AUTOMOTIVE JOURNAL

2023 + VOL 2

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New Innovation in Test Technology

Welcome to the Automotive Journal—a premier collection of inspiring stories, technical deep dives, and explorations of interesting things happening across the cutting-edge world of automotive test, with a focus on the intricacies of the software-defined vehicle as the convergence of EVs and autonomous technologies.

This edition will bring to life inspiring stories from the innovative companies driving change in the Automotive industry. From ZF's partnership on hardware-in-the-loop (HIL) test to the Battery Innovation Center's innovative testing of EV battery cell quality and yield, NI's test solutions are driving real and meaningful change for automotive leaders today.

We'll delve into the world of the EV battery, including an exploration of the battery pack and cell, an overview of how OEMs are ensuring quality, and a deep dive into the industry's first software-defined battery validation lab.

Join us as we continue a thrilling journey through the realm of EV batteries and ADAS, uncovering the innovations and challenges that lie ahead in the ever-evolving automotive landscape.

Table of Contents

Building Better Batteries with BIC

Improving EV Battery Cell Quality and Yield through Innovative Testing

The electrification of vehicles is driving a massive transformation in the automotive industry and beyond. A critical factor in achieving this transformation lies in the availability and production of better batteries. Never has one component held such far-reaching implications for the quality, safety, and performance of the final product. Recognizing this, NI and the Battery Innovation Center (BIC) are collaborating to enhance battery quality and yield through research on test utilization in the battery manufacturing process and the effective management of test data throughout the battery lifecycle.

Batteries present a unique challenge with testing due to their distinctive coverage requirements. For instance, testing a battery is closer to testing a human body than a circuit board. Like humans, batteries are highly dynamic as their conditions change based on their usage and environment, and each one behaves a little differently. Moreover, batteries come in a wide variety of form factors, sizes, chemistries, and capacities, necessitating test systems that are not only highly capable but also incredibly flexible.

To truly comprehend the inner workings of a cell to address quality objectives and ultimately minimize defects, are needed. The industry has traditionally relied on legacy methods of testing that can be characterized as highly manual, limited in coverage, and at the end of line. These methods ultimately provide insufficient insights and require significant testing time.

To overcome these challenges and build better batteries, NI has developed a **cell quality testing solution** based on the modular PXI hardware platform and open software environments. By more accurately and comprehensively profiling the impedance of the cell, using techniques such as AC-IR, DC-IR, and EIS, this solution helps engineers better understand a cell's behavior with more accuracy, at faster speeds, and in a smaller overall footprint.

However, advanced testing methodologies alone are insufficient. Scaling these techniques from the laboratory to the production environment poses its own set of challenges. Battery manufacturing can be a time-consuming process, spanning several days to weeks, with numerous steps that can introduce defects. The goal is to reduce manufacturing time from weeks to mere hours or days, while simultaneously minimizing points of failure. Achieving this requires a departure from relying solely on end-of-line testing. "By working with BIC, we're researching innovative ways to test throughout the battery manufacturing process so we can find defects sooner and closer to where they're being introduced," shared Eli Kerry, EV Battery Strategy Lead at NI.

Given the scale of battery production, integrating widespread test and measurement capabilities becomes a complex undertaking. Thousands of test and measurement nodes are required, necessitating streamlined test asset management.

BIC and NI leadership on stage at NI Connect 2023.

Eli Kerry, NI Battery Strategy Lead, highlights an NI battery cell testing solution at NI Connect 2023.

> "We're researching innovative ways to test throughout the battery manufacturing process so we can find defects sooner and closer to where they're being introduced."
>
> **Eli Kerry**
> EV Battery Strategy Lead

Connected and smart test systems provide the solution, enabling effective orchestration, control, and management of all endpoints. This means that anyone within an organization, anywhere in the world, can access, manage, or update test assets. Leveraging connected systems, new test measurement techniques can be deployed, extracting valuable data across different manufacturing processes.

Ultimately, the key to building better batteries lies in the data produced and its value across the battery lifecycle. Battery manufacturers and OEMs are increasingly focused on harnessing the power of data, recognizing that it extends beyond the results of a single test.

The true value lies in the comprehensive data obtained throughout the lifecycle of each battery and across all manufacturing activities. The utilization of this data through advanced modeling techniques allows manufacturers to better understand the characteristics of each battery cell. These evaluations are critical to improving yield and quality, and they pave the way for the next generation of high-performance batteries.

Through the collaboration between the BIC and NI, the path toward building better batteries is being forged.

Author

Jared Aho
Senior Director, EV Marketing, NI

Learn about our solution

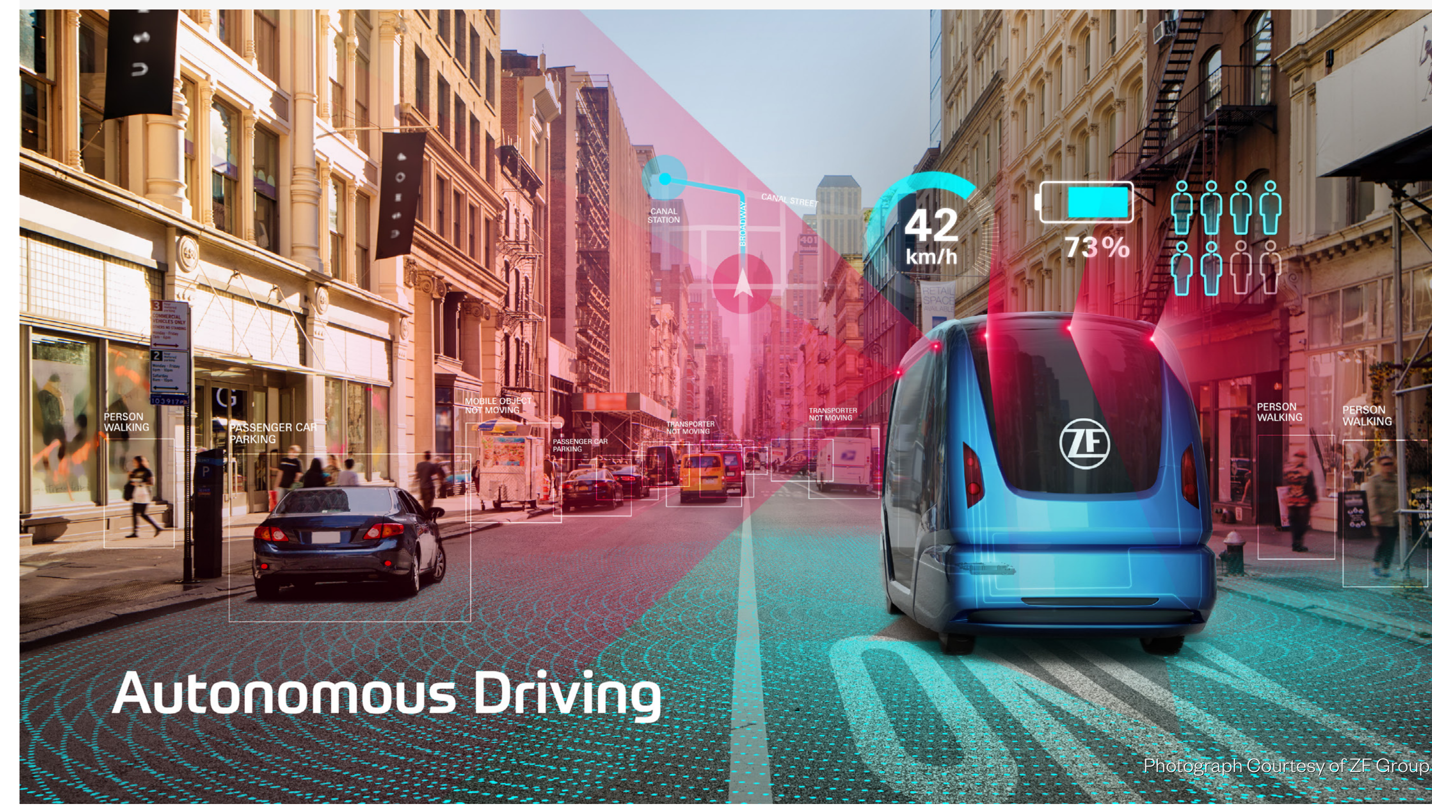
ADAS Validation with ZF's HIL System

Case Study Highlights

01 NI's open, data-driven, software-connected ecosystem plus PXI capabilities enabled ZF to develop a scalable ADAS HIL system to meet future requirements while keeping up with test programs.

02 ZF's ADAS HIL test system prototype was replicated to several systems to operate in a HIL farm, creating fully automated validation systems across numerous software test cycles.

03 ZF's team competencies led to the development of powerful modular HIL software libraries, serving as a basis for future projects and a path to become an NI Center of Excellence.



Photograph Courtesy of ZF Group.

The Challenge

The ADAS hardware-in-the-loop (HIL) test system must meet the continuously changing requirements of verification and validation of the advanced driver assistance systems (ADAS) and autonomous driving (AD) complex functions for autonomous vehicles to provide humans with the safety needed.

The Solution

ZF's ADAS Validation Department worked with NI to develop and tailored a scalable, flexible, and highly networked HIL test system that has been reused for testing ECUs for ADAS and AD systems while saving significant development time.

Software is Driving Next Generation Mobility at ZF

FIGURE 01

ZF Next Generation Mobility. Photograph Courtesy of ZF Group.

> "AD and ADAS require the combination of different test methodologies which is challenging but essential to provide driver and passenger safety and ultimately for AVs to become a reality. With NI solutions, we can build up systems and move one step closer to a comprehensive test strategy consisting of both real-world and virtual test efforts."

Dr. Thomas Herpel
Senior Manager Test System Development,
ZF Mobility Solutions, Ingolstadt, Germany

ZF Next Generation Mobility

As one of the world's biggest automotive Tier 1 suppliers, ZF committed itself to "vision zero," which aims for zero traffic accidents with fatalities and zero emissions. One major approach to reach this goal is making driving safer, more efficient, and more comfortable.

ZF's future strategy focuses strongly on shaping "Next Generation Mobility," describing viable mobility solutions that are electric, intelligent, connected, sustainable, safe, autonomous, and affordable.

ZF has a strong position in the market with its expertise and product portfolio to enable vehicles to see, think, and act. The maxim "See – Think – Act" summarizes concisely the company's leading theme. For example, ZF can interconnect cameras and sensor systems—such as radar or lidar, to provide a 360-degree panoramic view (See). In addition, ZF develops, produces, and connects the switching centers of the vehicle using a network of electronic control units or central high-performance computing platforms (Think). And naturally, the company can connect mechatronic systems in the drive, chassis, or steering system to create modern drive functions (Act). This makes vehicles not only safer but improves their efficiency.

Test System Development at ZF Mobility Solutions

ZF Mobility Solutions (ZMS) is a 100 percent subsidiary of ZF Group with its Headquarters in Ingolstadt, Germany. The mission of this portion of the company is to provide clean, efficient, comfortable, and affordable mobility by development and implementation of autonomous transport systems.

The ZMS Test System Development Department's vision is to develop innovative and high-quality test systems tailored to the specific demands of verification and validation of complex ADAS and AD.

The mission is to build prototypes for HIL-based test systems for ZF Group with hardware, software, and processes ready for use in serial development projects.

ADAS Validation Challenges

ADAS requires intensive validation at various stages in development. Testing must include real-world scenarios for complex functions that are highly networked. How safe should ADAS be before they are allowed on the road for consumer use? Real car testing requires a lot of time, is expensive, and sometimes provides only limited informational value—especially in terms of reproducibility of tests. While it is still necessary, there is an urgent need to shift from "a quantity of miles driven" to "the quality of the miles that need to be tested on the road" by including other test methodologies into the validation process.

More than ever, a well-elaborated validation strategy is an important pillar of being compliant to state-of-the-art norms and regulations such as the **ISO-26262 standard** or Automotive SPICE (ASPICE).

Using virtual reality (VR) technologies in development is one of the major trends; it allows for testing the system in earlier stages under realistic conditions. HIL-based test systems for open-loop data replay and closed-loop simulations are particularly suited for validation of ADAS functions on the target hardware and the determination of functional and non-functional key performance indicators (KPIs).

The requirements and combination of different test methodologies are essential to provide driver and passenger safety—and ultimately for autonomous vehicles to become a reality. NI solutions enable test systems to be constructed that contribute to a comprehensive test strategy consisting of both real-world and VR-based test efforts.

Requirements for Radar HIL Test System

ADAS put high demands on test system development as the focus and need for these systems is no longer only on high computing power, but more than ever on scalability, flexibility, and aspects of highly networked system operation. The system-under-test (SUT) is a ZF automotive-graded radar sensor for typical ADAS applications such as adaptive cruise control, collision avoidance, and pre-crash safety systems or copilot functions. As the complexity of the SUT increases, it is inevitable to think in platforms when developing new test systems.

Key aspects of such test systems are:

- **Modularity:** Plug and play of core HIL and add-on system components
- **Scalability**: From single ADAS ECU validation to high-performance 360° AD sensor data replay and closed-loop virtual reality simulation
- **Dependability**: 24×7 serial HIL farm operation with highest availability requirements
- **Compatibility:** Integration of new HIL test systems into existing ecosystems with respect to group IT infrastructure, existing tools, and processes
- **Smooth operability:** HIL farm setups for a broad range of serial validation with remote access, operation and maintenance, and diagnosis

For open-loop validation of ADAS ECUs with real-life recordings from proving grounds and test fleets, data reinjection must be enabled with high data rates over complex communication interfaces with a demand for highly accurate timing and synchronization. In addition to recorded radar data, the vehicle rest-bus communication signals must be reprocessed in parallel such as vehicle speed signals, yaw rates, or other status data. For radar data reinjection, the HIL test system must provide the appropriate interfaces and a robust and precise control of reinjection with high I/O data rate and sideband communication. Another key aspect of the HIL test system's software platform and interfaces is the requirement for full automation of HIL test runs, remote software deployment, and HIL operation in 24×7 HIL test farm operations.

Approach

The main drivers for ZMS to go with NI were the high-performance, real-time computing systems together with high-precision timing and synchronization capabilities. The **PXI platform** was also attractive, with its broad variety of interface cards and modules, such as up-to-date automotive bus system and analog and digital I/O cards.

NI's open software platform also allows for generating modular and application-specific software in HIL system development, especially regarding real-time software development with **LabVIEW** and system operation aspects covered by **SystemLink™** software.

The PXI platform supports modularity to switch work from one ADAS project to another without reinventing the wheel. This is achieved by setting up new parameters for each test case and relying on the existing basis of a core system that can be reused to test powerful ECUs for ADAS and AD systems while saving time. And it also brings scalability, as today ECUs with five to ten bus connections and data interfaces can be tested; tomorrow's tests can be scaled up to 30 interfaces or more.

The complete HIL simulator development included the mechanical and electrical design of the HIL rig, incorporating all aspects of work and product safety.

FIGURE 02

HIL Real-Time Core Simulation System

The configuration of the PXI system was as follows:

- PXIe-1082 chassis
- PXIe-8840 Intel i7 quad core, 8 GB RAM, 320 GB hard drive
- PXI-6683 timing and synchronization module
- 2 x PXI-8512 CAN-FD bus interfaces

Additional HIL system components:

- 19-inch HIL control PC with Ubuntu operating system
- Power supply for 12 V DC
- 16 ampere power inlet
- External MIPI/CSI-2 and SPI re-injection device

The software architecture for HIL real-time operation and data streaming for reinjection consists of:

- ROS (C++) nodes for processing of the recorded radar data
- LabVIEW components for HIL real-time operation, bus communication, and synchronization
- Scripts and additional software components to enable remote control and operation, and to connect to SystemLink servers

With the respective competencies at ZMS and within ZF Group, NI assisted in establishing processes and maintenance for software. This helped in building up a powerful and modular HIL software library, which serves as a basis for future HIL projects and created a path to become an NI Center of Excellence in 2022.

Software development at ZMS relied on existing processes for agile, Scrum-based software development and for continuous integration and continuous deployment (CI/CD), which is depicted in the following figure.

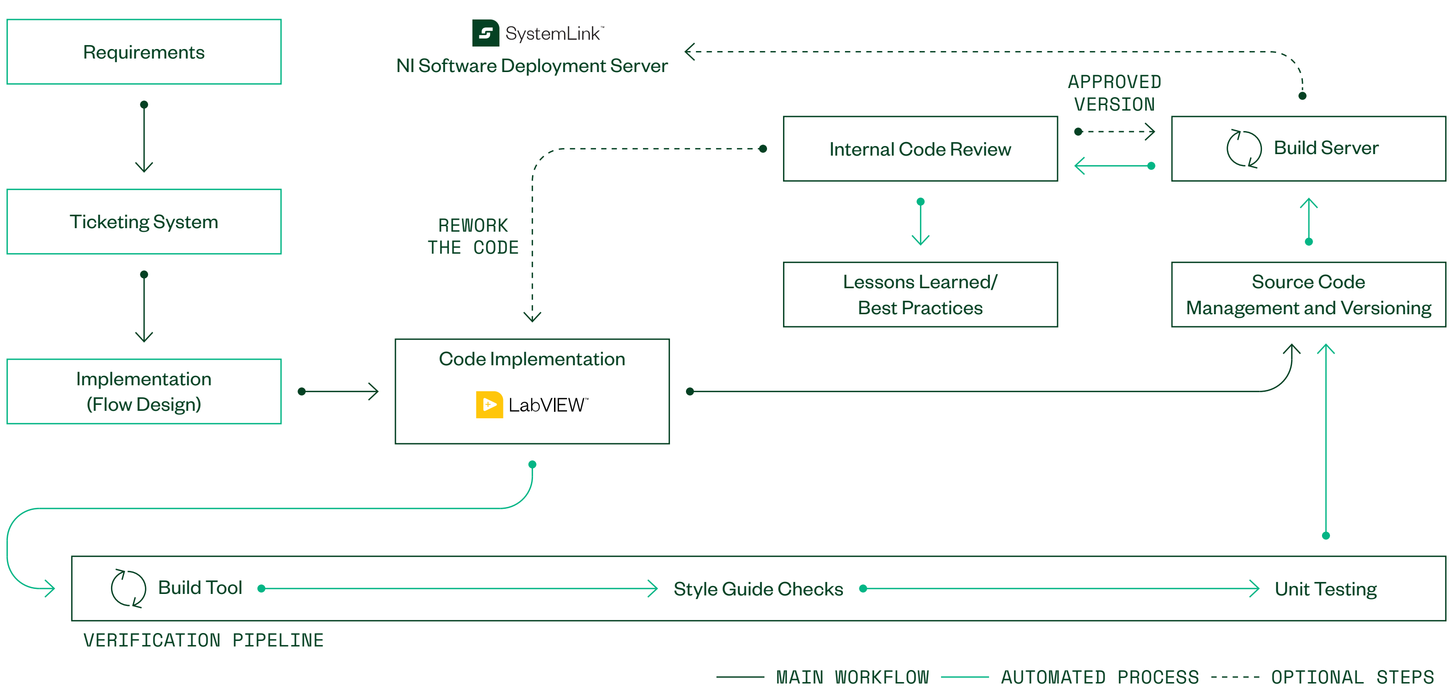


FIGURE 03

Software Development Process

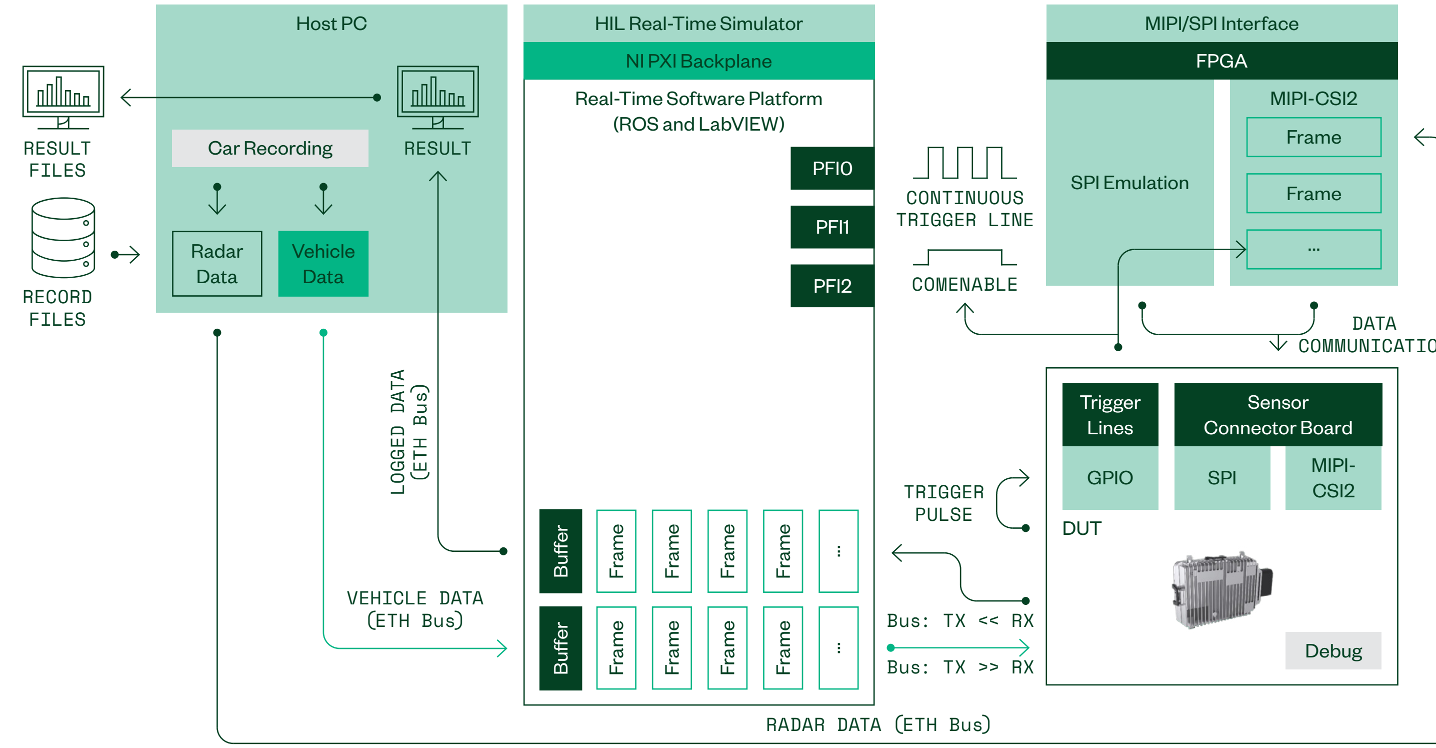


FIGURE 04

Software Development Process

Figure 04 provides an overview on the data flows and communication dependencies in the HIL test system setup.

Results

With the HIL system prototype being developed and replicated to several HIL systems operated in a HIL farm, radar system validation was performed across a significant number of radar software test cycles in fully automated HIL runs. This led to both a greater flexibility in on-the-fly testing of new software releases on the target ECU platform and high coverage in testing.

During radar system development, data equivalent to more than 600 days of proving ground test operations was successfully reprocessed in the HIL farm.

The integration of the various HIL test systems as an HIL farm into the system development and validation process is depicted in the following figure.

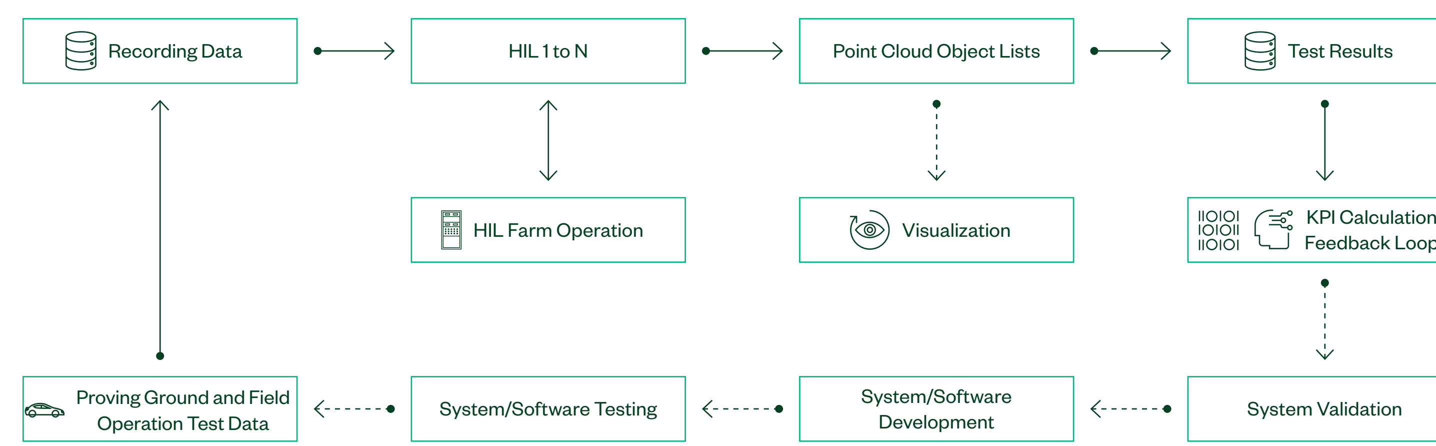


FIGURE 05

System Development and Validation Process

The capabilities of SystemLink for remote HIL real-time software deployment, system operation, and maintenance brought an additional benefit when scaling from HIL prototype development to a 24×7 HIL farm. NI's solutions save ZF time and enable scalability. This means ZF's test programs can keep pace with their own innovation timeline.

One remarkable achievement during the radar HIL development project was the certification of the Test System Development department at ZMS as an "NI Center of Excellence." The team was demonstrating engineering excellence, time-saving software development processes, scalable and extensible software design and architecture, as well as consistent training, mentoring, and learning.

Our strategic partnership will also empower us in the future to successfully bring safe and reliable ADAS and AD systems to the market.

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More about NI HIL Test Systems

ZF Team Impact

"I have an amazing team with me, who are highly motivated and real experts in what they're doing and fully committed to our projects and ZF's strategy. Together with our strategic partners such as NI, we bring our ideas successfully into reality."

Dr. Thomas Herpel
Senior Manager Test System Development,
responsible for setting the conditions to bring ZF strategy to the market

"Together with our colleagues from ZMS, we could successfully develop a HIL system that fulfills our requirements using NI components. The HIL system serves as one important pillar in the validation strategy of radar sensors."

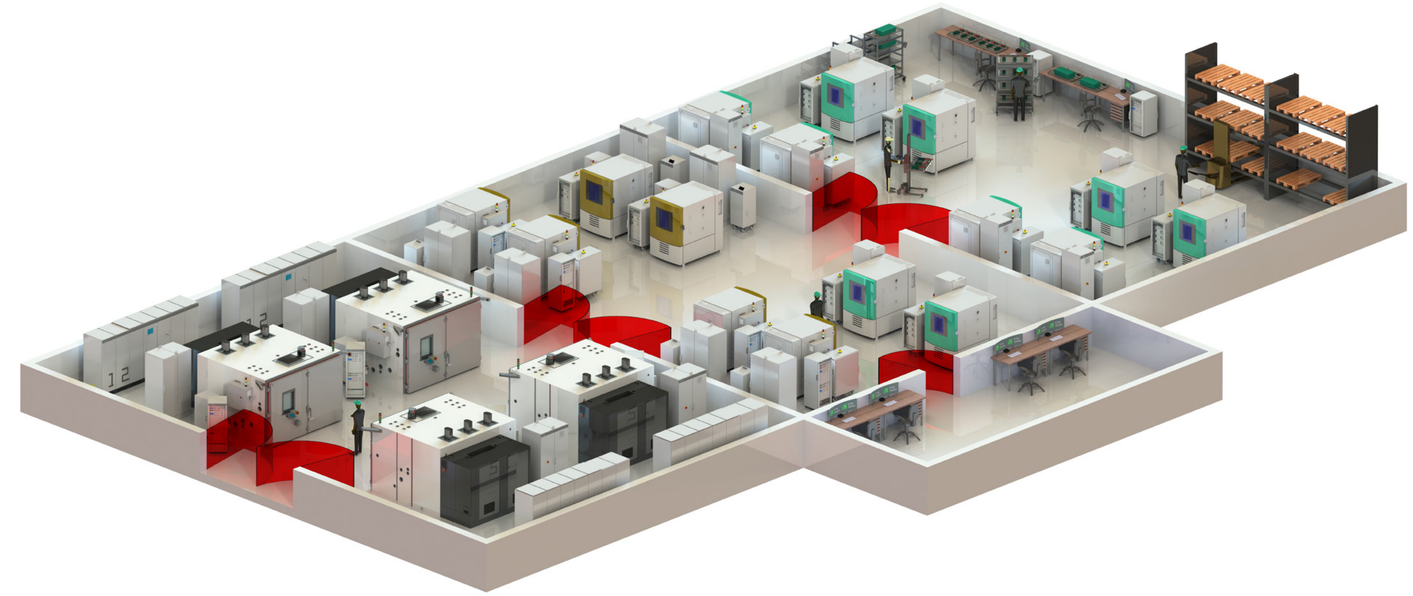
Philipp Strempel
Engineer at ZF's ADAS Validation Department
and Project Lead responsible for radar HIL Development

"Our team, consisting of radar and HIL experts from ZF and our technology partner ZMS, were able to develop a radar HIL together with NI, which fits perfectly into the existing highly automated ZF validation toolchains to further accelerate our test and development processes."

Michael Vogt
Engineering Supervisor for ZF's ADAS Validation Department,
responsible for HIL Development in ZF ADAS

"We need well-defined processes for LabVIEW development and must be precise about what we are doing, while automating as much as possible. Becoming a center of excellence has helped us to reduce the test efforts and impacted our daily work by saving time, being more efficient, and making the software better. I'm proud of the great collaboration."

Oleg Scherling
HIL LabVIEW Architecture Developer
and ZMS motivator to become NI Center of Excellence



Leading the Way with the Industry's First Software-Defined Battery Lab

The history of the automotive industry includes a variety of technological changes that each mark significant advances towards safe, dependable, and consumer-approved vehicles. These historical signposts include the electric starter, the automobile assembly line, automatic transmission, seat belts, and fuel injection, among many others. The electric vehicle (EV)—particularly the EV battery—represents another milestone in that history. The EV battery epitomizes the progress we've made in the automotive industry and is integral to the future of electrification.

The demand for reliable and safe EV batteries is ever increasing. Their central place as not only a necessary component within the electric vehicle, but as the most critical innovation in electric vehicles, has brought into sharper focus the need for **successful battery testing** and production. That need includes safety and reliability in testing, a strategy to go-to-market quickly, and an ability to scale production efforts.

Fundamental to the production of EV batteries in the automotive industry is a successful testing methodology that's efficient, safe, and scalable. Testing can consume 50 percent or more of product development time. This timeframe needs to be optimized so that all testing procedures and principles can be done efficiently to meet all the demands facing the EV industry, while maintaining high standards of quality.

NI has embarked on a strategy that focuses on the testing stage of EV battery development, which is already creating outstanding results for partners on the front lines. NI's CEO, Eric Starkloff, at NI Connect 2023 spoke and addressed manufacturers, "For 26 years I've been focused on solving a particular problem—how test can improve the performance of your products and your business; how it can be a competitive advantage for you." With that focus in mind, NI is in the business of disrupting the testing industry (again) through a software-defined approach.

Enter NI's industry-first **software-defined battery lab:** a comprehensive solution for large-scale battery testing. It's comprised of purpose-built, enterprise-grade software, modular and open battery test systems, and expert engineering and integration services. NI's test leaders are championing this software-defined approach today. These test leaders have discovered that NI's investments in electrification, comprehensive solution for testing, approach of scalable solutions, and the unique place of the software-defined lab in the industry all make for a strategy that will take EV battery manufacturers to new heights.

At NI Connect, we heard directly from NI leadership on what makes the software-defined battery lab unparalleled in the industry. NI's mission to offer a flexible, automated, and intelligent test strategy is paying off with enormous dividends. Let's explore.

Electrification Investments

NI is dedicated to making investments in electrification that will transform the whole industry. It may seem axiomatic that electricity is at the center of this movement of EV vehicles and batteries, and it certainly is. In fact, electrification will change everything as the work of **Vision Zero** puts electrification front and center to successfully manufacture vehicles with zero emissions.

This work will be successful only to the extent that testing is precise and that all parts of a vehicle are working in harmony.

NI's achievements in supporting electrification have accelerated in recent years to include the acquisition of companies that support test solutions within the software-defined battery lab. This portfolio includes NH Research, Heinzinger, Kratzer Automation, and SET, among others. By combining software capabilities from these partners and NI's PXI solution, NI offers fully integrated, comprehensive test system solutions to empower manufacturers with intelligent and automated battery testing and validation.

These investments are key to an evolving vehicle. Components that were once purely mechanical in nature are now controlled by sensors. Semiconductors and sensors are required to deliver battery energy to critical components in a car. One of NI's test leaders, Allegro Microsystems, a global leader in magnetic sensing and power IC solutions, has benefited from this investment by using NI's software tools for technologies such as its electromechanical braking application.

Comprehensive Battery Test Solution

A software-defined approach to testing is based on the idea that test is a strategic differentiator that delivers on critical business outcomes. NI Executive Vice President and General Manager of Global Business Units, Ritu Favre, recently identified three critical approaches to test for successful delivery: automation, standardization, and data analytics—and all are core to NI's comprehensive solution.

The software-defined lab gives engineers visibility into data across all stages of development—even across facilities and the supply chain—resulting in a global approach. The solution is cloud-based, open, and driven by enterprise-grade software. This kind of customer-specific software offers automated and parallel work that normally would be managed through manual processes. It also offers a more granular approach to testing at the battery cell level, identifying problems with the cell in how it responds to testing. Testers will gather the resulting data and add to the ongoing evolution of analyzing battery cells. This kind of digital transformation in software is critical to moving the EV battery industry forward.

Although standardizing remains a key factor, the flexibility of the software-defined lab is inherently agnostic and accommodating. This agnostic approach makes NI a testing differentiator by allowing the industry to evolve as testing methodologies evolve with it.

Addressing EV Battery Volume

The sheer volume of EV batteries being tested and produced today would have been incomprehensible a decade ago. Production revenues for EV batteries **tripled from 2021 to 2022**. Manufacturers know the pressure associated with testing and production all too well.

Compounding the challenge of volume is the time it takes to test and validate batteries. Many manufacturers have found that at least 50 percent of development time is taken up by testing—a number that consumes precious development time and exacerbates already challenging production schedules.

Unique to the Industry Methods

In an industry dependent on testing that requires both precision and a quick ramp to production, only a software-defined battery lab that increases the speed of results while maintaining quality is sustainable enough to help EV manufacturers stay ahead of the curve.

It should be clear that this type of battery lab is an unparalleled asset to the ever-collaborating and enormously expanding EV industry. A common acronym in the automotive industry is ACES—Autonomous, Connected, Electrified, and Shared—and NI's software-defined battery lab can be the game-changing engine to take the industry forward in this vision and the creation of electric vehicles of the future.

Author

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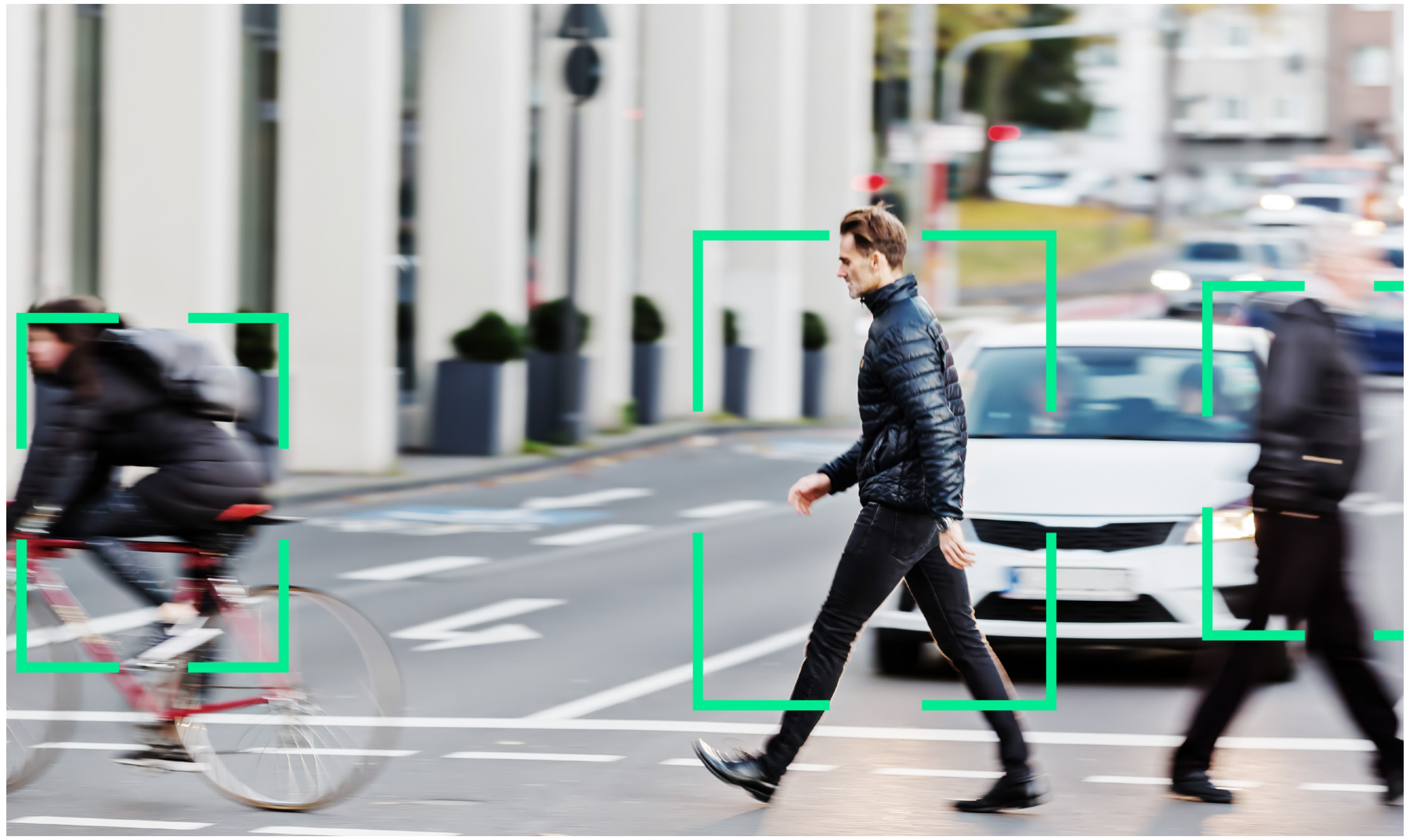
More about our commitment



When the Toolchain Becomes as Important as the DUT

The car of the future will be an ACE: it will provide Automated driving, Connected services, and it will be Electrifying for sure. This has been the vision for multiple years now. But to achieve this, the foundation needs to be there, and this is the software-defined vehicle. The software-defined vehicle is the key enabler and an expectation of the end user. Ever since the victory of the smartphone, redefining the entire personality of an electronic device through software has become the norm.

This personalized experience is what drivers and passengers are looking for as well; nobody wants to purchase a car anymore that stays the same for five or more years. Over-the-air updates are mandatory. Consumers want these updates for new convenience functions, as well as efficiency boosts like extending the range of an EV, and even for the latest innovative safety features. Safety and reliability are the highest priorities when **working on advanced driver assistance systems (ADAS) or Autonomous Driving (AD) features,** but they have three main challenges (Figure 1), which highlight the complexity and why it is so hard to bring trusted safety to the roads.

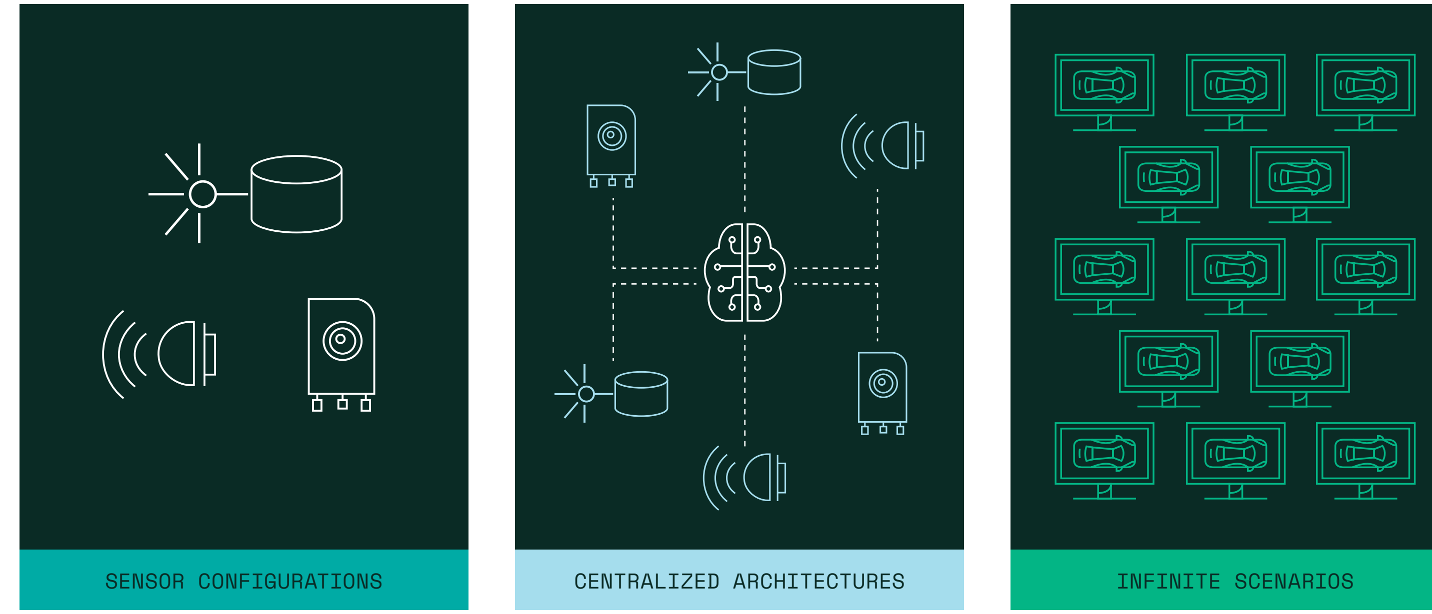


FIGURE 01

The three main challenges of developing and testing assisted and highly automated driving (HAD) functions.

Three Main Challenges for ADAS/AD Test

First, developing and testing cars including automation features means that every OEM—and in fact every model—has a unique sensor configuration which needs to be considered. These configurations greatly vary in the number of sensors and the different sensor modalities like camera, radar, and lidar—just to name a few. On top of that, OEMs are combining sensors from multiple suppliers to get the best and most cost-efficient variants into their products.

The second challenge is the move toward a more centralized compute architectures referred to as zonal or multi-domain controllers. Here, the industry is increasingly mimicking a centralized brain. Lastly, ADAS and AD functions based on Artificial Intelligence (AI) must be trained and tested against countless scenarios. Unknown unknowns can occur everywhere and everywhen, which creates an infinity problem.

The introduction of the eScooter (Figure 2) provides the perfect example of the infinite scenario challenge and why the software-defined vehicle makes the difference. Several years ago, eScooters did not exist. Therefore, their driving behavior and characteristics were unknown by mankind. The good thing is that human beings can learn quickly as they engage with eScooters not only while driving a car, but every day and night, as well as whenever they are encountered (also outside of traffic).

The human being can turn these experiences into common sense and anticipate the aforementioned driving behavior and characteristics to handle eScooters also while driving a car in traffic.

When considering AI, the story becomes a bit different, as it only learns when it engages with a new road user. So therefore, when compared to the human being, the amount of time to learn to adapt to these new situations is already limited. Furthermore, the AI algorithm will start to compare and classify the eScooter against what it knows and what it has been trained against. The eScooter might be perceived as a cyclist, as the bicycle has wheels as well and it can move relatively fast. Still, the person is sitting on the bike and the legs of the bicyclist are moving most of the time, while the driver of the eScooter stands still, but is also moving quickly. The eScooter could also be misinterpreted as a pedestrian. Again, the person on the eScooter is standing still, yet moving fast and it has wheels—so this classification does not really make sense either. The only thing that can fix the problem of automated cars learning to handle new and unidentified obstacles and scenarios quickly is an over-the-air software update—and this is the true power of the software-defined vehicle.

How Valeo Uses NI Technology for ADAS System Validation

Valeo is known as a leader and global Automotive Tier 1 supplier covering electrification, comfort and driving assistance, and smart connectivity. Valeo supplies cameras, radars, and lidar sensors to OEMs along with other components. But with the disruption of the automotive industry, they have further evolved to a tech company that provides full functions like 360-degree view and parking assist, all the way up to connected valet parking to OEMs. Valeo must deal with all the complexities and dependencies of a system of systems. After the completion of the design phase of the front- and back-end of the product, systems validation is the key to solving the previously mentioned challenges.

The toolchain architecture and the definition of a comprehensive validation plan become crucial elements to deliver according to Valeo's quality and coverage standards. Because of the complexity of the systems under test, the test team at Valeo decided to split the validation process into three levels.

The first level is to validate the system in a fully controlled environment in a deterministic way. The second one is to collect statistics around the system performance in open road testing, and the third one is to use AI and other alternative methods to generate synthetic data to cover any gap that is not covered in the previous two attempts.

Data acts as the bloodstream and flows through all the different stages of the product development lifecycle from the moment it is acquired at the vehicle all the way up to data archival. Most of the systems at hand are predominantly vision- or radar-based systems. NI test benches (Figure 3) are instrumental for the validation of the systems under test, especially when it comes down to resimulation and processing big data. Valeo operates eight hardware-in-the-loop (HIL) farms all over the globe, most of them equipped with NI equipment and supported by NI engineers.

FIGURE 02

New road users like eScooters need to be handled quickly by AI algorithms.

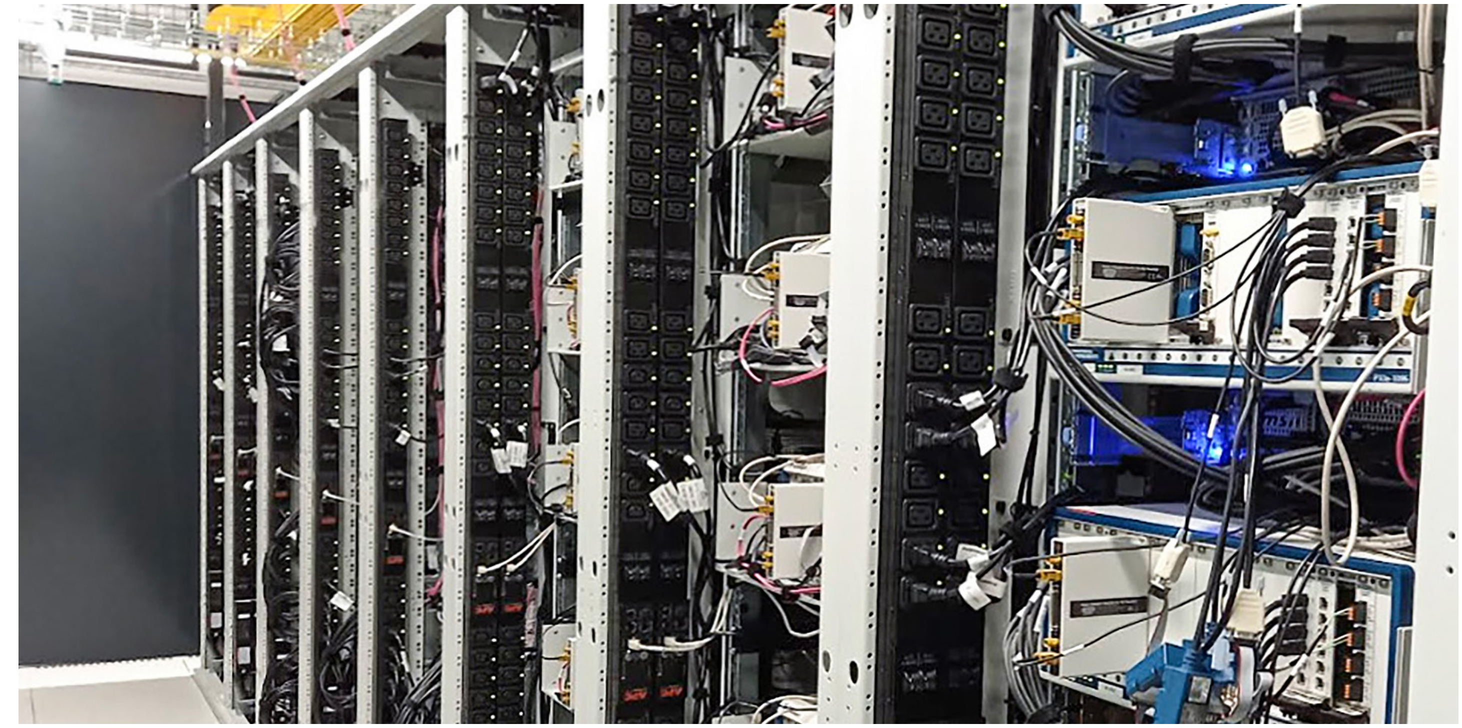


FIGURE 03

HIL Farm Based on NI Systems at Valeo

Bringing Our Kids to School Safely

The multi-year journey and strong alignment between Valeo and NI has resulted in a trustful collaboration. Speaking of results: Working together with NI, Valeo was able to increase their Verification & Validation throughput by 6x for their camera portfolio. Moreover, Valeo utilizes NI test systems and software from design verification to validation and up to manufacturing test, enabling a true data- and software-connected test workflow.

The mission of Valeo's systems is to make the vehicle safer for its occupants and for other road users. "And for me personally, the system validation job is done when I'm comfortable to putting my kids into a running vehicle or to have them crossing the road in front of a running vehicle safely, knowing that the system will do the job," says Dr. Yahia—certainly something all of us can relate to as the ultimate litmus test.

> "NI built its technology roadmaps based upon the needs of the industry and the needs of key partners, including Valeo. On top of that, NI has the technology and the engineering capabilities and most importantly, those engineers are always there whenever we need them."
>
> **Dr. Maymoon Yahia**
> System Validation Director for Comfort and Driving Assistance (CDA) Systems at Valeo

Author

Daniel Riedelbauch

Chief Solutions Marketing Manager, ADAS & AD Test, NI

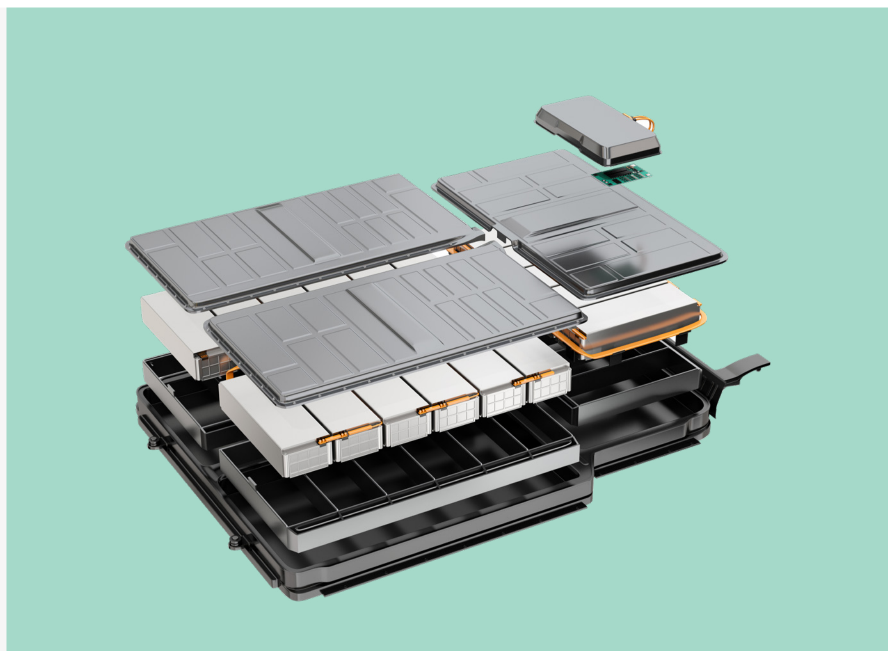
Watch the keynote

CATARC Uses Battery-in-the-Loop Simulation to Meet Battery Test Trends

Case Study Highlights

01 NI's open, software-connected ecosystem enabled CATARC to add battery pack in traditional HIL test method to meet the trends of battery test.

02 A BIL system supports abundant test scenarios and boundary conditions. They combine the scene/road/vehicle model, reflecting the real conditions.



"Through the BIL test method, it is possible to accurately control the extreme working conditions such as overcharge, overdischarge, overcurrent, and overtemperature in an environment close to the real vehicle."

The Challenge

The traditional signal-level HIL test has been well established at the level of BMS functional strategy verification, but the battery pack performance verification capability is seriously insufficient. The road/field test of the real vehicle can obtain the most realistic battery pack performance, but the coverage of the test conditions is too narrow, and the requirements are too high.

The Solution

The battery-in-the-loop (BIL) test solution largely fills the test gap between HIL test and real-vehicle road/site test.

Evolution of Battery Test in the Evolving Chinese Market

As an important strategic direction in China, the development of the automobile industry is in the early stage of commercialization with rapid technological evolution and accelerated industrial layout, and the development of the industry is facing opportunities, risks, and challenges. In this context, pure electric vehicles have great potential to improve economic and industrial competitiveness and attract investment in major developable markets. To avoid the problem of functional safety of automotive software, the automotive industry has developed the **vehicle functional safety standard ISO 26262**, which is currently the most important international standard in the automotive industry. The standard primarily improves the functional safety of electrical and electronic (E/E) systems by avoiding hazards that can result from malfunctioning behavior of automotive E/E systems.

Complexity of Battery Test in EV Design and Validation

Based on the research of electric vehicles in various countries, there is a common phenomenon: the battery is the most problematic component in the entire realm of electric vehicle research. In the design process to ensure the safety of the battery system, in addition to the characteristics of the battery cell, the design of the battery module, the structure of the battery pack, and the exhaust design, the battery management system (BMS) is the most dominant. Many new energy vehicle companies regard the battery management system as the core technology of the enterprise. In recent years, most of the core intellectual property rights applied by a leading OEM are related to batteries, which shows the importance of power battery systems for electric vehicles.

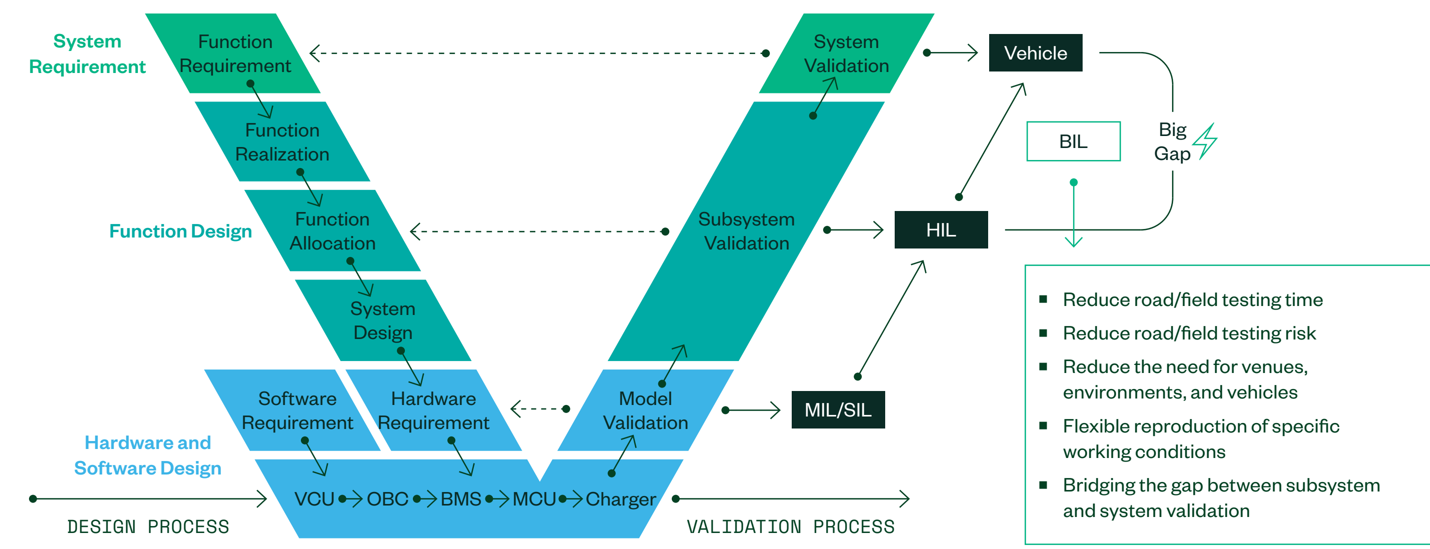


FIGURE 01

V-Cycle Development Flow

In the development and testing of electric vehicle controllers, the V-cycle development process is generally adopted—as shown in Figure 1, which improves development efficiency, reduces development risks, and reduces workload. The V-cycle development process can complete system requirements, functional requirements, software and hardware design, model verification (MIL/SIL), **hardware-in-the-loop testing** (HIL), and real vehicle testing, in which HIL testing of the controller plays a key role. The hardware-in-the-loop test platform can be used to establish a virtual controller operating environment, and the functions of the controller can be verified by giving some input signals and detecting output signals.

The traditional signal-level HIL test has been well established at the level of BMS functional strategy verification, but the battery pack performance verification capability is seriously insufficient. The road/field test of the real vehicle can obtain the most realistic battery pack performance. But the coverage of the test conditions is too narrow, and the test conditions are required to be high. And if you want to carry out the real vehicle test in a specific environment, such as high- or low-temperature extreme conditions, the environmental requirements are higher.

CATARC's Battery-in-the-Loop Real-Time Simulation Platform

To improve the authenticity and reliability of the user's battery pack performance test, CATARC (Tianjin) Automotive Engineering Research Institute Co., Ltd., uses simulation and test to propose a set of battery-in-the-loop (BIL) test solutions. BIL test largely fills the test gap between HIL test and real vehicle road/field test.

When compared with real vehicle road/site test, it can minimize the demand for field, environment, and vehicle, which has obvious advantages. The advantages and disadvantages of BIL and real vehicle testing are shown in Table 1.

Test Methodology	REALISM	SCENE RICHNESS	TEST FLEXIBILITY	TEST EFFICIENCY	COST
Road Test	High	Low	Low	Low	High
BIL Test	Relatively High	High	High	High	Middle

TABLE 01

Comparison of Different Test Methods

Its system framework includes four main parts: load simulation, environmental simulation, DUT, and vehicle simulation, as shown in Figure 2. Under virtual working conditions, virtual roads, and virtual energy requirements, the system controls the real charging and discharging system. The real environmental system conveniently simulates various real road conditions and obtains experimental data.

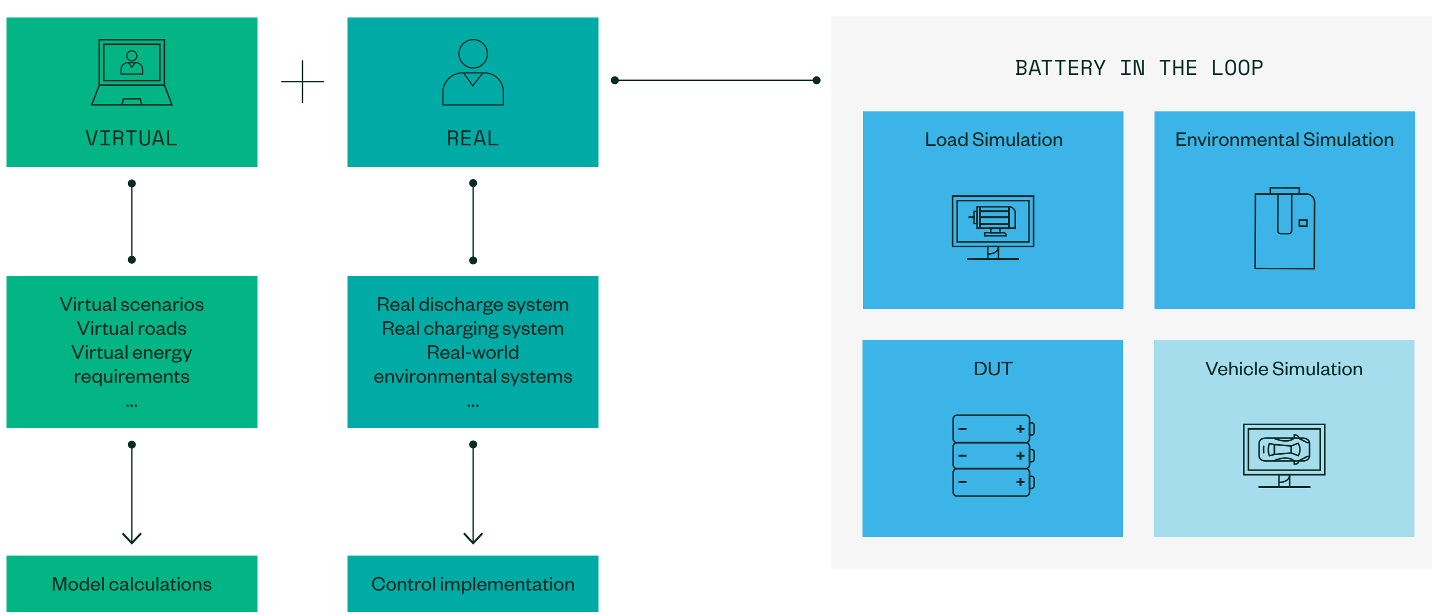


FIGURE 02

Battery-in-the-Loop Test System Framework

CATARC specifically realizes the battery-in-the-loop test scheme. As shown in Figure 3, the whole system is equipped with environmental chamber, water cooler, virtual load, and other equipment to achieve the real state under the specific working condition test of the battery. Among them, the virtual load of the battery acts as a charging pile and a load to charge and discharge the battery pack. The main control system communicates with the battery virtual load, battery pack environment simulation system, and BMS through the CAN protocol; the BMS realizes the fast-charging function through the CAN protocol. The cooling/heating system of the battery pack mainly realizes the thermal management function of the battery, which is connected to the main control system through Ethernet and is mainly controlled through **LabVIEW**. Among them, the vehicle dynamics model and road model are built by CarMaker, and other strategy algorithm models are built using MathWorks® MATLAB® software and Simulink® software. The system has the following three advantages:

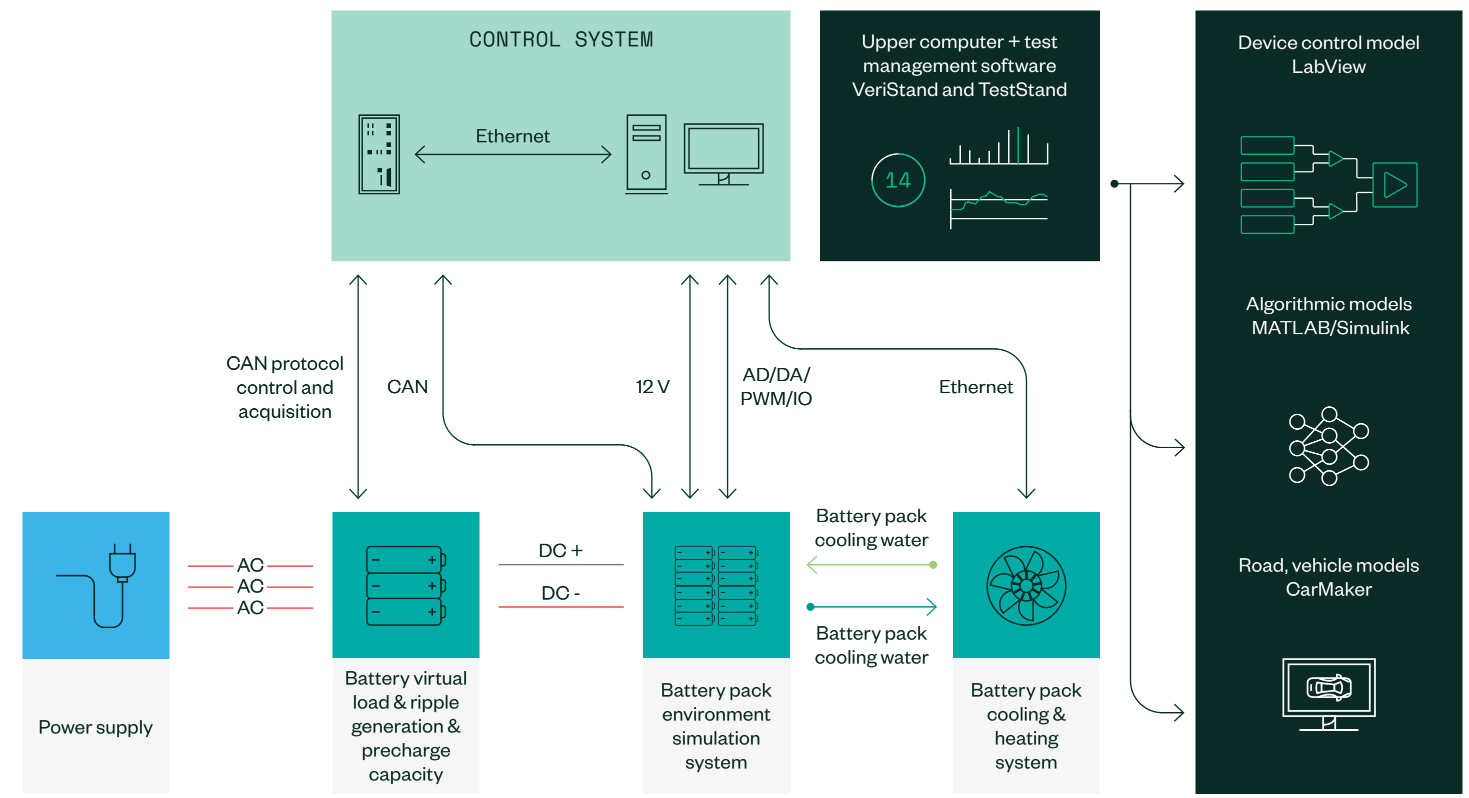


FIGURE 03

Battery-in-the-Loop Test Scheme

01 It conveniently simulates various real road conditions and extreme working conditions, greatly reducing the demand and time of real vehicle testing.

02 It accurately plays back real vehicle data and efficiently finds target performance improvement solutions.

03 The interface is open and flexible to adapt to the needs of various models.

In terms of industry cooperation ecology, CATARC has provided battery-in-the-loop testing services for a leading car company. CATARC has provided a large number of test cases and a rich driving scenario library, and has also built a complete BIL simulation test platform. The test platform includes software such as Vehicle Dynamics' CarMaker, automated testing using NI TestStand, and hardware such as HIL cabinets, battery packs, charging and discharging equipment, and water coolers. Through the BIL test system, the realization of test items such as SOX, cycle life, capacity calibration, DCR, pulse charge and discharge characteristics, overcharge/overdischarge rate, thermal management, and so on can be realized. The BIL test platform can customize the test scene, better reproduce the real state of the real vehicle and environment, simulate winter/summer standard working conditions, and complete the real vehicle battery pack charge/discharge performance test requirements.Taking the discharge condition as an example, the main test steps of the BIL test system are:

- Configure the CarMaker kinetic parameters to be consistent with the real vehicle, build a virtual road, and set the target vehicle speed curve.
- Control the charging and discharging equipment and adjust the battery SOC to the initial value of the test.
- Set the temperature of the ambient chamber and adjust the temperature of the battery cell to the initial value of the test.
- Set the temperature and flow rate of the water cooler and adjust the battery waterway circulation to the initial state of the test.
- Simulate real vehicle interaction for low-voltage/high-voltage power-up.
- Obtain the discharge energy requirement through the CarMaker simulation.
- Control the discharge equipment to absorb the battery and release energy until the end of the test condition.

In addition, through the BIL test system, it is possible to accurately control the extreme working conditions such as overcharge, overdischarge, overcurrent, and overtemperature in an environment close to the real vehicle. The safety objectives are fully verified, and the verification requirements for the functional safety requirements of the battery management system for GB/T 39086-2020 electric vehicles can be realized.

In the future, CATARC will continue to:

- Focus on the research and development of automotive engineering application technology
- Provide automotive enterprises and relevant government departments with automotive performance engineering development, common key technology research, development and verification testing, and related policy and technical consulting services
- Partner with NI to provide higher quality services for intelligent vehicle enterprises and scientific research institutions
- Deploy plans in advance to meet regulatory requirements and laboratory capacity building of high-level autonomous driving functions, leading the key and common technology progress of the automotive industry

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How to Select a Battery Cycler for Testing EV Modules and Packs

Overview

The EV battery market is moving towards increasing production volumes to reduce overall cost, while doing this rapidly without compromising safety or quality. When it comes to testing batteries, there's a wide range of challenges from temperature dependencies to safety issues and time-to-market pressures. A software-connected test strategy is key for battery testing, but also requires flexible test equipment that can be synchronized, orchestrated, and operated effectively.

So, what battery cycler do I choose to test better, faster, and safer?

Each battery lab has varying test objectives, parameters, and environments for various battery packs. Whether requiring just an individual test channel or an entire battery lab solution, it's important to start with understanding what goals need to be achieved before selecting the right solution.

Examples of Industry Battery Lab Test Requirements

NI has a portfolio of high-performance battery cycler options to cover a wide range of capabilities that address specific test requirements across the battery lifecycle from R&D, validation, to production, end of life, and remanufacturing. Let's evaluate a few real-world use cases and share why a solution was selected.

01. Reproducing Real-World Signals from Record and Play

Battery Lab A is a large, advanced battery R&D validation lab evaluating new high-power battery architectures up to 1500 V. The goal of the lab is to emulate real-world measured conditions to investigate battery performance, dynamics, and the impact of life loads and battery life.

The customer wanted to measure and record dynamic profiles and recreate a specific system dynamic at frequencies of 10 kHz. Ideally, the solution needs to provide cycling capability with a frequency of at least 20 kHz to accurately reproduce those signals—including ripple emulation and battery characterization.

The **HPS-17000** was selected because it can test up to 1500 V products while allowing for high-frequency test signal production. Its high-performance capability allows running high-frequency, high-fidelity waveforms at high resolution in microseconds. The unit can inject higher frequency signals to observe how the battery reacts, record, and measure its signal, and replay it on the battery. The HPS-17000 is ideal for testing HIL applications using time-stamped setpoint and measurement streaming over Ethernet at rates up to 100 kHz, which far surpasses the required frequency of 10 kHz.

FIGURE 01
HPS-17000 Battery Cycler

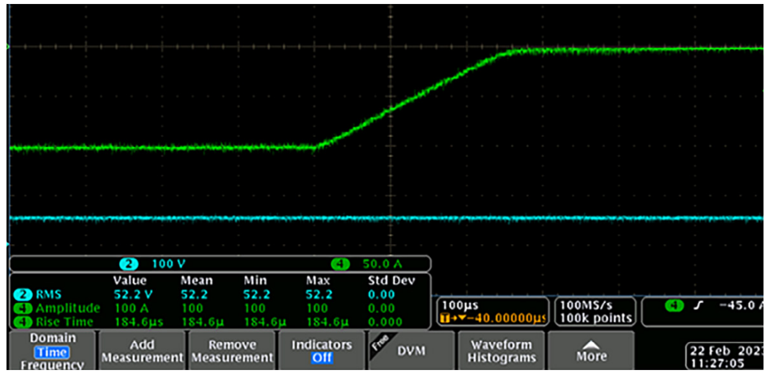


FIGURE 02

HPS-17000 provides high-frequency test signal production step response from 0 to 100A in .25 ms.

Figure 2 shows a scope measurement of a rate-controlled step response from 0 to 100 A with the step completed in 0.25 milliseconds. This illustrates the capability of the HPS-17000 to inject signals with high-frequency content in a controlled manner.

02. Testing Multiple Battery Dimensions Simultaneously

Battery Lab B is a large battery R&D validation lab that requires testing battery packs with multiple dimensions that range widely in voltage and power. The packs are in different areas and labs within the facility as well as remote facilities. This requires reconfiguring the cyclers to increase and decrease the power levels in just a matter of days. The types of testing span far and wide including lifecycle testing to peak performance, operational efficiencies, safe system validation, thermal cycling performance, product endurance, and refining the BMS for end application.

The NHR-9300 battery cycler was selected for its easy and flexible reconfiguration, setup, and mobility. Its modular power blocks of 100 kW can be scaled up to 2.4 MW and downsized as needed to optimize setup and scheduling to test multiple systems inside a battery pack. The engineers are constantly reconfiguring their overall size and application from 100 kW, 500 kW, and 2 MW. A few of the cyclers are sometimes separated and shipped to another department where capital assets such as temperature chambers are located.

FIGURE 03

NHR-9300 Battery Cycler

FIGURE 04

NHR-9300 provides modular and scalable power in 100 kW building blocks for easy reconfiguration.

The NHR-9300 is mobile-friendly with a higher power density, enabling the cabinets to move around easily on wheels and allowing the customer to scale power as needed.

The multiple control options, including the large visualization panel, provide the operator with an easy, user-friendly way to get up and running with out-of-the-box capability for simple tests and programming capability for more sophisticated tests.

03. Running Battery Tests under High NEMA-Rated Conditions

Battery Lab C is a validation lab testing battery packs in which the battery undergoes harsh physical and environmental conditions to test the lifecycle of an EV battery with typical load profiles and charging cycles, as well as excessive amounts of power overload.

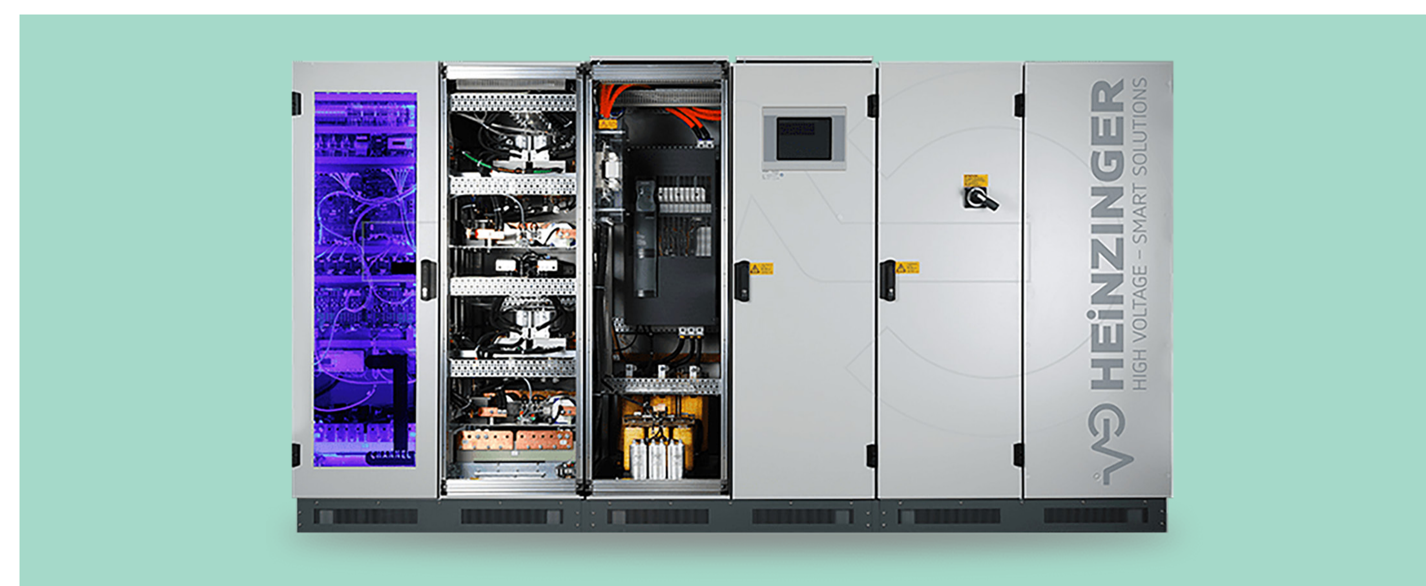


FIGURE 05

ERS-BIC

The lab is set up with temperature and environmental condition chambers controlled by one or more ERS-BIC systems. These systems can be clustered efficiently to deliver higher voltage, current, and power ratings with easy master and slave control. The ERS-BIC has a unique capability to manage excessive amounts of power overload in case there is a spike in power that goes way above the nominal. This is useful when the test stand is planned for nominal power requirements, but there are use cases where substantially more power is required for a short period of time. In this case, the nominal power is used during recovery time.

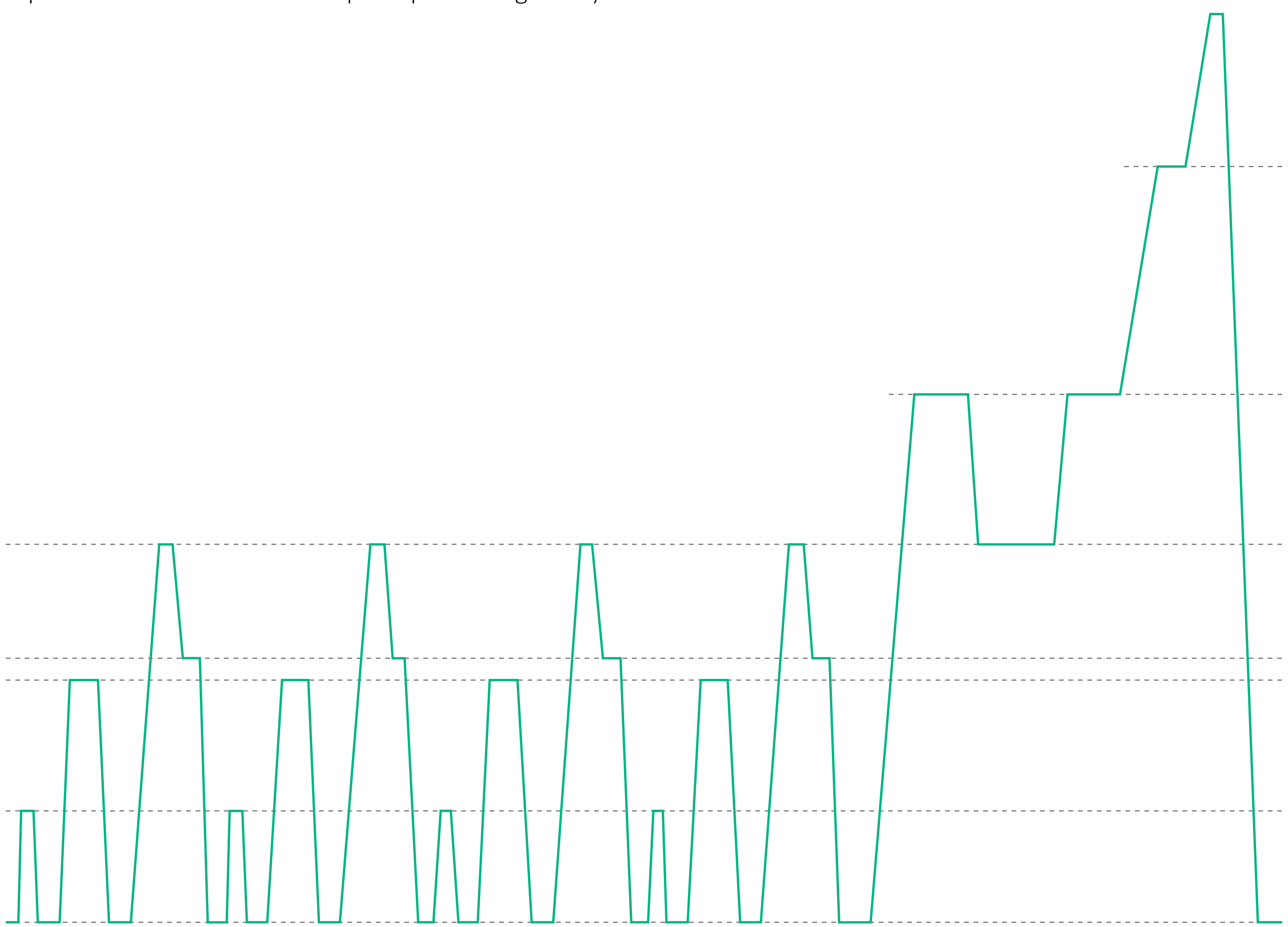


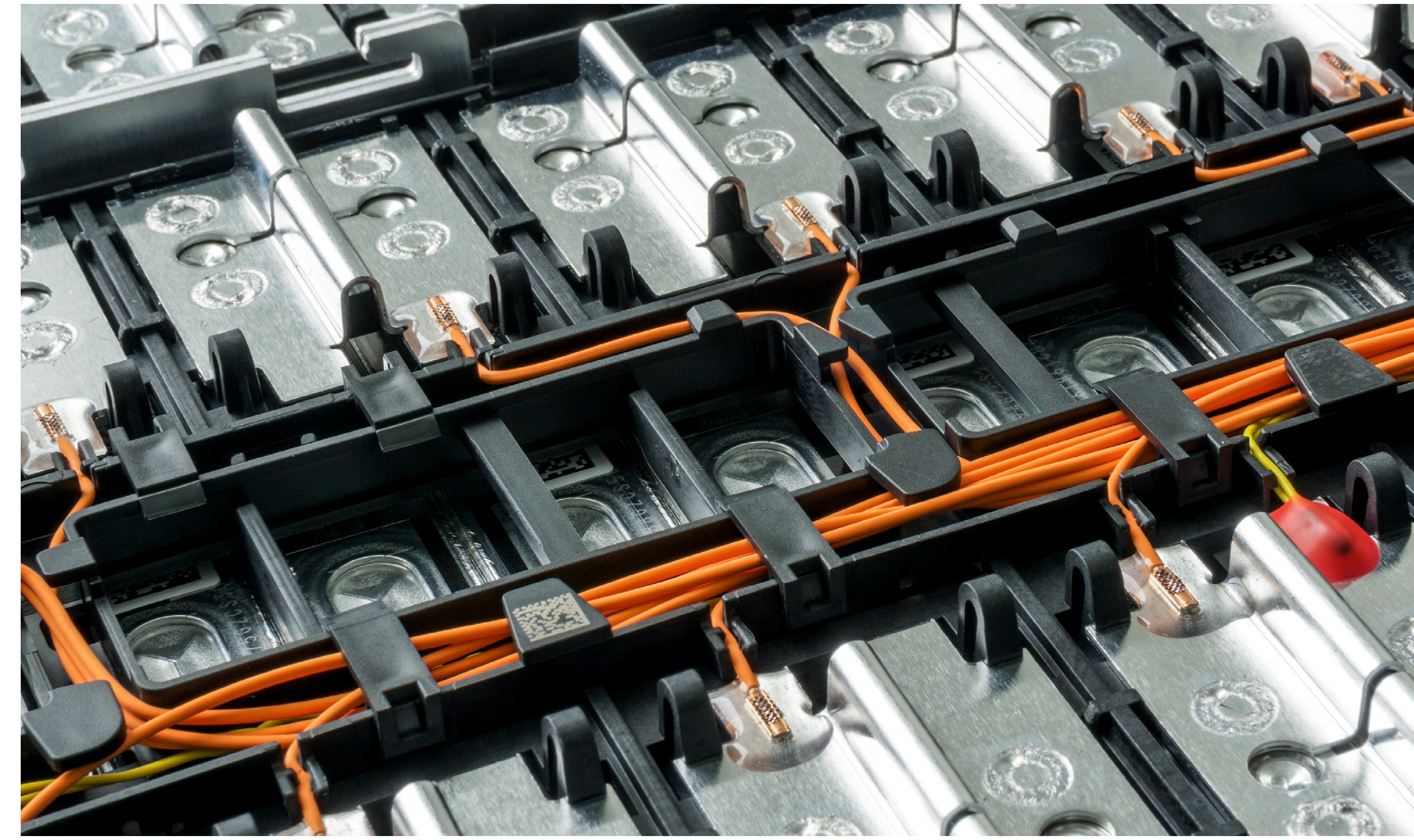
FIGURE 06

ERS-BIC provides overload capability and fast recovery up to 180 percent of power for 30 seconds.

The ERS-BIC unit has a water-cooled design which allows it to handle overcurrent and overpower pulses or high current power pulses without requiring an equivalent amount of cooldown time. This is unique in the industry and allows you to do more testing in a smaller footprint. Its water-cooled design also makes it possible to reach higher levels of IP or NEMA ratings for dirty, dusty, or contaminated environments if needed with IP ratings up to IP54.

Consult Our Battery Test Experts

At NI, we have a wide-ranging portfolio to address your test requirements. While the industry use cases shared here are not the only test scenarios or advantages, they demonstrate the importance of evaluating specific lab test requirements to determine the best near-, mid-, and long-term battery cycler for your needs. **Contact us to learn more about NI's battery cycler options for EV battery module and pack test.**



The Evolution of EV Battery Test Approaches

The EV battery market is moving toward increased automation to reduce complexities for the user and speed up workflow. As the demand for better battery designs increases, engineers need to have automated solutions for testing R&D, production, and post-manufacturing objectives. Software is becoming more critical to manage data seamlessly, to align with market requirements, and to ensure customer success. Battery test solutions have evolved from manual testing to automated and next-generation battery test systems. This article describes the evolution of these methodologies over time to align with the evolving test requirements.

FIGURE 01

Battery test approaches are becoming more automated and sophisticated in capability.

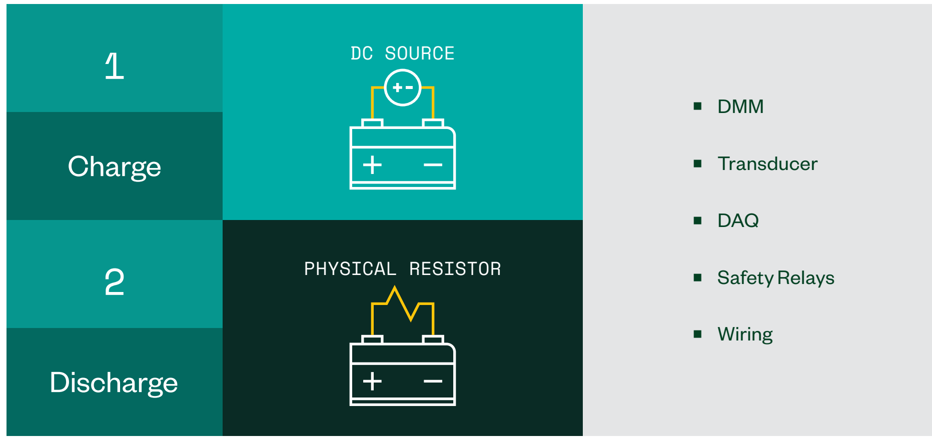


FIGURE 02

Manual method of battery testing uses two independent setups to charge and discharge the battery.

Manual Testing

Although manual battery testing is a legacy method, it is still used today. Testing a battery manually involves two independent test setups to cycle the same battery. Charging requires connecting the battery to a DC source and discharging requires connecting the battery to a physical resistor. Furthermore, a number of external pieces of equipment, such as DMMs, relays, and transducers, are required to take measurements and need to be switched between sourcing and loading. All these instruments must be manually set up, controlled (start/stop), managed independently, and manually recorded by the user.

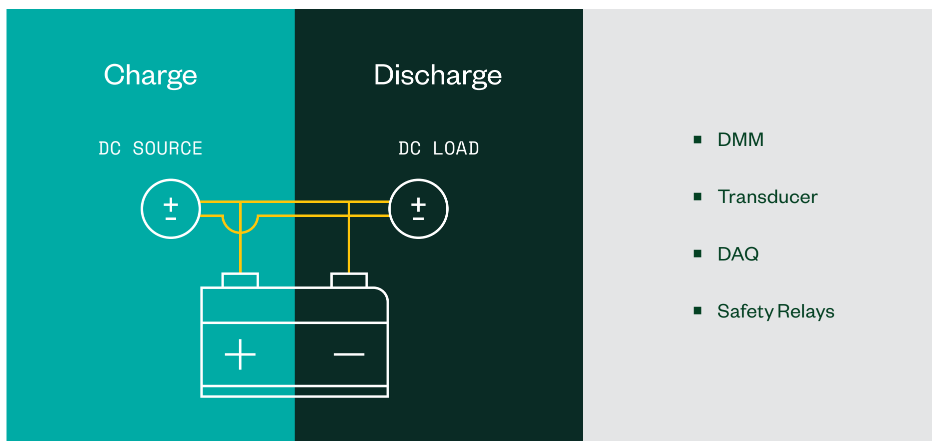


FIGURE 03

A DC load connected to a DC source battery test setup is controlled separately and adds complexity.

Electronic DC Source and DC Load

An approach engineers often take is to build their own battery test setup using an electronic DC source and DC load. These types of general-purpose test equipment are found in most power electronics labs. This approach provides an opportunity to automate testing by programming the test parameters within the source and load. However, these instruments still need to be controlled separately, and external equipment is also required to collect measured data.

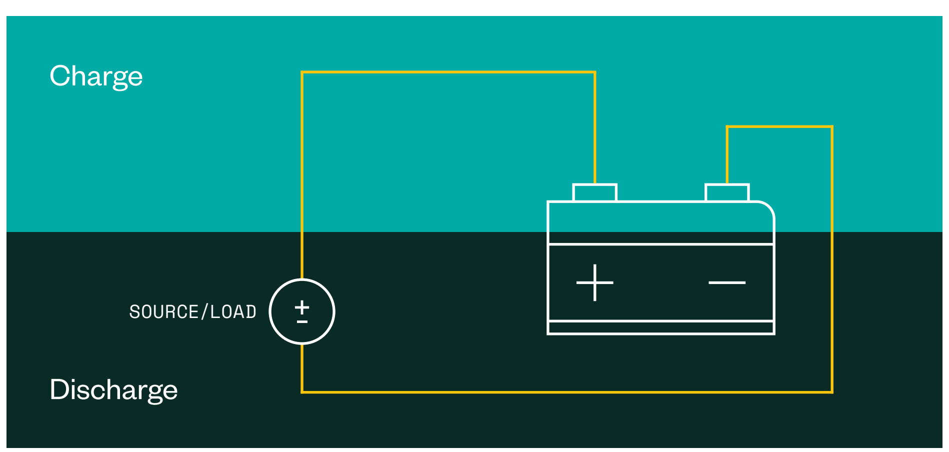


FIGURE 04

Automated test systems integrate the DC source and load within a single product.

Automated Battery Test Systems

Automated battery test systems integrate an electronic DC source and load within a single product along with advanced built-in automation tools and improved measurement capability. These test systems range from custom-engineered to commercial off-the-shelf (COTS) options. These systems vary in technological approaches, capabilities, and limitations.

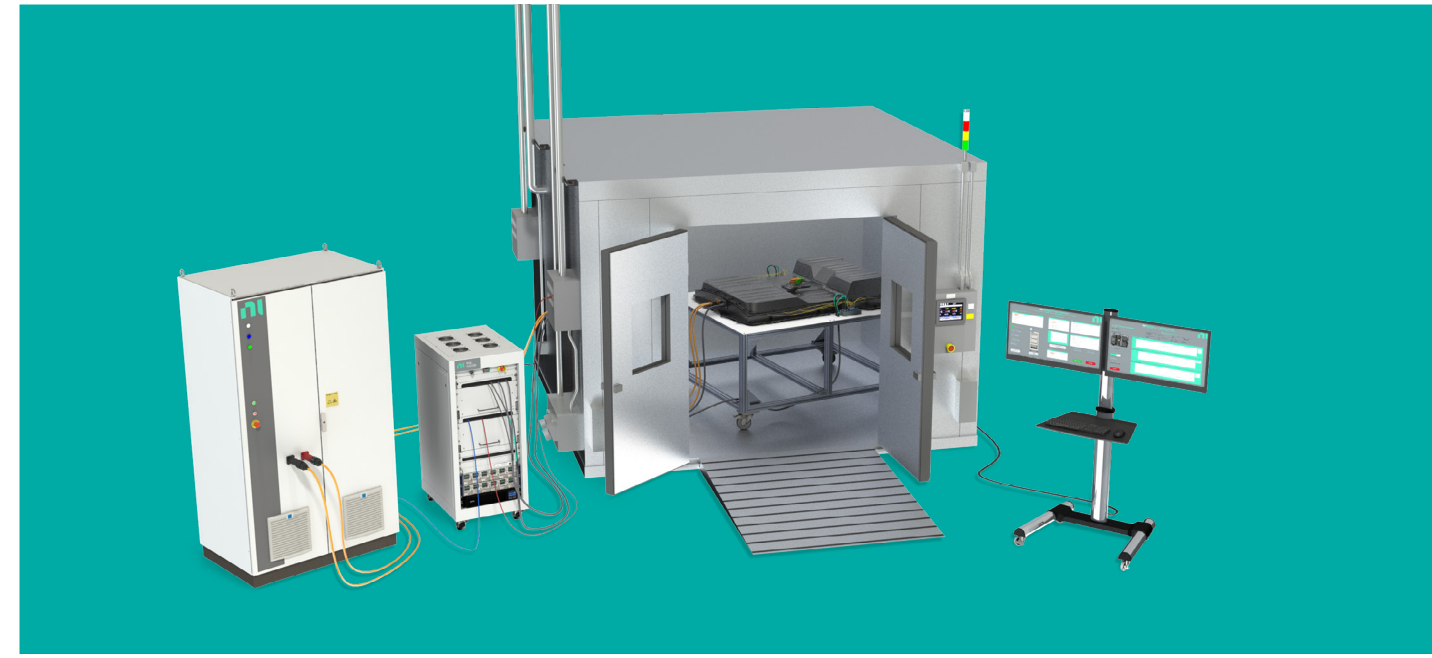


FIGURE 05

Next-generation battery test systems are open, flexible, and can easily integrate with hardware and software to control an entire test environment.

Next-Generation Battery Test Systems

Modern battery test systems continue to evolve, providing new capabilities to address changing technology and business needs. Key battery test technology trends include higher voltages for faster charging, wider power ranges, faster response times to emulate real-world conditions of e-mobility, and more environmental testing with broader adoption. On the business side, key trends include declining battery costs, increased use of lithium and alternative materials, shorter design cycles to address increased competition and market growth, and increased outsourcing of testing due to limited talent availability.

To address these trends, battery test systems now require wider operating envelopes (especially voltage and power), modular configurations with scalable and expandable power, multiple layers of integrated safety features, fast transient response times, built-in measurements, and easy third-party integration. To select the right test solution, it's important to develop a test plan that addresses the technical, user, and business needs of today and the future. Important elements of a test plan include automation software, battery cycler hardware, and other external equipment including chambers, data acquisition, relays, I/O, and auxiliary loads or sources.

Next-generation battery test solutions provide different options to automate that include multiple programming languages or a powerful test executive that can simplify and reduce software development time and complexity. With respect to hardware, battery cyclers need advanced hardware performance to ensure accurate, scalable, and repeatable test results. Voltage and current transitions, or slew rates, of the test system must be faster than the battery under test to emulate real-world settings. Flexible and scalable power enables users to address future power requirements with no or minimal investment in new infrastructure; having multilayered, built-in safety measures dramatically reduce safety hazards.

Battery test involves more than battery cycling. Users often need the flexibility to have easy integration with third-party tools such as software communication interfaces, temperature chambers, or DAQ systems. Many automated test systems do not easily integrate with third-party tools and as a result, limits testing capability and takes a long time. The ability for a battery test system to interface with and control an entire test environment is critical. Today, data has the power to transform the way companies do business and bring products to market faster. Engineers need to have a **connected ecosystem of flexible battery test systems and software automation tools** to efficiently test batteries, validate performance, and scale testing.

The Benefits of Next-Generation Battery Test Systems

- Reduce time to market and improve engineering productivity
- Decrease capital expenses (CapEx) and operating expenses (OpEx)
- Eliminate use error and ensure repeatable testing
- Reduce safety hazards
- Provide future-proofing to address future power levels

Watch the webinar

Charging Ahead: Battery Cell Quality Testing in EV Production

Overview

The automotive industry is going through a massive transformation to electrify vehicles, and batteries are front and center. Perhaps no component has ever had such a far-reaching impact on the final product while also undergoing its own rapid pace of technological changes.

Batteries present unique test coverage requirements. Automakers are accustomed to testing electromechanical systems, but batteries also comprise chemistry. This introduces an additional layer of complexity that requires not only electrical and mechanical testing procedures but also necessitates understanding and monitoring the electrochemical processes integral to a battery's operation and performance.

You could argue that testing a battery is closer to testing the human body than a circuit board. Like humans, batteries are dynamic, their condition changes due to their environment and usage, and each one behaves a little differently.

To break down some of the complexities, let's look at the basics of battery cell quality testing, scaling high-performance battery production, and future-proofing your strategy and investments.

The Basics of Battery Cell Quality Testing

A variety of tests are used to verify aspects of battery cell quality and performance. Each test has different objectives, advantages, and disadvantages.

Visual Inspection

Although it's prone to subjectivity and human error, visual inspection is a simple test to check for physical defects or abnormalities. An inspector may check electrode coating, weld integrity, and the cell structure.

DCIR

Direct current internal resistance (DCIR) tests measure resistance to direct current flow. The battery is injected with a pulse of current of relatively high intensity to measure the ohmic response of the cell. Pulses are applied when the battery is at different states of charge to map the response across the cell range, both charging and discharging, providing insights into the internal condition of the cell and its functionality.

ACIR

Resistance to alternating current flows is measured with alternating current internal resistance (ACIR) tests. A sinusoidal current is applied to the cell, and the voltage reaction is measured at specific frequencies (typically 1 kHz). By analyzing the voltage response, it is possible to characterize the AC dynamic of the cell and detect critical defects.

EIS

Electrochemical impedance spectroscopy (EIS) tests are the most advanced type of impedance test. Instead of applying the sinusoid at one frequency and amplitude like an ACIR test, the stimuli are applied at many frequencies (typically from 0.1 Hz to 10 kHz or more). EIS tests help identify defects that would otherwise go undetected by ACIR and DCIR tests.

OCV

Open circuit voltage tests measure the cell voltage when it is at rest. This simple, non-intrusive test characterizes how the cell degrades over time and rates the cells before being assembled in a module or pack.

Leakage

Leakage tests are helpful for the early detection of leaks, cell damage, or deterioration. These tests are performed in numerous ways to assess the quality of battery cells and packs. Leakage tests are continuously evolving, and the industry is currently researching new techniques that produce repeatable results in less time.

Scaling Up Battery Production with Automated Testing

Most people associate quality with **safety and performance**, which are undoubtedly vital, but battery cell quality is also critical for **scaling up production** and responding to customer demands.

McKinsey estimates that global battery producers only have about 10 percent of the capacity required to meet 2030 targets. The availability and production of better batteries are critical for helping the automotive industry stay on course and meet its projected demands.

By performing the right tests as early as possible in production processes, issues are detected before investing costly raw materials into a potentially faulty product. However, due to high volumes, long testing times, and the footprint of the production line, battery cell testing is adding complexity to traditional production challenges.

An **integrated test solution** comprised of hardware, software, and automation allows you to analyze trends, identify crucial steps in the process for testing, streamline workflows, and tackle bottlenecks. An investment in modernizing test will boost production throughput with less rework while reducing scrap and raw material costs.

Future-Proofing Your Battery Test Strategy and Investments

Keeping up with today's market demands is challenging when you are also trying to grow and innovate. **Battery technology** is changing faster than industry players can dissect test data and establish standards.

Many of the industry's current test procedures evolved from legacy technology, but **emerging battery technology demands we change the way we test**. As technology takes strides forward, it's critical to continuously evaluate your test strategy and systems.

Hyper-automation, artificial intelligence, and machine learning are integral components of a long-term test strategy that require action today. Incorporating these technologies will improve accuracy, optimize efficiency, and produce quantifiable business results for battery providers who invest.

Navigating Data

Fragmented systems often lead to inconsistent data storage practices and manual analysis. Over time, this limits your organization's ability to efficiently perform root cause analysis, solve problems, and innovate.

As the ability to connect and collect vast amounts of data has increased, advanced analytics has worked to solve fragmentation issues. Advanced analytics is an approach to data analysis leveraging statistical, machine learning, and operational research techniques to discover patterns, gain insights, and predict outcomes from large data sets.

By tracking volumes of data across production lines, from the cell level to the pack level with advanced analytics, you can connect and analyze test results to make data-driven decisions, prevent defects, and improve battery performance. A robust **battery analytics solution** streamlines collection, aggregation, and analysis for identifying urgent red flags as well as long-term trends.

Driving Standardization

The tiniest variables and environmental factors can impact battery performance; tight controls are essential to reduce noise in test results and improve defect detection. The consistency of your testing hardware, software, and processes helps with the comparability and reproducibility of results across different batches, products, or suppliers. Additionally, standardization is critical to meeting various national and international regulatory requirements and audits.

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Watch the keynote

The Dos and Don'ts of Working the Data- and Software-Connected Workflow, Part 2

"Hi, it's me again! Dan Eaton, Chief Field Application Engineer at NI. I have been working in the Engineering domain since 2005—so more than 17 years—covering ADAS- and Autonomous Driving (AD)-related topics for about five years. In my role, I get to work closely with our customers in the automotive industry, in particular with major global OEMs.

With this second part in a series of articles, I will continue to share insights and experiences I have gathered so others can apply best practices and avoid pitfalls through lessons learned. Well, let's drive right into this and pick up the pace from where we left last time."

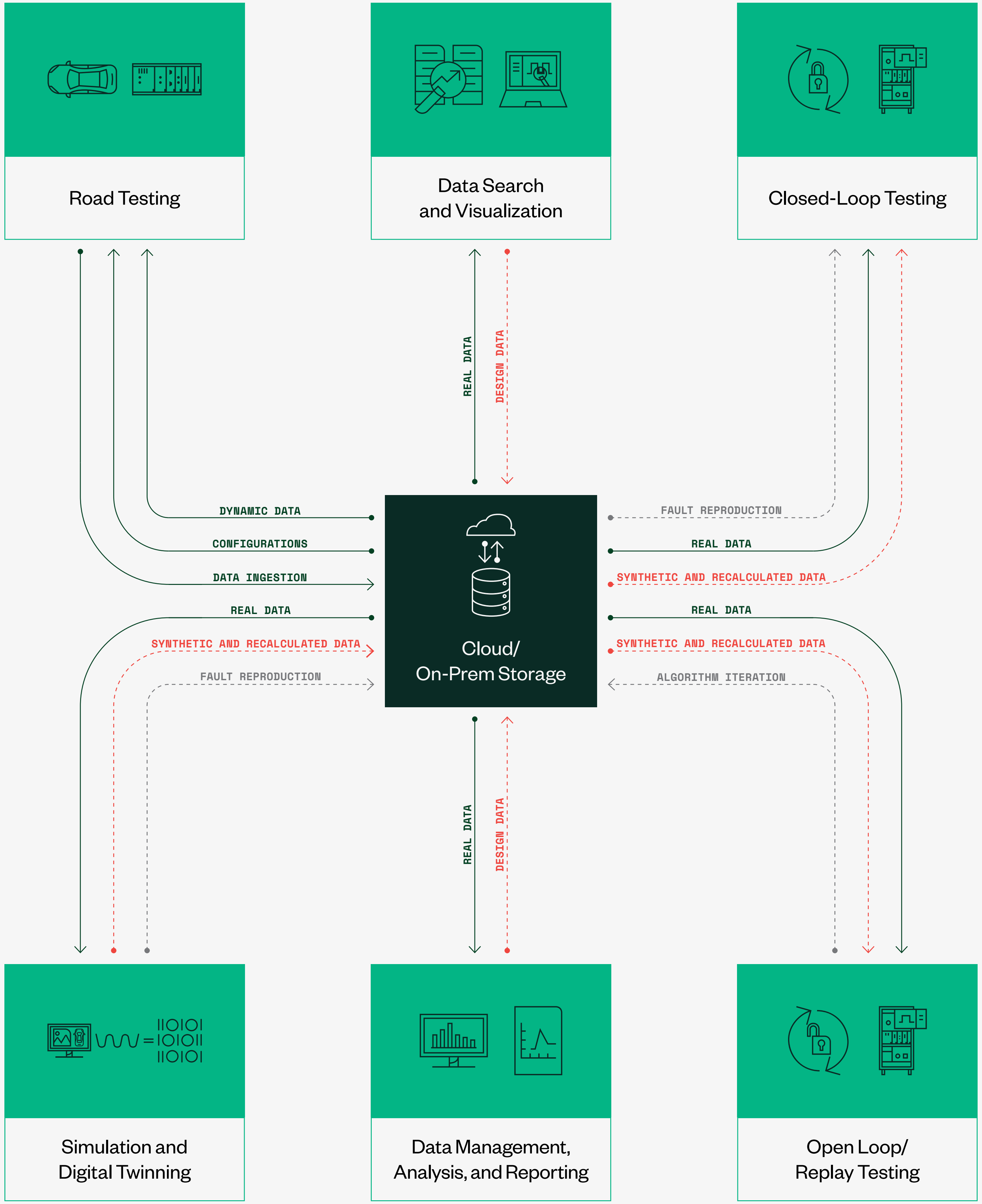


FIGURE 01

The End-to-End Validation AD Work and Data Flow

Road Testing and Data Logging (continued)

In the last issue (**Automotive Journal 2023 Volume 1**), we already covered data throughput and synchronization for external loggers. Today, we will continue our journey through the software-connected workflow (see Figure 1) with the third obvious specification for ADAS/AD data logging, which is data storage.

Data Storage for ADAS and AD Data Logging

As part of the first article, we realized that the amount of data that gets captured and needs to be stored per vehicle can easily reach hundreds of terabytes per day. Remember, a continuous eight-hour drive might require up to 144 TB of storage capacity (5 GB/s × 3600 s/hour × 8 hours). This requirement means that onboard storage with both high throughput (write speed) and huge amounts of capacity are a must. But after the data is acquired and saved onto a storage device within the vehicle, the challenge does not end there—this is where it actually starts. How do you unload or offload these data sets quickly? How do you securely upload these massive data volumes into your cloud or IT infrastructure to bring them into the lab to use the data for actual algorithm training and validation? How do you do this with a fleet of 100+ vehicles all around the world—from well-connected metropolises to rural to no-man's-land areas? I have seen organizations struggle with these questions. Let's review these topics one at a time, starting with the first step—the pure onboard storage capacity.

One might think that it would be easy to purchase some SSD storage drives that can hold 100 terabytes or more. Perhaps if you work in a nicely regulated IT environment, this statement might be true. But once we talk about running IT- or server-grade devices in a vehicle, it becomes trickier. Multiple factors add challenges that make it difficult to impossible to use IT storage systems within a car. Challenges that first come to mind are supply voltage (typically 12 VDC), temperature range, humidity, dimensions, power consumption, mechanical robustness (shock and vibe), and so forth. Oh yes, don't get me wrong—you will find IT storage devices that meet some of these criteria, but all of them in one that really is the big challenge.

Oftentimes, this need leads to the usage of smaller, non-IT-grade storage devices, like portable expansion drives. Decent capacities of up to 20+ terabytes can be found on the market, typically with USB 3.x or maybe Thunderbolt™ connections. These drives provide plug-and-play connectivity, but they cannot deal with sustainable data throughput rates of multiple gigabytes per second. Furthermore, even if these portable expansion drives might be sufficient in terms of capacity and at lower data transfer rates, it is often forgotten that these drives are not purpose-built for high and frequent read and write usage. This mistake can quickly lead to quality issues, wearing out your data storage. There is nothing more painful or a bigger cost driver than logging multiple hours out on the road and returning without any data, not to mention useful and relevant data. Compromises must be found for these applications, which means that the IT world and the automotive logging world need to get closer to one another.

NI has partnered with Seagate to handle the hard drive workflow challenges mentioned here. Seagate provides their Lyve Mobile Array drives with up to 92 TB SSD (at the time of writing) with 5+ GB/s write speeds. These drives use standard redundant array of independent disks (RAID) technology and are hot swappable. With a direct connection to the PCI Express bus through a cabled PCI Express Gen 3 card, the required data throughput can be guaranteed. If even more data throughput or disk space is needed, another cabled PCI Express Gen 3 device and Lyve Mobile Array can be added to scale to the new requirements.

Offloading ADAS and AD Logging Data

OK, now that we have looked at the first step for in-vehicle storage focusing on capacity and the already mentioned data throughput, let's look at what's next: how to offload or offboard data from the vehicle—or more precisely, from the vehicle fleet (Figure 2). Three potential approaches immediately come to mind. The first is wireless or mobile data transfer, the second is a cabled connection after the car is back at a garage or workshop location, and the third is physically removing the storage device(s) or drive(s) from the vehicle.

Wireless or mobile data transfer would be preferred since it provides data access from everywhere at every time. But let's be realistic; mobile data coverage around the globe varies quite a bit. Moreover, even with 5G or the 6G future, these massive amounts of data—in the multi-gigabytes per second—cannot be handled by these networks. For the majority of the logged data, mobile networks are impractical. Even though there are niches like transferring a specific, single corner or edge case scenario back into your lab for urgent usage, let's face it: Mobile or wireless data transfer is really not a viable option.

The next stop is cabled data transfer—similar to the way we charge our EVs. (Isn't it great how we have seen progress in reducing the time it takes to supercharge our cars?) Unsurprisingly, time is again the critical factor when offloading recorded data from your ADAS, especially camera systems.

Let's do some math again, considering 144 TB per vehicle and a 100 Gbit (12.5 GB/s is theoretical) Ethernet interface for offboarding. We can quickly see that charging our logging car will be the smaller issue, as the data transfer for this amount will easily take more than three hours (144 × 1024 GB / 12.5 GB/s ≈ 3 hours, 16 minutes). Overnight offloading might be a viable option, but this process must be paired with an onboard storage device that can handle logging campaigns up to 150 TB per day.

Finally, there's physical extraction of the storage device(s) from the car to consider. As mentioned earlier (see **Automotive Journal 2023 Volume 1**), a USB drive can't be considered an option, simply because of the limited storage capacity as well as other factors discussed earlier in the portable expansion drives section. Apart from these criteria, what else is there to consider for physical offloading?

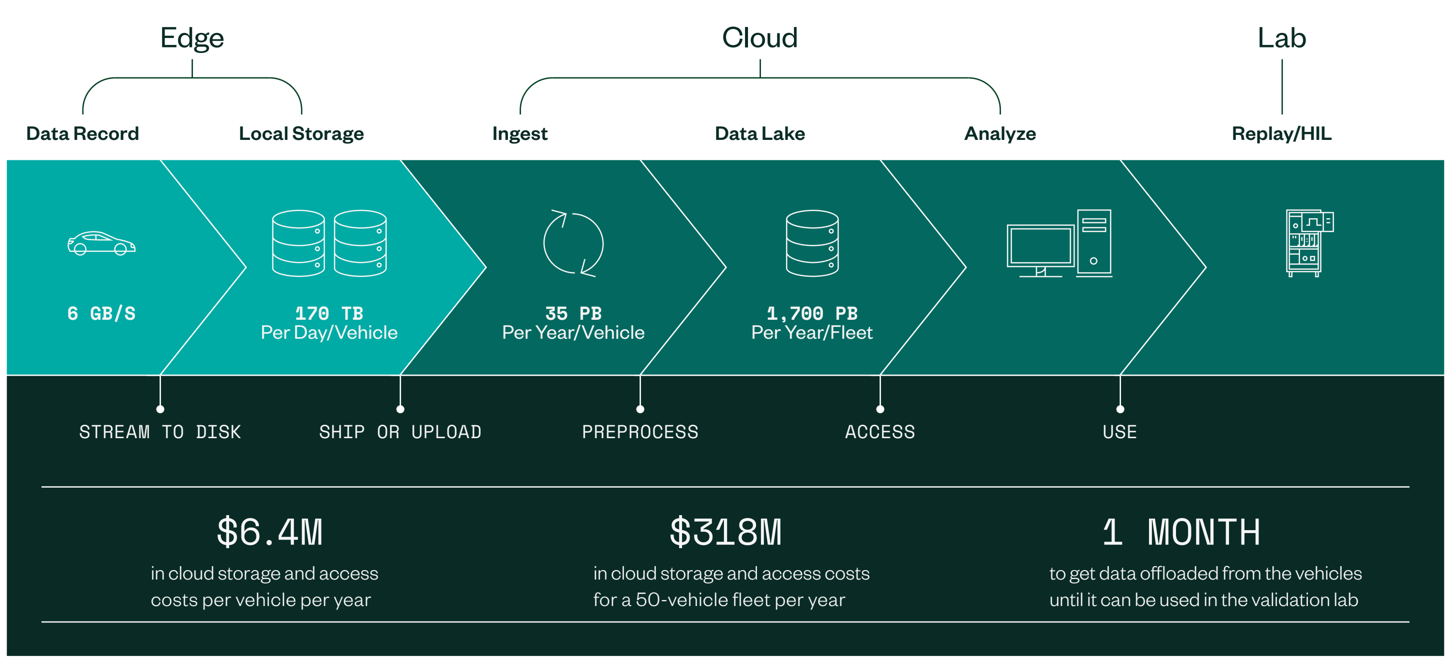
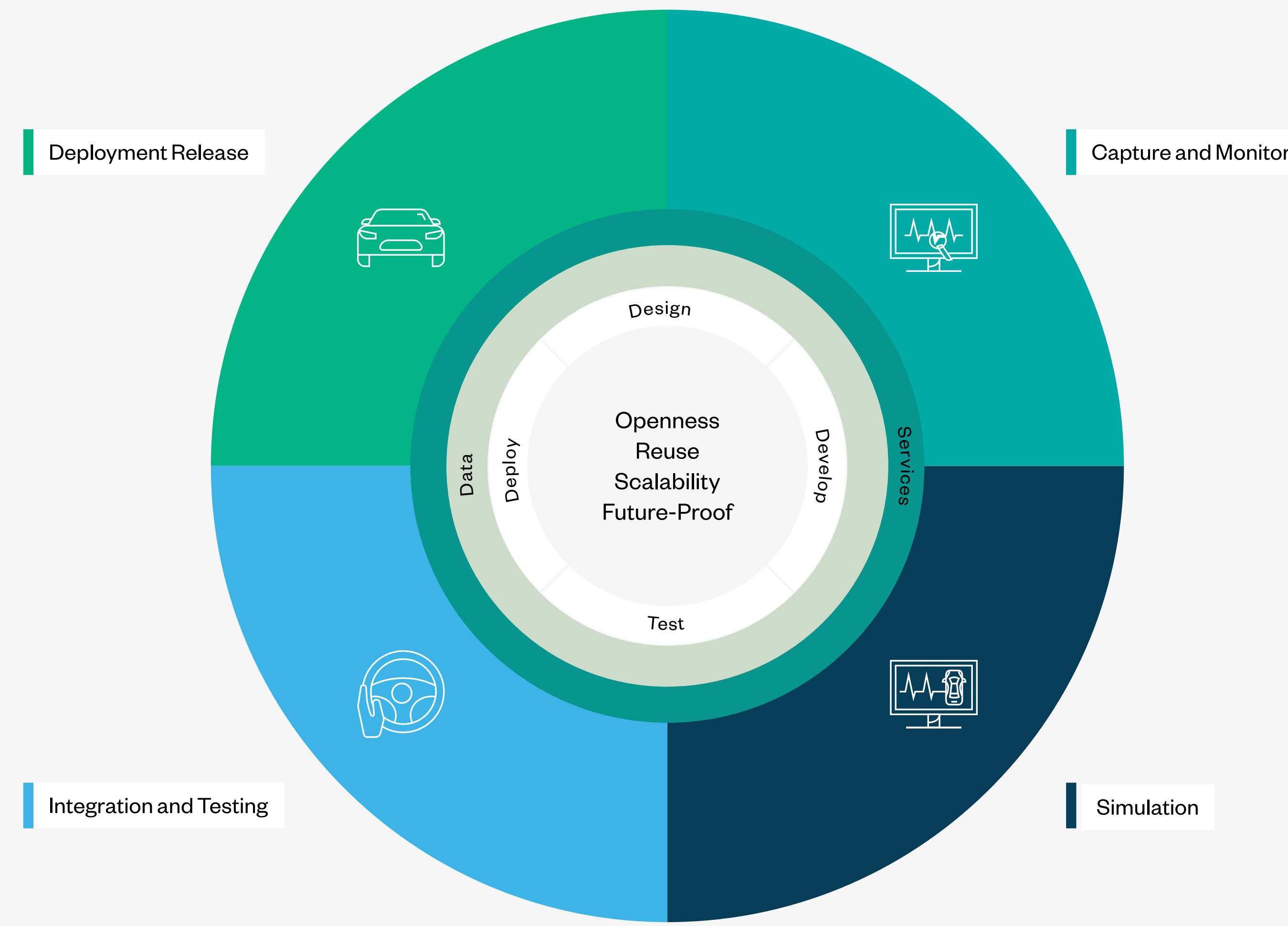


FIGURE 02

Automated test systems integrate the DC source and load within a single product.



Deployment Release

End of Line
- Sensor Production Test
- ECU Production Test

Regression Testing
- Platform Reuse
- Hardware-in-the-Loop Farm

Data

Data and Test Management
- Asset and Fleet Management
- Data Visualization and Analysis
- Test Coverage and Analysis

Integration and Testing

Replay/Hardware-in-the-Loop
- Injection Techniques
- Fault Injection
- Third-Party Simulation

Hardware V&V
- Endurance, Temperature
- Characterization

Capture and Monitor

ADAS/AD Data Record
- Storage
- Smart Triggering
- Pre-Labeling
- Data Compression and Annotation

Services

Engineering and Consulting
- Methodology Consulting
- System Integration
- Certified Solution Delivery Partners
- Testability Studies

Simulation

Virtual Validation
- Third Party (Open Interfaces)
- Preferred Environment Simulation

FIGURE 03

The NI Solution Portfolio Enabling the Data- and Software-Connected ADAS/AD Validation Workflow

Let's take a closer look at the following three areas:

- Ease of use—the driver must be able to easily swap the storage devices (remove the full drive from the vehicle and mount an empty drive back into the vehicle), so they can do it without the need for deep technical expertise and without taking a lot of time.
- Physically mounting and unmounting electronics often comes with the risk of wearing out the connectors. Robust mechanical setups are another must-have for the lifetime and uptime of a logging solution. You don't want this to be limited by a low number of possible plug and unplug cycles, and mechanical robustness also goes hand in hand with ease of use, of course. You want to make sure that improper use or handling of the storage mounting and unmounting will not be another source of failure by damaging data transfer or power connections. Keep in mind, we are talking about RAID systems.
- How to get these offboarded drives to a data ingest station, a data center, or straight into your validation lab to do the actual copying of the data. Don't forget, you also need to have empty storage devices available to continue logging wherever your fleet of vehicles are out in the field!

Suddenly, this data logistics challenge is not only limited to the digital world; it becomes a challenge in the physical world because of the requirement to ship hardware globally. Along those lines, we clearly have seen the need for data security, as nobody wants these valuable assets—again which are traveling in the physical world now—to be exposed to data manipulation or even data theft. Data encryption as well as key management are key topics to bake into the strategy and implementation of your data pipeline.

This concludes the article on best practices and lessons learned implementing the data and software connected workflow.

Dan will continue to share his insights within the next issues of the **Automotive Journal**. It is NI's goal to enable organizations through a set of software and hardware solutions to implement a data- and software-connected workflow (Figure 3). NI wants to help its customers and partners accelerate development and turn test into a strategic advantage that unlocks greater product performance.

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Learn more

NI-Spirent Automotive GNSS Simulator

Our Automotive GNSS Solution brings Spirent's best-in-class, proven GNSS simulation models into the NI environment. The Spirent GNSS Simulation Solution is a software personality that enables the USRP-2974 to act as a powerful GNSS simulator. The solution produces a comprehensive range of emulated multi-GNSS, multi-frequency RF signals with class-leading flexibility, coherence, fidelity, performance, accuracy, and reliability.

Customer Needs

01

Testing of automotive GNSS receivers and in-vehicle infotainment (IVI) systems.

02

Signal injection for ADAS prototyping and testing.

03

Open and Closed Loop RT trajectory injection.

04

Performs in any HIL simulation platforms with ultra-low latency.

05

Dead Reckoning (DR) and Radio Technology Commission for Maritime Services (RTCM).

Spirent + NI Solution

01

Support for vulnerability, multipath, and spoofing.

02

1 RF and/or 2 RF configurations for multi-device testing for up to 32 channels in one chassis.

03

Supported by any OS or programming language that can provide a TCP message.

04

Scenario Creation, data streaming, and data logging.

05

Able to generate all GNSS constellation types in multi-frequency operation.

06

Fully future-proofed for all advances in GNSS systems, signals, modulations, codes, and data.

The Spirent Advantage

Integration Capability

- We ensure 40 ms latency. In closed-loop HIL, with car at high speed (e.g., motorway scenario), this can become critical.
- Continuous integration/support ensure compatibility with third-party latest releases.

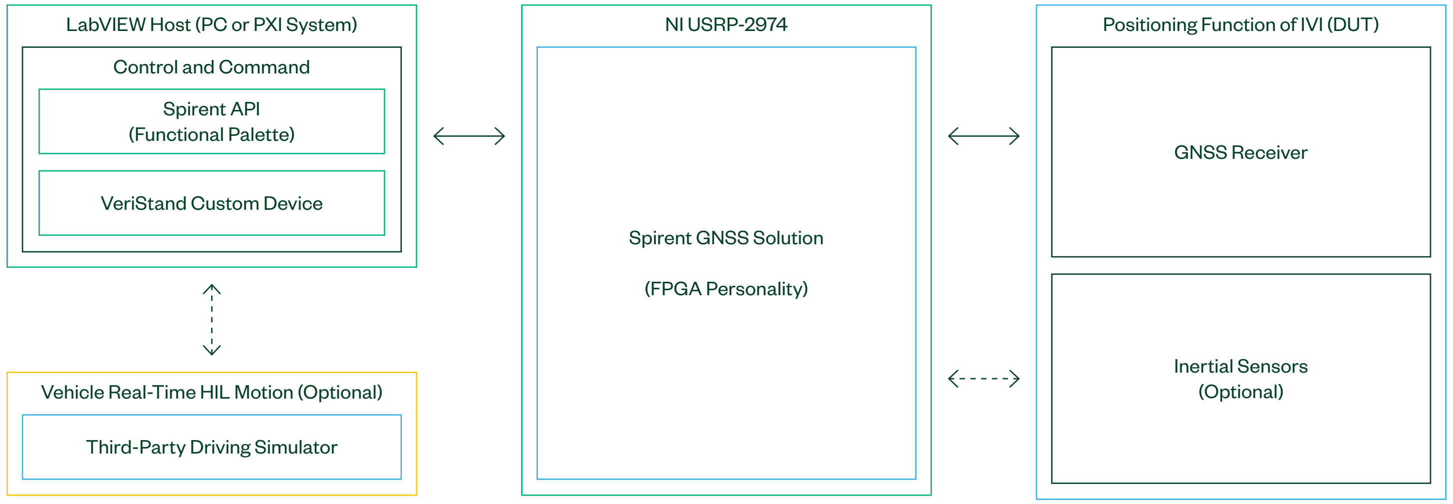
Realism and Performance

- Superior signal performance, and vehicle and orbital models available
- Global support—latest CDs implementation, with close ties to most GNSS operators and chipsetsdevelopers

Flexibility

- Different software levels to meet the customer's needs and budget
- 2 RF output option

NI-Spirent GNSS Simulation Overview



Control and Command:

- Seamless integration into the NI environment via custom LabVIEW Spirent API
- Complete control over the scenario, GNSS space, and user segments
- Option for real-time remote motion
- Latest GNSS signals ICD supported

Leverage the NI USRP-2974:

- 1 or 2 RF output for multi-trajectory and multi-device testing
- Up to 36 channels (visible GNSS satellites)
- RF level control +15 dB to -40 dB ; 0.2 dB resolution
- 100 Hz SIR and 40ms HIL latency

ADAS/AD Environment for GNSS Receivers:

- Fundamental performance tests, including TTFF, acquisition/reacquisition/tracking sensitivity, navigation accuracy
- Resilience tests: satellite errors, multipath
- Inertial sensors (IMU) option for sensor fusion testing

KEY SPECIFICATIONS	
PARAMETER	DETAILS
Satellite Support	GPS (L1, L2, L5), Galileo (E1, E6), GLONASS (L1, L2), Beidou (B11, B1C, B21, B2a, B2b, B31), IRNSS (L5), QZSS (L1, L2, L5, L6)
Freq. Band and Range	Depending on the used constellation. Refer to the Nominal Signal Level table within the IPA.
RF Signal Level	+15 dB to -40 dB; Resolution: 0.1 dB
Signal Accuracy	Pseudorange Accuracy: 3mm RMS
Signal Stability	Internal 10.00 MHz OCXO (after warm-up) ± 2.5 x 10-8
Scenario Duration	23 days 23 hours 59 minutes
Latency	40 ms (Simulation running at 10 ms SIR.)
Relative Velocity	±30,000 m/s

To learn how you can increase product quality and shorten test timelines, contact your account manager or NI at (888) 280-7645 or
info@ni.com **ni.com/transportation**

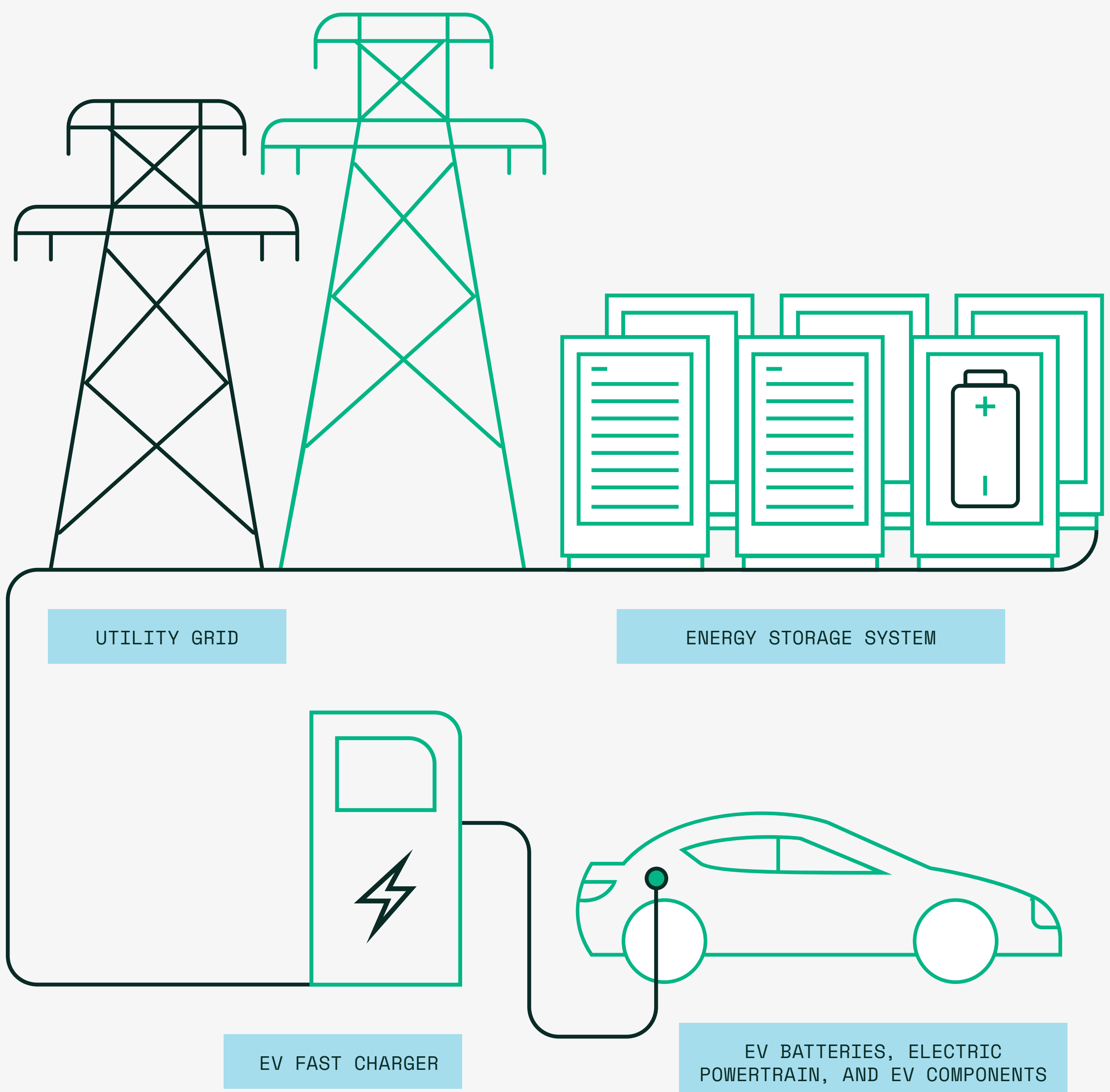
The Role of DC and AC Power in EV Testing

Overview

With the accelerated growth of electric vehicles, engineers must address new testing challenges. Higher voltages permit faster charging and increased power transfer while reducing vehicle weight. These factors are driving development for higher performing batteries, electric drivetrains, power converters, and inverters.

DC and AC power test solutions emulate real-world conditions and are critical for the testing and validation of EV components and systems, as well as the charging infrastructure in which they need to coexist. Let's explore the EV components and systems that need to be tested.

Testing Power from the EV to the Grid



Battery Cell, Module, and Pack Testing

EV battery cells, modules, and packs require rigorous EV lifecycle, drive cycle, and performance testing. Battery test systems need to provide modular and scalable power, flexible configurations, advanced performance hardware, and built-in safety. However, testing batteries is more than just cycling a battery—it involves testing multiple systems that need to communicate with each other. NI's **comprehensive, software-defined approach to testing batteries** provides a path forward from offering battery cyclers to a large-scale lab deployment with battery test software.

EV Components and Systems Tests

Electric Powertrain Testing

Testing the electric powertrain requires fast-transient speeds and accuracy to emulate real-world conditions of the battery and wheel power. Unlike other battery simulators or bidirectional power supplies, NI's battery emulators are specifically designed to emulate a battery's characteristics to provide real-world performance. Their robust topology provides the capability to emulate real-world conditions over a traditional battery simulator.

NI's battery emulators sink and source power to maintain voltage regulation and accept back EMF which prevents safety hazards. They have isolated input and output paths to eliminate single points of failure.

DC Fast Charging Testing

DC fast charging is much faster compared to AC charging. The AC power from the grid is converted into DC power in the charging station and supplies power directly to the EV battery. More power can be delivered because it bypasses the limitations of the onboard charger.

Using batteries as power sources for testing fast charger systems is extremely time-consuming and costly. The ability to emulate a wide range of vehicles, regardless of their battery characteristics and power levels, dramatically simplifies testing. NI's unique battery emulation capability can substantially reduce test time, energy consumption, and operating costs. NI's grid simulator can emulate the grid, and the DC/battery emulator can emulate the EV. This bidirectional source can also emulate the fast charger or a high-voltage battery that can accept fast charging with layered, built-in safety features.

EVSE, OBC, V2G Testing

Testing the EVSE, OBC, or V2G applications requires simulating dynamic waveforms. Further development is taking place to optimize AC home charging and the use of V2G as a form of energy storage capacity to support the utility grid. V2G allows the utility grid to use the EV's battery during high peaks of energy consumption. NI's grid simulator can emulate the source, or power from the grid, and NI's AC load can simulate any inductive, capacitive, resistive load for testing.

NI's DC and AC Test Solutions

NI has complete DC and AC test solutions to test everything from the battery to the utility grid. In-house battery cyclers, battery emulators, and DC loads can test and emulate the EV battery and DC power, while the AC grid simulators and loads can verify the AC product performance.

NI offers a leading portfolio of AC and DC power electronics to cover all EV testing needs including:

- **HPS-17000**: High-Performance Cycler/Emulator
- NHR-9300: Mobile Pack Cycler/Emulator
- NHR-9200: Module and Pack Cycler/Emulator
- NHR-4800: High-Density Module Cycler/Emulator
- ERS-BIC: High-Power Pack Cycler/Emulator
- NHR-9500: High-Power Grid Simulator
- NHR-9400: Grid Simulator and V2G

View high-power test solutions

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