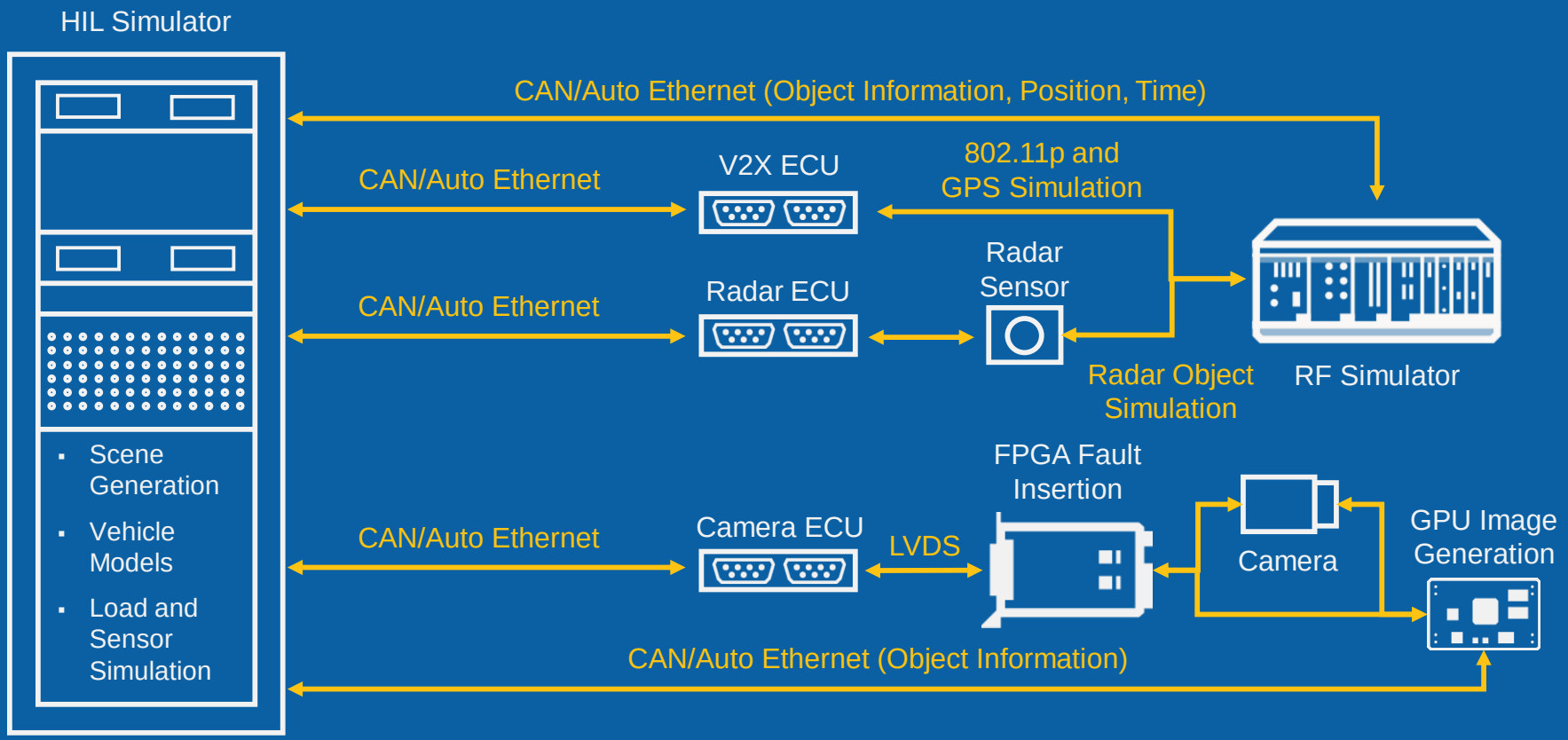
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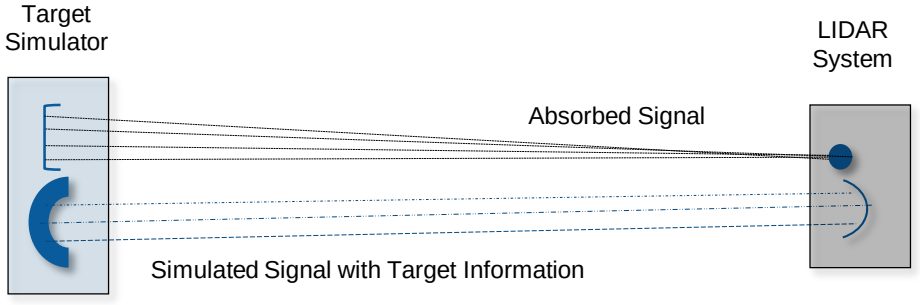
Load and
Sensor
Simulation
FPGA Fault
Insertion
CAN/Auto Ethernet
Camera ECU
LVDS
Camera
GPU Image
Generation
CAN/Auto Ethernet (Object Information)

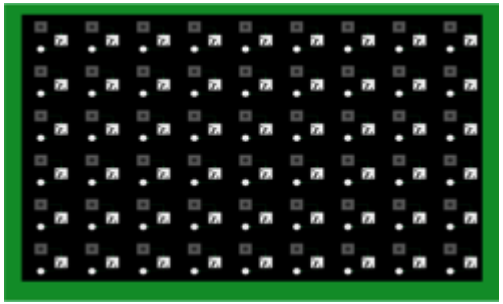
LIDAR

Automotive LIDAR - Target Simulator

LIDAR Target Simulator for
Distance, Velocity, Angle of Approach

- Signal Detection of LIDAR system
  - Signal absorption
  - Synch Trigger
- Generated Target Signal via
  - Laser Diode Array or
  - Rotating Laser
    with Angle Synchronization





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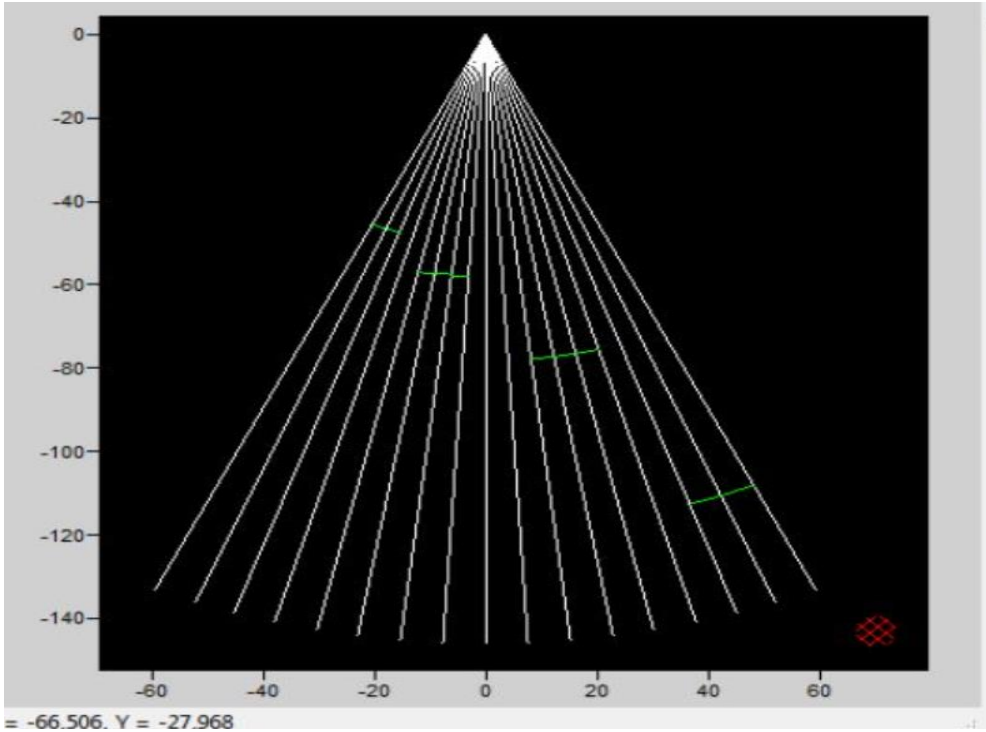
Automotive LIDAR - Target Simulator

LIDAR Target Simulator



Raw Detections

Min Amplitude: 0,0

Max Amplitude: 1024,0

Min Distance: 0,0

Max Distance: 200,0

☑ 1	☑ 9		
☑ 2	☑ 10		
☑ 3	☑ 11		
☑ 4	☑ 12		
☑ 5	☑ 13		
☑ 6	☑ 14		
☑ 7	☑ 15		
☑ 8	☑ 16		

☐ Freeze

Seg	Distance	Amplitude	Flags
1	118,359	7,8	1
2	118,395	0,8	65
4	78,461	2,3	1
5	78,482	3,0	1
6	78,530	1,6	1
10	58,002	2,4	1
11	58,046	4,4	1
12	57,976	2,4	1
15	49,840	2,1	1
16	49,840	3,2	1

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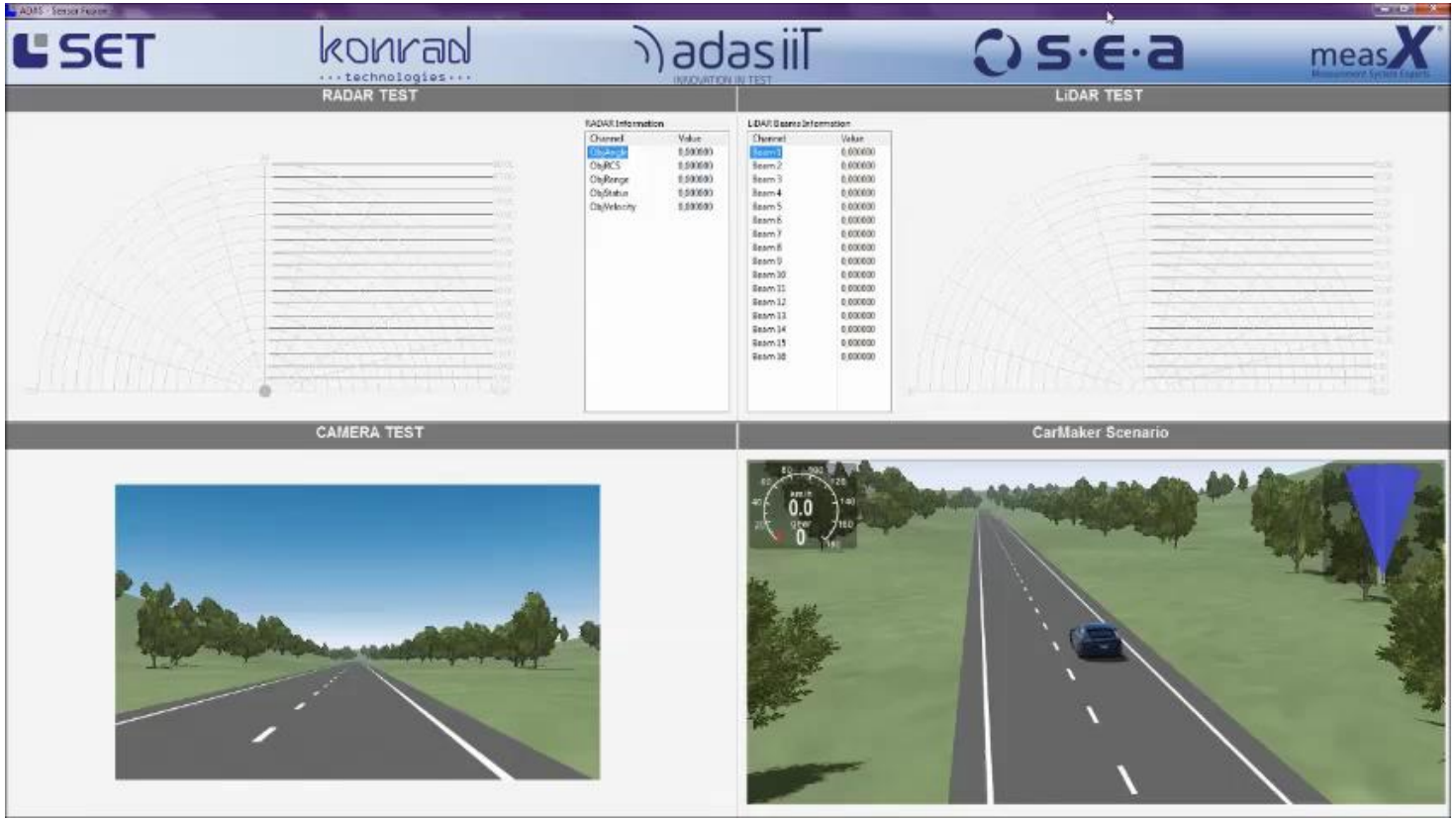
Combined ADAS HIL Simulation



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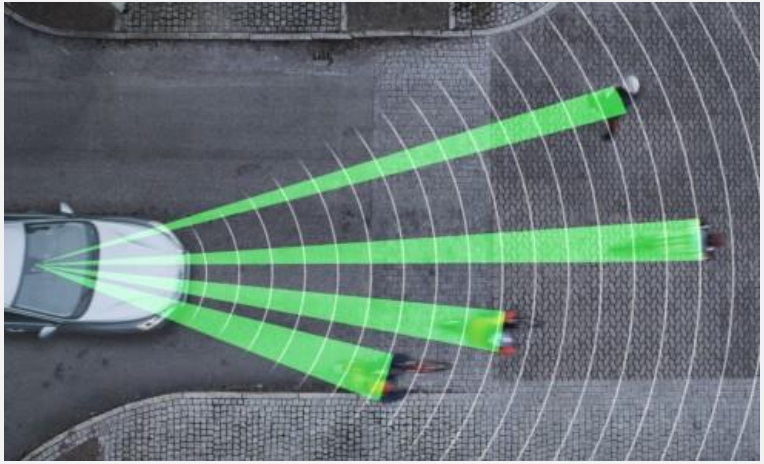
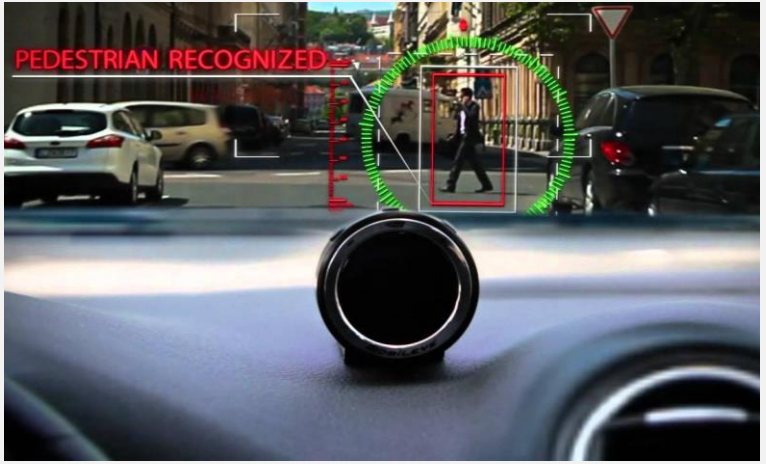
Sensor Fusion

Cameras and Radar Working Together



Object Detection Using Radar



Object Classification Using Cameras

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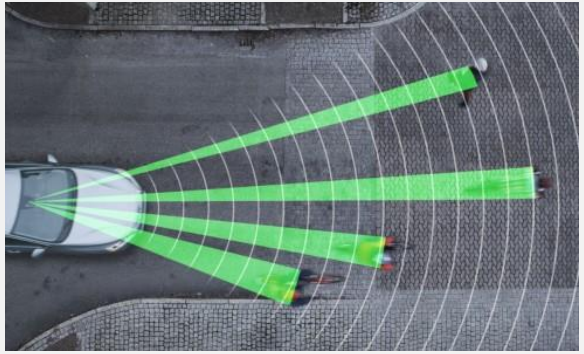
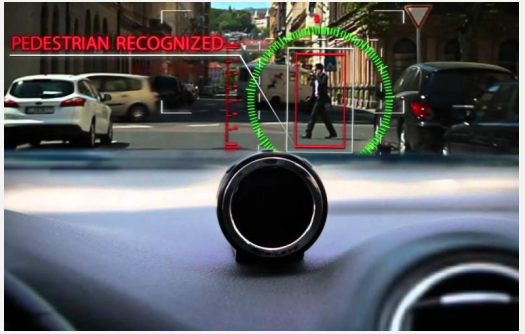
Cameras and Radar Working Together



Object Detection Using Radar

Synchronization



Object Classification Using Cameras

ADAS ECU for Safety Operations

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Testing Sensor Fusion Embedded Software

Radar Target Emulation

Video Stream Manipulation

ADAS ECU for Safety Operations

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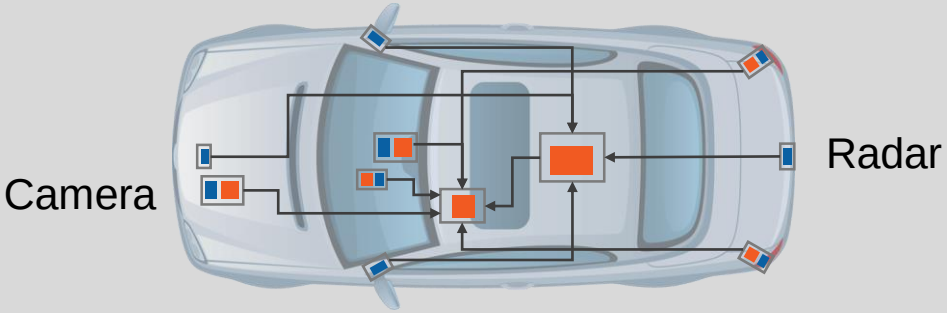
Hardware-in-the-Loop Test

CAN Interface

GNSS Simulation

Radar Target Simulation

Image Simulation



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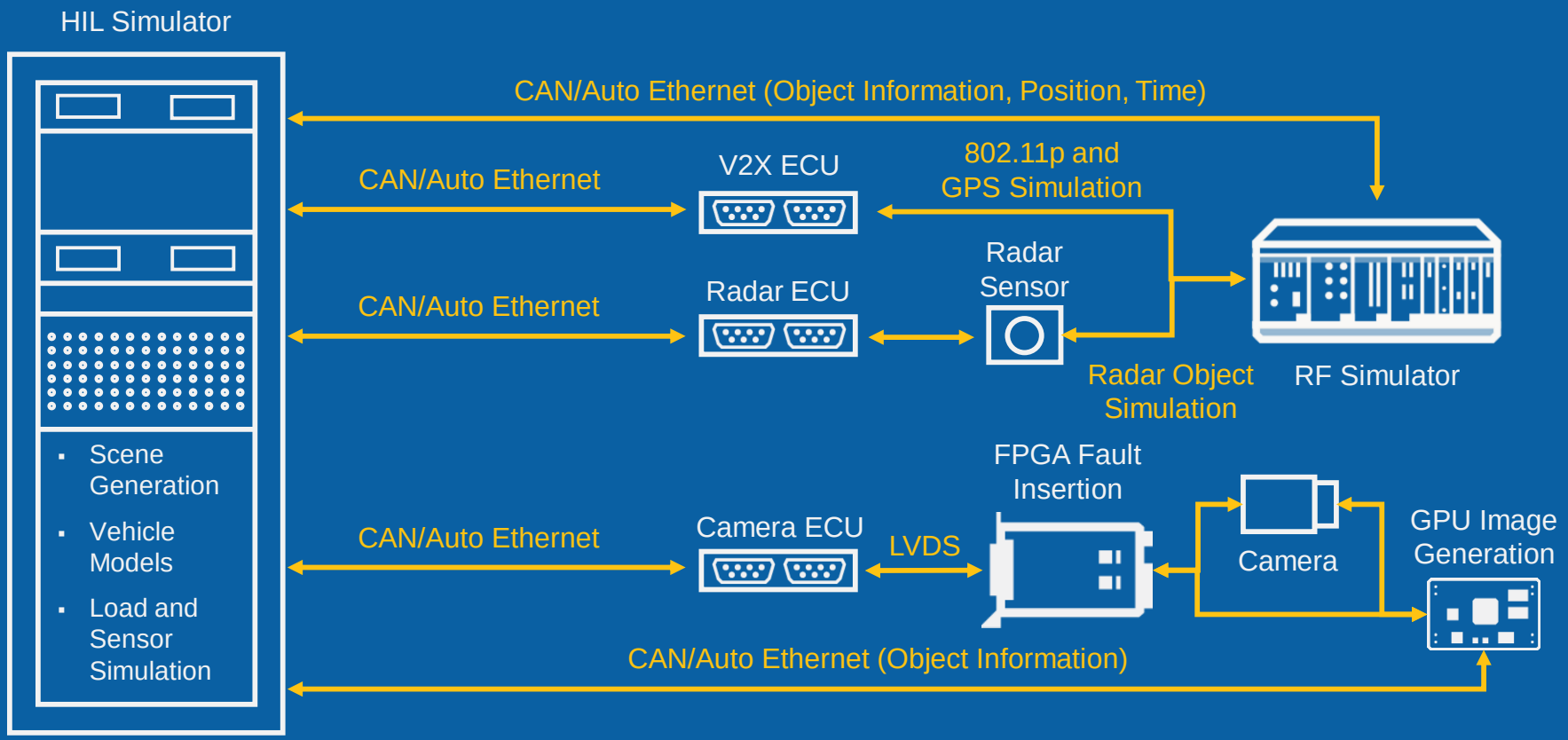
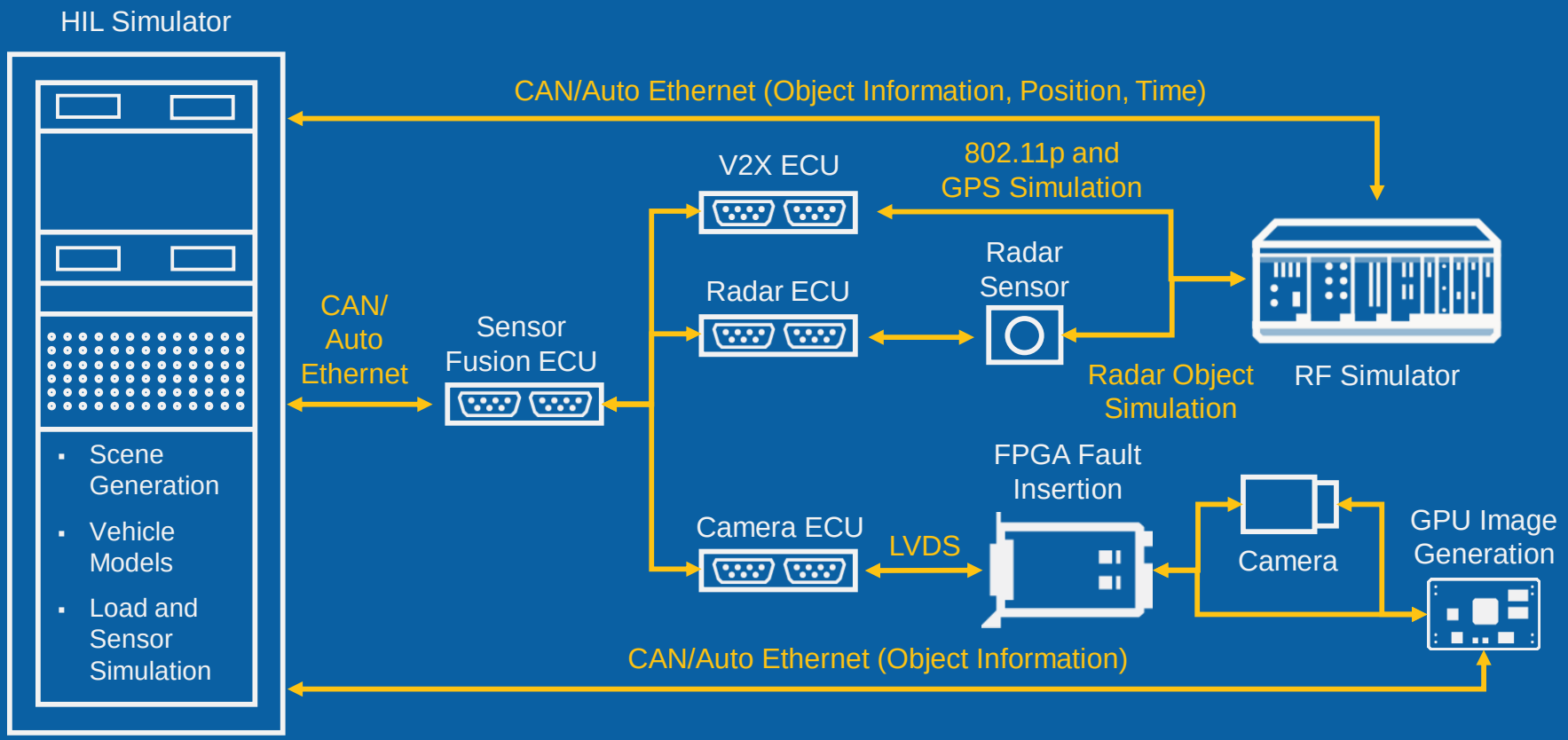

HIL Simulator
CAN/Auto Ethernet (Object Information, Position, Time)
CAN/Auto Ethernet
V2X ECU
802.11p and
GPS Simulation
CAN/Auto Ethernet
Radar ECU
Radar
Sensor
Radar Object
Simulation
RF Simulator
Scene
Generation
Vehicle
Models
Load and
Sensor
Simulation
FPGA Fault
Insertion
CAN/Auto Ethernet
Camera ECU
LVDS
Camera
GPU Image
Generation
CAN/Auto Ethernet (Object Information)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