FIRST EDITION // *AUTOMOTIVE AND TECH CONVERGE* // *HYUNDAI IMPROVES TEST TIME* // *CASE STUDIES*

NI AUTOMOTIVE JOURNAL

TEST THE VEHICLES OF TOMORROW TODAY

A NATIONAL INSTRUMENTS PUBLICATION **Q2 + 2019**

NATIONAL INSTRUMENTS™

In This ISSUE

Q2 + 2019

NI has been working with radar, cameras, and RF communications for decades in different industries, and natively supports all the I/O types that need to be tested in today's and tomorrow's vehicles.

Autonomous and Tech Industries Converge

As the automotive industry moves forward it is integrating two very different test methodology worlds.

Radar Sensor Production Test

Test as quickly and efficiently as possible while maintaining high-quality standards.

Hyundai Kefico Improves Test Time by 15%

Achieving flexible test system configurations of all powertrain ECU types and re-usable test scripts using the NI test platform.

Testing the Autonomous Vehicles of Tomorrow Today

Autonomous vehicles will change the way we view transportation and even live our lives. The obvious main goal is to increase safety and reduce traffic deaths, but reducing emissions and providing better mobility solutions are also benefits to be realized. To accomplish this, new vehicles are integrating technology that helps them provide advanced driver assistance systems (ADAS) functionality and will eventually lead to fully autonomous operation. These technologies like radar, camera, and RF communication will work together with a sensor fusion approach to give the vehicle a more complete view of the world around it.

Through this new *NI Automotive Journal* quarterly, we will present the latest trends in the automotive industry, specifically related to best practices in validation and production test. This is an exciting time in the automotive industry, and I am inspired by the opportunity to collaborate with you to accelerate the future of transportation.

Chad Chesney, Vice President and General Manager, Transportation Business

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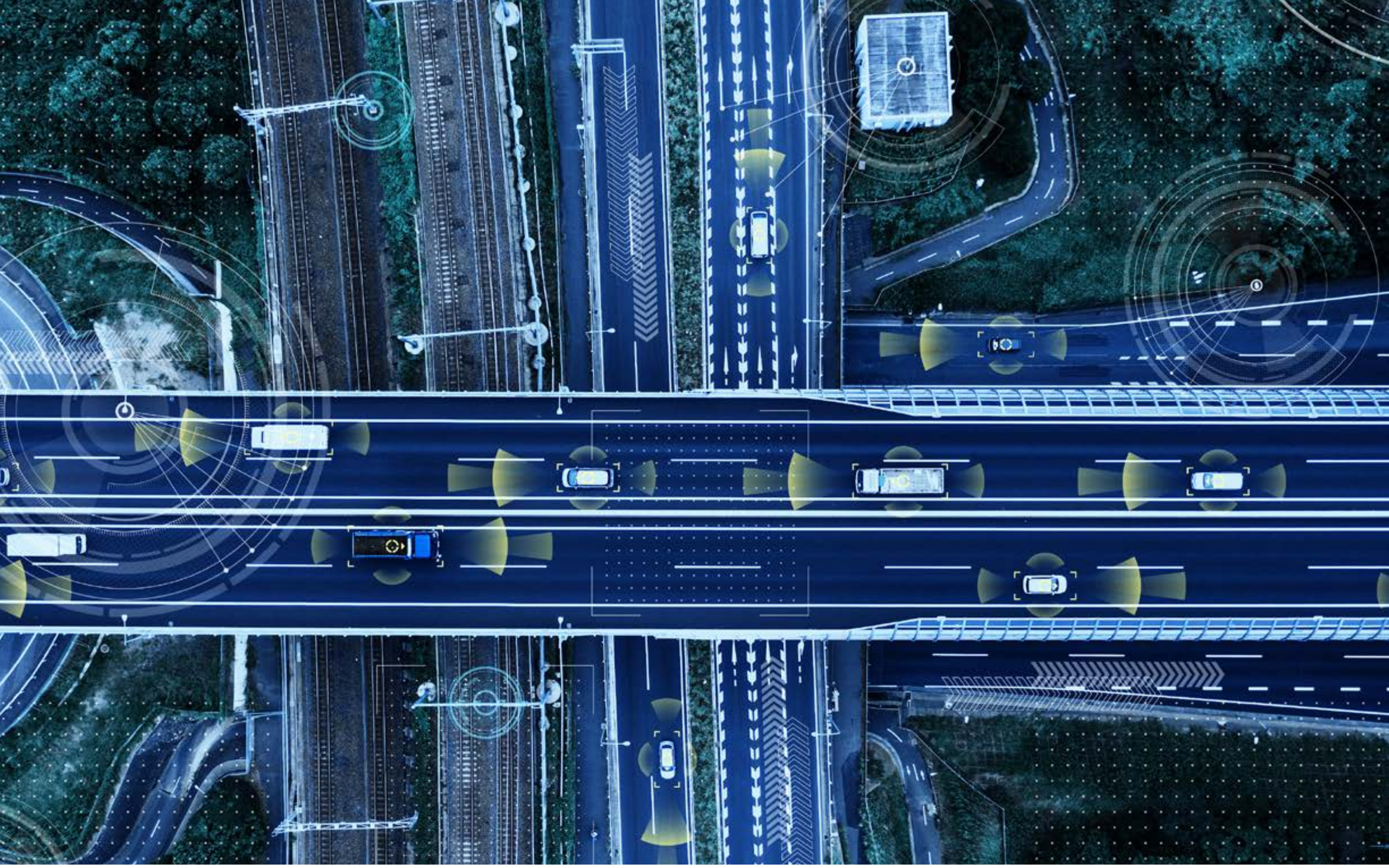

FEATURED ARTICLE

Automotive and Tech Industries Converge

As we head closer to the 2020s, it's becoming increasingly clear that automotive and tech companies are deepening the initial collaborations they started several years ago. The automotive market is eagerly embracing some exciting new technologies in its efforts to build better, safer cars. In fact, in many ways, today's cars offer some of the most advanced technologies that consumers can now buy.

And yet, despite the obvious convergence of industries, there are still some critical differences between the two, particularly regarding the production and test of key technology-based hardware components and system software. Though the tech industry has embraced advanced test and validation methodologies, many auto industry vendors are still holding on to older procedures that aren't well suited to the demands of newer, advanced technology components.

The Software-Defined Car

One of the trends highlighted at recent trade shows was the impact of vehicle electrification. Each new car model has more semiconductors and other electronic components in it than the previous one, and these components are controlling larger portions of the vehicles' capabilities. Plus, the chips being integrated are increasingly powerful ones. Vendors like Nvidia, Qualcomm, Intel, and ARM—primarily known for designing chips for the computing and smartphone markets—are grabbing more attention away from automotive suppliers like Renesas and NXP and are driving the creation of extremely powerful car computers.

In addition, the automotive semiconductors are expanding beyond their traditional role of powering the in-vehicle infotainment (IVI) system and are providing capabilities for advanced driver assistance systems (ADAS) and even sensor

fusion. Big tech vendors like LG and Dyson are now delving into electric powertrains, while others like Panasonic and Harman (which is now owned by Samsung) continue to build increasingly sophisticated in-car digital cockpit experiences.

A Conceptualized Cockpit in a Software-Defined Car

These increasingly powerful chips are also enabling more sophisticated software solutions, with well-known tech vendors like Google, Apple, Microsoft, and even BlackBerry starting to build car interfaces that are as advanced as any other tech devices. The software efforts extend well beyond just the UI, however, as state-of-the-art virtualization software is allowing the powerful electronic control units (ECUs) housing the advanced chips inside new cars to take on new tasks that were previously done by physical controllers. The end result is extremely sophisticated automotive computers that increasingly function as software-defined cars.

Testing Needs

Given all this complex technology, it makes sense to presume that the same kind of test procedures used on products like smartphones and other mobile devices would be used on automotive ECUs. Unfortunately, however, that's simply not the case. Because of the legacy nature of the automotive business—remember that the first Model Ts rolled off the assembly line over 100 years ago—many of the test methodologies in the automotive industry are still based on more mechanical approaches.

To be clear, testing cars has always been a tough task because of the many sophisticated electromechanical systems that allow today's automobiles to function as well as they do.

For modern cars, however, the test requirements are much more challenging. Because of both the software-based nature of much of the vehicle's key systems and the growing complexity of interactions across multiple digital components, the test, validation, and simulation requirements for modern cars are very difficult to meet.

Unfortunately, the combination of traditional automotive test approaches and the advanced capabilities now required has led to some mismatches that can slow the process of delivering advanced cars to market in a timely fashion. In addition, the disconnect between test processes and new requirements has created several practical challenges. For example, many Tier 1 automotive suppliers as well as the carmakers themselves often test ECUs in a serial manner—one at a time—instead of the common method of parallel test for modern digital devices. Though this seems fairly basic, it's a function of an industry that used to evolve at a much slower pace.

In addition, many of the test suites developed for modern cars don't have the level of sophistication they need to accurately catch potential flaws, especially given the extremely large amount of code now found in today's vehicles. Also, with the rapid-fire nature of today's software development environments, many of them are not equipped to handle the fast, iterative testing of new software builds. To solve these kinds of issues, automakers need to look at both the kinds of test equipment they're using for these tasks and

Unfortunately, the combination of traditional automotive testing approaches along with the advanced capabilities now required has led to some mismatches that can slow the process of bringing advanced cars to market in a timely fashion.

the more sophisticated software test development tools now available (and that the tech industry relies on).

Of course, to the automotive industry's credit, its emphasis on reliability and safety-based test is unrivaled. Due to both extensive governmental automotive safety regulations around the world and carmakers' vested interest in producing cars that protect their customers as much as they can, there are extensive safety test efforts in place for the automotive industry, particularly around physical controls and systems.

The challenge for the automotive industry moving forward is integrating these two very different worlds from a test and methodology perspective. As has been commonly pointed out, though blue screens of death may be annoying on tech devices, they can lead to actual loss of life in automobiles, so new approaches that integrate the best of both worlds need to be developed.

In addition, as cars start to incorporate features that make driving decisions on behalf of the driver, the need for building trust among potential buyers becomes critical. In order to do that, companies have to thoroughly test and vet these capabilities to help consumers overcome some of their potential fears. Of course, this all has to happen without adding significant costs to the vehicle. This, in turn, has a real-world impact on not only the cost of goods necessary to enable these features but also the development and test time needed to bring them to life.

From a test perspective, this means creating parallel test architectures, automating tests, designing for software upgradability, testing new usage and ownership models, validating interactions with new technology ecosystems, and so on. To help achieve this, companies need not only the most sophisticated test tools they can get but also ones that have proven themselves over the years in equally challenging environments like smartphones and other mobile devices.

Part of what needs to be done includes creating innovations in the test environment. This means evolving from testbeds that were designed with fixed functionality in mind to a more flexible, software-based approach that allows modular hardware and software components to be integrated as needs change.

Companies like NI have a long history of building these kinds of sophisticated test environments for major tech vendors. With NI's flexible platform-based approach, automotive test teams can own the test system IP and make changes quickly rather than relying on third-party vendors.

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As automotive manufacturers evolve from carmakers to mobility providers, it's time for them to take a fresh look at their test tools and approaches. They need to overcome the pressure of new and rapidly changing test requirements using an open and easily upgradable platform that is designed for test system flexibility, and that enables them to test the vehicles of tomorrow today.

Bob O'Donnell, TECHnalysis Research Chief Analyst

*Bob O'Donnell is the president and chief analyst of TECHnalysis Research, LLC, a technology consulting and market research firm that provides strategic consulting and market research services to the technology industry and professional financial community. He is widely regarded as an expert in the technology market research field, and his original research and advice are used by executives in large technology firms all over the world. Twitter @**bobodtech**.*

ADAS Record and Playback

You can record field data from advanced driver assistance systems (ADAS) sensors and play it back in the lab to simulate driving and increase test repeatability and test coverage. Real, recorded data is better for test because 3D-rendered scenes can be misinterpreted by algorithms designed for the real world.

Application Requirements

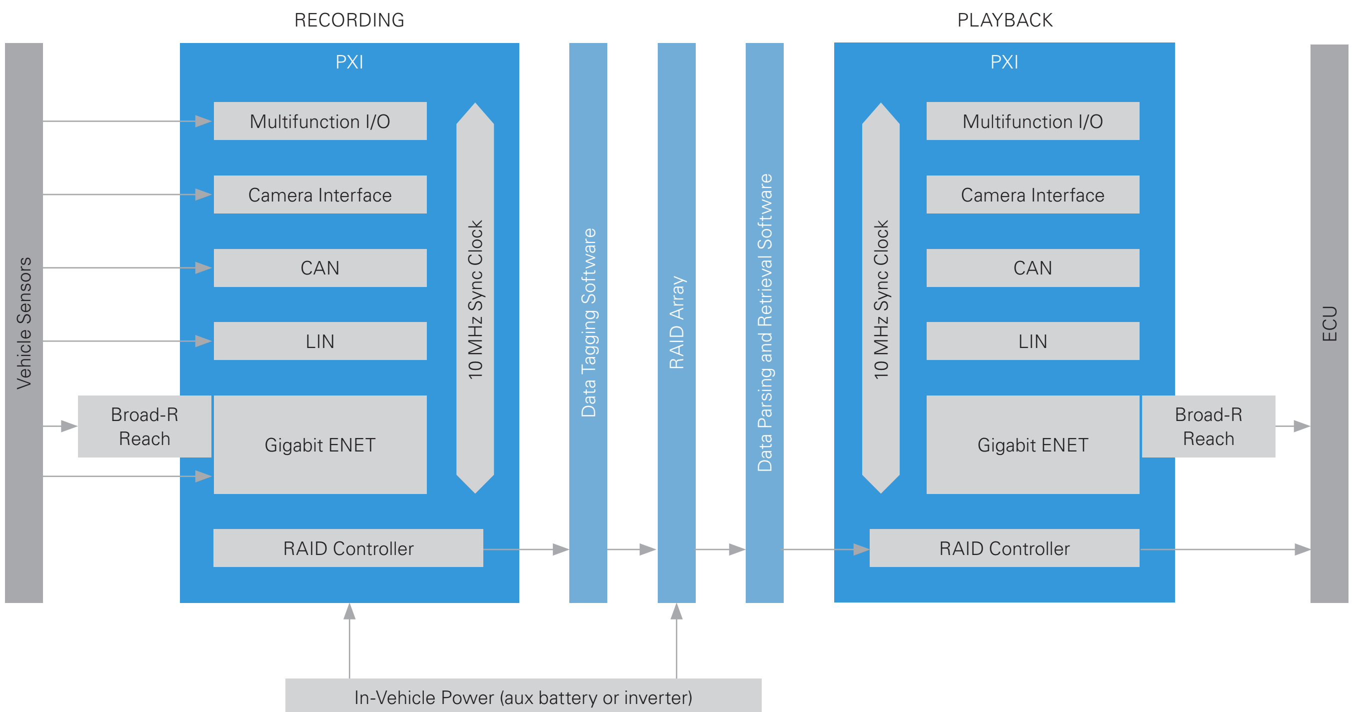
- Synchronize data within <1 µs for both recording and playback to properly simulate driving
- Interface with many different I/O types including camera, radar, and vehicle networks
- Record and play back all raw data in real time at roughly 15 GB/s in the most complex ADAS

NI Solution

- Synchronize interfaces to the microsecond for automotive networks, various camera interfaces, radar, and general-purpose I/O
- Stream terabytes of data at up to 15 GB/s with NI or third-party RAID storage options that easily interface with a PXI system
- Easily tag and manage your data files and quickly parse them for playback with the Data Management Software Suite

The NI Advantage

- Reduce implementation time, capital costs, and sparing costs by using the same hardware platform for data recording and playback
- Future-proof your system against changing requirements with the modular, software-defined PXI platform
- Don't worry about missing data; the performance of PXI ensures you can stream all of it with hardware



> “We typically deploy a PXI chassis in a vehicle and interface it to live camera, ultrasonic, vehicle bus, and environmental sensor data from typical driving situations. We use this live data to train and validate our computer vision deep learning algorithms at the bench later.”
>
> ***Derek O’Dea, Measurement Equipment and Tools Development Manager, Valeo***

Key Specifications	
Maximum Data Rate	15 GB/s
Storage Capacity	>96 TB
Synchronization	<1 µs
Camera Interfaces	MIPI CSI-2, FPD-Link, GMSL, HDMI
Vehicle Bus Support	CAN FD, LIN, FlexRay, Automotive Ethernet
Radar Support	Through vehicle bus
Lidar Support	Through vehicle bus
Ultrasonics	Through vehicle bus

Radar Sensor Production Test

As radar volumes continue to aggressively ramp, the need to test as quickly and efficiently as possible while maintaining high-quality standards is paramount. Additionally, test systems should be built to adjust for future requirements like higher bandwidth sensors or different antenna designs.

Application Requirements

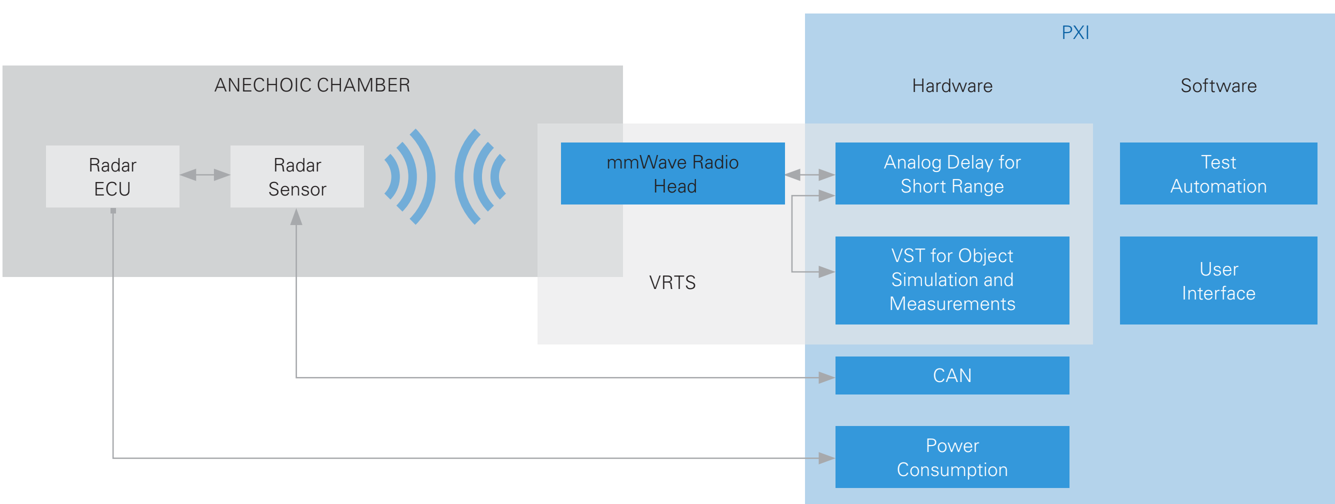
- Take parametric measurements and simulate radar targets for 77 GHz and 79 GHz bandwidths
- Achieve fast test time and fast test development and deployment to meet production targets
- Integrate handling, actuation, and an anechoic chamber with the measurement instrumentation

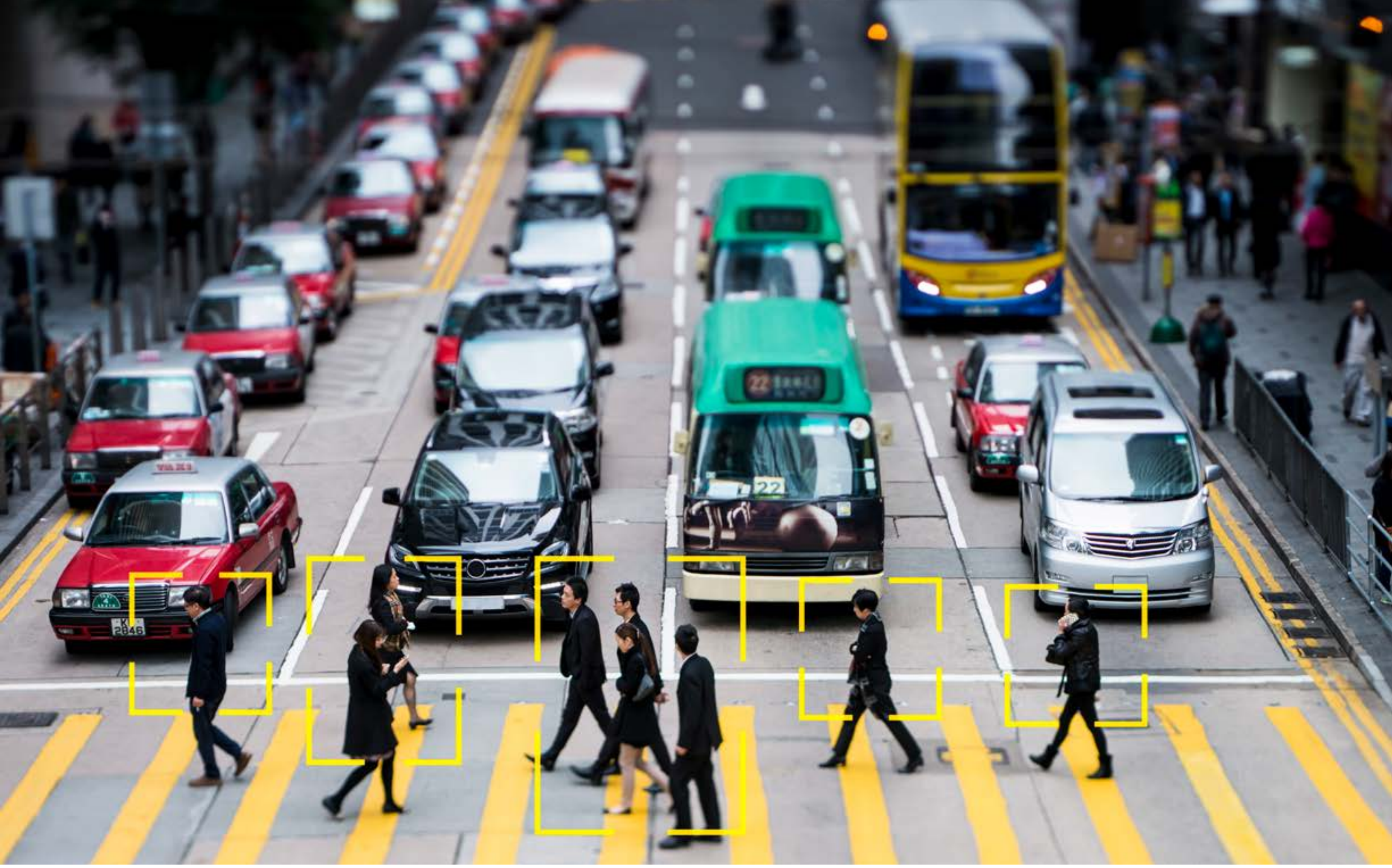
NI Solution

- Use the Vehicle Radar Test System (VRTS) to perform best-in-class radar target simulation and parametric measurements in parallel and reduce test time with a single instrument
- Upgrade your platform investment for future radar bandwidths with this modular solution
- Get help from VRTS Specialty Partners, who design complete radar test solutions and have experience integrating NI RF test systems into production environments including anechoic chambers, mechatronics systems, actuation systems, and software

The NI Advantage

- Reduce test time, capital expenses, and footprint by performing parametric and simulation test in parallel with a single device and generating multiple targets at once
- Future-proof your investment with a modular solution that you can upgrade for future technology like 79 GHz and different polarities
- Leverage work across design, validation, and production to speed implementation by using a single platform that can work across all three





“NI’s mmWave radar technology provides the industry’s widest bandwidth and low-latency software, which helps us develop automotive radar technology research in great depth. Through NI’s flexible platform-based approach, we could finish both radar performance test and radar simulation, helping us accelerate the process of autonomous driving.”

Geely Automotive

Key Specifications	
Frequency RangeW	76 GHz to 81 GHz with 1 GHz instantaneous bandwidth >96 TB
Simulated Distance (not including setup distance)	2.5 m to >300 m with 10 cm resolution
Simulated Velocity	0 km/hr to >500 km/hr with 0.1 km/hr resolution
Radar Cross Section	50 dB minimum with ≤1 dB resolution
Out-of-the-Box Measurements	Equivalent isotropically radiated power (EIRP), phase noise, occupied bandwidth, radiation pattern, beam width, chirp analysis

Hyundai Kefico Improves Production Test Time by 15 Percent Using a Standard Common Platform Tester

Automotive technology is accelerating faster than ever before. Trends like powertrain electrification, wide adoption of advanced safety systems, and enhanced driving and comfort functionalities significantly increase the amount of software needed. As a result, electronic control units (ECUs) are more complex and in higher demand. One of the most important of these is the powertrain ECU. Beyond ensuring proper operation of the powertrain that moves the vehicle, these ECUs impact the environmental performance of the vehicle, its economy, and driving experience, which are factors buyers seriously consider.

Hyundai Kefico, a subsidiary company of Hyundai, has provided powertrain automotive electronics since 1972. Like other automotive suppliers that want to remain competitive on the market, our engineers at Hyundai Kefico faced increased test demands and tighter emission regulations while managing budget and timeline challenges. When our powertrain ECUs reached 200 pins and the functional test needed to ensure quality stretched to 20,000 test steps for an increased variety of ECU types, it became clear that we could not use traditional test engineering approaches to keep up with the pace of vehicle electronics. We needed a change.

A New Approach

In the past, an ECU functional tester required that we design sensor/actuator emulators, vehicle communication modules, test execution engines and applications, test procedures, and test result management tools for each type of ECU. In other words, we developed a new tester for every new ECU, with minimum reuse of test engineering assets and a negative impact to the cost of test.

> For the first 17 CP-Testers, we achieved a 45 percent better project ROI and saved over $1M compared to our previous solution.

To solve this problem, we started with the development process and created the Common Platform Tester (CP-Tester) and the standardized ECU Functional Tester development process (Figure 1). We based the CP-Tester on standardized test assets called CP-Standard, which define sensor/actuator emulation, vehicle communication, test execution (test engine), operator interface (test application), and test result management.

System Success

The CP-Tester has a few key components that streamline the test development process. R&D or product engineers can use a test scripting modeling tool called CP-Editor to configure each test step and parameter by choosing from over 200 prebuilt functions to develop test sequences. They can map these test steps to the appropriate hardware I/O and reconfigure them for different ECU types. The CP-Server is another component that engineers can use to effectively manage test result data to improve upon new test requirements.

The Challenge

We needed to sustainably meet manufacturing test deadlines for increasingly complex powertrain electronic control units (ECUs) with over 200 pins and 20,000 test steps while ensuring test times comply with throughput needs and reducing the cost of tests to remain competitive in the market.

The Solution

Using the NI test platform to build a standard architecture, we achieved flexible test system configurations of all powertrain ECU types and reusable test scripts and procedures that guarantee test coverage alignment from R&D to manufacturing while allowing global, standard test deployment and operation.

Our engineers can realize these three benefits from the CP-Tester:

- Shorter tester development times because of its adaptability to various types of powertrain ECUs
- Efficient use of test engineering assets because it can reuse and reconfigure test steps from R&D to manufacturing
- More value out of manufacturing test data due to data handling and traceability in a standard format

We chose the NI PXI platform because it is better suited to deal with the complexity of our powertrain ECUs. Benefits of NI PXI solutions include:

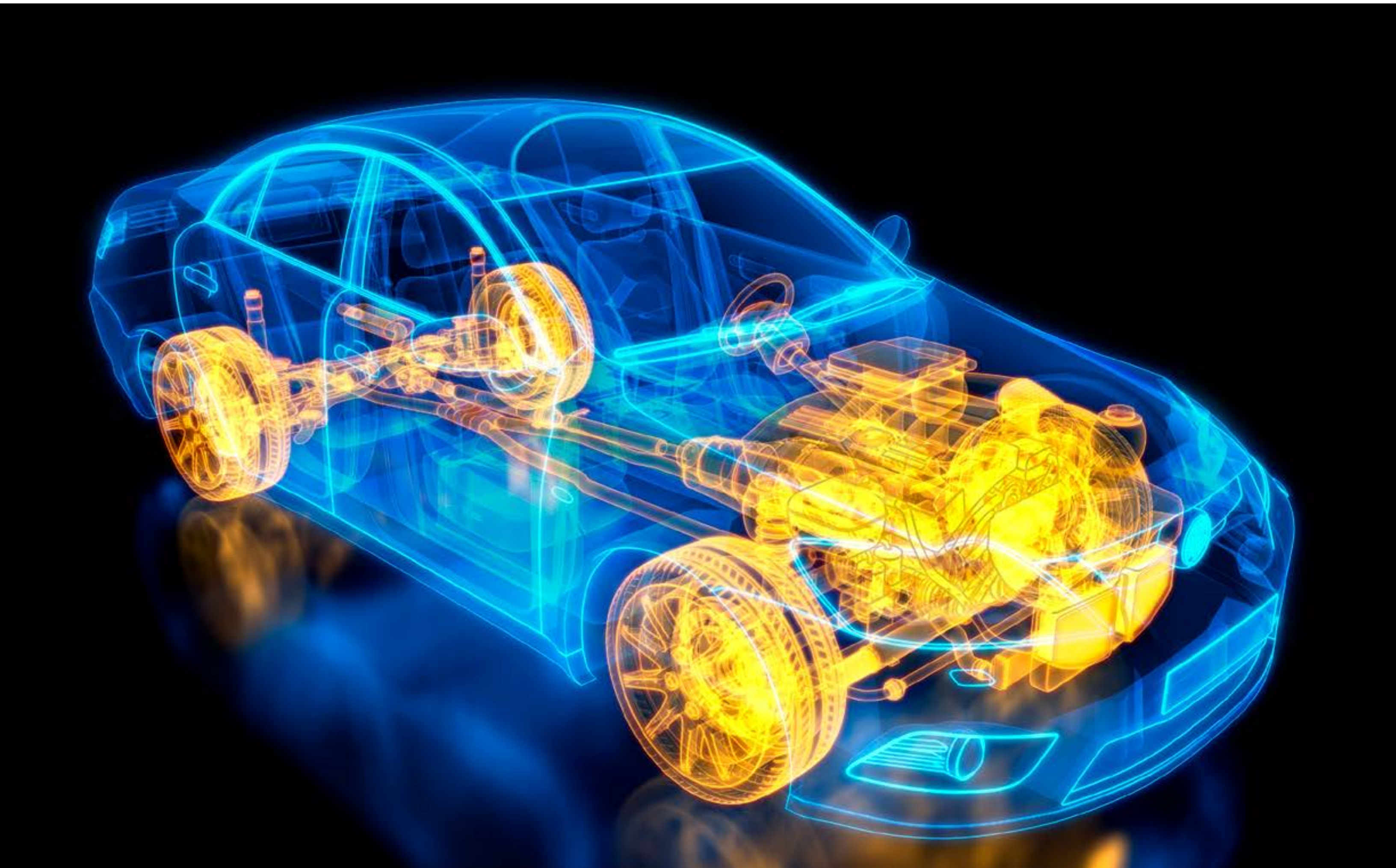
- High and flexible channel counts (over 200 pins) with different layouts
- I/O configuration with source and measurement capabilities
- Ability to connect dummy loads (resistance and inductance) to properly test ECUs
- Wide variety of switching options and ease of use with NI-SWITCH to increase I/O flexibility
- Ability to customize I/O through FPGAs to implement special sensor communication protocols such as SENT (Single Edge Nibble Transmission and SAE J2716)

Most turnkey ECU testers on the market require 10 to 12 months to adopt new test plans for new products, and they still require significant interaction with the vendors and high costs. Given the importance of a short development time, we took advantage of NI's automated test solutions to become independent and develop our own flexible standard tester within three months. This resulted in an 80 percent reduction of development time while giving us the ability to add functionality like CAN with Flexible Data-Rate in the future, as product requirements evolve.

At the company level, given the higher demands for ECUs, the NI PXI timing and synchronization features improved our test time by 15 percent and cut the test system cost by 30 percent, which has helped us be more competitive in the market. In addition, we can procure and assemble the CP-Tester at any of our manufacturing sites around the globe thanks to NI's global presence.

For the first 17 CP-Testers, we achieved a 45 percent better project ROI and saved over $1M compared to our previous solution.

Minsuk Ko, Minho Yoo, Hyunjick Lee, HyoungJoo Kim, Hyundai Kefico



Automotive Industry Changes at CES 2019

It used to be easy to spot a car. Even with generalized characteristics, a car has a distinguishable look, sound, scent, and feel. Now, it's different. At the Consumer Electronics Show (CES) 2019 in Las Vegas, I discovered a "flying car" that looks like a helicopter and a "walking car" that looks like a robot.

Change is everywhere in the automotive industry, and nowhere is that more evident than at CES. Read on to find out what I discovered while trying to keep up with change, including how it's driving tomorrow's automobile testing to ensure safety, security, and reliability.

Perhaps Full Autonomy Is Not the Ultimate Goal

One of the biggest changes between CES 2018 and CES 2019 was company positions on autonomy. There's a small-but-prevalent belief that active safety features can decrease accidents and injuries enough to not warrant additional investment in full autonomy. In fact, a National Highway Traffic Safety Administration report cited impressive traffic improvements linked to vehicles equipped with active safety systems:

- 40% reduction in rear-end collisions
- 14% reduction in lane-change crashes
- 11% reduction in single-vehicle, side-swipe, and head-on crashes

As these L1/L2 ADAS become more commonplace, we could see this trend continue. Toyota showcased progress toward its Chauffer and Guardian modes—Chauffer, a fully autonomous mode in which the driver can sit back and relax, and Guardian, designed to amplify human control. Toyata's demonstration used an interesting fighter-jet analogy wherein a low-level control system translated the pilot's stick movements to instruct the plane.

Imagine a World With Full Autonomy

Based on the concepts at CES, it took little imagination to envision a world with autonomous vehicles. Forget the debate about autonomy's necessity; instead, consider the possibilities.

Faurecia's engaging example showed a smart cockpit with many system improvements, including climate control and information displays. Particularly interesting was the high-definition infotainment screen that popped out of the instrument panel when the vehicle entered self-driving mode.

Kia demonstrated its Real-Time Emotion Adaptive Driving system, with artificial-intelligence-based biometric sensors that analyzed the driver's emotional state to optimize and personalize the cabin. I took a test sit (that's what it's called when the car doesn't move, right?) in one of Kia's concept cars, which showcased an infotainment system designed for the commuter. It featured a videoconferencing setup, calendar and contact connectivity, and V-Touch navigation, which interprets a subtle gesture in front of you as your intended "touch". It felt like touching a button in virtual reality.

At Hyundai's display, I was (un)fortunate enough to demonstrate the rowing functionality, where I pulled a rowing-machine handle out of the dash and tried to row simultaneously with my fellow riders. As with any car-based synchronized rowing session, we virtually joined other commuters in their cars doing the same. The race was on!

We lost.

Other demonstrations included display panels that ran the entire width of the dashboard (Byton), holographic in-vehicle infotainment displays (WayRay), and driver-monitoring systems to eliminate discomfort or mitigate unsafe emotions (Continental).

Starbucks or Food Trucks

I had a fascinating conversation with the folks at Ridecell, a startup partnering with DENSO to explore fleet management, which is a topic picking up steam as fleets of cars deploy for testing. Our autonomous-vehicle fleet-maintenance debate centered primarily on the Starbucks model (a maintenance depot "pod" at many convenient locations) versus the Food Truck model (fewer locations, more mobility).

Electric scooter companies are now tackling transportation fleet management challenges (it's hard to drive in Austin without seeing someone zooming around on a Bird or a Lime). Of course, diagnosing and fixing an autonomous electric vehicle is far more challenging than doing so for an electric scooter, but the tracking, managing, and asset-failure-identification infrastructure can be similar. Companies are likely to try different approaches in real time until they collect enough failure-rate and cost data.

Flexibility Is Critical

As a test vendor, NI's measurement technology must meet today's needs and flexibly adapt as they evolve across the entire product design cycle, throughout test phases, and into postproduction asset management. If I believe that it's getting harder to keep up with automotive industry changes, I can only imagine being one of the many engineers charged with ensuring vehicle safety and reliability! Flexibility, adaptability, and customizability are paramount and NI is here to help every step of the way.

Jeff Phillips, NI Head of Automotive Marketing

Vehicle Radar Test System

Built for Automated Design Validation, Test, and Measurement

The Vehicle Radar Test System (VRTS) provides automated radar measurement and obstacle simulation capabilities for 76–81 GHz vehicular radar systems. Engineers can use the VRTS to test both the hardware and software subsystems of a vehicle, including radar sensors, ADAS subsystems, and embedded software. The VRTS's flexible obstacle generation capability allows engineers to test the embedded software of radar and other ADAS through the simulation of a wide range of generated scenarios. In addition, the combination of high-performance mmWave Radio Heads and the PXI Vector Signal Transceiver (VST) also allows engineers to conduct precision RF measurements for beam characterization and testing. As a result, engineers can utilize the same measurement hardware for all phases of ADAS and radar system development, from R&D to high-volume manufacturing test.

The VRTS is part of a platform-based approach to test and measurement, so it easily integrates with other PXI measurement hardware as part of a comprehensive automotive test system. In sensor fusion test applications, engineers can combine and synchronize the VRTS with other measurement hardware to simultaneously simulate multiple sensor types. Typical test systems are often configured as part of a hardware-in-the-loop (HIL) simulation in which the test equipment simulates the behavior of the environment to test embedded software.

VRTS Detailed View

The VRTS is a modular system capable of providing automotive radar obstacle generation and measurement capabilities in 77 and 79 GHz automotive radar bands. At the heart of the VRTS is a PXI system containing the PXIe-5840 vector signal transceiver and NI-5692 variable delay generator (VDG). These modules operate in conjunction with an NI mmRH-3608 mmWave radio head, which provides the RF interface to the radar sensor. The mmWave head also features an alignment laser to ensure accurate alignment between the radar DUT and the test system radio head. A block diagram of a typical test configuration is represented in Figure 1. A key component of the VRTS is the PXIe-5480 VST. This instrument provides two critical functions to the system; calibrated radar measurements and obstacle emulation. Using the VST's onboard FPGA, engineers can simulate the complex movements of a radar obstacle. When performing radar obstacle emulation, engineers can use the VRTS to simulate up to four or more objects. Obstacles appear at a range from four to >300 m with a range resolution of 10 cm to 12 cm, depending on obstacle range. In addition to range, users can dynamically set object radar cross section (RCS) and velocity (Doppler effect) in the software.

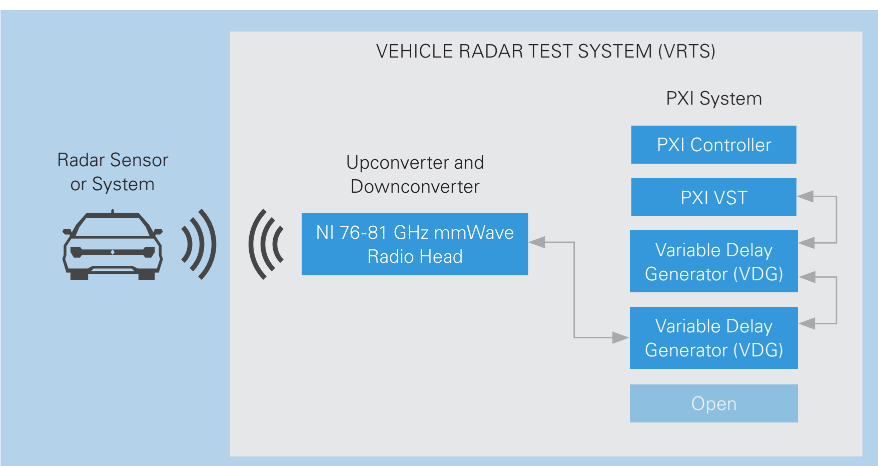


Figure 1. Block Diagram of Typical VRTS Configuration

The VST's RF signal generator and analyzer provides calibrated measurement results for automated radar sensor test. Using this instrument, the VRTS allows engineers to perform measurements including antenna beam radiation pattern, effective isotropic radiated power (EIRP), phase noise, spectrum occupancy, beam width, chirp demodulation, and more. The combination of obstacle simulation and measurements capability can reduce production test floor space and total test time by integrating the functions of two common dedicated test systems.

The modularity of the VRTS enables NI Alliance Partners to customize the exact hardware configuration in order to best suit the needs of specific applications.

Nine-Slot System for Production Test

For production test applications, the VRTS is configured with one VST and up to two VDGs as illustrated in Figure 2. This configuration supports generating up to two full-range radar obstacles and features the lowest footprint and cost.

The production test VRTS is also capable of the full radar measurement suite for beam characterization test, EIRP measurements, and functional test. The system configuration in Figure 2 includes:

- 1x PXIe-1078 nine-slot chassis
- 1x PXIe-8840 multicore embedded controller
- 1x PXIe-5840 vector signal transceiver
- 2x NI-5692 variable delay generators

Eighteen-Slot System for Validation, Characterization, and Research and Development

For advanced applications, engineers can utilize the PXIe-1085 18-slot chassis to support up to four full-range radar obstacles. This configuration includes two VSTs and four VDGs and is illustrated in Figure 3. Both the production test and advanced VRTS can be expanded to support additional simulated radar obstacles via cabled expansion of the system to additional PXI chassis. System configuration in Figure 3 includes:

- 1x PXIe-1085 18-slot chassis
- 1x PXIe-8840 multicore controller
- 2x PXIe-5840 vector signal transceivers
- 4x NI-5692 variable delay generators

Note that the configuration in Figure 3 also contains an empty PXI slot, which can be used to add more instrumentation or control additional PXI chassis. Available instrumentation includes power supplies, oscilloscopes, data acquisition modules, CAN/Ethernet interface modules, and more.

mmWave Radio Head Options

In addition to multiple PXI configurations, VRTS features multiple radio head options for both bistatic and monostatic antenna configurations. The bistatic option features independent Tx and Rx ports and up to 50 dB Tx to Rx isolation. In contrast, the monostatic option features a signal combined Tx/Rx port with up to 30 dB of Tx to Rx isolation. The bistatic radio head is illustrated in Figure 4.

Figure 2. VRTS Configuration for Production Test

Figure 4. Bistatic VRTS mmWave Transceiver Radio Head (with and without cover)

Figure 3. Advanced VRTS Capable of Generating up to Four Radar Obstacles

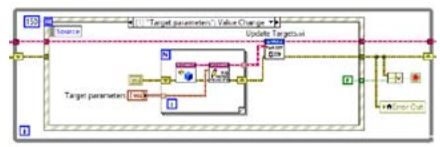


Figure 5. Customize measurements and scenarios using LabVIEW and LabVIEW FPGA.

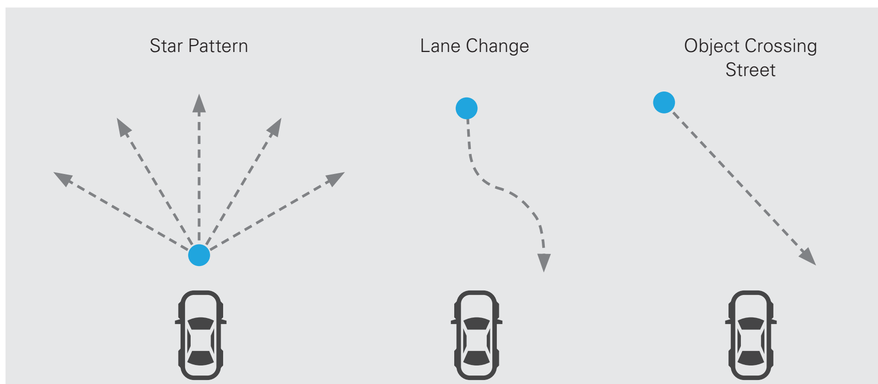


Figure 6. Common Driving Scenarios

Radar Obstacle Emulation

The flexibility of the VRTS allows NI Alliance Partners to configure highly customized software applications that are uniquely tailored to suit the requirements of specific applications. Using the powerful graphical programming environment of LabVIEW and LabVIEW FPGA shown in Figure 5, NI Alliance Partners are able to develop software applications ranging from stand-alone obstacle simulators to full-featured HIL simulation systems. With each of these software applications, NI Alliance Partners build on top of the low-level VRTS hardware API and augment it with customized software.

One of the benefits of NI's flexible obstacle generation architecture is that it enables engineers to add new test cases as reliability standards and requirements evolve. For example, in applications involving embedded ADAS software test, engineers can use NI Alliance Partner software to simulate common driving scenarios, illustrated in Figure 6, including star pattern, lane change, and an object crossing the street. The behavior of each of these scenarios can be controlled via three key parameters; range, velocity, and radar cross section.

Engineers using VRTS can configure the system to simulate a wide range of obstacles, and simulated obstacles adhere to the conditions in Table 1.

Radar Test and Measurement

In addition to obstacle simulation, the VRTS is designed to perform RF measurements of radar sensors and systems. As part of the low-level hardware control, NI includes measurement science required for typical radar measurements. The measurement science for each of these measurements is based on the NI-RFmx measurement API, which delivers extremely fast and accurate measurement results. Typical measurements supported by the VRTS include:

- Radiation pattern
- Equivalent Isotropically Radiated Power (EIRP)
- Noise
- Spectrum occupancy
- Beam width
- Chirp analysis: linearity, overshoot, recording, tagging

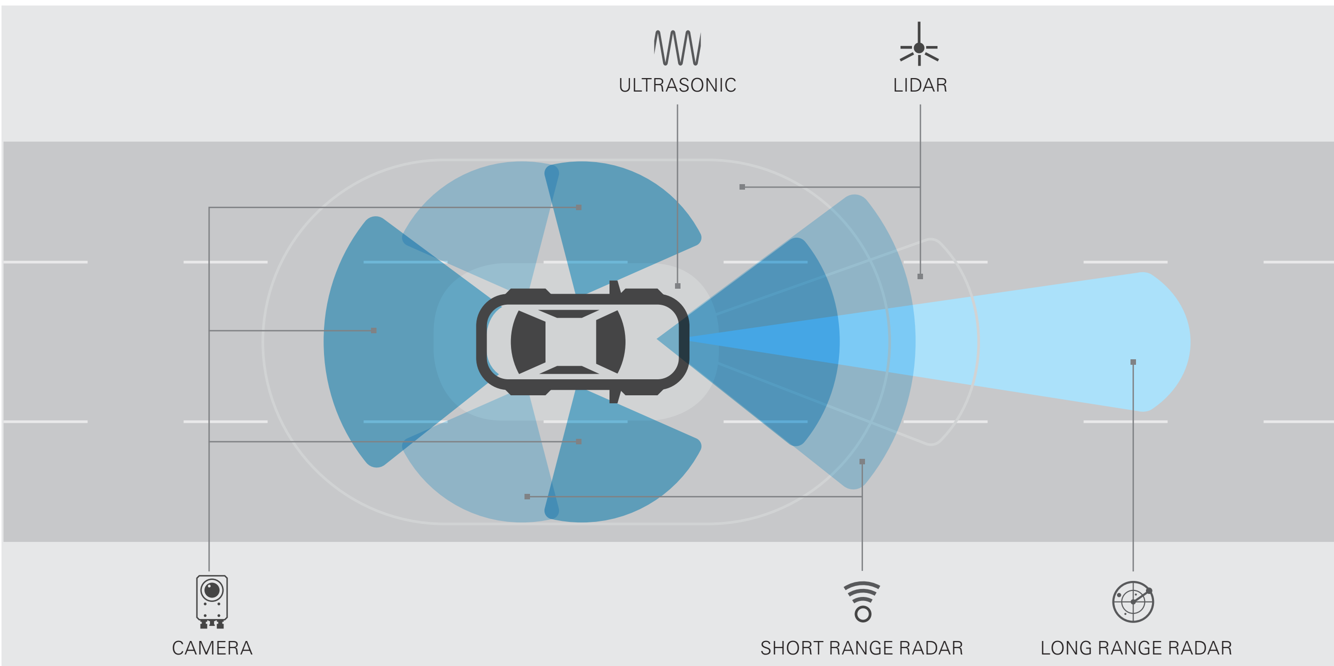
Table 1. VRTS Obstacle Simulation Specifications

Parameter	Specification
Number of Simulated Objects	1–4 (full range)
Range	4 to >300 m
Range Resolution	10 cm (near obstacles)
Distance Accuracy	±15 cm
Object Velocity (Doppler Frequency Shift)	0 to ±500+ km/hr (75 kHz)
Doppler Resolution	0.1 km/hour (15 Hz)
Radar Cross Section Range (RCS)	50 dB min
RCS Resolution	≤1 dB
Distance between VRTS and Radar DUT	0.7 – 3.0 m

Table 2. VRTS Hardware Performance

Parameter	Specification
Frequency Range	76–81GHz
Instantaneous Bandwidth	1000 MHz
Transmit/Receive Isolation	30 dB for monostatic 50 dB for bistatic
Rx Noise Figure	12 dB
Tx Maximum Output Power	+10 dBm
Phase Noise, 77 GHz @ 100 kHz Offset	-90 dBc/Hz typical

Hardware-in-the-Loop Testbed for Sensor Fusion-Based ADAS



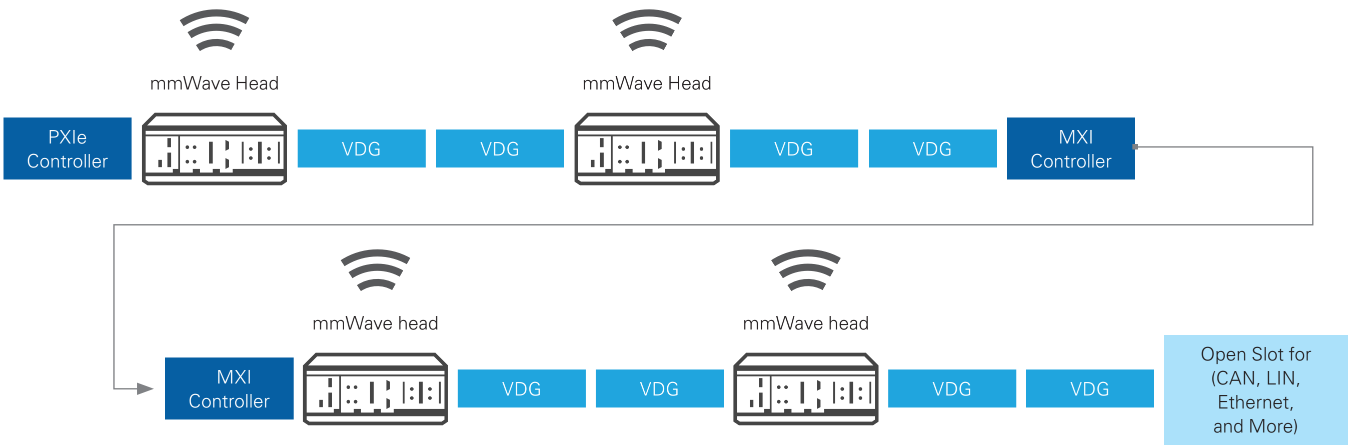
Sensor Fusion in Today's Vehicles
Sensor fusion can be relevant with all types of sensors. A typical example is the fusion of information provided by a front camera and a front radar. A camera that works in the visible spectrum has problems in several conditions like rain, dense fog, sun glare, and absence of light, but it is highly reliable when recognizing colors (for example, road markings). Radar, even at low resolution, is useful for detecting distance and is not sensitive to environmental conditions.

Typical ADAS functions that use the sensor fusion of front camera and radar include:

Adaptive Cruise Control (ACC)—Adapts speed to traffic conditions. Speed is reduced when the distance to the vehicle ahead drops below the safety threshold. When the road clears or distance to the next vehicle is acceptable, the ACC accelerates back to the set speed.

Autonomous Emergency Braking (AEB)—Controls the braking system by reducing the speed in the case of a certain collision or by alerting the driver in critical situations.

Scaling Up
The existing setup with one NI Vector Signal Transceiver (VST) and one mmWave head can generate two targets with the same angle of arrival. Thanks to the flexibility of the system, we could easily scale to simulate multiple targets with multiple angles of arrival. A configuration with four VST and four mmWave heads can simulate up to eight different targets with four angles of arrival.

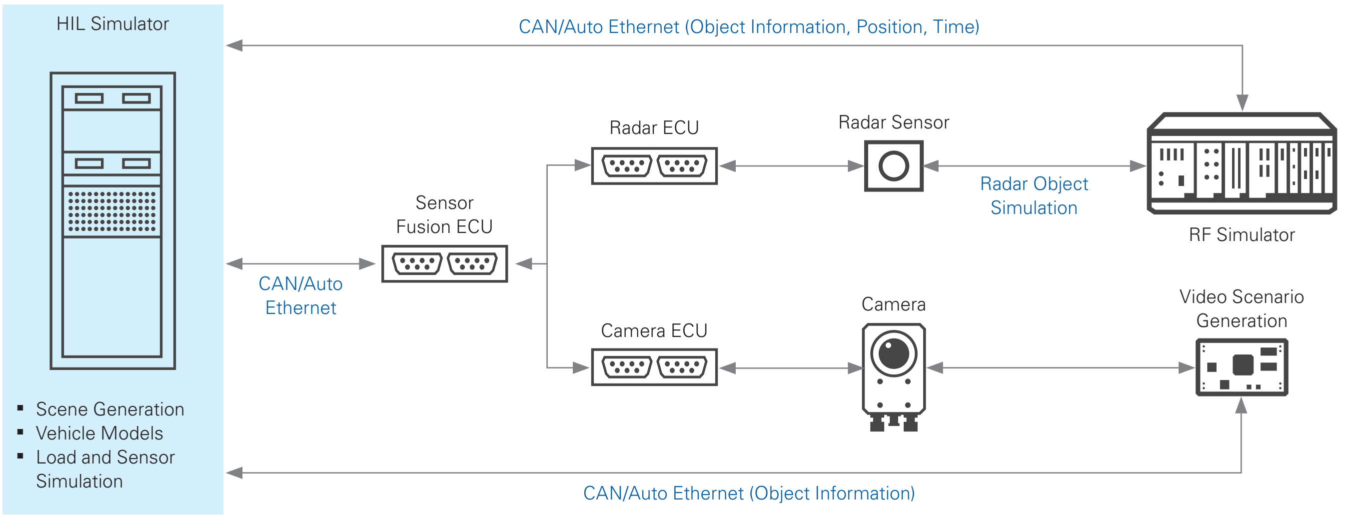


Conclusion

ADAS are safety critical, so the ability to test in the lab before conducting vehicle tests is a crucial step. Validating in this manner means we can anticipate validation prior to the availability of the vehicle to allow corrective actions that otherwise would come too late in the production cycle. Overall development time is greatly reduced because tests can be started before the vehicle is available with a system that can work all day long seven days a week. No-regression tests can be carried out in less time with minimal cost compared to using the assembled vehicle.

As a global leader in engineering and R&D (ER&D) services, Altran offers its clients a new way to innovate by developing the products and services of tomorrow. Altran works alongside its clients on every link in the value chain of their projects, from conception to industrialization.

Giuseppe Doronzo, Marino Difino, and Matteo Moriotti, Altran Italia



Sensor Fusion HIL With Scene Generation

Integrate scene generation tools with hardware I/O to play back simulated scenarios for validating the sensor fusion and decision-making algorithms on ADAS controllers. Scene generation increases test coverage because you can create scenarios that meet specific test requirements rather than relying on road tests or previously recorded data.

Application Requirements

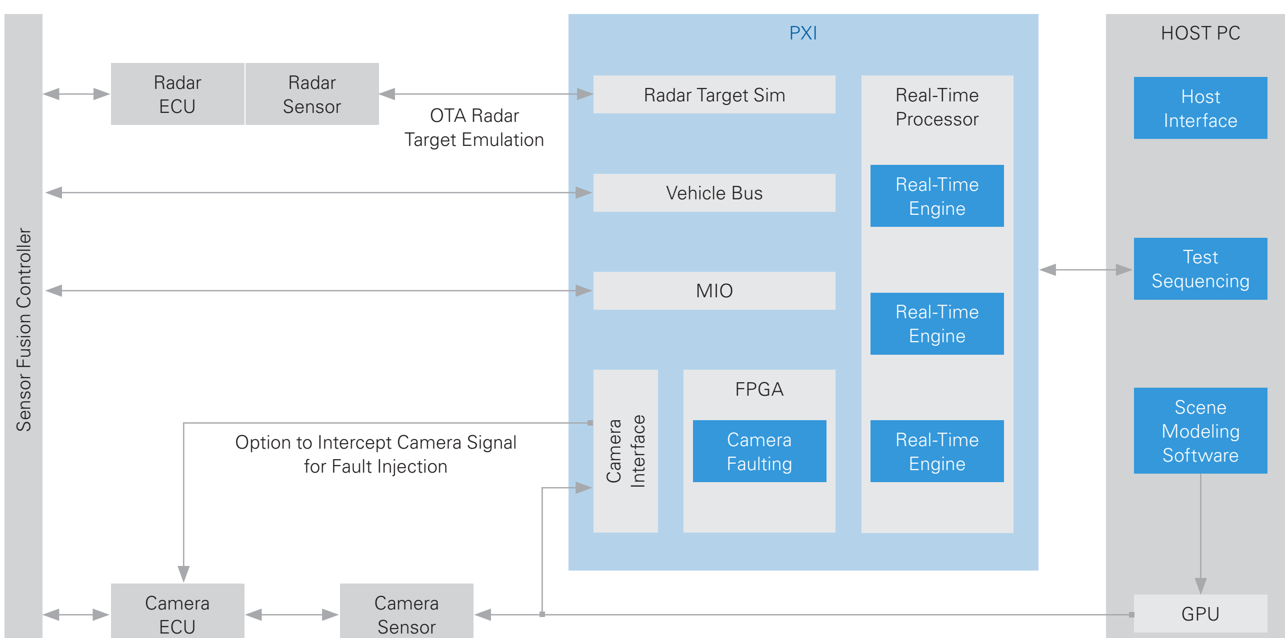
- Integrate hardware I/O with scene generation tools like IPG CarMaker, VIRES VTD, or TASS PreScan
- Synchronously generate I/O signals
- to interface with the ADAS controller; with tight control over timing,
- you can test faults like frame delays
- or phase coherency
- Maintain flexibility for future I/O requirements as systems continue to add more cameras, radar, and I/O types like lidar

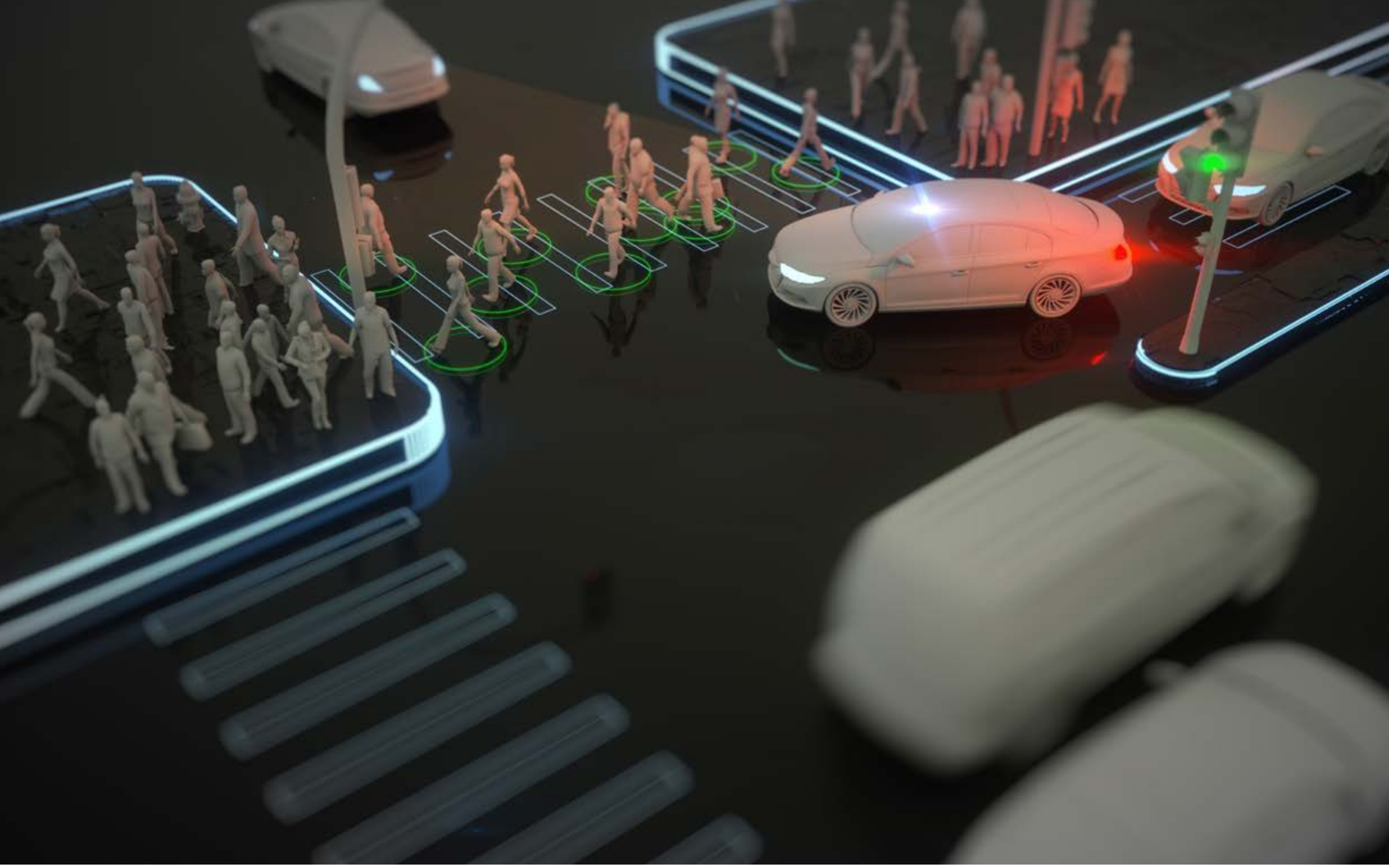
NI Solution

- Integrate with a wide variety of third-party scene generation tools using VeriStand real-time test software, so you can choose the tool that works best for you
- Use PXI modular hardware to generate OTA radar signals, camera signals, vehicle bus traffic, and general-purpose I/O; it also features hardware and software faulting capabilities and nanosecond synchronization and timing control
- Implement test sequencing with TestStand automated test software or Python scripting to automate test vectors and increase test coverage in shortened test schedules

The NI Advantage

- Achieve the greatest control over your test system and maximize your test coverage using the openness of the NI toolchain
- Change camera interfaces, inject bitstream faults, test radar sensors with real over-the-air (OTA) reflections, or add new sensor types without significant costs or hardware changes
- Future-proof your system with a modular, software-defined platform like PXI combined with VeriStand; you can simply add an I/O module to the system as your requirements change





"The flexibility, modularity, and scalability of the NI system enable users to easily integrate it with other I/O as part of a comprehensive HIL tester for radar design and test applications and to use the same system for both target emulation and radar device measurements, lowering the cost of device and system test."

Giuseppe Doronzo, Advanced Architect, Altran Italia

Key Specifications	
Synchronization	<1 µs
Scene Generation Support	Anything with an API (IPG, TASS, VIRES, Unity)
Camera Interfaces	MIPI CSI-2, FPD-Link, GMSL, HDMI
Radar Sensor Support	77 GHz, 79 GHz (coming soon)
Minimum Emulated Radar Distance	2 m
V2X Emulation Protocols	DSRC, 4G C-V2X
Location Emulation Protocols	GNSS, GPS, GLONASS
Other I/O	General-purpose I/O, CAN, LIN, FlexRay, Automotive Ethernet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