







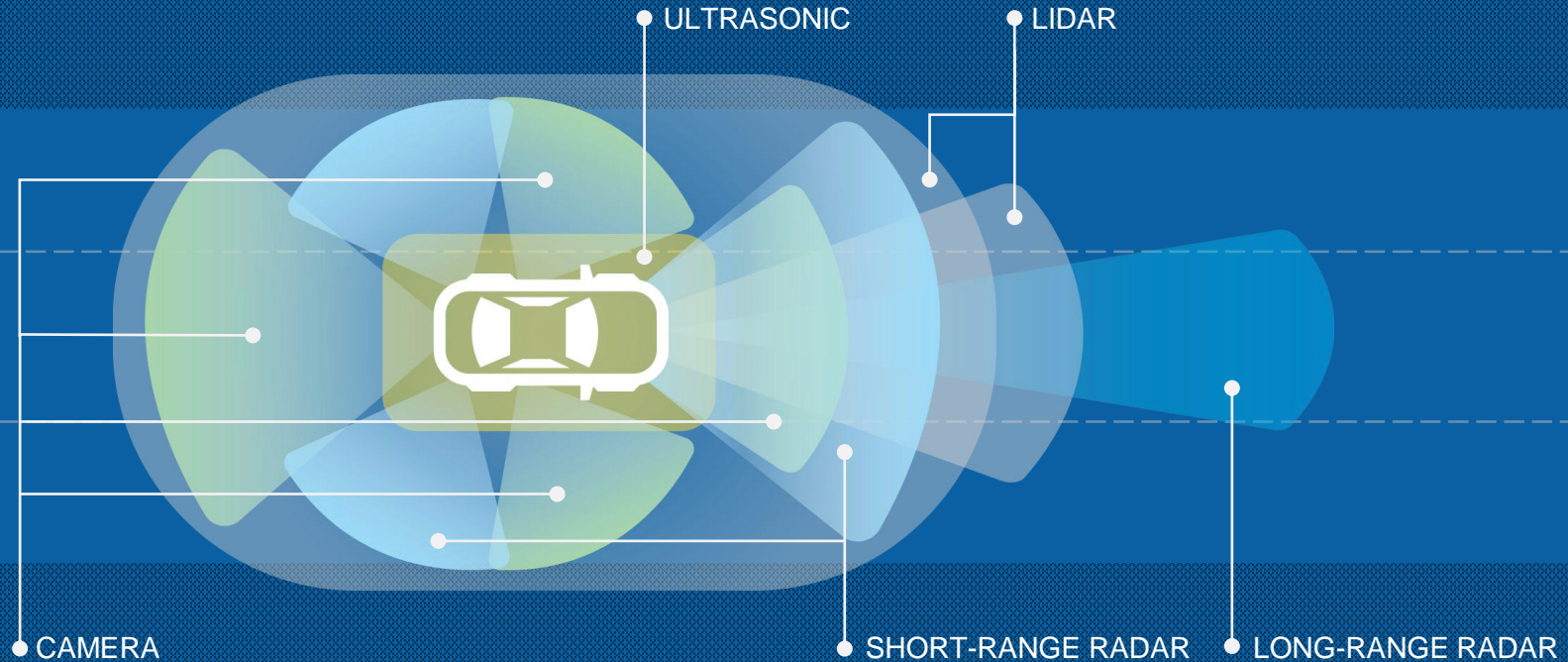
# The Challenges of Testing Multi-Sensor Systems: An Automotive Case Study

Smarter Test for Smart Vehicles

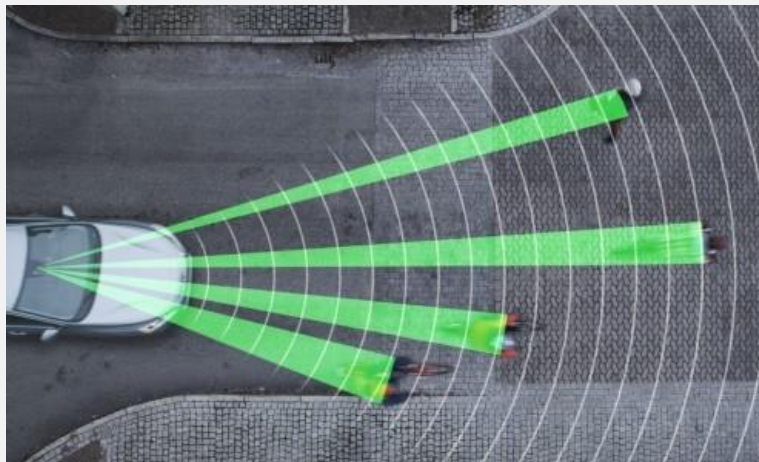
Ashish Naik

Automotive Northern Europe

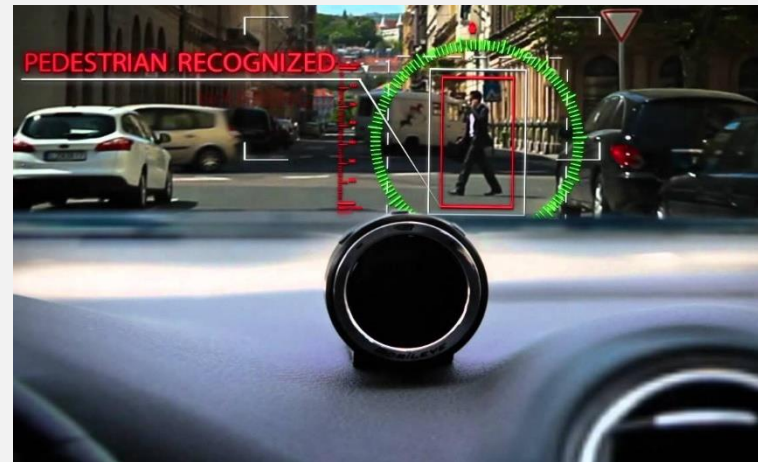
# Major ADAS Sensor Types and Applications



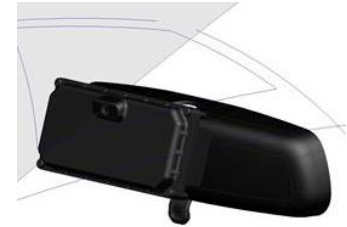
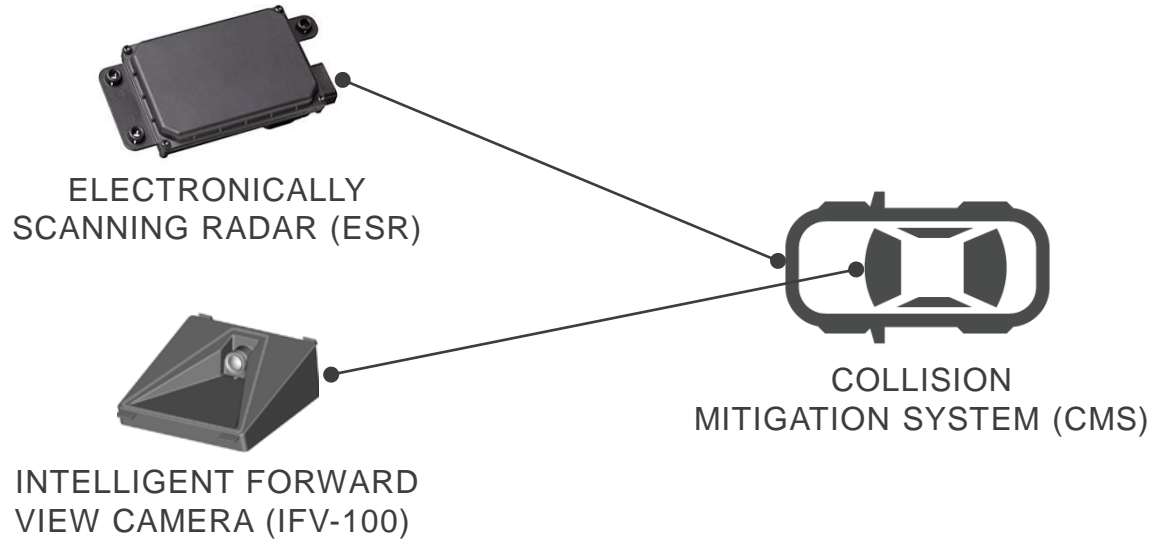
# Cameras and Radar Working Together



Object Detection Using Radar



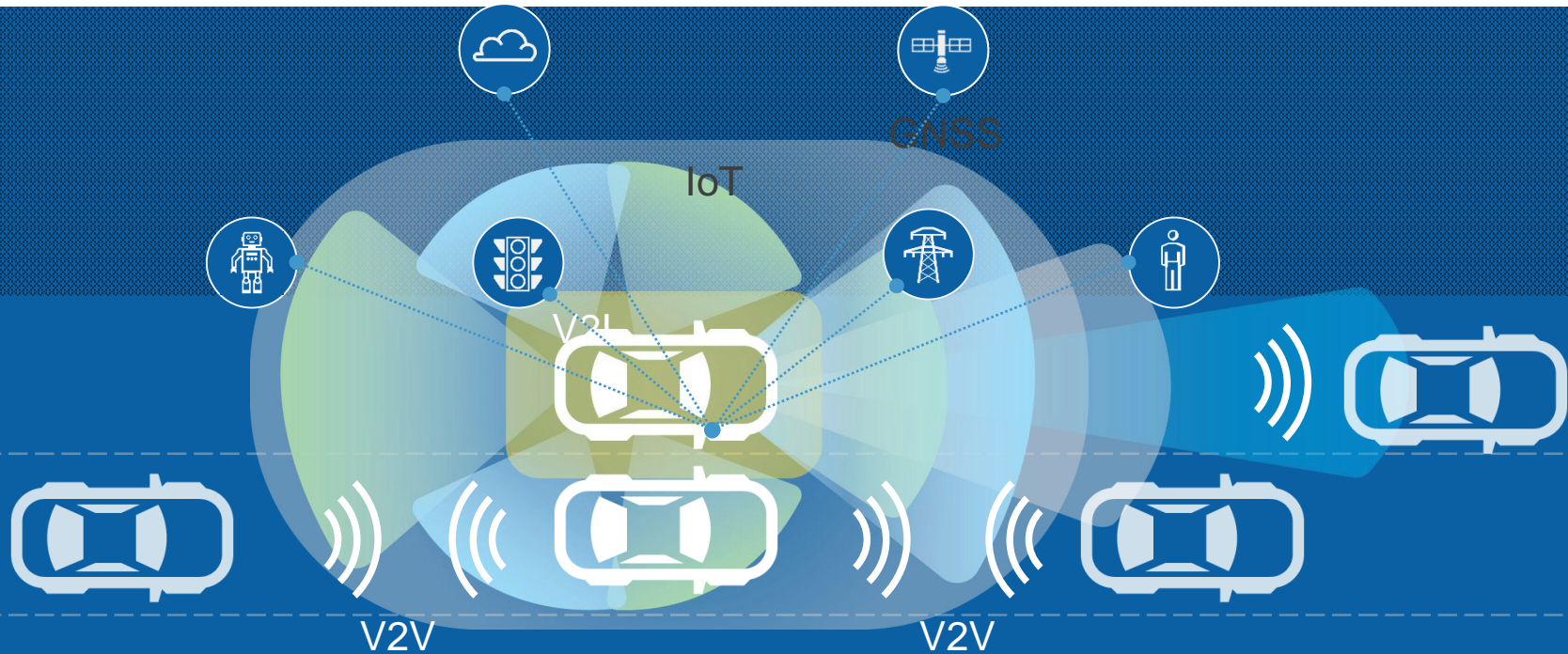
Object Classification Using Cameras



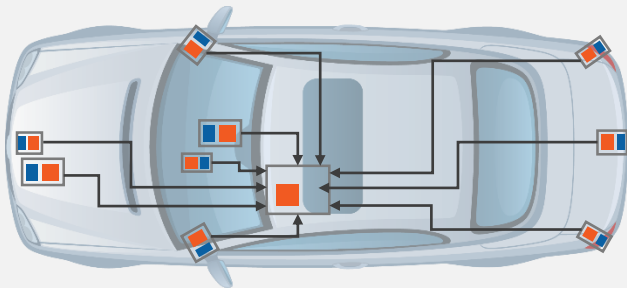
RACAM  
(RADAR + CAMERA)

## ADAS Sensor Fusion Evolution: Delphi Example

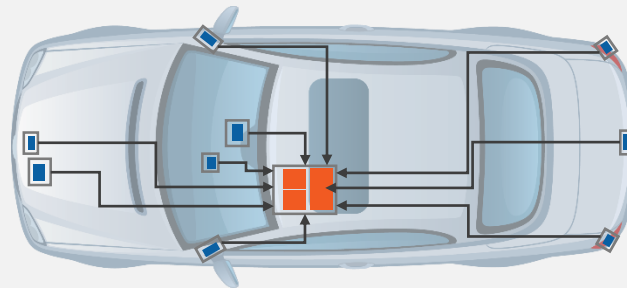
# The Connected Car



# ADAS Architectures Continue to Evolve

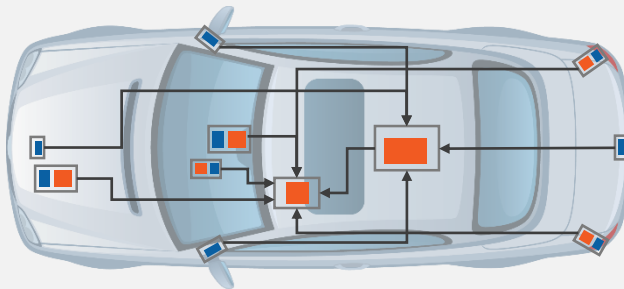


SMART SENSORS/DECENTRALIZED PROCESSING



RAW SENSOR DATA/CENTRALIZED PROCESSING

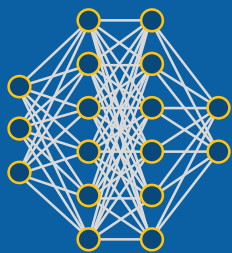
■ Sensor  
■ Electronic Control Module (ECM)



HYBRID SENSOR/PROCESSING

Source: electronics-eetimes





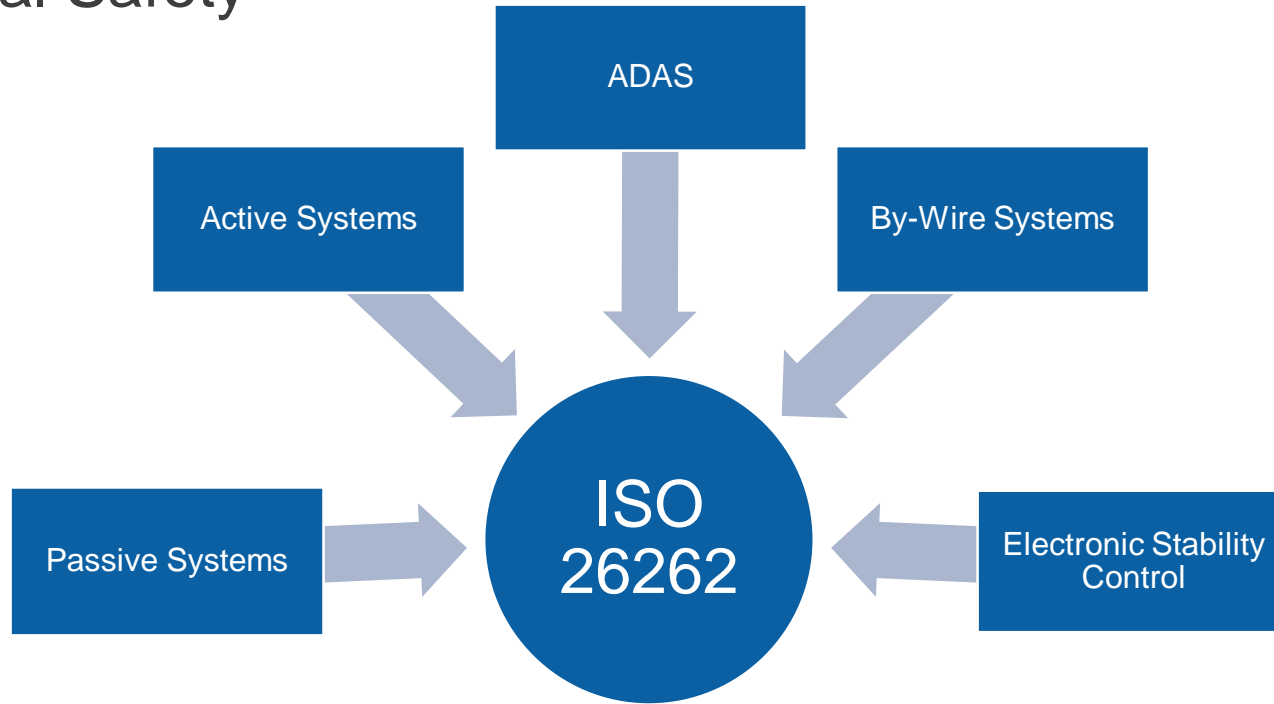
DEEP NEURAL NETWORK

# Deep Learning for Self-Driving Cars

- Environmental perception is key to autonomous driving, e.g., lane position
- Traditional feature recognition and image processing techniques don't scale to needed complexity
- Deep neural networks learn efficient feature representation
- Inductive learning leads to evolving software operation that is challenging to test

# 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.

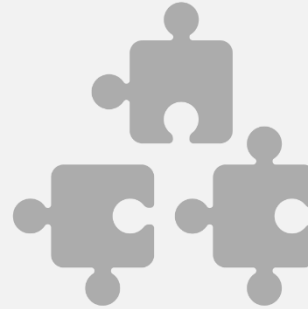
# Challenges of ADAS Testing



Regulatory  
Uncertainty



Volume  
of Tests



Testing Systems Instead  
of Discrete Components



Integrating New Technology  
Into Existing Systems

# Approaches to Test and Measurement

## CLOSED

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



## PLATFORM

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

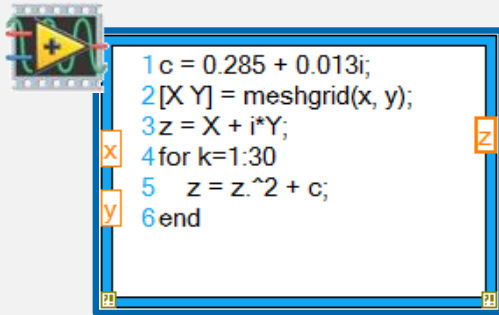


# Test Methodology

# Benefits and Trade-Offs of Testing Approaches

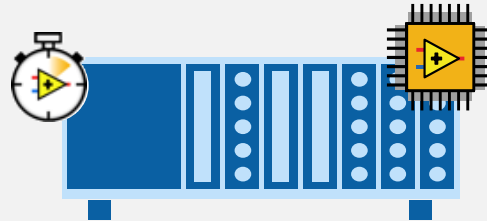
## Simulation

- 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

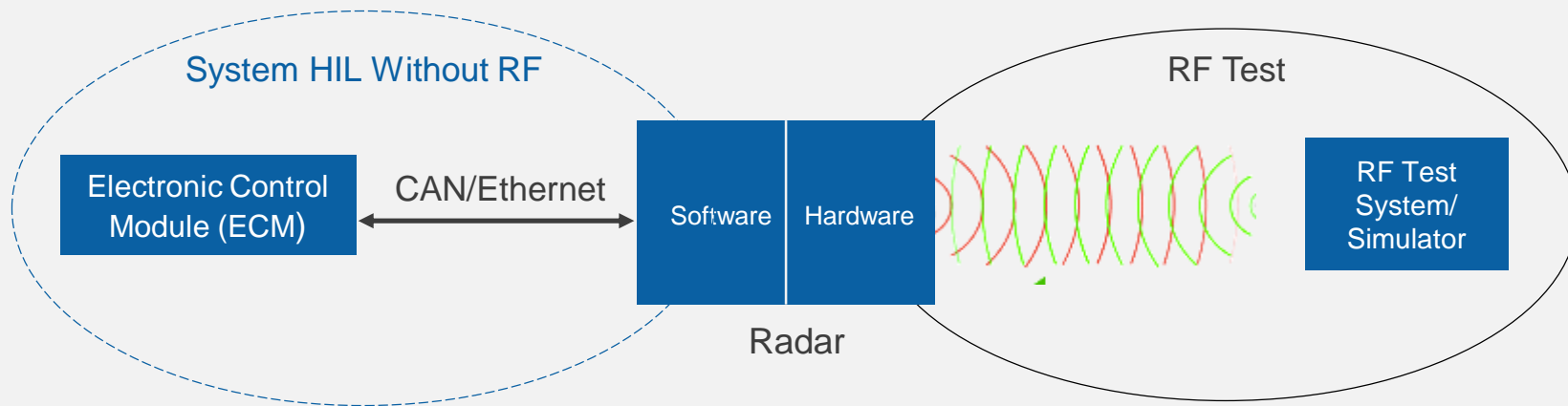


## Field Test

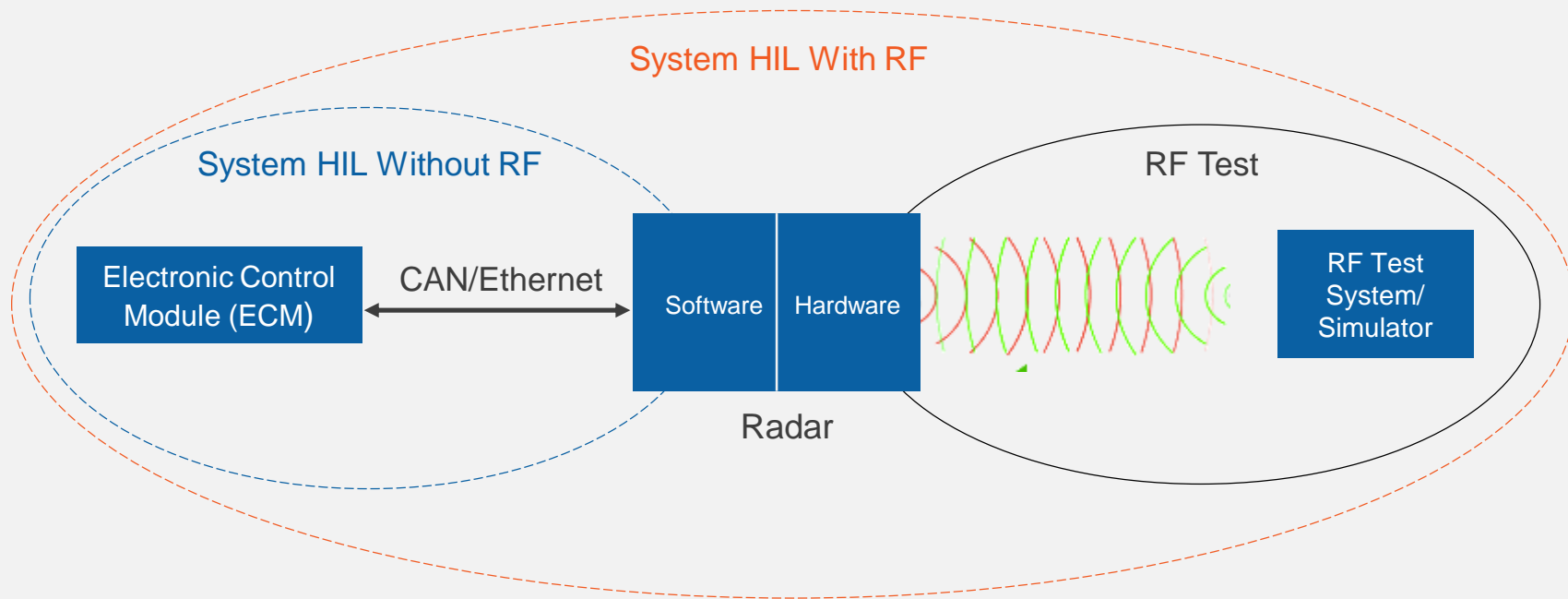
- Offers true real-world test
- Is difficult to set up and scale
- Limits test case coverage due to time and space complexity



# Automotive Subsystem Test Cases

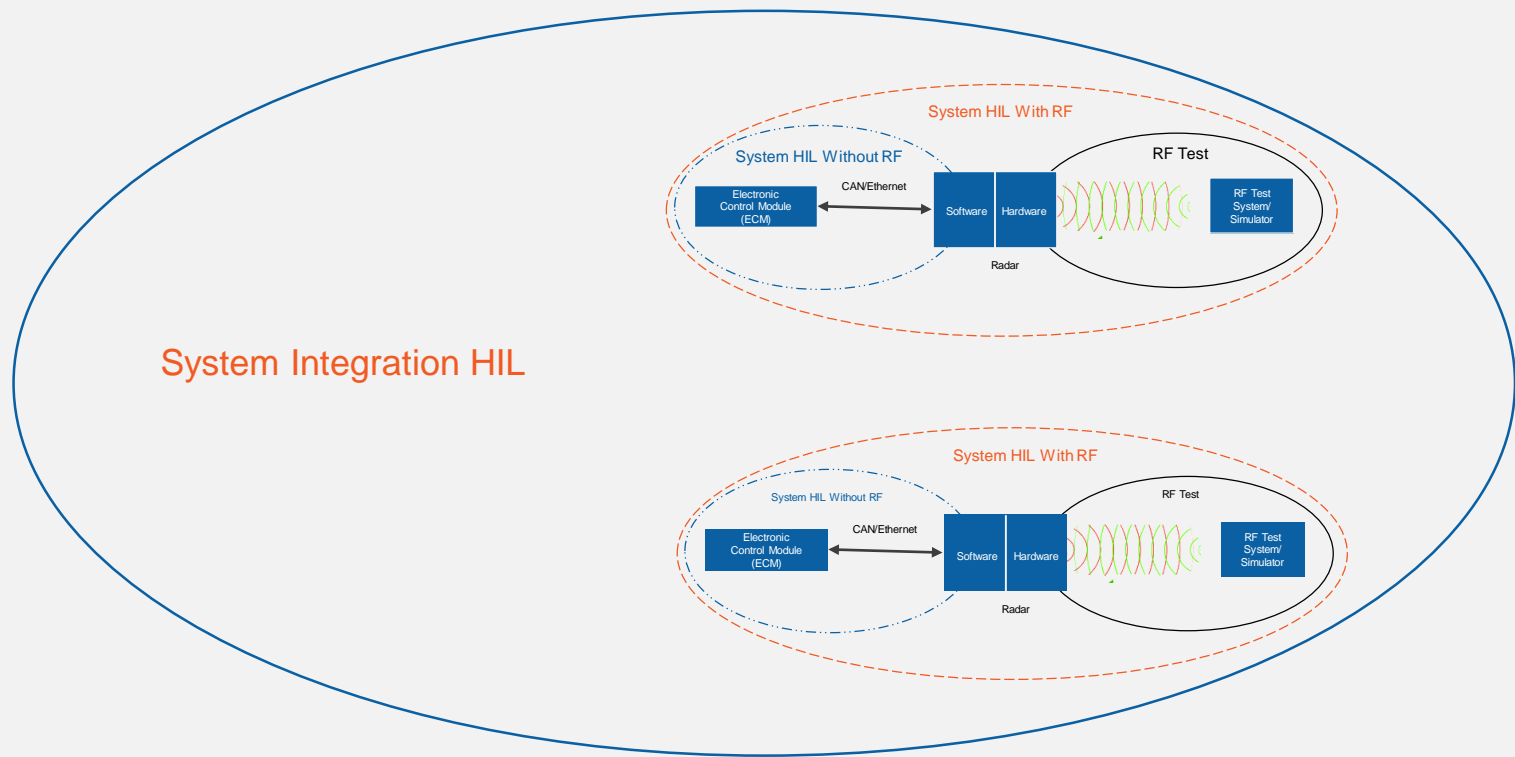


# Automotive Subsystem Test Cases

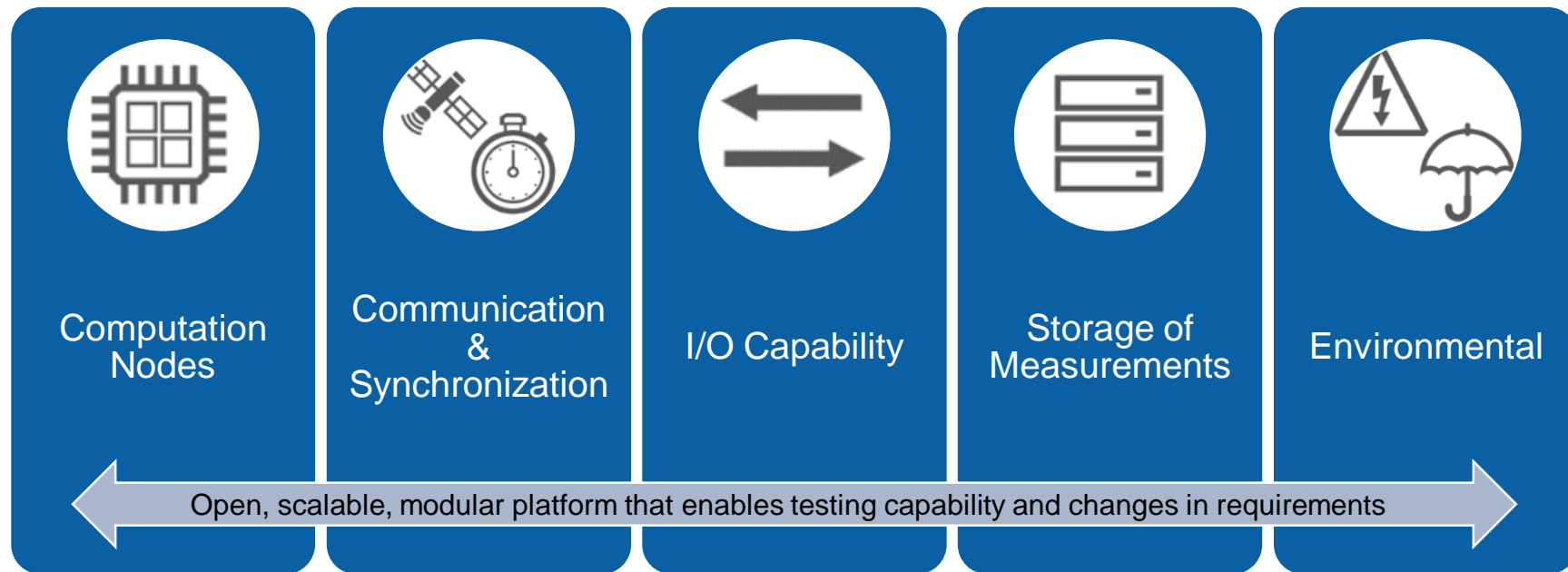




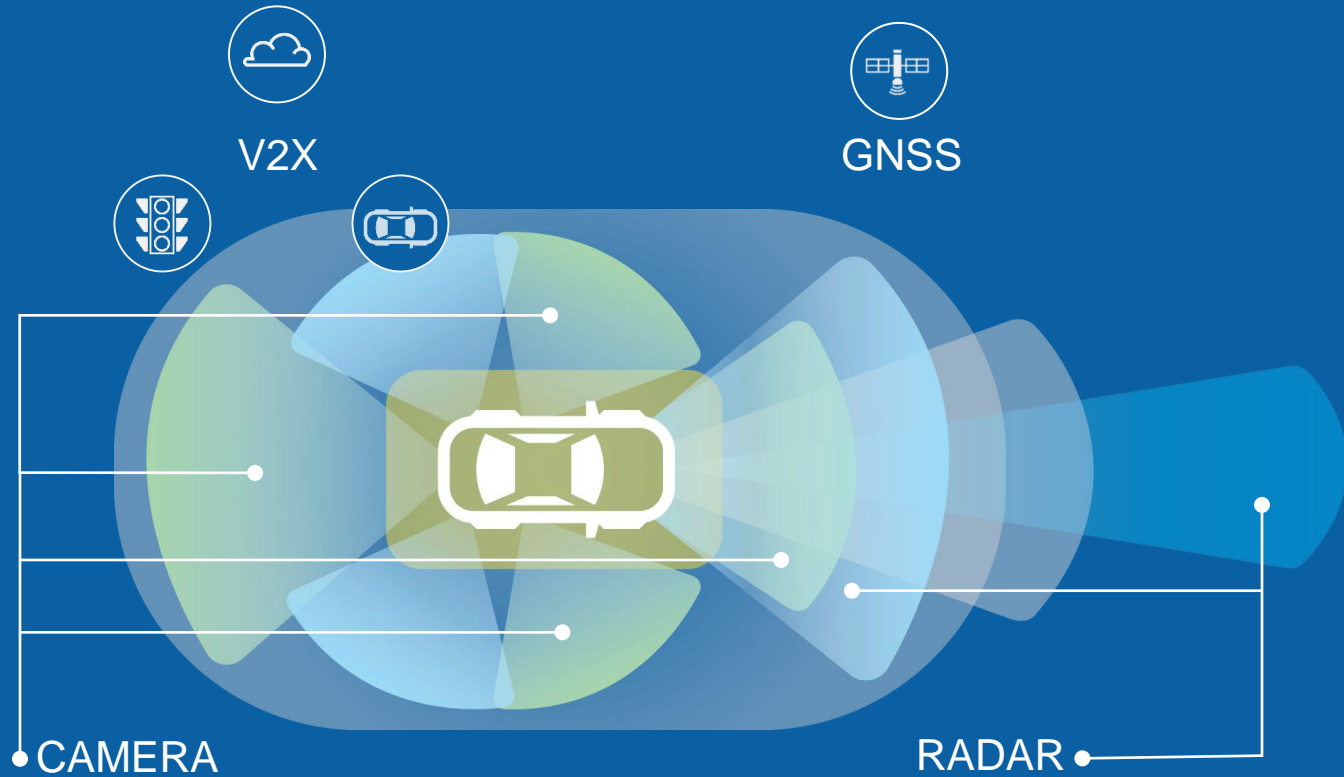
# Systems Integration Test



# Main considerations



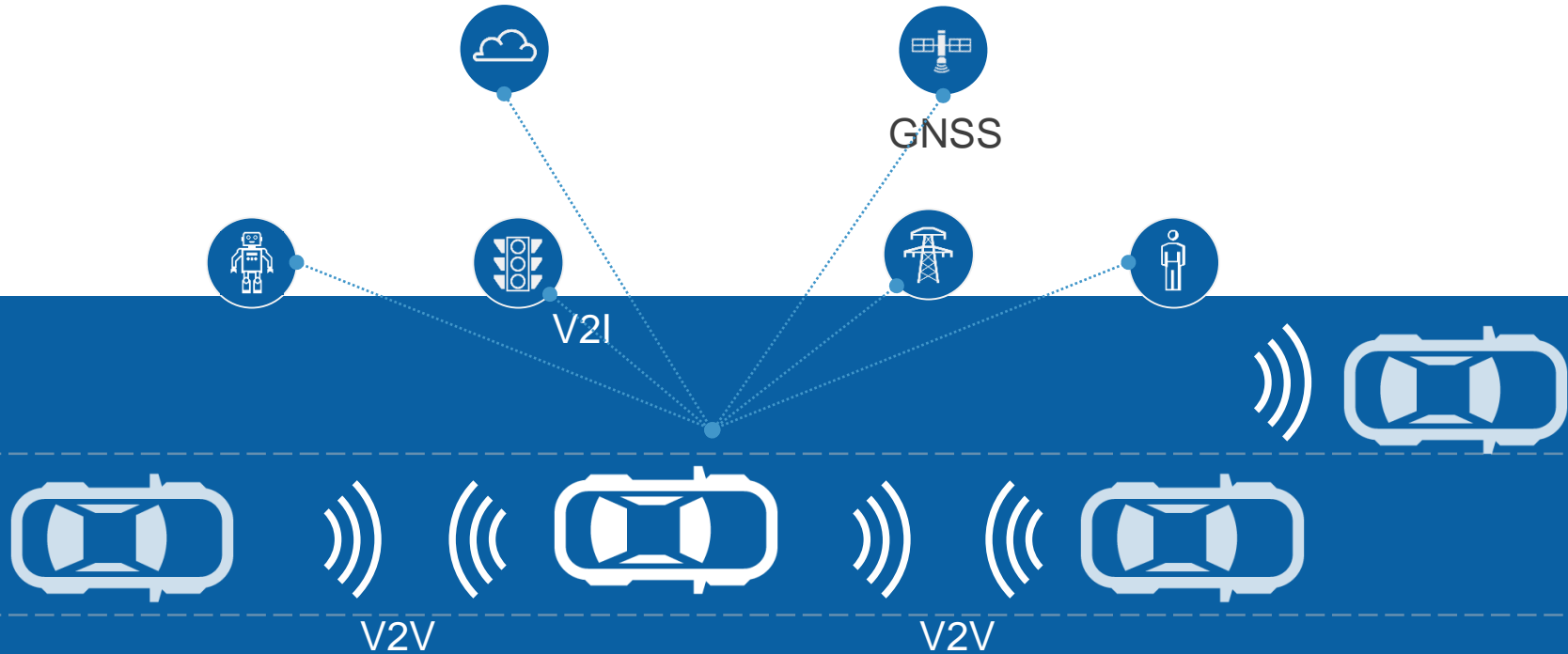
# Major ADAS Technologies



# Communications

## V2X and GNSS

# The Connected Car



# V2V and V2I Communications With 802.11p and LTE

## IEEE 802.11p (DSRC)

- Referred to as Dedicated 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



# 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

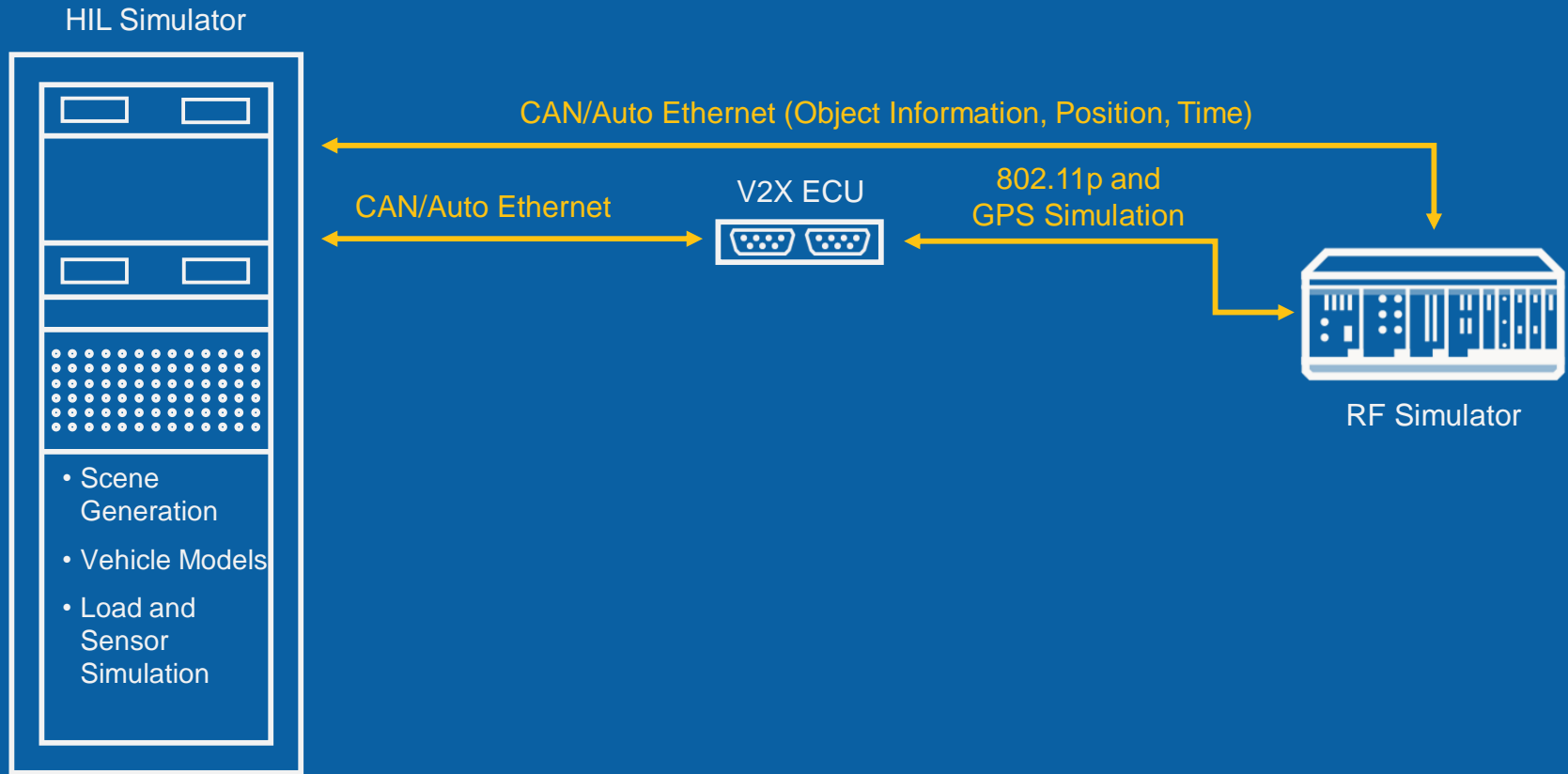
CDMA2k

FM/RDS Generation

LTE/LTE-A (TDD & FDD)

Wireless measurement algorithms execute on PXI controllers and reconfigurable FPGAs.







# Radar

# Trends in Automotive Radar

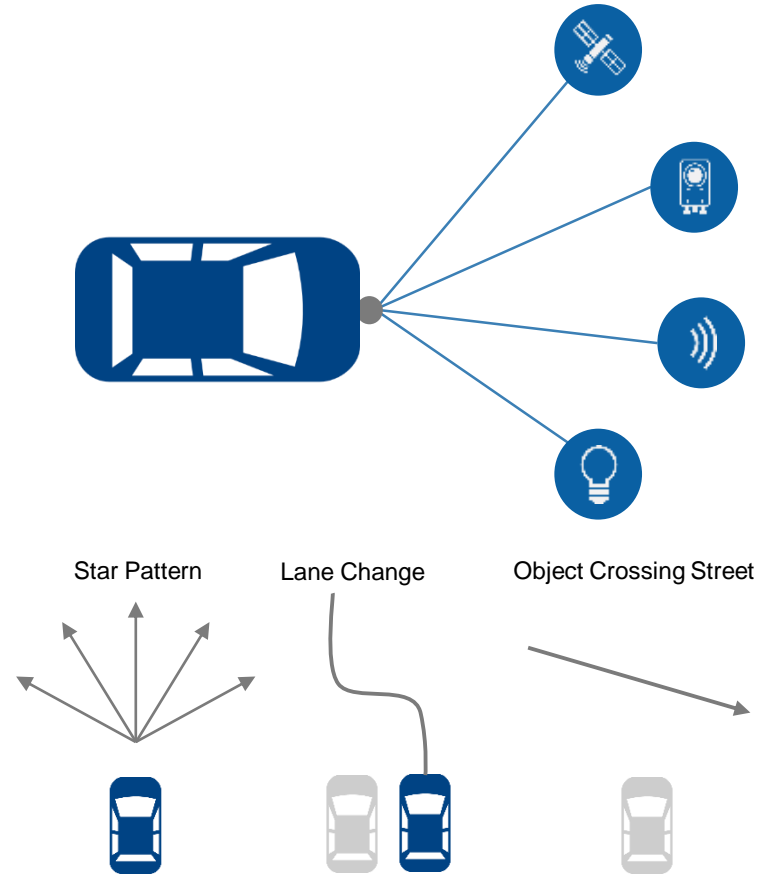
## Focus on Safety

- 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//>



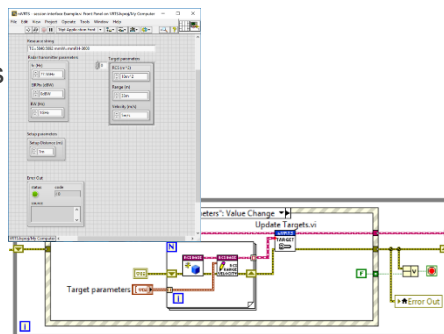
# Vehicle Radar Test System (VRTS)

## FEATURES AT A GLANCE

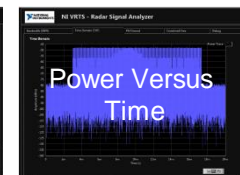
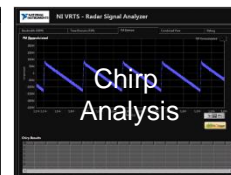
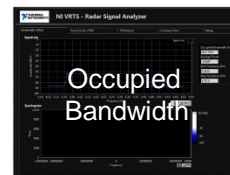
- Single system performs both obstacle simulation and radar measurements
- Obstacle simulation settings include velocity, range, RCS, and angle of arrival (AoA)
- Measurements include: radiation pattern, EIRP, phase noise, spectrum occupancy, beam width, and chirp analysis
- Tight synchronization with modular PXI hardware for hardware-in-the-loop (HIL) and ADAS test applications

## KEY SPECIFICATIONS

- Frequency Range: 76 – 81 GHz
- Number of Obstacles: 2 to 8+
- Obstacle range: 4m to 300+ meters
- Minimum VRTS to DUT: 70 cm
- Range resolution: 10 cm
- Range Accuracy:  $\pm 70$  cm
- Velocity: 0 to 500 km/hr (75 kHz)



*The NI VRTS is a flexible test system that combines PXI hardware with modular millimeterwave radio heads*



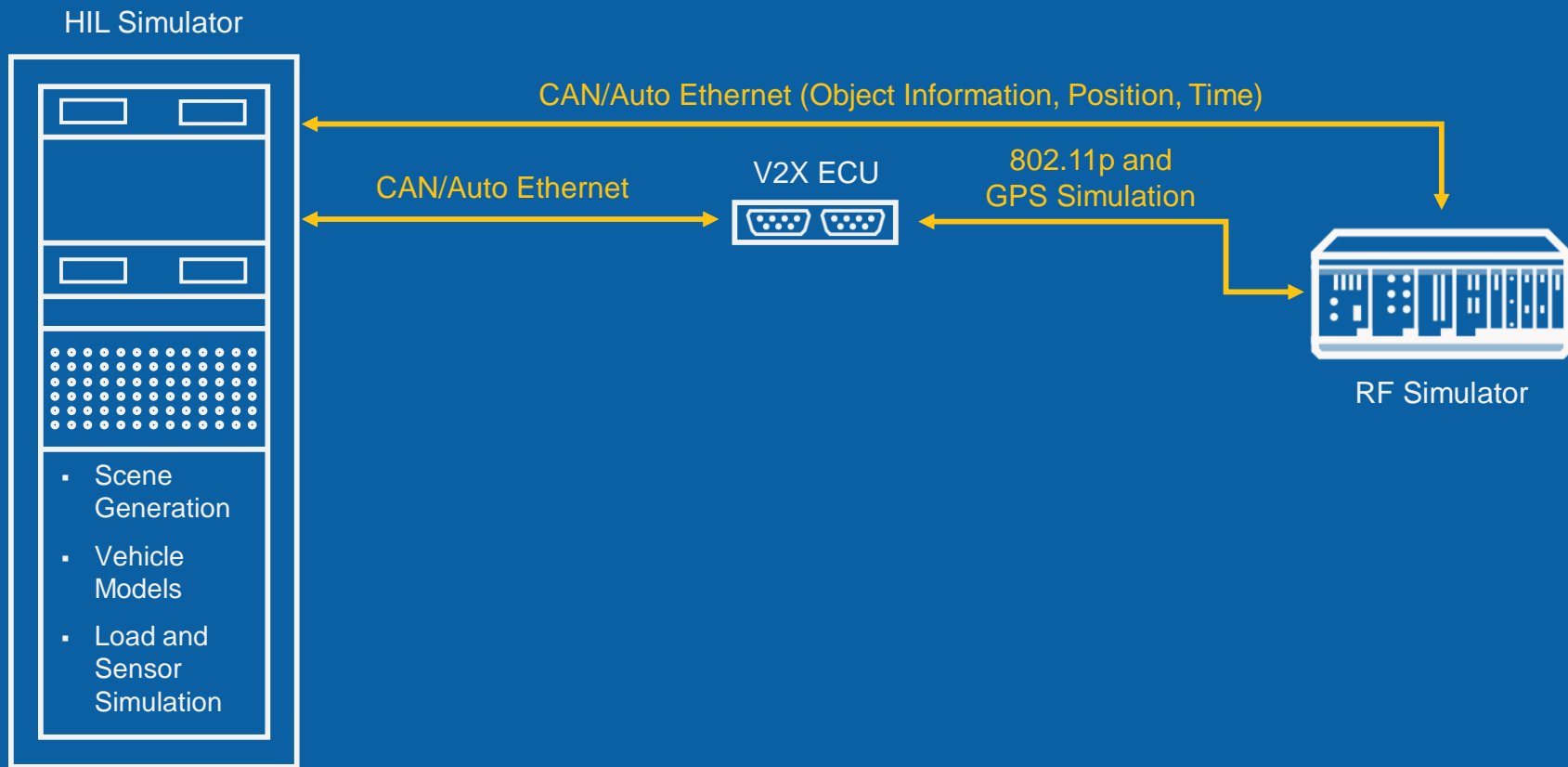


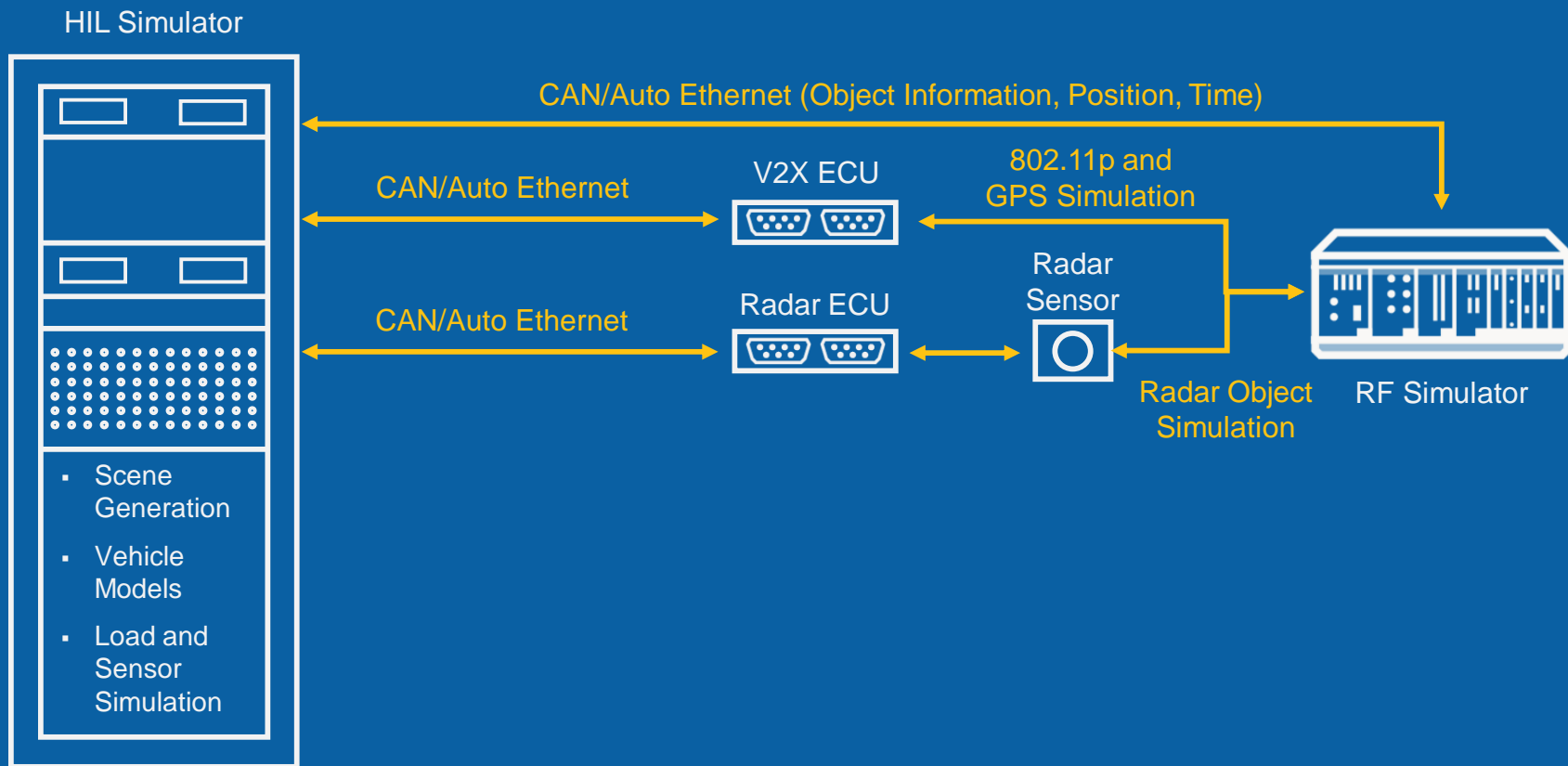
“With the PXI Vector Signal Transceiver, the combination of the industry’s widest bandwidth and low latency software has allowed us to discover our automotive radar sensors as never before.”

—Niels Koch, Audi



[ni.com/smarter-test](https://ni.com/smarter-test)

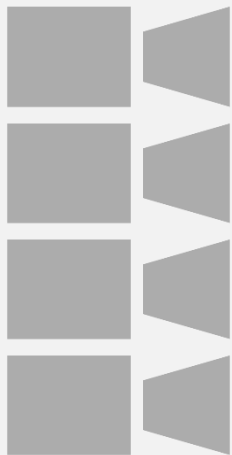




# Camera

# Challenges of Camera Test

## Increasing Number of Cameras

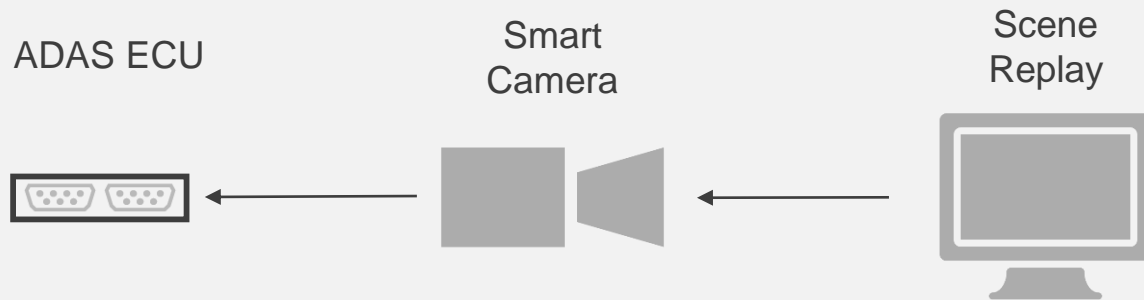


## Properly Simulating Conditions



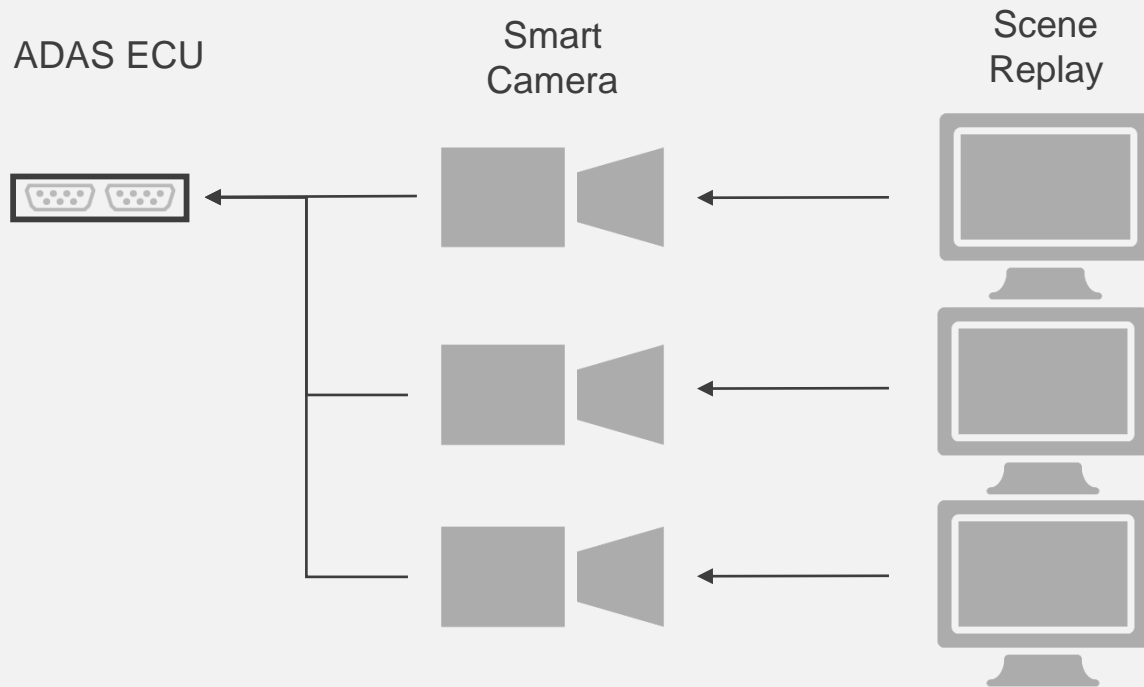


# Approaches to Camera Test

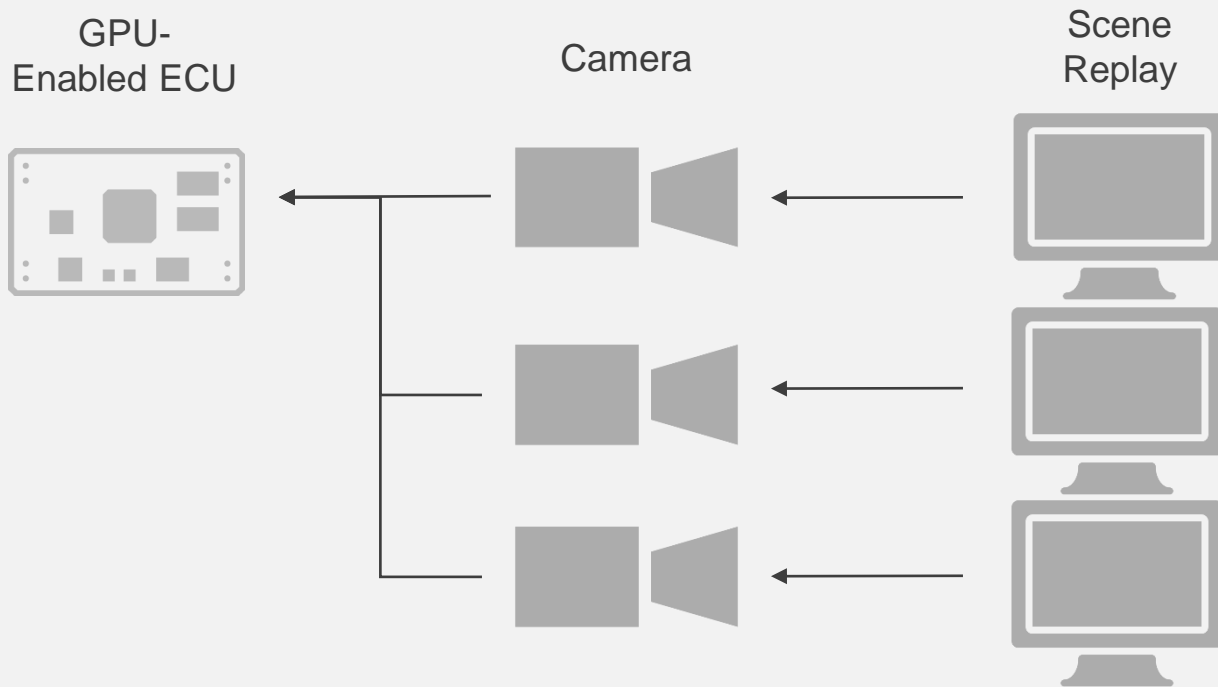


# Demo

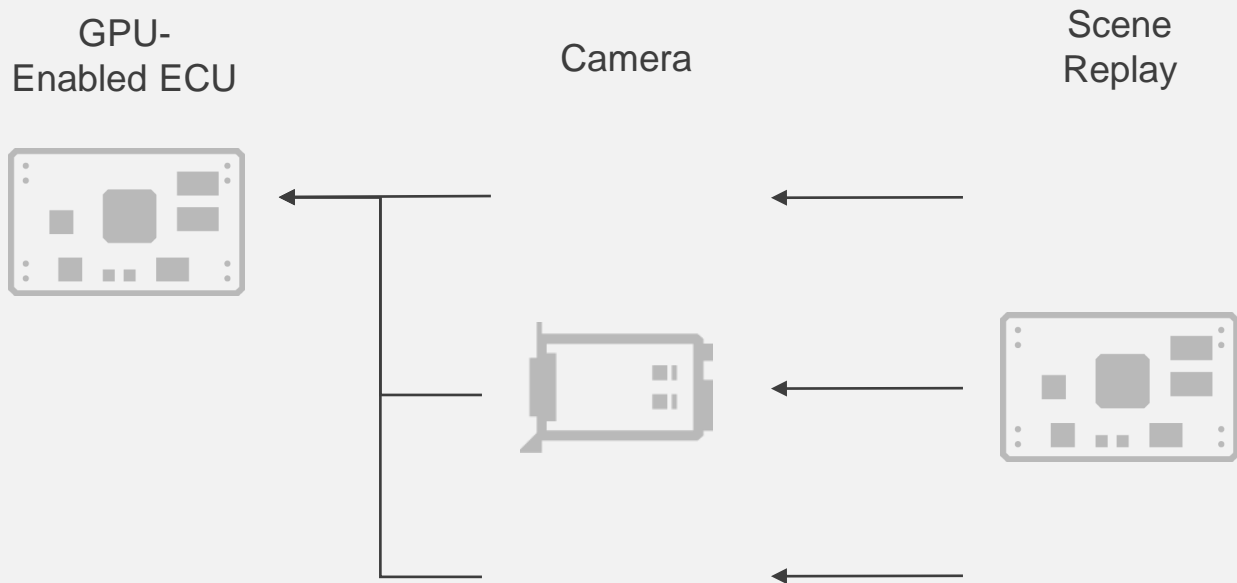
# Approaches to Camera Test



# Approaches to Camera Test



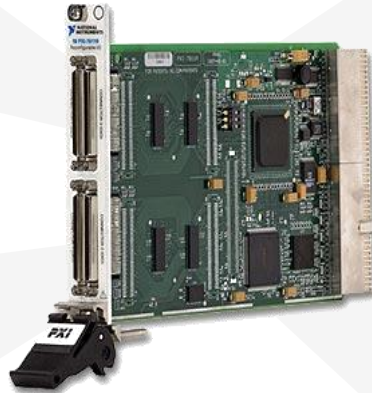
# Approaches to Camera Test



# Image Manipulation With FPGA

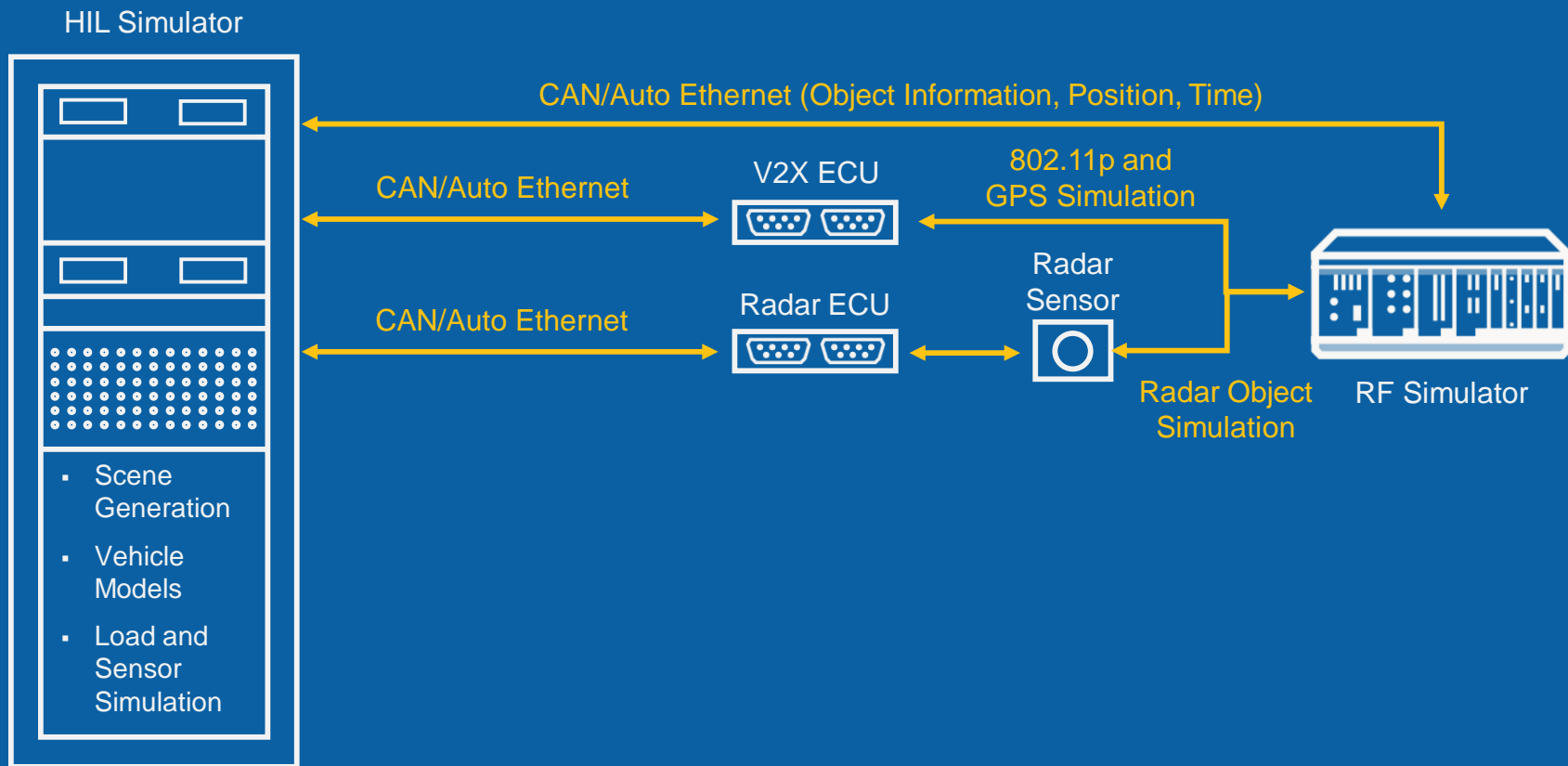
Dropped Frames  
or Frame Delay

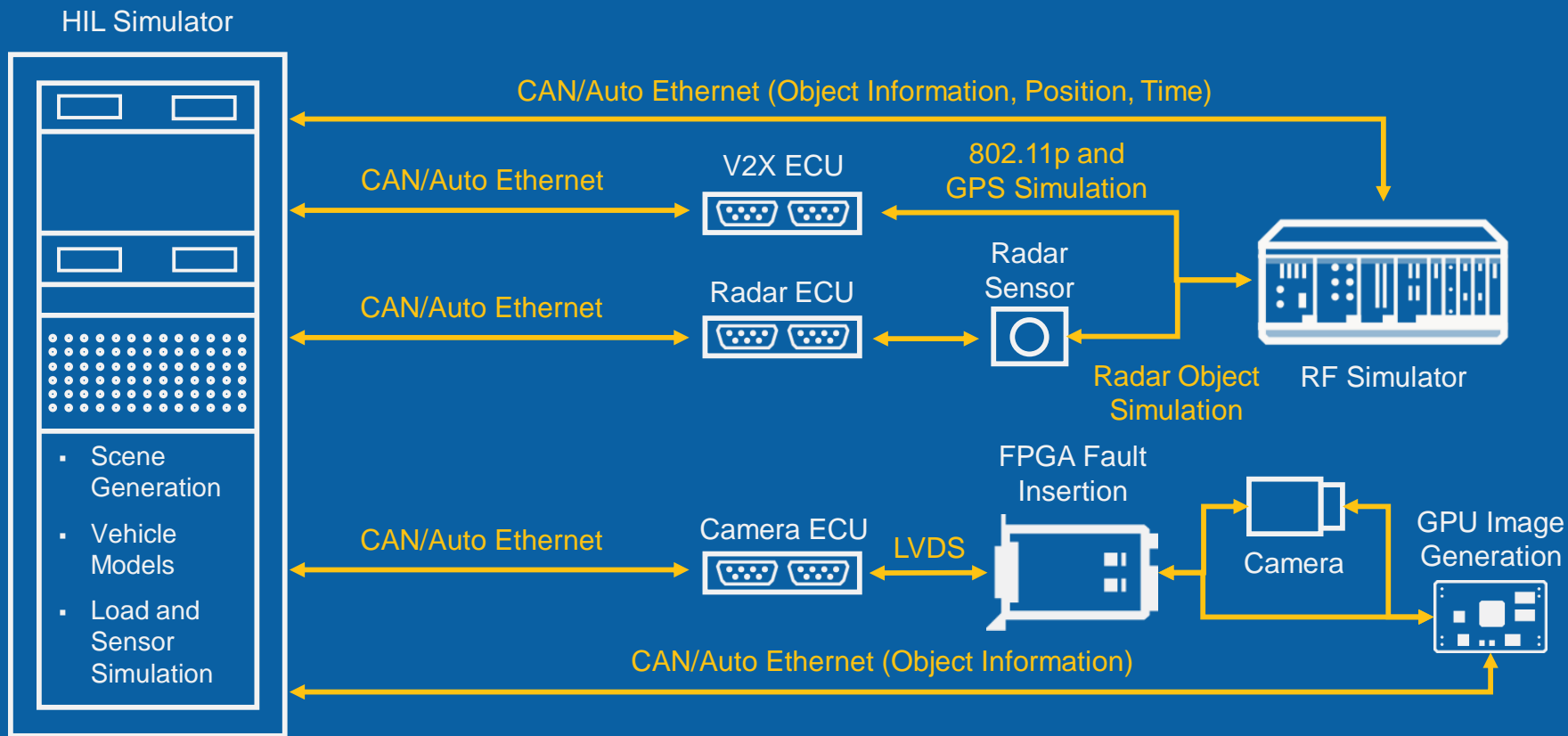
Noise and  
Error Injection



Bitstream  
Manipulation

Custom  
Protocols

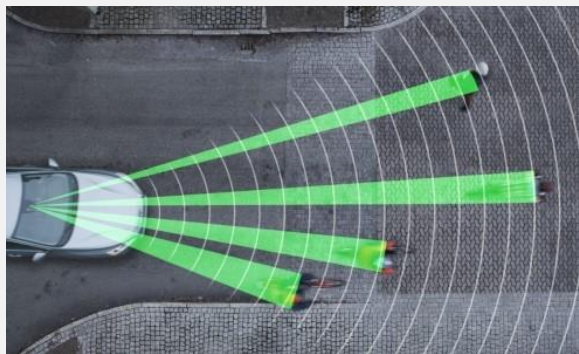






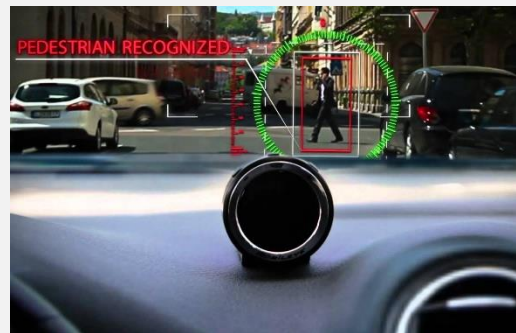
# Sensor Fusion

# Cameras and Radar Working Together



Object Detection Using Radar

Synchronization



Object Classification Using Cameras



ADAS ECU for Safety Operations

# Testing Sensor Fusion Embedded Software



Radar Target Emulation



Video Stream Manipulation



ADAS ECU for Safety Operations

# Hardware-in-the-Loop Test

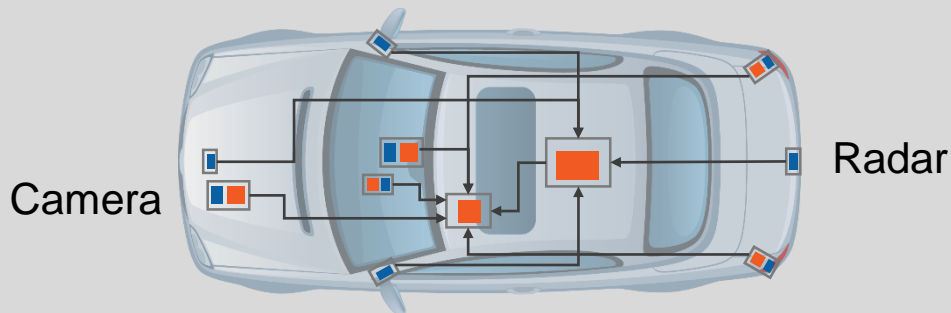


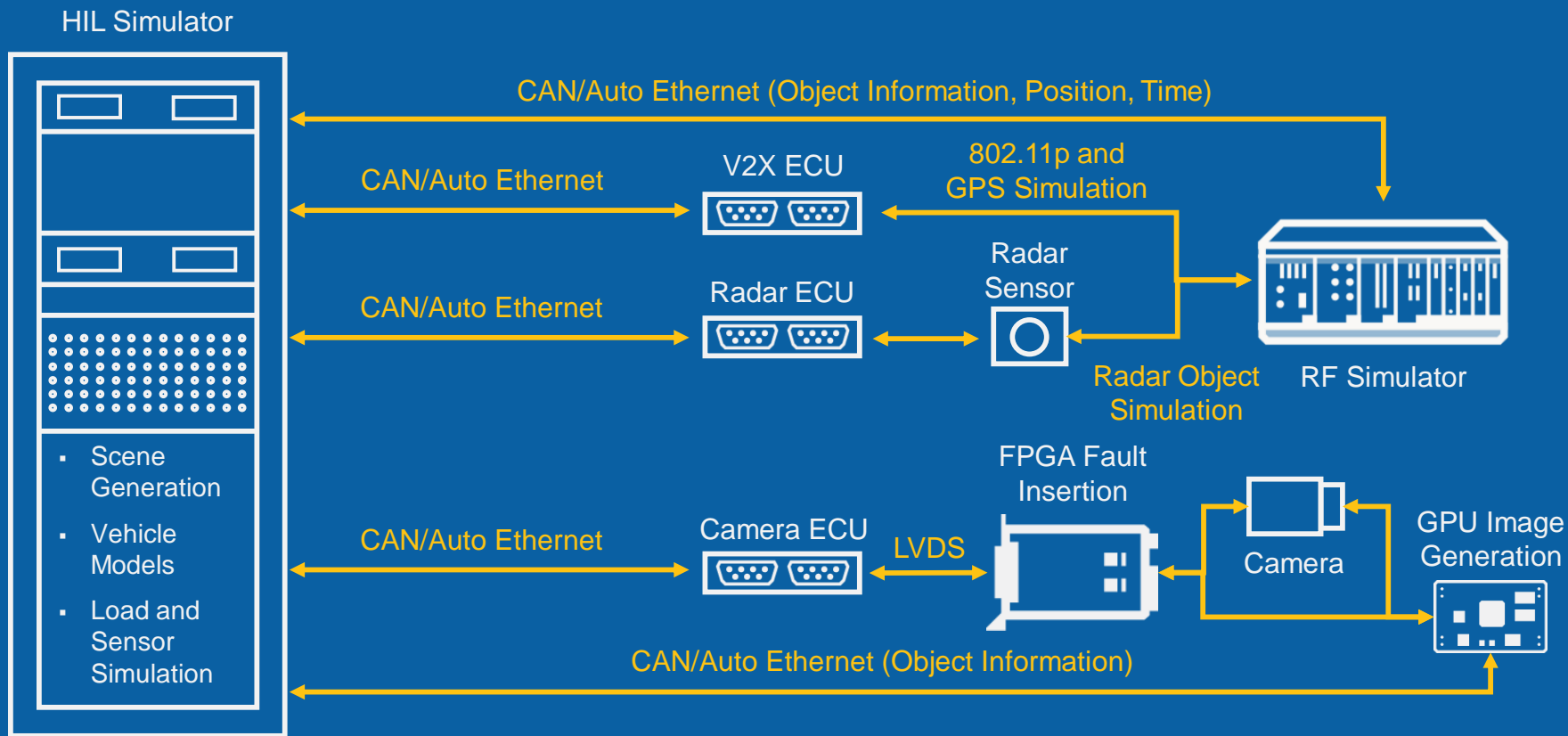
CAN  
Interface

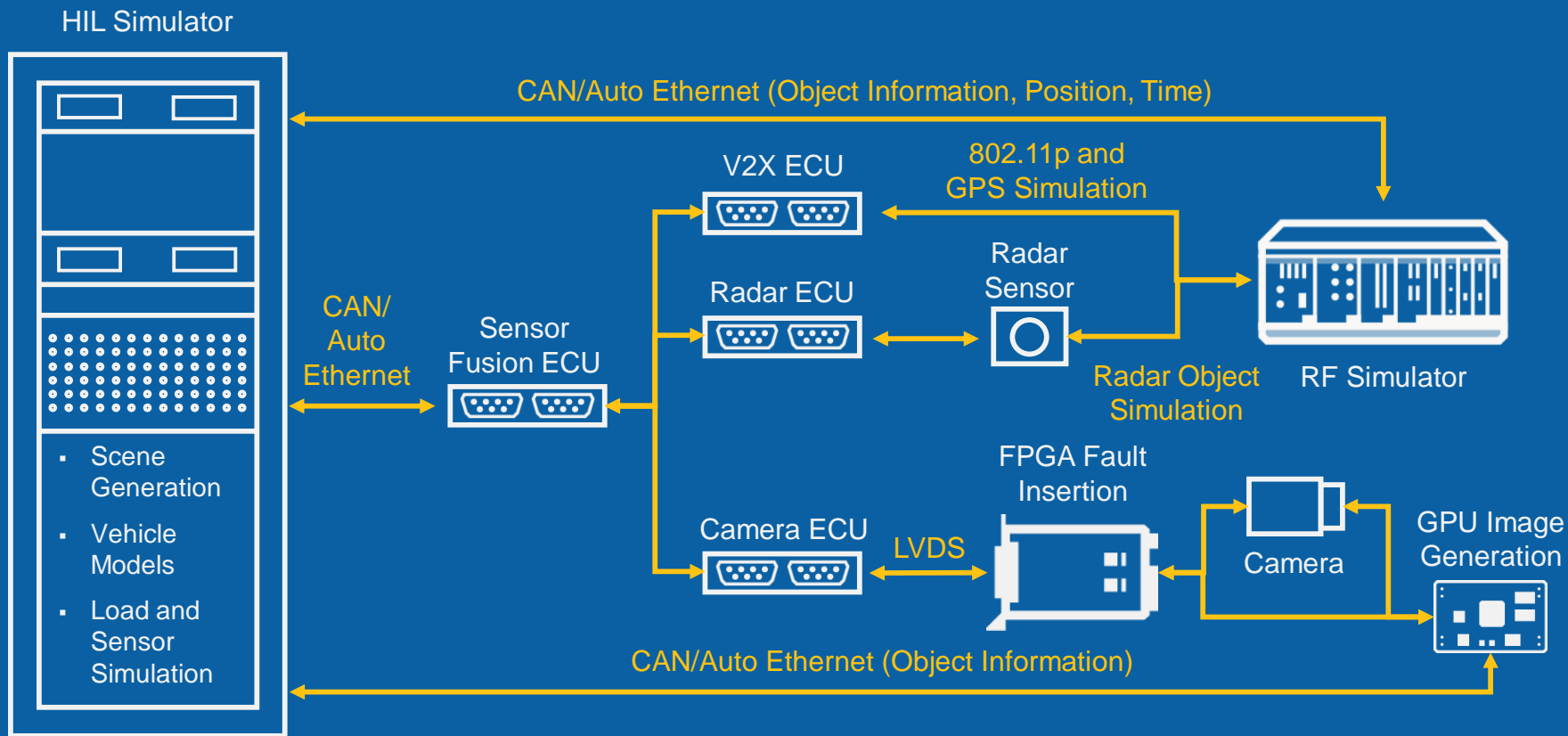
GNSS  
Simulation

Radar Target  
Simulation

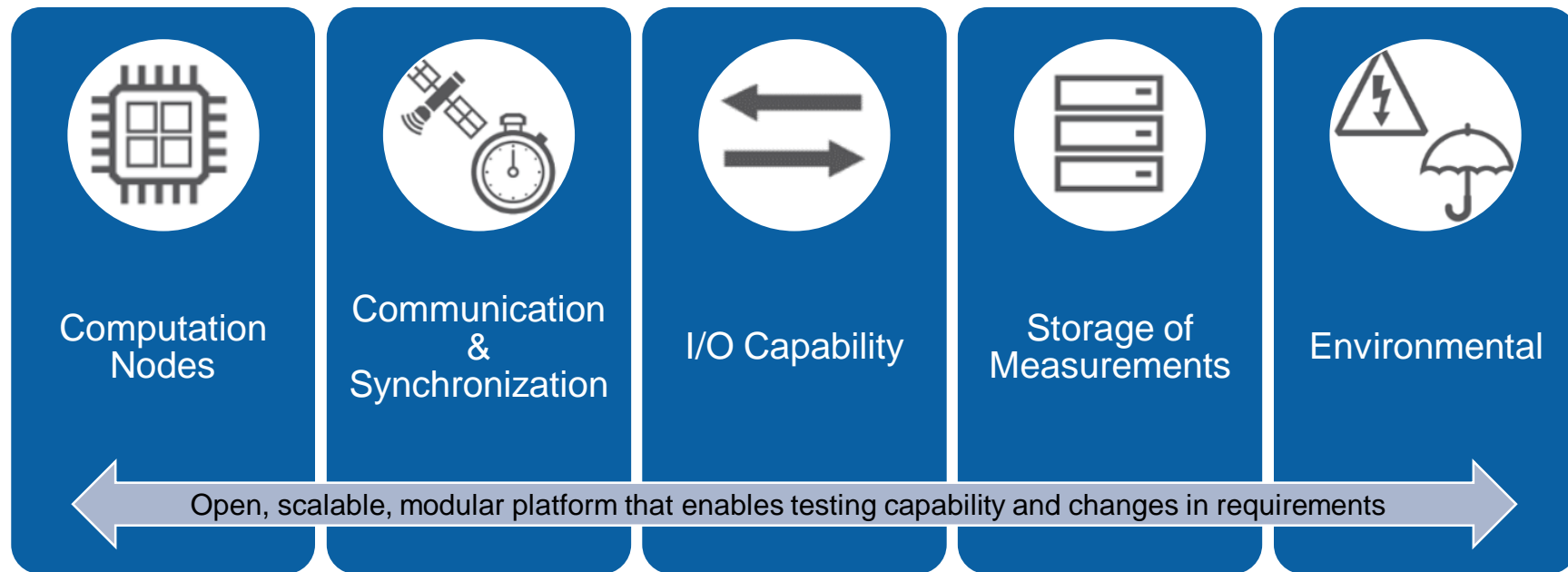
Image  
Simulation







# Main considerations





# AUTOMOTIVE **TEST AND VALIDATION DAY**

In collaboration with Warwick University and Industry Partners  
7<sup>th</sup> December 2017

<http://www.goo.gl/BmiUme>



