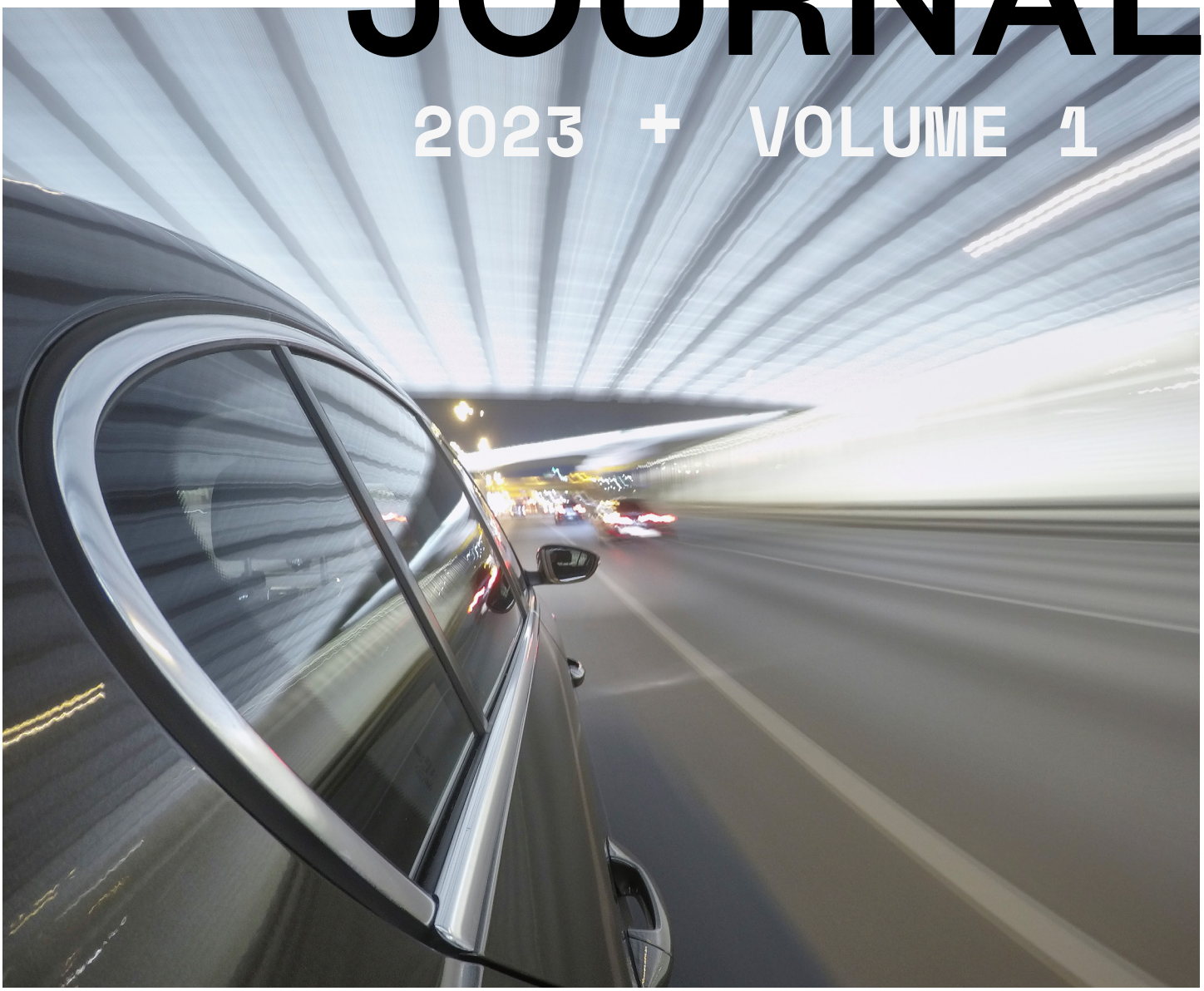
AUTOMOTIVE JOURNAL

2023 + VOLUME 1



Your Battery Validation Lab Is Already Obsolete. Or Is It?

Safe like a Robot. Drives like a Human.

Making (and Testing) the World's Greenest Battery

ni.com/automotive

Evolving with Our Industry

For many, the natural evolution of the annual calendar brings about notions of change. Life springs back from wintry conditions, resolutions of better self-care, and typically a much-needed break from the pace of “normal” and an opportunity to relax with those we love and gain perspective. For Automotive leaders, however, this feels all too familiar.

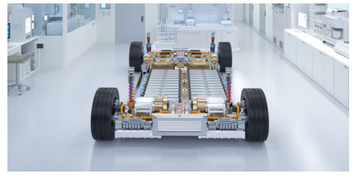
Collectively, the automotive industry has some momentum. The cost of the electric powertrain continues to fall, EV sales are expected to surpass 25 percent of total sales, and the technology world looked to CES to showcase new promises of innovation. That’s not all that feels familiar. Economists are predicting a recession, COVID-19 variants continue to cause challenges, and automotive leaders are still looking to extract value from their data across the business to drive down cost and increase quality.

While much is changing, much remains the same. What else is new? Dr. W. Edwards Deming once wrote, “Survival is not compulsory. Improvement is not compulsory. But improvement is necessary for survival.”

If you’re ready for a change, there is a better way.

Let us show you how.

Table of Contents



06 Your Battery Validation Lab Is Already Obsolete. Or Is It?

Modernize your lab to conquer speed, cost, and volume challenges.

14 Better Data Management Starts Here

Improve your data collection, analytics, and decision-making processes.

16 Safe like a Robot. Drives like a Human.

Jaguar Land Rover partners with NI to achieve a data-driven approach to validation.

20 Making (and Testing) the World's Greenest Battery

Northvolt is optimizing battery performance and closing the loop, sustainably.

24 NI Innovation Centers around the Globe

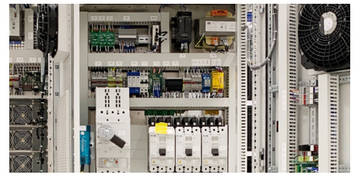
NI solutions help foster our customers' industry-leading innovations.

26 Maximize Test Coverage with Your ADAS/AD Replay and HIL Test System

Real-world and virtual test efforts can help autonomous vehicles become a reality.

28 Closing a Critical Coverage Gap in ADAS/AD Camera Validation

Enable testing production release software with real-time emulation like never before.



32 Flexible and Scalable EV Battery Cycler

Scale operations with easily synchronized, orchestrated, and operated lab equipment.

34 Mobility Solutions for a Better Tomorrow

New shifts in automotive technology will require adaptive, integrated solutions.

40 The Dos and Don'ts of Working the Data and Software Connected Workflow

Avoid pitfalls through lessons learned and get to the right solution faster.

Your Battery Validation Lab Is Already Obsolete. Or Is It?

Have you been in a situation in which what you think you know is strongly challenged?

A few weeks ago, I was showcasing NI's battery validation lab solutions to a diverse group of people and one of the best questions I got was spot on. **Where is the novelty?**

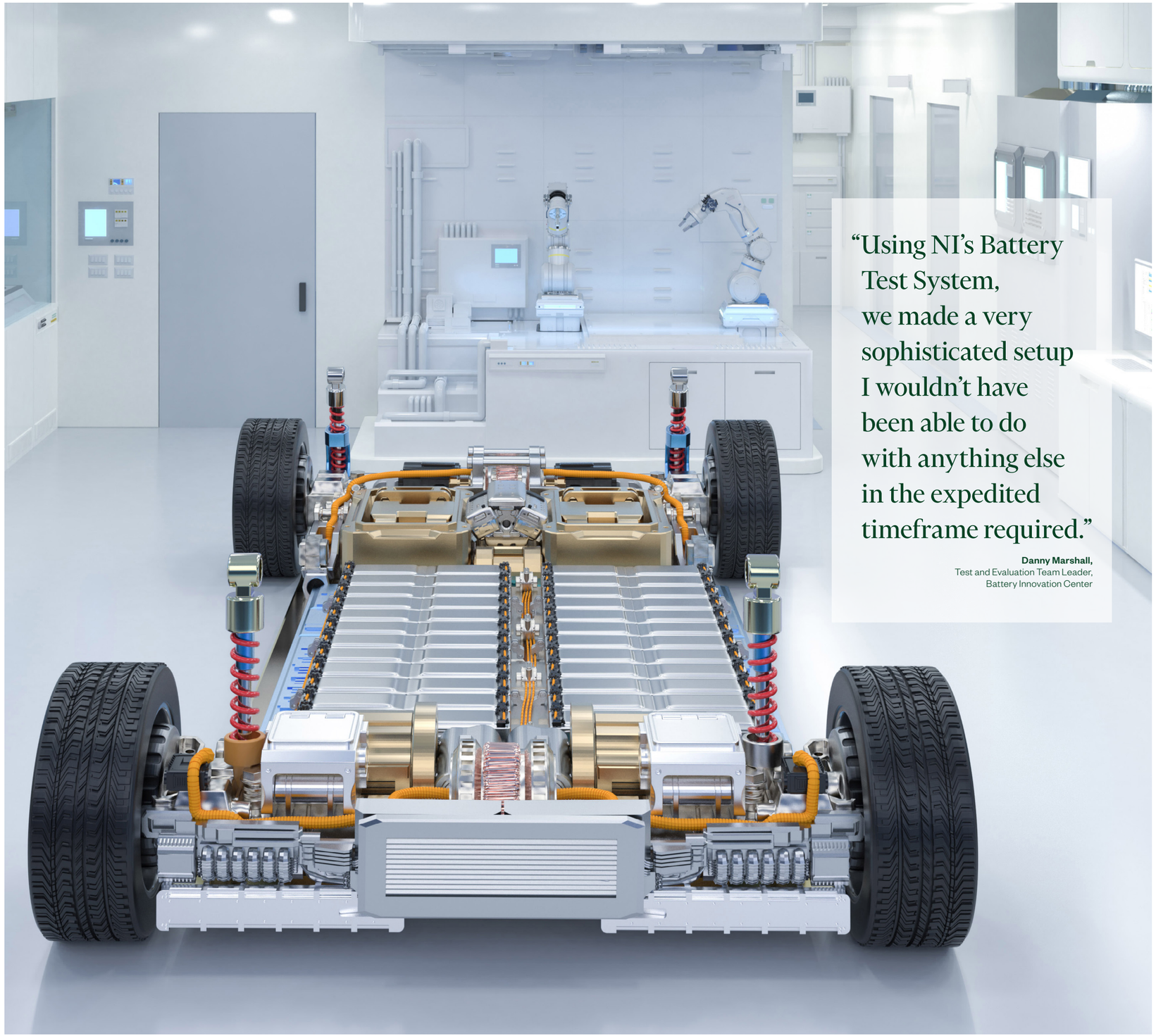
I appreciated how the question framed the NI solution in a different context and made me restate the problem we're solving: obsolescence. In the context of a battery validation lab, calling it obsolete is harsh because any recently built lab still works to find design flaws and ensure battery safety. However, we constantly hear from the engineers we work with that labs quickly become insufficient as demands for speed, cost, and volume of work get tougher. So rather than obsolete, let's consider what makes a lab insufficient and explore what's missing.

Typical Battery Validation Lab Challenges

The fundamental components of a battery validation lab include the cyclers to inject and draw power from the batteries, the measurement and instrumentation equipment, the chamber to ensure environmental and/or safety conditions over the test, and the software that runs the whole test cell.

All these components are already commercially available, include software interfaces, return some sort of data, and can be integrated—at the right cost—to operate together and perform the test on the batteries. Such lab setup is entirely possible, albeit fragmented, but brings challenges such as:

- Inconsistent data storage practices
- Manual asset management
- Inconsistent software approach
- Too many instrument and system types
- Limited automation
- Inconsistent test methodologies



> "Using NI's Battery Test System, we made a very sophisticated setup I wouldn't have been able to do with anything else in the expedited timeframe required."
>
> **Danny Marshall,**
> Test and Evaluation Team Leader,
> Battery Innovation Center

> “We get the openness to integrate existing assets and proprietary protocols, so we can maximize reusability of our existing equipment and speed up test.”
>
> **Henrik Rudelius,**
> Director, Validation and Simulation, Battery Systems, Northvolt

The real problem though, comes in the form of **limited product insight, high engineering costs, and slower development time.** The consequences of these challenges vary from case to case depending on the engineering resources available or the level of investment possible. Another factor is the risk-tolerance to a “test enough” approach in which all regulations and requirements are met, but there are no extended efforts to optimize the battery performance and the test operations. In summary, individual companies will have to find a reason to want to change their test and lab setup approach in line with the potential consequences of inaction.

Just like a typical lab setup could be sufficient for a given company (although we do not see that often), optimization may mean different things for different battery suppliers and OEMs. We can make the safe assumption that there’s always something to optimize and improve, but there’s no single way of modernizing a battery lab. How do we go about optimization when so many things could be optimized?

The answer: software and data.

From Insufficient to Modern

Modernizing a battery validation lab is not about equipment, interfaces, or services, but about the value it brings to the test operations. For example, some of the most common requests we hear from customers seeking to optimize their battery validation operations are:

- Increasing automation to reducing manual work
- Providing a common solution across battery cells, modules, and packs
- Integrating to existing equipment to continue leveraging investments
- Providing on-demand data access to all relevant stakeholders

This is no easy task—and we’ve found that a comprehensive set of features like flexibility, openness, scalability, and deterministic hardware synchronization are required to set such a lab up for success. These features are invariably enabled by a software- and data-centric approach to the lab, and particularly targeted to the most painful problems:

PROBLEM	WHY IT’S PAINFUL FOR THE TYPICAL LAB	HOW IT’S SOLVED IN THE MODERN LAB
Too many changes, too fast	Making changes to individual equipment is resource intensive.	Common software toolchain with out-of-the-box functionality is used to automate tasks for cycler operation, taking measurements, and reporting on test results.
Disruptions to long test process	Test can’t be effectively simulated before running—and once running, it’s not monitored as one, so errors or failures in execution are not timely detected, wasting time and causing test reruns.	Real-time hardware provides reliability in execution while test software continuously monitors test conditions to timely trigger alarms and corrective actions.
Too much to manage as lab grows	Lack of centralized lab operation generates confusion and inconsistencies in test execution, forcing time-intensive manual work to schedule, run, and report on test, as well as monitor equipment utilization.	A higher-level software layer oversees all assets alongside test and operational data, providing laboratory information management system (LIMS) functions on a server-based platform. It also helps define tests independently from equipment using hardware abstraction and optimizes utilization and operational costs through facility monitoring.
Batteries are difficult to understand	Data is stored inconsistently, generating manual work to aggregate, report on, and make sense of it to derive insights. It also slows down the feedback to the right stakeholders to make design decisions from a clear understanding of battery behavior.	A data-centric solution can ingest any format of data from any tool, contextualize it, and create web-based dashboards on demand through standard visualization tools. Any stakeholder can review test data, perform analysis, and make decisions from it. Automation can be programmed for anomaly detection and timely reporting on faults.

Software for the Modern Battery Test Lab

Connected Data—From Instruments to Insight—Accelerates Time-to-Market, Improves Product Performance

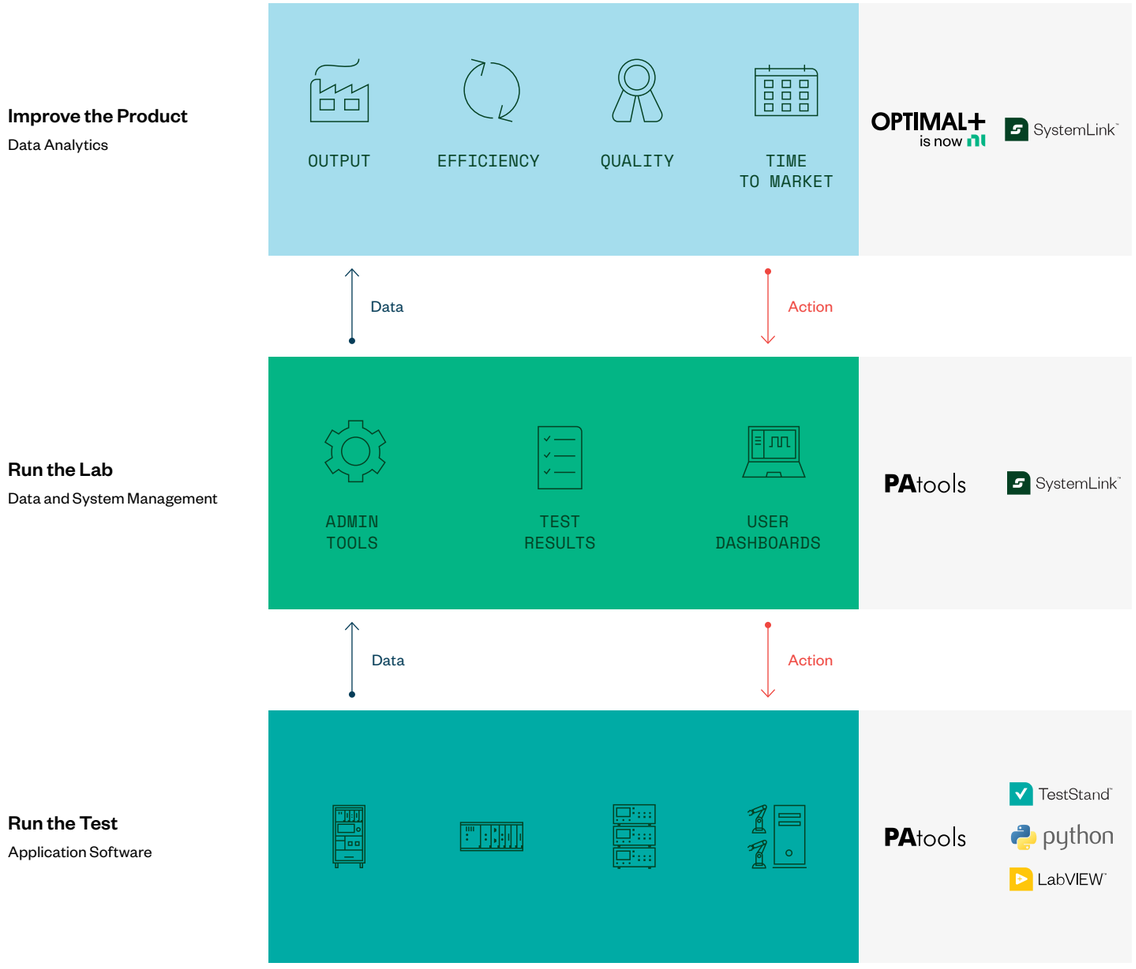


FIGURE 01

Software must enable the flow of data and commands to close the cycle from running the test, running the lab, and improving the product being tested.

How to Move toward Modernizing the Lab

Now that we understand what would take a battery validation lab from quickly becoming insufficient to being modern, comes the big question: how do we do it?

The first big decision to make is what needs to be optimized. Very similar to standardization, modernizing a battery validation lab is a complex process that targets problems in a systematic way to avoid unnecessary disruptions and costs, while setting it up for long-term success.

There are generally three levels where the previously described pain points would be (Figure 01). An inward-looking analysis of where your current challenges are most significant will guide you toward the first set of steps to take. Some reference use cases to highlight are:

Run the Test:

The Battery Innovation Center (BIC) in Indiana is one of the most diverse customers we work with. Rather than scaling up on one dimension (type of battery, type of test, etc.), they require the ability to change test setups quickly and drastically, for a myriad of batteries under test. BIC engineers can use hardware abstraction layers, plugins, and other automated tools to save time from configuration, setup, and reconfigurations when responding to changes. Using the NI Battery Test System, they've been able to reduce their setup times from weeks to days, and quickly run tests as their customers require.

Run the Lab:

Northvolt runs one of the most ambitious test operations as they strive to make the world's greenest battery. To run their labs, they needed openness to connect to existing equipment, program proprietary protocols, and orchestrate the test so data can be used to improve their batteries, even after they're deployed (read more on page 20). Future work will help optimize energy usage, reduce CO_2 footprint, increase utilization, better manage downtimes, and ensure reliable data collection from the whole battery test facility as well as the individual DUTs.

Improve the Product:

General Motors is betting big on their Ultium battery platform; to scale up, they need accurate, on-demand access to battery test data for their subject matter experts. Working with NI solutions, they've saved thousands of hours of manual work through automation and have gained the insights they need to improve their batteries.

> "With NI's SystemLink™ Software as part of our architecture, we can bring our test data to all engineers in a secure and easy way, thus enabling them to view their data and save templates for follow-up tests, all in near real time."
>
> **Ciro Spigno,**
> Group Manager, Battery Systems and Analytics Engineering, General Motors

NI's Modern Battery Validation Lab: What's the Novelty?

At NI, we have solutions installed at more than 80 OEMs and Tier 1 suppliers, more than 20,000 battery test channels installed worldwide, and decades of success automating test tasks to accelerate time to market, reduce cost, and optimize test operations.

The novelty of NI's solution is that it drives value for state-of-the-art labs as well as for those in need of a full overhaul. Regardless of whether you need high-mix or large-scale test, and independently from the existing infrastructure, NI's solution components and services are targeted at delivering value where you need it, with minimum incremental costs. We can work with you on a plan to modernize your battery lab and deliver solutions that help you get to market faster and keep your engineering resources focused on testing to make better batteries.

Author

Arturo Vargas Mercado
Chief Marketing Manager, EV Test, NI

Learn more

CONNECT
2022 MUNICH

KEYNOTE

Industry Leaders Shed Light on How to Use Test and Data to Increase Product and Operational Performance

JAGUAR · LAND ROVER · northvolt · SEAGATE · ...

THE VALIDATION TEST DATA WE GET FROM NI SYSTEMS ENABLES OUR ENGINEERING TEAMS TO LEARN MORE ABOUT OUR BATTERIES AND FIND WAYS TO IMPROVE THEM EVEN AFTER THEY'RE IN THE FIELD.

- HENRIK RUDELIUS, DIRECTOR, VALIDATION AND SIMULATION BATTERY SYSTEMS, NORTHVOLT

LARGE PARTNER PRESENCE

OPAL-RT TECHNOLOGIES · SEAGATE · S·E·A · NOFFZ TECHNOLOGIES · Averna · konrad technologies · ALIARO · AKKODIS · measX Measurement System Experts · ...

TRANSPORTATION RECAP

PRODUCT INTRODUCTION

EV Battery Cycler Spans Wide Voltage Range

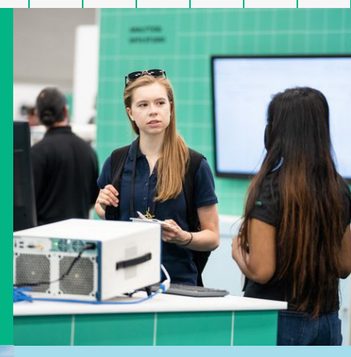
Modular design, high scalability serves needs of battery validation labs.

BUILT TO SERVE BATTERY TEST LABS, THE HPS-17000 COMPLEMENTS NI'S PORTFOLIO OF BATTERY CYCLERS, OFFERING A SOLUTION THAT IS IDEAL FOR TESTING IN A FAST-PACED ENVIRONMENT THAT NEEDS TO BE SCALED AND EASILY SERVICED.

- EENEWS AUTOMOTIVE

CONNECT
2023 AUSTIN

SAVE THE DATE



MAY 23–24

Better Data Management Starts Here

Collecting and analyzing the large amounts of data your team is collecting is a problem that may only be getting harder to solve as testing requirements increase, timelines shorten, and talent and resources change roles over time.

To help organize your thoughts about where to focus and prioritize your efforts, use the following questions to review your current implementation and how it might need to adapt and change to be maintainable, scalable, and actionable. As you perform your self-evaluation, mark the column that most aligns with where you are and then set up a working session to decide with your team what the best path forward is for addressing the items that will have the biggest impact for you.

COLLECTING DATA	GREAT	COULD USE IMPROVEMENT	NOT STARTED
Can you easily make an update to one or more data sources (i.e., deploy new software)?			
Do you have a process to consolidate data into a single location?			
Can you compare data across the product lifecycle such as simulation vs. prototype results?			
Will you be adding more test systems in the future and will your existing process and tools scale?			

DATA PREPARATION	GREAT	COULD USE IMPROVEMENT	NOT STARTED
How is the data saved and how easy is it to find and view a test result?			
Does all data you collect have metadata?			
Is the metadata consistent across all tests?			
Do you have an easy way to harmonize data that may have different units or spellings (litre vs. liter)?			
Do you have a way to harmonize data coming in from multiple labs, facilities, or locations?			
Do you translate your data to a universal data model to ease comparison of test results?			
Is your process to prepare data documented so that you can scale your operations?			
Is your process adaptable to quickly align with changing test requirements or if you need to add additional test channels?			
Do you have a way to connect to parametric data or test steps?			

VISUALIZATION	GREAT	COULD USE IMPROVEMENT	NOT STARTED
Do all users have access to the visualization tool of your choice?			
Is it easy to set user permissions to limit access to dashboards and results?			
Can you easily make changes to align to any changes in your testing and reporting needs?			
Are your dashboards documented so that they scale with your test operations?			

ANALYSIS	GREAT	COULD USE IMPROVEMENT	NOT STARTED
Are all of the analysis tools you are using compatible with each other?			
Can you assign user permissions to limit access to certain analytics if necessary?			
Can you easily update an analysis routine and ensure version control?			
Are your analysis routines documented including a history of changes?			

BUILDING A BETTER PRODUCT	GREAT	COULD USE IMPROVEMENT	NOT STARTED
Are reports easily shared with key stakeholders?			
Can you easily share modified views with different departments?			
Do your current processes and deliverables support quick and efficient action to be taken?			
Do you document decisions and have a searchable archive?			
Can you perform a root cause analysis if an issue is identified from your test results?			

As you work with your team to prioritize efforts to improve your data collection, analytics, and decision-making process, some questions to get the conversation started could be:

- What is your largest frustration with your existing data analytics and decision-making process?
- How do you foresee your data needs changing in the near term? What about longer term?
- How would leaving things the way they are affect your team/project now and in the future?
- What would be the business value if you were to implement a better data analysis and decision-making routine?
- What results could you achieve that you aren't getting today?

NI ADAS & AD Data Record Vehicle (left) and Jaguar Land Rover Ground Truth Data Logging Car (right) at NI Connect Munich.

Safe like a Robot. Drives like a Human.

Relax in your vehicle, while traveling long or short distances, totally avoiding any sort of congestion and preventing any collisions that lead to harm for traffic participant. This is the amazing future that autonomous mobility will bring to us. To make this a reality, you have to start from the very foundation and build purpose into your brand DNA. This is what Jaguar Land Rover did and continues to do, by driving their reimagined strategy to fulfill their vison—creating the world's most desirable luxury vehicles, the best driving experience, and of course, new digital services.

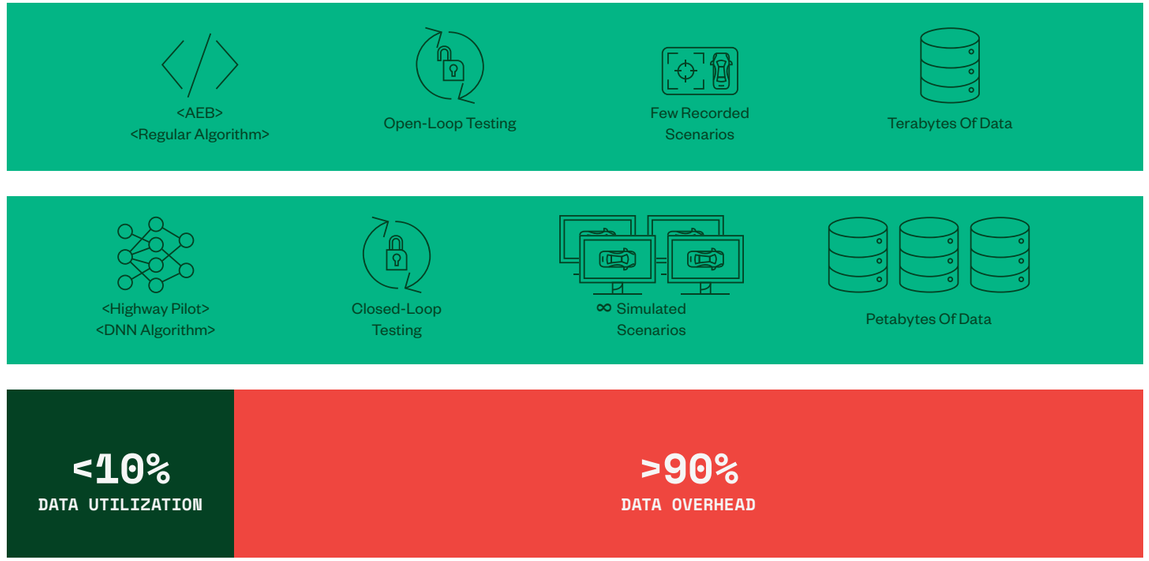


FIGURE 01

Comparison of a typical Level 2 assisted driving feature vs. a highly automated driving function.

Challenge

Develop and implement an open and flexible validation test strategy that covers both the data needs and provides the test coverage for neural-network-based assisted and automated driving features to enable modern luxury by design while making mobility an even safer place.

Solution

Using the same common NI hardware and software platform across Jaguar Land Rover's Verification and Validation workflow to generate data from both systems under test and from reference systems has been a key to their success.

"My passion is in assisted and automated driving, to make roads a safer place to be. There are still too many accidents happening. With assisted and automated driving, we can help to reduce those. To make the car behave like a robot but drive like a human—this is, I think, one of the best engineering tasks that you can think of," says Joerg Schlinkheider, Chief Engineer for Assisted and Automated Driving (AAD) at Jaguar Land Rover. But to get there, we still have to maneuver around a couple of roadblocks. So, let's drive right into this and explore how the fine engineers at Jaguar Land Rover are engaging in partnerships, setting up their test strategy, and utilizing data to bring forward the promise of highly automated driving together.

Data and Test Challenge

There are many challenges to put vehicles out on the road, as they need to be safer while at the same time utilizing higher levels of automated driving. For example, a level 2 feature like automated emergency braking (AEB) can be found in many cars today. One of the key performance indicators for an AEB function is false activation. One of the main test methods is based on replaying a finite set of recorded scenarios in an open loop. The main parameter to consider is the change of distance between the ego vehicle and the target in front over time. This makes the amount of data still reasonable, and the test complexity remains manageable.

But as we move toward higher levels of automation, safety features become more complex. Functions are now based on neural networks and therefore they do not only require thorough validation, but they must be trained first. This means that an extra set of training artifacts has to be created and then exercised by the neural network before the actual testing can happen. In addition, features for highly automated driving interact much more with the ego vehicle. They not only take control of the brakes, like in our AEB example, but they also plan and steer the trajectory of the ego vehicle. Hence, a tight closed-loop validation approach becomes a necessity and the number of scenarios for testing converges towards infinity. As the amount of both simulated and recorded data at Jaguar Land Rover is massive already, their clear focus is on maximizing the utilization of those datasets to further optimize time, effort, and cost of test.

Data and Test Strategy

It's all about data. Data and data analytics have become the new fuel for automotive products that Jaguar Land Rover develops and manufactures. The end-to-end relationships with many other interfaces and systems around the vehicles are increasing and are calling for an end-to-end validation strategy. A very structured, layered, and data-driven approach is the key that unlocks product potential and performance. A lot of data gets pushed into the cloud, where the teams at Jaguar Land Rover are running data analytics, e.g., to understand in which situations or scenarios an interface has passed or failed. They undergo a very rigorous systems engineering and validation design process; both the left and the right side of the V-model have to be absolutely synchronized. Every requirement has to be traceable to achieve the necessary robustness of their products, which will then get released to customers.

Obviously, there is a strong focus on the early stages, utilizing the shift left or front-loading strategy for design, development, and test. Close collaboration between the validation engineers, the systems engineers, and software architects is essential. The well-known principle of system engineering also applies to agile development. If you don't specify and get your requirements right in the beginning, it will be very costly in the end. To avoid this, every requirement needs to be traceable, as it is key for validation engineers to influence the model-based system design already in the early stages. All the data that gets derived from test cars, test rigs, or test assets are being pushed into the cloud to make data-driven decisions. Essentially, this makes sure that the most robust safety features go along with new modern luxury as well.

Verification and Validation Test Strategy

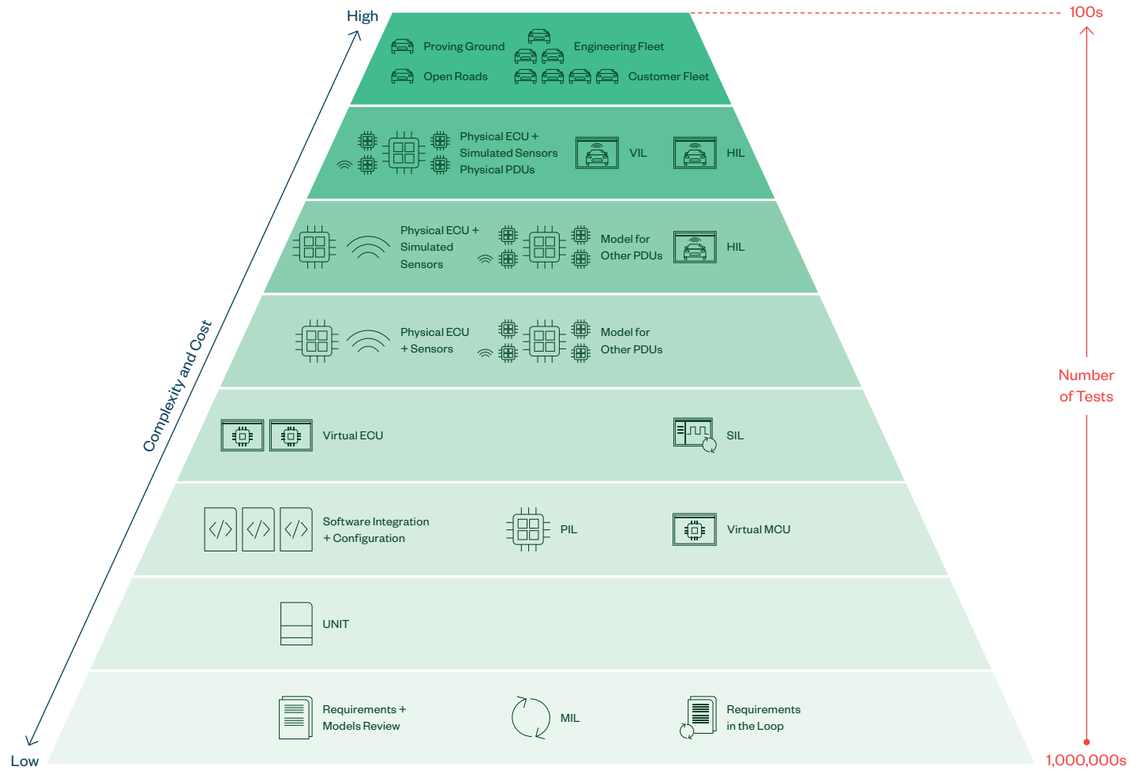


FIGURE 02

Jaguar Land Rover's Verification and Validation Test Strategy

> "NI is a company we work very closely with. We see a lot of really good engineering that fits to the way we want to design our products and to the mindset that we have in our validation teams."
>
> **Joerg Schlinkheider,**
> Chief Engineer for Assisted and Automated Driving (AAD), Jaguar Land Rover

Jaguar Land Rover and NI are implementing this data and test strategy together. Multiple, different testing methodologies like lab-based testing using software-in-the-loop (SIL), hardware-in-the-loop (HIL), and open-road testing must be orchestrated in perfect harmony. Using the same common NI hardware and software platform to generate data from both systems under test and from reference systems has been a key to the success of Jaguar Land Rover. Using XIL test environments like SIL, HIL, and vehicle-in-the-loop (VIL) make their verification and validation (V&V) more robust and efficient. This leads to better quality overall—quality in V&V and quality of the end product. The openness of the NI toolchain allows Jaguar Land Rover to adjust the toolsets to their processes and not the opposite. Furthermore, Jaguar Land Rover is partnering with NI on joint future developments like AI-based scene detection. This will allow them to identify interesting and relevant scenarios, so they can quickly bring them into their sophisticated validation process. Converting these highly relevant datasets to virtual scenarios to close the loop will further enable them to test with scenarios driven by real-world situations, leading to lower cost of data and higher data efficiency.

Partnerships

The Automotive industry has seen quite a paradigm shift in terms of future product creation and delivery. The classic Tier 1 to OEM relationship already feels like a fond memory of the past. New technology and infrastructure needs are both required to either be the next innovation or to fuel the next innovation. Jaguar Land Rover believes in strong partnerships, and therefore has joined forces with NVIDIA—a powerhouse in software, AI, and System on Chip (SoC) development. Both engineering teams are working closely together on a white-box software collaboration to create the next generation of driver assistance systems and autonomous driving.

As mentioned before, Jaguar Land Rover is already collaborating deeply with NI to put their test strategy into action. One of the big pluses for Jaguar Land Rover is that NI also works with many other companies in different areas and industries such as aviation and defense; considerable knowledge and experience can also be transferred to Automotive from these other domains. This is where Jaguar Land Rover believes that they can also learn from NI and its ecosystem to achieve their robust, structured approach to validation. Another important partnership that NI introduced to Jaguar Land Rover is the connection to Seagate Technology. Logging and storing data is critical for Jaguar Land Rover's ground truth data systems. Seagate has expanded their LYVE portfolio into rugged enterprise grade high performance storage combined with consumer ease of use, data logistics, data operations, and many other services. This again highlights a very specialized area of expertise that only a global player and subject matter expert like Seagate can address; therefore, they are a perfect match for Jaguar Land Rover within NI's data logger solutions.

Nobody Is Perfect, but a Team Can Be...

Jaguar Land Rover is on a continuous improvement journey and to achieve their reimagine vision with confidence, the goal is to get the data coming in and, of course, pass all their test cases. This can only be done by utilizing the power of great teams—and Jaguar Land Rover is forming one of the best global teams right now. They have been transforming their business to agile, tearing down silos and hierarchy. Engineers are now empowered to lead and make decisions from wherever they are in the world. They are creating the new products for an even safer future of mobility.

"At Jaguar Land Rover we are reimagining our brands through the power of our people, our partnerships, our new data-driven products and of course through cutting edge design. And that means we need to recruit the best people and we need to partner with the best," says Schlinkheider.

Author

Daniel Riedelbauch
Chief Solutions Marketing Manager, ADAS & AD Test, NI

Watch the keynote

Making (and Testing) the World's Greenest Battery

Northvolt's mission is simple: make the world's greenest battery. One of the most important aspects of their operation is considering the battery production as a circular process, like a loop. This "loop" goes from sourcing raw materials, through battery production, and to recycling so the active material can be reused to make new batteries (Figure 01). As an example, Northvolt aims at making 95 percent of cell material reusable after end-of-life, thus closing the loop and restarting the process. This is critical to attain the sustainability goals that include less dependency on "new" raw materials, more recycling, and cleaner batteries all around.

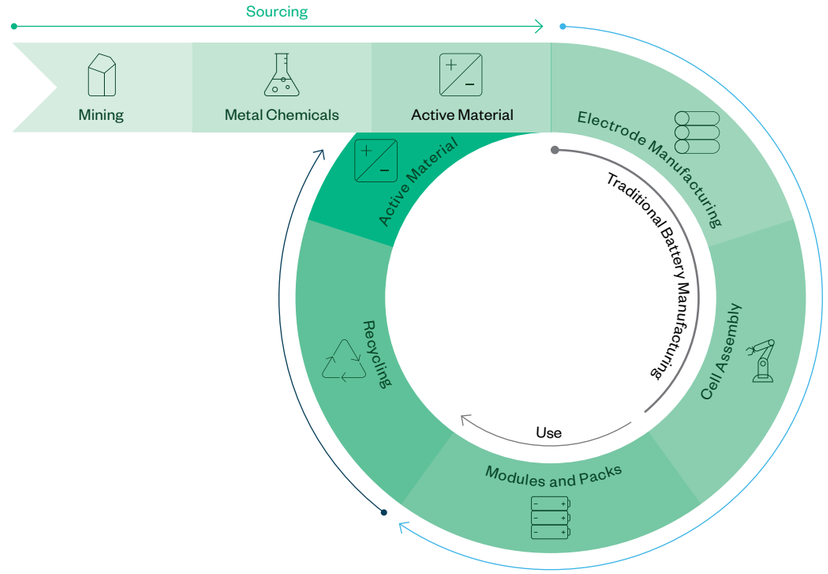


FIGURE 01

Northvolt's battery manufacturing as a circular process that maximizes sustainability and drives them toward their goal of making the world's greenest battery.

> "The validation test data we get from NI systems enables our engineering teams to learn more about our batteries and find ways to improve them even after they're in the field."
>
> **Henrik Rudelius,**
> Director, Validation and Simulation, Battery Systems, Northvolt

This perspective of a circular process is applied to Northvolt's test strategy as well. Their test engineers are challenged to "close the loop" by using as much data as possible to feed back into the manufacturing and test processes. This data must be used to drive conclusions and actionable insights that help optimize and improve both the processes and the battery themselves.

Using this approach and data-driven technologies, Northvolt can test batteries beyond safety and quality, to ensure they are sustainable, traceable, and recyclable. Of course, this approach comes with significant challenges that we'll explore further.

The Dot vs. the Comma

Northvolt uses a wide variety of equipment and solutions that provide data that's potentially useful. With the variety, differences can be expected (shocking!). One example of the different ways the data is recorded is the decimal place, which can be either noted as a dot or a comma. While it is intuitively simple for engineers to distinguish between 120.5 V and 120,5 V, the data platform used by Northvolt needs to automatically address that difference, so the data can be correctly read, correlated, and used to derive insights. Programming this one behavior is not a hard thing to do, but with thousands of battery cells and battery systems deployed in the field, along with large-scale manufacturing and test facilities, these differences add up and can hinder a speedy test development process by forcing engineers to do tasks that don't add significant value.

Challenge

Develop test systems that enable Northvolt to "close the loop" in the battery testing process, ensuring that all available data can be proactively used to improve upon the process as well as the batteries themselves.

Solution

Leverage NI's platform openness to develop data-centric test systems that empower Northvolt's engineers to quickly find insights from data, adjust their processes, and continuously optimize battery performance.

Even if all data from all sources came in the same format—which it doesn't—other challenges cause headaches for engineers. Perhaps the biggest one is the lack of synchronization.

A lot of testing of Northvolt's battery systems is done outside the lab and around the world, after their batteries are deployed. By getting the data of on-the-job batteries, Northvolt gets better insights on the batteries' performance that help its engineers understand and eventually improve them.

This data is automatically uploaded by the batteries' telemetry systems, through many wireless communication capabilities like Wi-Fi, Bluetooth, or cellular. To minimize the effort it takes to use the uploaded data, there are strict guidelines to be followed on how it is recorded, time-stamped, sent to the cloud, and made available for analysis. Doing this at the source certainly saves time—but with limited engineering time, there's always room for improvement and time saving.

Moving on to the analysis side, after data is consistent, usable, and in the cloud, a productive interface is needed to get to actionable conclusions and insights. Capabilities like interactive plots, flexibility to use Python scripts, and easy and intuitive filtering, are proving to be significant time-savers for Northvolt engineers. And to further improve productivity, some analysis can be directly performed in the cloud, thus saving time from downloading large amounts of data. Let's look at how this is achieved.

Connected Battery

Northvolt has developed what they call the Connected Battery, a solution that involves capabilities for online telemetry, as previously described, as well as for fleet management, local and remote diagnosis, and online software updates to their battery systems.

Through this solution, Northvolt engineers can see and analyze data at a very granular level. Variables like voltage, current, temperature, state-of-charge, and state-of-health, are available to be correlated, analyzed, and used to make fact-based decisions. All of this happens on a secure, web-based interface which also includes capabilities for one-click diagnostics, end-of-life management, or warranty extensions, to name a few.

Through auto-synchronized and interactive plots, engineers can zoom into specific pieces of the data to drive conclusions and insights about the battery. This enables them to continuously make improvements and, in agreement with their customers, push software updates to the battery systems already deployed.

The development time required to come up with a solution like Northvolt's Connected Battery is heavy, so some limitations regarding scale are starting to surface, driving their engineers to evaluate ways of achieving scalability with minimum development overhead.

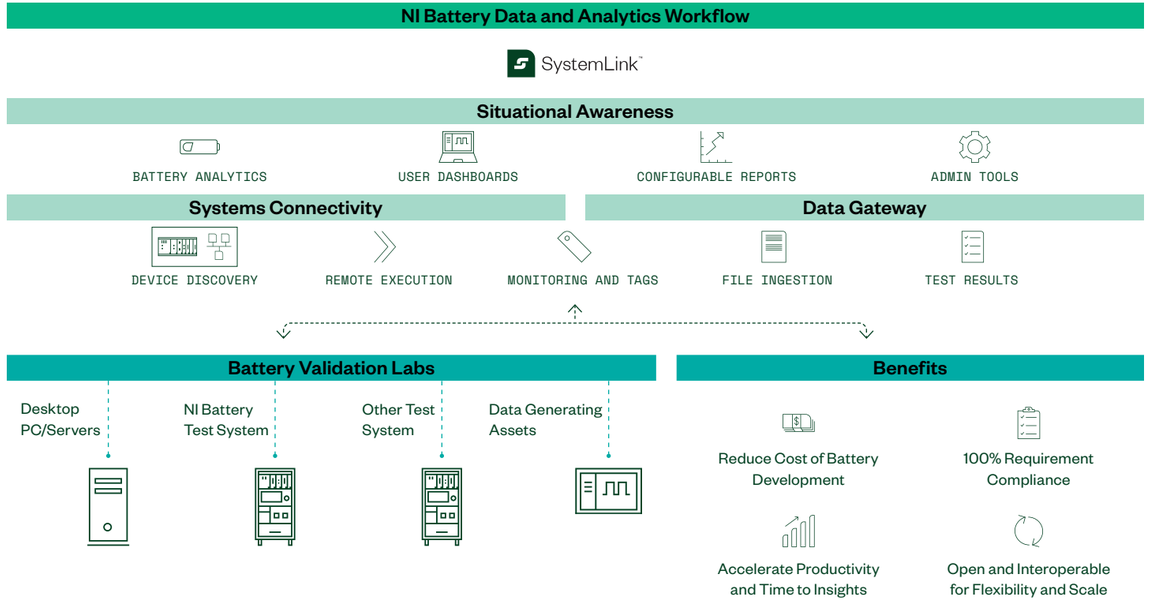


FIGURE 03

NI's data approach to battery test automates the end-to-end process to help engineers derive insights from test data and harness operational, economical, and technical benefits.

Product Development

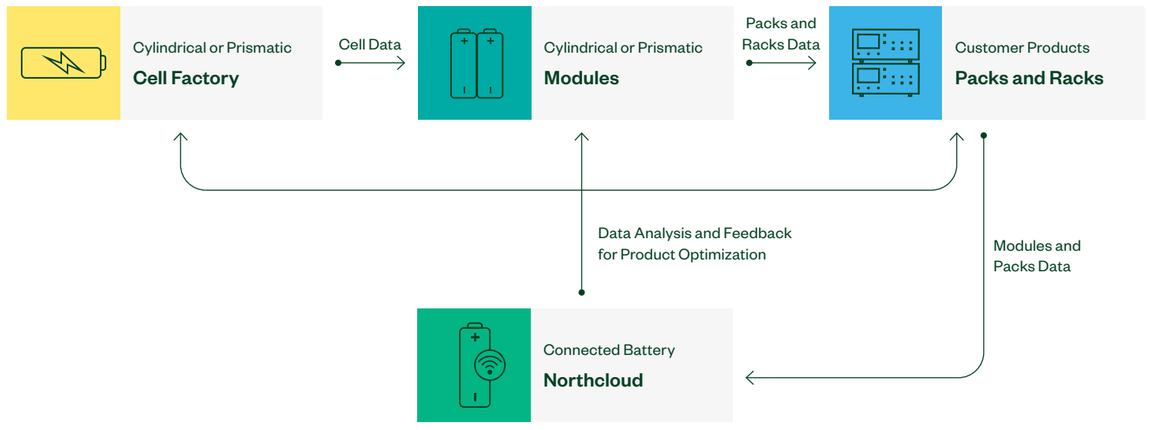


FIGURE 02

Closing the loop at Northvolt drives test teams to effectively use all relevant data from product development and in-the-field batteries to feed back into their processes and improve their products.

Closing the Loop, Sustainably

Companies like Northvolt are extremely capable due to their in-house capabilities and their continuous pursuit to improve upon their solutions. A critical requirement for any new solution to evaluate is the openness to be compatible with Northvolt's existing equipment and proprietary protocols. Recently, they've started to evaluate NI's battery test solutions such as the Battery Test System, NHR Cyclers, and SystemLink™ software to complement their capabilities with positive results:

- Engineering teams can quickly implement, change, or customize functions to adapt test systems to new battery products effectively.
- System openness enables integration of existing assets and proprietary protocols to maximize reusability and speed up test.
- SystemLink's management of validation test data meets their engineering teams' expectations to learn more about the batteries to find ways to improve them.

From this evaluation, it's expected that Northvolt will continue to reduce cost of battery development, accelerate their productivity, and comply with all requirements necessary to make the world's greenest battery.

Commitment to Test Data

At NI, we seek to elevate the role of test from a pass/fail process to an enabler of product performance. We invest in EV test and lifecycle analytics solutions to enable battery manufacturers like Northvolt to use test data to transform their businesses, achieve their missions, and collectively drive the world to a greener future.

Author

Arturo Vargas Mercado
Chief Marketing Manager, EV Test, NI

Watch the keynote

NI Innovation Centers around the Globe

At NI, we work together with our customers to innovate solutions that ensure quality and shorten time to market while assisting organizations in achieving their goals. NI's Innovation Centers are essential for prioritizing the demands of the client through promoting our industry-leading innovations.

China Innovation Center

In 2021, NI welcomed officials and representatives from the Chinese government, industry associations, key partners, and customers to join us for the opening ceremony of NI's China Innovation Center (CIC) located in our Shanghai office. The CIC is an important milestone in our China journey to showcase what NI has to offer. Building upon this positive impact, we aim to become a leader in our targeted China markets by keeping pace with innovation and next-generation technology development to be more competitive in global markets. Our presence in China is helping to deliver more value to local customers by shortening the iteration time to market and customer insights to solution development and delivery.

Austin Innovation Labs

In February 2021, we introduced the NI Innovation Labs at our main campus in Austin, Texas. The state-of-the-art labs feature more than 32,000 square feet of dedicated space geared toward enabling our Systems and Product R&D teams to collaborate, innovate, and build systems with our customers at the forefront of what they're doing every day. The lab space is split amongst our business units yet configured in such a way as to foster collaboration and allow our engineers to take advantage of advancements in innovation from any particular industry. Our Transportation lab space consists of a few battery and high-power EV labs, an ADAS and Autonomy lab, a power conversion/inverter lab, and an ECU test lab. With this facility, we continue to push the pace of innovation and help make our commitments to our customers faster and more effective.

Michigan Innovation Center

In Spring 2023, NI is opening a Michigan Innovation Center in Novi, Michigan. This new facility will provide the latest technical and engineering resources and will feature our ADAS/AD and EV demos for a variety of industries and applications. Our customers will be able to visit us and experience the latest innovations for battery test solutions, cell quality, and ADAS/AD workflow in a live and immersive environment. Our presence in Michigan is yet another commitment NI is making for our customers in the Midwest region of the United States.

Tokyo Co-Engineering Lab

In July 2022, we opened Co-Engineering Lab in Tokyo, Japan. This lab space holds many of NI's complex test systems with cutting-edge technology. Over time it has become a place where test vendors, OEMs, Tier 1s, and tool vendors work together on innovative solutions and try to solve their engineering challenges. Going beyond mere demonstration, our customers have a space where they can consult with our experts and collaborate on solving their most complex problems.

Maximize Test Coverage with Your ADAS/AD Replay and HIL Test System

Validating the perception, planning, and control algorithms running on ADAS electronic control units (ECUs) is key to ensuring that ADAS and AD functions are safe and reliable when they reach the market. The industry needs to efficiently scale test coverage capacity by implementing different test methodologies such as Replay and Hardware-in-the-Loop, which increases test coverage by moving the bulk of testing from the road to the lab.

Testing complex algorithms on ECUs requires replicating scenarios by injecting real-world road data exactly as it was acquired in the vehicle. Testing must also expand coverage to include scenarios that are extremely difficult or dangerous to encounter on the road. Simulation enables you to create a nearly infinite number of edge scenarios that will be required to ensure the safe operation of ADAS and AD functions.

Replay Test Needs

01

Feed the system with external data in the same way as it would be done with the vehicle during actual test drives

HIL Test Needs

01

Stimulate the perception systems with advanced processing and data manipulation techniques to convince the ECU that it is performing a real-world scenario.

02

Integrate hardware I/O with multiple environmental simulation and modeling tools.

Common Test Needs

01

Integrate hardware I/O with multiple environmental simulation and modeling tools.

02

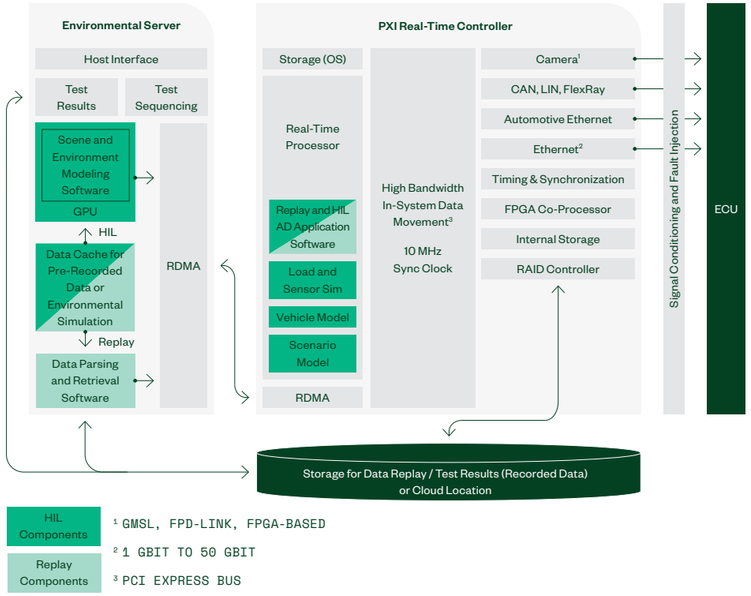
Maintain adaptability for future I/O and test requirements as systems continue to add more cameras, radar, lidar, and other ADAS sensor types.

03

Increase test coverage reliability and repeatability through direct injection techniques to insert faults, frame delays, and more into the sensor bitstream.

NI Replay and HIL ADAS and AD System: Advantage

- Ensure **synchronous data feed** from either your NI record systems or other timestamped recording files.
- Integrate simulation from modeling software and inject signals from different sources for **maximum interoperability of test tools.**
- **Maximize test coverage** by running more test cases and scenarios in lab and simulation to decide which tests must be performed on the road.
- **Hardware and software customization, flexibility, and third-party openness** to future-proof your system.
- Develop faster by leveraging work across design and validation through NI's toolchain to perform **reliable test** at each stage.
- Keep requirements from outgrowing your test capability with NI's **range of I/O** for cameras, radar, V2X, lidar, and GNSS sensors and buses.
- A **unified test system** architecture to move back and forth between data replay and HIL test with the same system and single platform for data record.



"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, ZF Mobility Solutions

01

Replay and HIL AD software for data throughput, timing and synchronization, direct interface with ECU, full customization, data repositories, and simulation interfaces.

02

PXI technology provides hardware and software faulting capabilities—down to nanosecond synchronization and timing control for reliable execution of test cases.

03

Modular hardware generates signals to emulate ADAS sensors interfaces, vehicle bus traffic, and general purpose I/O to test sensor fusion on the ADAS controller.

04

Hardware integration openness to interface with Hexagon (Vires), Applied Intuition, IPG, Ansys, aiMotive and more simulation, and modeling software providers.

05

Open software-centric approach to interface and source data from IT infrastructure and cloud service providers like Microsoft Azure, AWS, Seagate, and more.

System Integration on Your Terms

NI offers a variety of solution integration options customized to your application-specific requirements. You can use your own internal integration terms for full system control or leverage the expertise of our worldwide network of NI Partners to obtain a turnkey system.

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**

Closing a Critical Coverage Gap in ADAS/AD Camera Validation

Testing production release software for camera-based advanced driver assistance systems is difficult due to the integrated safeguards for meeting functional safety requirements. To satisfy the validity checks of the device under test and stimulate behaviors similar to test driving, NI provides dedicated hardware and software for emulating image sensor functionality on three different layers, helping to avoid the need for a dedicated testing mode software build for validation (known as HIL-mode).

Vision-based Advanced Driver Assistance Systems (ADAS) are an integral part of modern vehicles and supplement the vehicle's view of the world in the visible electromagnetic spectrum. They provide important autonomy functions, improving road safety through automated vehicle trajectory planning based on object detection and classification. At the core of many ADAS Electronic Control Units (ECUs) lies an ASIC accelerating Neural Network (NN) inference on sensory input. Mobileye Global, Inc., provides one of the most widely used chipsets for these NN-based subsystems.

For car manufacturers and suppliers, validation and homologation of such systems present a new class of challenges. From conventional quality assurance methods, only testing is effectively applicable to NN-based ADAS ECUs. A lot of investments are made in the testing phase before start of vehicle production. One popular approach due to economic and reproducibility reasons is functional testing in a lab-based environment, clustering relevant ECUs in a hardware-in-the-loop (HIL) setup while the rest of the vehicle bus is simulated. The sensor stimulus is then injected into the ECUs on a digital path.

ADAS ECUs responsible for safety critical vehicle functions are required to self-diagnose faults and relinquish control of the vehicle in a safe manner (failsafe). For a vision ECU, that means observing the operational status of the image sensor(s) and validating the provided video stream in real time.

Modern image sensors provide multiple ways of securing the data paths to and from the downstream video processor against errors: Some manufacturers enable CRC checksums on the side-channel transactions. The video stream can be configured to include alive counters and configuration state snapshots in the image. Some sensors include an ERROR interrupt output pin. The MIPI CSI2 specification additionally provisions for CRC guards and frame counters on the protocol level.

These and other safeguards are employed to make sure that autonomous vehicles can yield control to the driver quickly to avoid following a ghost trajectory due to faults in the image path. Simply injecting a video stream or a previous recording into an ECU will, thus, trigger the failsafe mechanism.

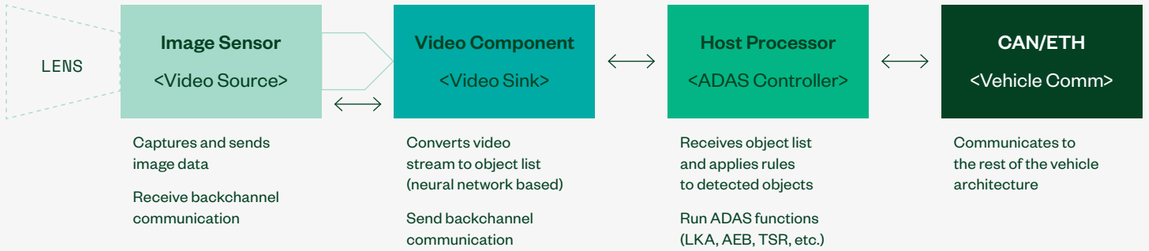


FIGURE 01

Typical Architecture of an ADAS Camera System (Simplified)

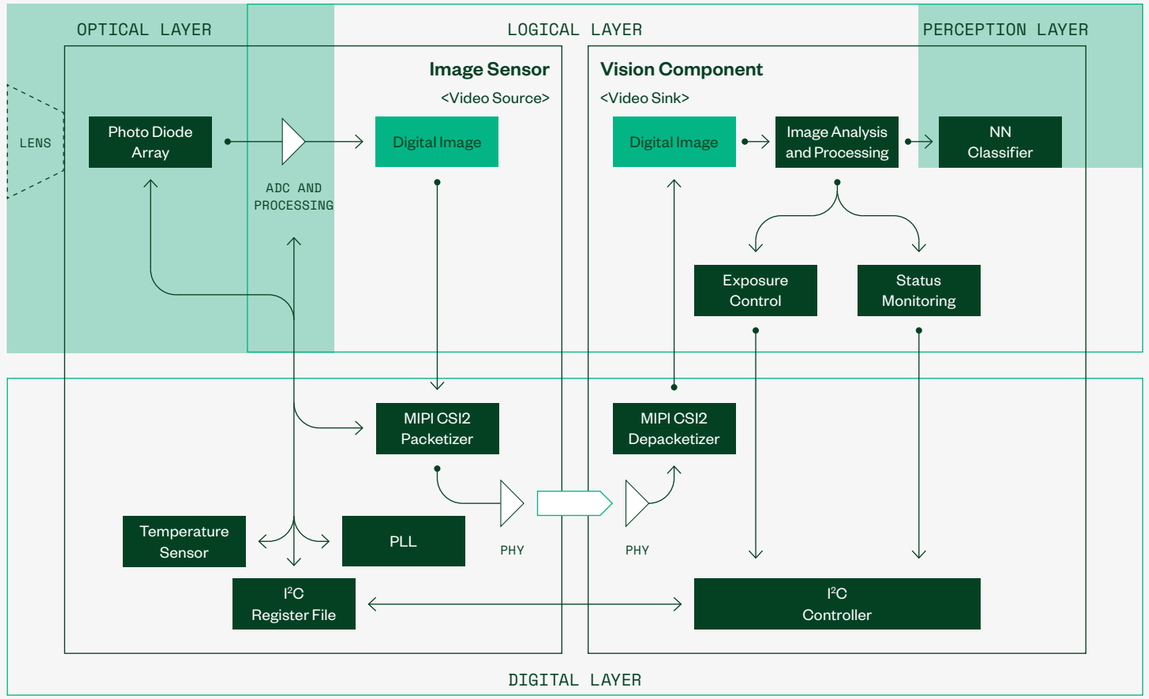


FIGURE 02

Simplified View into an Image Sensor and a Downstream Vision Component

This challenge has been known from day one and the obvious remedy was to turn off ECU software health monitoring and status validation altogether. This is better known as "HIL-mode" for vision ECUs which is also supported by Mobileye and other vendors like Bosch or Continental. While this is a valid mechanism to enable perception layer and application software testing, the inherent downside of this approach is that the software release under test is **not** the software that will be deployed in the field later. Therefore, validation tests miss parts of the test coverage, which are only present in the production software.

One solution here is to reverse engineer and emulate the image sensor's behavior in real time to enable production-release ECU software testing.

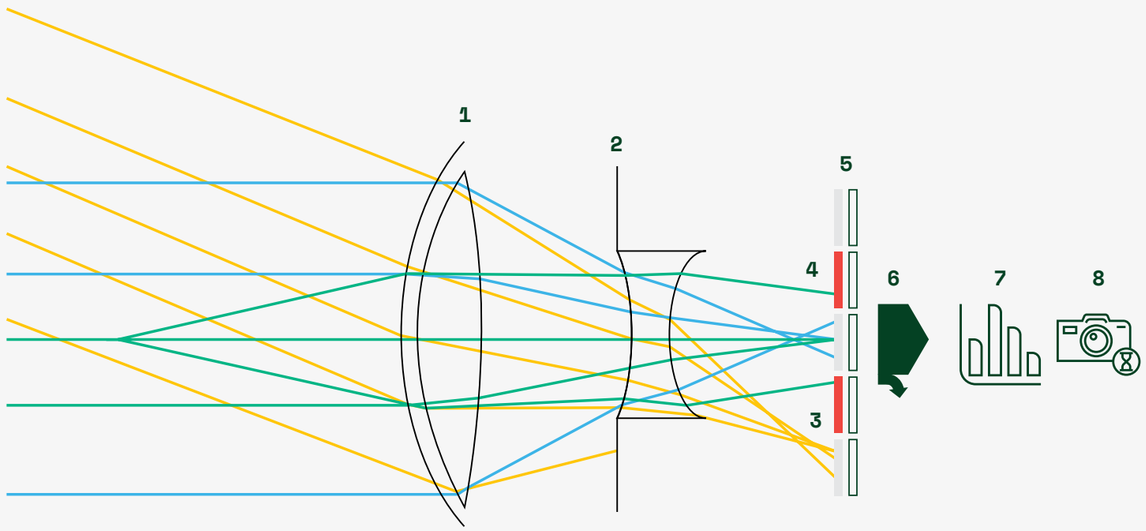
Figure 02 depicts a simplified conceptual model of an image sensor acting as the video source and a connected vision component as the video sink. At the logical level, digital images are produced in the image sensor and consumed by the vision component.

Each incoming image is analyzed before being forwarded to the perception layer. Specific image properties, such as the average brightness, histogram, etc., are fed to a control module responsible for tuning the image sensor to produce properly exposed images suitable for object classification.

Status monitoring will extract alive counters and validate the sensor's configuration state by extracting information from embedded data within the image. This is the module that makes it difficult to provide any generic video stream to the ECU in a HIL environment without using pre-release software including ECU "HIL-mode."

An injection system needs to emulate the behavior of multiple sensor sub-components in real time to avoid triggering failsafe measures in the vision component and produce reliable test results for detection performance.

Simulation of the optical layer is the domain of the host computer generating the sensor input data. In open-loop regression tests, a previous recording from a similar camera ECU is replayed to the DUT. Generating live synthetic data using a visualization tool enables closed-loop tests for scenario exploration, functional, and performance testing. The quality of the generated data is directly linked to the fidelity of the optical sensor model.



1 Special Transmission Coefficients of Lens Coatings

2 Vignetting

3 Lens Distortion and Aberrations

4 Depth-of-Field

5 Spectral Transmission Coefficients of Photo-Diode Color Filter Array

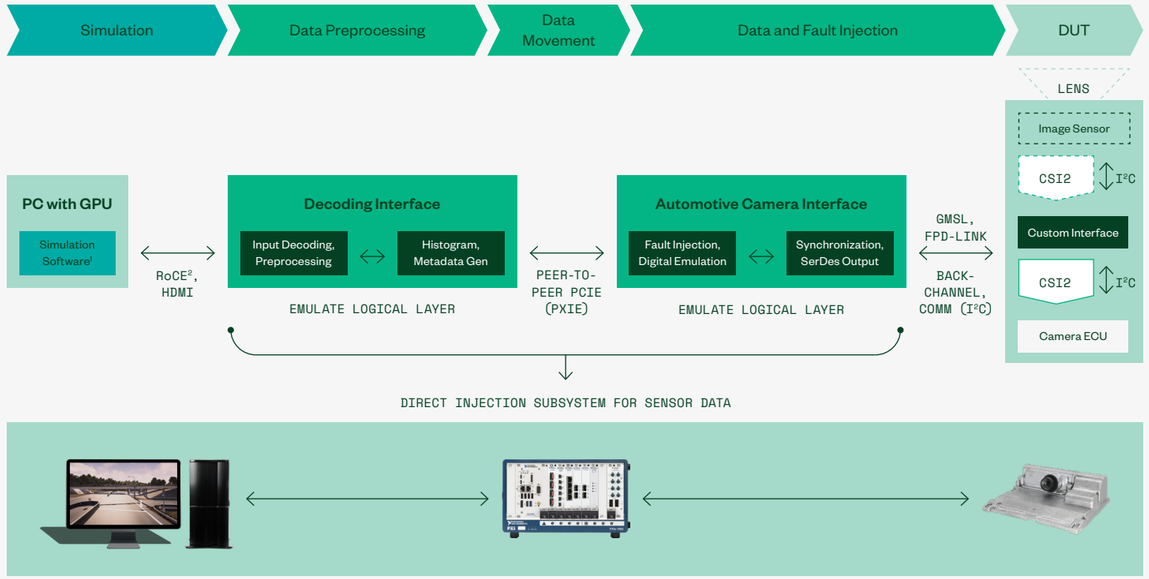
6 Conversion Efficiency/Sensitivity

7 Noise Modelling (Poisson vs. Gaussian, ADC Non-Linearity)

8 Exposure Time Emulation

FIGURE 03

Effects on the Opto-Electrical Path



[1]Interoperable with third-party software [2]RDMA over Converged Ethernet

FIGURE 04

NI HIL System Architecture for Direct Data Injection Using Production Release ECU Software

The optical properties that are usually covered, to varying degrees, in a synthetic simulation are shown in Figure 03.

On the logical layer, the bulk of emulation efforts will usually be dominated by on-line digital image manipulation. Some vision systems might have the sensor dynamically crop the image and place the readout window across the active pixel array. Sensors with color filters provide individual color channel amplification for white balance tuning in varying lighting environments.

The intensity of the incident light may sometimes exceed the capacity of the photodiodes to capture the whole dynamic range of the scene, especially at night. To increase the captured dynamic range, modern sensors allow for multiple analog-to-digital conversions during the exposure time. Each individual conversion yields 12 bits of brightness information that is then internally stacked to a final 20-bit digital image. To save bandwidth, the 20-bit image can then be compressed to 12 bit or 16 bit using a dynamically configurable, non-linear transfer function.

Downstream processors may depend on image statistics provided by the sensor to correctly control the exposure time. Image sensors can generate dynamically configurable histograms with the image output.

The digital layer is shaped by low-level protocol and electrical parameters. While these also dictate the PCB design for the ECU interface, the relevant configuration parameters internal to the sensor include online configuration of the MIPI CSI-2 communication module and the clock rates generated by the Phase-Lock Loop (PLL), ultimately driving the output frame rate. Additionally, sensible outputs from the Register File need to be provided (e.g., temperature sensor and status flags readout).

Real-time embedded systems have tight design timing constraints (latency and throughput) that need to be respected when building instrumentation interfaces. In addition to emulating the image sensor functionally, great care must be employed to react to requests and provide data streams within the timing constraints of the target device under test.

NI's solutions portfolio covers all the aforementioned topics providing modular and customizable testing systems for ADAS/AD ECUs (see Figure 04).

Leveraging a strong partner network, NI can provide customized instrumentation interfaces for all but the most tightly integrated ECUs.

The real-time core of the image sensor emulation IP is realized on a dedicated high-performance scalable hardware platform capable of supplying multiple UHD video streams in parallel, covering the needs for modern vehicle vision systems. In addition, the emulation core is capable of deliberately inserting faults into various processing stages to enable test coverage of the error handling mechanisms in the DUT.

On the simulation side, NI hardware provides scalability and openness to third-party software simulations that can be connected to the loop via a bi-directional high bandwidth RDMA over Converged Ethernet data link. Compatibility with optional third-party simulation tools is given by adapting HDMI data sources.

In summary, ADAS ECUs, being safety-critical systems, use status monitoring safeguards that make video injection a non-trivial task. A sophisticated, multi-layered, real-time image sensor emulation model must be used to satisfy the validity checks in the ECU and to generate video streams that elicit behavior from the perception layer similar to real-world test driving.

NI's sophisticated optical simulation and real-time emulation for image sensors allows for comprehensive verification of current and future vision based ADAS/AD ECUs worldwide. NI solutions enable validation tests based on production software for vision ECUs, which closes a coverage gap that has existed since the introduction of "HIL-mode" using pre-release software.

Author and Co-Author

Dimitrij Gester
Senior Offering Application Expert, ADAS Simulation, NI

Daniel Riedelbauch
Chief Solutions Marketing Manager, ADAS & AD Test, NI

Flexible and Scalable EV Battery Cycler

The need to quickly increase EV battery testing capacity is making validation labs harder to manage and forcing engineering teams to explore ways to sustainably scale up their test lab operations.

From few to dozens of test cells, managing power from the battery cyclers is one of the main challenges that impacts lab efficiency, CO_2 footprint, and operational expenses.

A software- and data-centric test strategy can help but requires flexible test equipment that can be synchronized, orchestrated, and operated effectively.

Battery cycler flexibility and openness is critical to achieve the scale needed in modern battery validation labs.

Customer Needs

01

Test existing 400 V and 800 V EV battery architectures, and future-proofing for higher voltage and test capacity needs

02

Define battery validation lab layouts that work for current and future needs

03

Maximize lab equipment utilization and integrate existing equipment

04

Monitor and manage full lab operation to optimize operational cost

NI HPS-17000

01

150 kW battery cycler with low- and high-voltage modes of operation, up to 1500 V

02

Parallel cycler operation without physical proximity, providing flexibility to lab layout

03

High maintainability with modular design and swappable power bricks

04

NI's software-connected approach to automate configuration, execution, and reporting on test operations

HPS-17000: Advantage

- **Layout Flexibility:** Microsecond synchronization with time-sensitive networking enables parallel operation of cyclers regardless of location in the lab.
- **Application Coverage:** In addition to battery cycling, its sub-ms dynamic performance makes it suitable for battery test, inverter testing, and dynamometer applications.
- **Easier maintenance:** Individual SiC-based power modules (PMSiC) can be replaced and stocked for higher uptime.
- **Standardization:** Power- and application-specific breakout sections in the cabinet support lowering the cost of service across applications.

Specifications

OUTPUT POWER, MAX	±150 kW	
RATED SUPPLY VOLTAGE	480 V rms, 3-PHASE DELTA (NO NEUTRAL)	400 V rms, 3-PHASE DELTA (NO NEUTRAL)
RATED INPUT CURRENT, FULL-LOAD AMPERES	230 A	270 A
RATED FREQUENCY	60 Hz	50 Hz – 60 Hz
SHORT-CIRCUIT CURRENT RATING SCCR (UL)	25 kA rms SYMMETRICAL @480 V MAX	
OUTPUT VOLTAGE, MAX	750 V DC (HIGH CURRENT MODE) 1500 V DC (HIGH VOLTAGE MODE)	
OUTPUT CURRENT, MAX	+/- 480 A (HIGH CURRENT MODE) +/- 240 A (HIGH VOLTAGE MODE)	
DIMENSIONS (L X W X H)	925.2 mm X 1408 mm X 2123.6 mm (36.4 in X 55.4 in X 83.6 in)	
WEIGHT	1650 kg (3638 lb) – CYCLER ONLY 1830 kg (4035 lb) – CYCLER WITH CRATE	
COOLING	FORCED AIR 900.0 mm (35.4 in) MIN CLEARANCE FRONT AND BACK	

System Integration on Your Terms

NI offers a variety of solution integration options customized to your application-specific requirements. You can use your own internal integration terms for full system control or leverage the expertise of our worldwide network of NI Partners to obtain a turnkey system.

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

Mobility Solutions for a Better Tomorrow

In the last few years, we have experienced significant changes and new challenges for the automotive industry, facing shifts in technology with the introduction of electric and autonomous vehicles.

Today more than ever, it is clear that the traditional approach to automotive tests can no longer deliver the technical insight and business performance to solve dynamic problems. In both autonomy and electrification, software defines the performance of the system, creating incredible adaptability to evolve and improve as engineering teams learn more about their designs.

Companies with a software approach, such as China Euro Vehicle Technology (CEVT), are disrupting the business by applying new approaches to the design, validation, and test phases by using data and simulation and investing in toolchains that can scale and adapt to new technologies.

CEVT is the European R&D and innovation center for ZEEKR, a Zhejiang Geely Holding Group Co. Ltd. company. It is based in Gothenburg, Sweden, and has the mission to be at the forefront of new developments in the world of mobility, striving to achieve a different and better tomorrow.

Established in 2013, the business began with the mission of setting a revolutionary vehicle architecture, CMA, designed with full scalability to accommodate a wide range of propulsion systems and technology solutions.

CEVT has since evolved to become a world-leading, core hub for mobility innovation, taking ownership of a broad range of projects and registering hundreds of proprietary inventions per year. In that time, the business has expanded from eight employees to incorporating some 1,700 personnel in Gothenburg.

With the mobility industry evolving rapidly, the concept of personal transportation is also transforming, with new ways of thinking about the vehicle as a product. CEVT is leveraging its world-leading expertise and agility to pursue exciting mobility innovations, helping to power the shift towards electrification and craft a different, better future.

CEVT headquarters: Uni3 building at Lindholmen, Gothenburg

Meeting the Demands of Tomorrow

Being a relatively new team in the automotive business in this era comes with several advantages, as it allows you to think outside the box and innovate to find a world of new possibilities to serve the industry's demands faster.

This is the case of the Vehicle Hardware-in-the-Loop (HIL) Systems team at CEVT formed by HIL engineers with experience working with different vendors. The team is led by Bengt Augustsson, who has an IT and software engineering background, which helped to bring a different mindset to solve test challenges innovatively and efficiently than what would be traditionally expected.

HIL is a test methodology well-established in automotive validation. Vehicle systems are increasingly using complex electronic, intelligent, and interconnected systems to provide advanced safety and comfort features to vehicle occupants. It is more important than ever to be capable of performing and scaling from subsystems' component level to multidomain HIL systems for full vehicle integration tests.

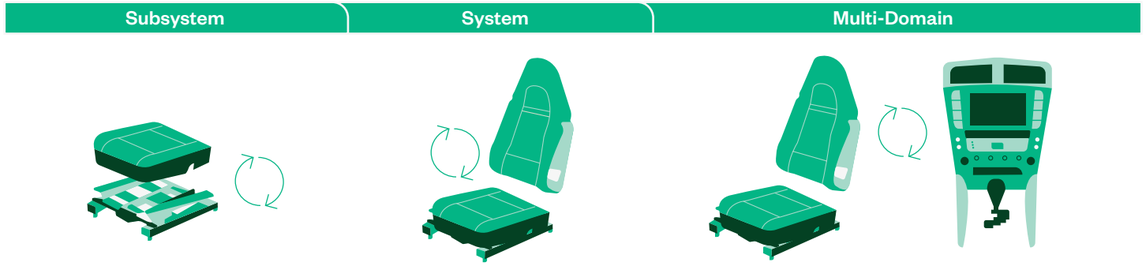


FIGURE 01

Scaling from Subsystem to Multidomain HIL

Six years ago, when the team started to define the project framework, they discovered the traditional solutions for vehicle tests are static systems that have a lot of dependencies on deliveries from different suppliers creating a bottleneck across the process. As the team goal and focus relied on shifting to the left in the validation process to provide data and results faster to their suppliers and customers, they decided to look outside the "traditional" turnkey solutions for new possibilities by developing a solution innovatively.

Initial Requirements and Specifications Provided

All they knew was that they needed a full test system that could perform the test as soon as possible—well before having access to the physical components, one that was capable of adapting quickly to unknown requirements across projects and time.

Project Scope

Simulate the environment of automotive components as realistically as possible. They can have up to 200 different types of car components that need to be tested within the system, where a third part of the components normally also contained software elements. Without having access to the product, the team must ensure the software and hardware pieces will work together as designed.

Based on the requirements list and project scope, they started looking for an open, flexible software-based solution that could change, grow, and adapt along with their customers' requirements.

At the Forefront of Mobility Solutions

The success in this area relies on the ability to seamlessly integrate toolchains, test cases, and models into one system. NI's modular hardware and open software make this integration possible. The PXI platform allows engineers to extend current test capabilities with a wide range of modules to meet different system integration testing needs as new ECUs are added to the system. VeriStand supports the inclusion of new and existing models in an HIL test system. Compliance with standards such as ASAM, AUTOSAR, and FMI ensure that customers can incorporate additional suppliers' offerings in the future as requirements change.

Selecting a modular, open platform allows hardware and software to be reused as testing scales from component level to system level to full vehicle system testing.

Transitioning from system-level to multidomain simulation is achieved through the NI and ALIARO components and integration approach. The xMove master rack with a controller allows you to integrate across multiple domains and is based on Switch Load and Signal Conditioning (SLSC) modules with multi-purpose I/O channels. In particular, the reconfigurable AL-1010 Multifunction SLSC plus the xMove Configurator Software are key as allows engineers to deploy new I/O allocations maps in minutes, as each physical pin can switch between different signal types through the software, therefore reducing the time and cost between tests, projects and programs.

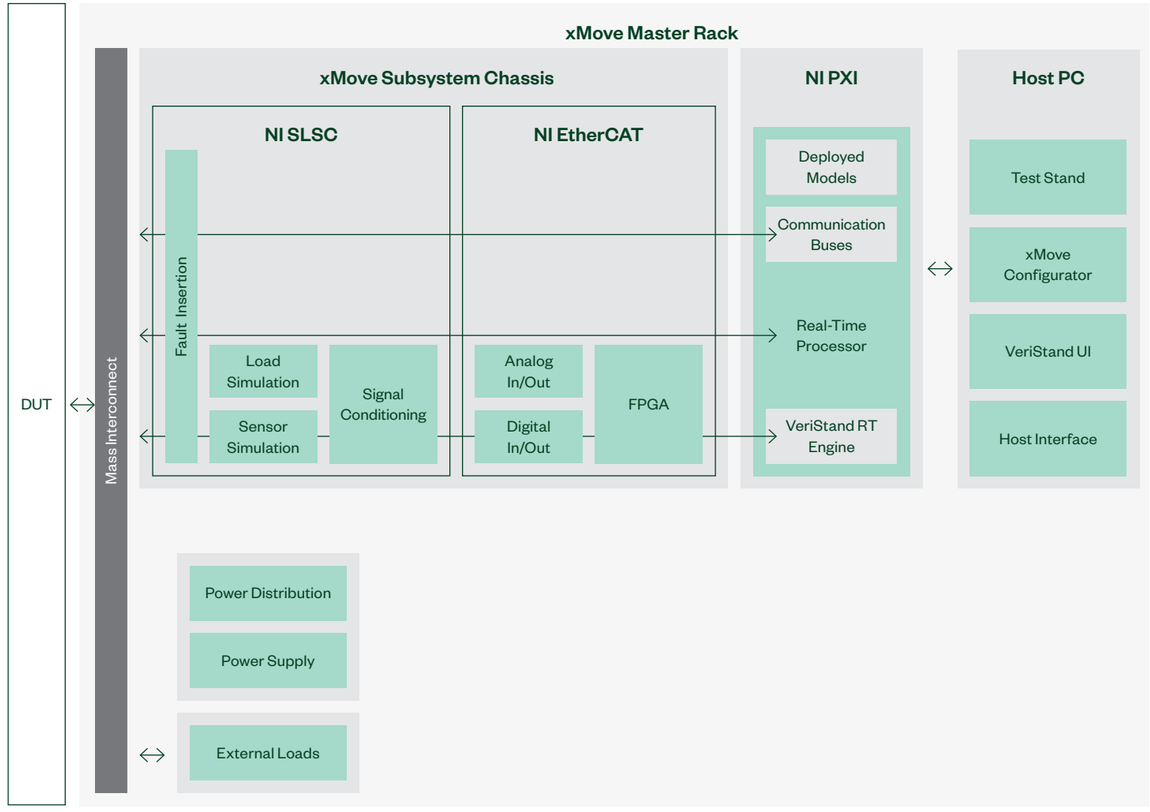
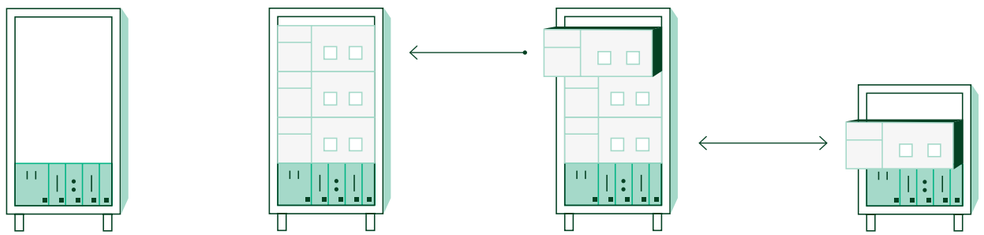


FIGURE 02

NI + ALIARO xMove HIL Test System Architecture



Hardware Change	System HIL with Three Subsystem Units and One PXI	Remove One Subsystem Unit to Enable a Separate Subsystem HIL and a System HIL with Three Subsystems	Subsystem HIL with One Subsystem Unit and One PXI
Software Change	System HIL with Preconfigured System Definition File and Running VeriStand on PXI Controller	System HIL with Preconfigured System Definition File with Reduced I/O and Running VeriStand on PXI Controller	System HIL with Preconfigured System Definition File for Running Subsystem HIL and Running VeriStand on PXI Controller

FIGURE 03

Subsystem to Multidomain HIL for Future Expansions

Similarly, system definition files can be merged as new vehicle domains and racks are introduced into the system, providing excellent flexibility and extensibility of the system for many years to come, simplifying test setup.

Driving the Shift Toward Tomorrow's Mobility

By working with NI Partner ALIARO as the prime supplier for the integration of a solution that can match a multi-vendor environment, the HIL team was able to find problems early in the design process, before even having a prototype vehicle for testing. This enabled their engineers to save valuable time, reduce operational costs associated with addressing the identified issues, and avoid potential costly recalls for bugs otherwise not found by conventional testing.

This helped CEVT to successfully integrate multidomain HIL testing into their validation process with the flexibility and adaptability they needed to test quickly—even considering the unknowns on the projects' specifications.

A main goal for the project was to build one system that can serve across different project with different configurations at the same time without to restart everything each time. The NI + ALIARO open turnkey solution provided complete control to the HIL team to upgrade and adapt the solution over time. They still maintain the same hardware configuration and components as when they started. Most of the updates and time have been focused on the software configurations to adapt and meet the specifications of the different projects that have come through the team. Also, their systems are fully automated with remote access, which allows them to serve projects across the globe.

> "By using NI's PXI and VeriStand platform as the core of our HIL system and ALIARO knowledge and expertise to provide turnkey flexible and adaptable solution we were able to build a Vehicle HIL system that meets and adapts across time to our different vehicle programs. The way our HIL rack is configured gives us the confidence that we will be using it for a long time, by integrating software updates to serve the rapid automotive industry changes."
>
> **Bengt Augustsson,**
> HIL Team Leader, CEVT

FIGURE 04

CEVT Multidomain HIL Rack Systems

Across the different test teams within CEVT, Bengt Augustsson's group is normally the first option stakeholders reach out to in order to perform the early tests. Because they are faster to respond, they can quickly adapt to the new needs and specifications through software and provide a complete report and overview of how the complete vehicle HIL product will look like.

The impact and contribution from the team to CEVT is huge and a well-known success inside the company and among their customers. This one flexible HIL rig has facilitated software validation of several platforms and numerous car programs throughout the years. By having a HIL system that can serve different cars' projects with their own uniqueness on their configurations and across ranges, stakeholders can also come and look at the deliveries and gain access to the systems and the data.

As a technology supplier, we are proud of what the CEVT team has built together, by incorporating different ways of thinking and problem-solving capabilities. But as they like to call it, there is always a world of possibilities to keep improving. The CEVT HIL team is looking forward to keeping impacting positively by providing innovative solutions along with the right partners and ecosystems and interconnected and integrated solutions capable of adapting quickly to serve the mobility industry.

Interviewed People:

Bengt Augustsson,
HIL Team Leader, CEVT

Jonas Axelsson
HIL Architecture Design and Maintenance Engineer, CEVT

Author

Brenda Vargas
Senior Solutions Marketing Manager, ADAS & AD Test, NI

The Dos and Don’ts of Working the Data and Software Connected Workflow

“Hi, my name is Dan, and I am a 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 5 years. In my role I get to work closely with our customers in the Automotive industry and in particular with major global OEMs. With this series of articles, I would like to share my insights and experiences that I have gathered so others can apply best practices and avoid pitfalls through lessons learned. Well, let’s get moving, as the future of autonomous mobility will not be waiting for us.”

The Enterprise-Level Challenge

Storing, finding, sharing, and using data in a way that scales has always been a challenge for organizations. The scale around AD is having an exponential effect.

The scale of data in an AD system is exploding. Systems are going from the standard of one or two cameras and a single radar to 20 cameras (multiple forward-facing ADAS cameras, 360° surround view, electronic mirrors, driver monitoring systems, etc.) and five radars as the new normal for level 3 automation and above. Even though this is common knowledge, it is very hard to fully understand how far-reaching the ramifications are.

With simple setups like a single camera and a single radar, you might be dealing with roughly 70 MB/s (1.3 megapixel, 12-bit grey scale, 36 frames/sec.). An entire 8-hour drive will fit on a 2 TB USB thumb drive. At the end of the day, you could pull the thumb drive, visualize data locally on your standard laptop at “real time“ speeds, then duplicate the thumb drive overnight, put the thumb drive copy in an envelope, and mail it back to your V&V lab to use that data as part of your validation process. Guess what? We have talked to multiple OEMs that were still using this approach as of 2022!

The next generation of autonomous cars requires around 5 GB/s. Let that sink in. 70 MB/s became 5 GB/s, in one generation. And we are already hearing people talking about up to eight and even 10 GB/s! A continuous eight-hour drive nowadays requires 144 TB of storage capacity (5 GB/s × 3600 s/hr × 8 hrs). That doesn’t fit on a single SSD of your standard laptop—let alone a USB thumb drive. Manually backing up the data becomes impractical, so RAID-based storage systems become a requirement. This effectively “doubles” the required hard drive space. These two factors result in multiple SSDs that can no longer be mailed but must be shipped. Instead of leaving an envelope at the hotel front desk, the driver has to plan stops to a parcel service every day. But still, this is about as far as people see today, and we believe these ramifications are still just small ones. So, let’s dig a level deeper.

Most company-issued laptops have SSDs that are somewhat limited at about 3 GB/s read/write speeds. Gigabit internet can push a theoretical maximum of 125 MB/s. Typical software applications tend to cap out around 4 GB of memory and even fully 64-bit systems typically come with 8 GB of physical memory. At 70 MB/s, the current generation data stays nicely under all of these limits.

Data can be streamed from disk, over a network, or buffered in memory. At 5 GB/sec, data can't be loaded from disk in "real time" (more like .5x speed), streamed over a network in "real time" (.025x speed), or buffered for more than a second in memory. In short, the customer's laptop and overall workflow went from effective to useless trying to utilize raw data—again, in just one generation!

AD organizations are rapidly expanding in head count. OEMs and Tier 1 suppliers are restructuring their workforce. The shift from areas focused on internal combustion towards vehicle electrification, automated driving, and simply software development in general is visible everywhere. We have witnessed OEM organizations putting orders of 1,000+ engineers on AD feature development as a starting point. Some businesses are even going further, both in terms of sheer volume as well as carving out this massive amount of engineers and putting them into a separate, start-up-like organization. One way or another, all those users want access to the massive data described above. But how do you handle getting 1,000+ people data that can't be used on their standard laptop, to people distributed around the globe and literally "working from anywhere" including their homes? How do you effectively scale not only with the data, but also with the users?

Another huge shift is in ownership. The current generation of ADAS ECUs is completely owned by the Tier 1 supplier. They own the IP, the perception integration, the ECU hardware, the validation tools, the visualization tools, the data loggers—simply speaking, they own it all. The OEM pays for all of it but keeps none of it. It is basically a subscription model. When the OEM changes suppliers, all the infrastructure and tools leave with them. To avoid this, we see OEMs bringing the next generation of technology in house. The classical model of the Tier 1 supplier feeding its technology into the OEM is shifting, but many of them are starting, mostly, from scratch.

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

Figure 01 shows how the data is used throughout the organization. Data originates in road testing (upper left) and gets ingested into cloud storage (center). From there, users search the data to visualize it (top), build data sets, and start analysis (bottom). They move into simulation and the synthetic world for iterative testing (bottom left) and eventually get to hardware with open-loop and closed-loop testing (right). At each stage, new data is generated and put back into the central cloud storage, the data lake. We will cover each of these areas in greater detail, touching on specific lessons learned from customer conversations.

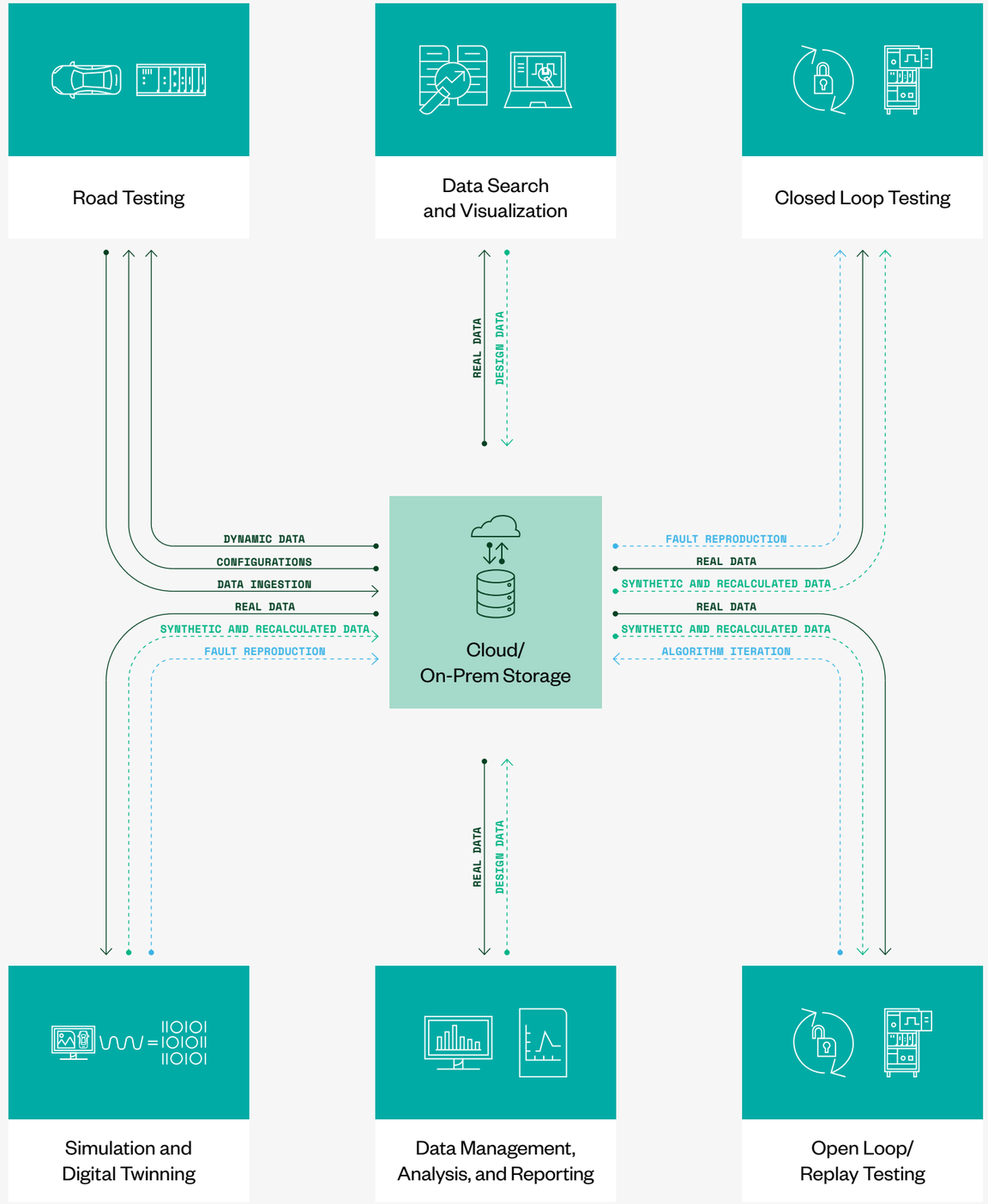
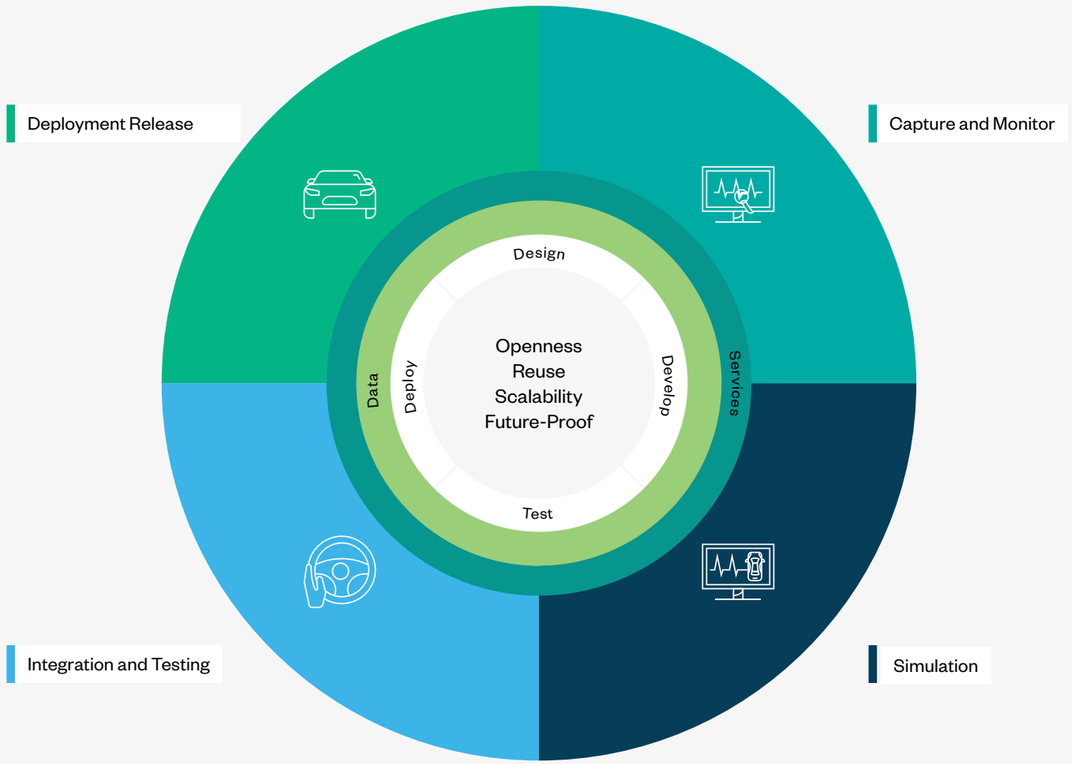


FIGURE 01

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



Deployment Release	Data	Capture and Monitor
End of Line ▪ Sensor Production Test ▪ ECU Production Test **Regression Testing** ▪ Platform Reuse ▪ Hardware-in-the-Loop Farm	**Data and Test Management** ▪ Asset and Fleet Management ▪ Data Visualization and Analysis ▪ Test Coverage and Analysis	**ADAS/AD Data Record** ▪ Storage ▪ Smart Triggering ▪ Pre-Labeling ▪ Data Compression and Annotation
Integration and Testing	**Services**	**Simulation**
Replay/Hardware-in-the-Loop ▪ Injection Techniques ▪ Fault Injection ▪ Third-Party Simulation **Hardware V&V** ▪ Endurance, Temperature ▪ Characterization	**Engineering and Consulting** ▪ Methodology Consulting ▪ System Integration ▪ Certified Solution Delivery Partners ▪ Testability Studies	**Software-in-the-Loop** ▪ Physics-Based Sensor Models ▪ Environment Simulation ▪ Simulation at Scale ▪ Third-Party (Open Interfaces)

FIGURE 02

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

Road Testing and Data Logging

A lot of the data originates from recordings done in the field—or from the road, to be precise. Let's start here and follow the data lifecycle throughout the validation process. There are two distinct approaches in use for ADAS data logging. The first approach uses an external logger installed in the vehicle. The second approach uses the internal AD ECU to record and upload events.

When looking at external data loggers, there are a couple of key specs that these need to fulfill. The obvious ones are data throughput, tight synchronization of all data streams, and saving every single bit without any loss to a large enough storage device. In addition, the data recorder needs to be modular and flexible in both hardware and software architecture to adapt to any changes. Having a path to expand for future sensor sets is of high importance. Companies trying to take on AD responsibilities directly are typically starting with a low variant (fewer cameras) but will quickly be following on with the full system setup. Similarly, if future vehicle architectures go beyond 5 GB/s, you want to be prepared and not locked into an architecture or solution that will not allow you to keep up the pace, or only doing so by purchasing a completely new data logging system.

NI provides high-end, high-throughput logging that can handle 12 camera setups like Mobileye's SuperVision or Nvidia's DRIVE Hyperion. Again, these vehicles are pushing 5 GB/s. Getting the data in a time synchronized way, from acquisition hardware to backplane to hard drive is clearly one of our strengths. Even if more data throughput is required, it is just a matter of adding more systems, staying synchronized, and scaling. Physical space and power requirements will be the only real limiters for a multi-system setup when it comes down to sheer throughput. External loggers need to make sure that all of the data streams are going to be synchronized and timestamped accordingly, so that later on in a replay scenario the data can be injected into the ECU in a time synchronous fashion.

Only this way you can guarantee the perception algorithm on the ECU will get its data for cameras, radars, and lidars at the exact right timing to then draw the right conclusion; for example, is this object a vulnerable road user, a car, truck, where is it currently and where is it moving to, and so forth. The NI-based solution comes with built-in timing and synchronization capabilities, which allows users to synchronize interfaces, channels, and data streams down to the microsecond level. Furthermore, various timing and sync mechanisms and sources can be used, such as GPS, IEEE 1588, gPTP network synchronization, and many more.

So, we covered data throughput and synchronization today. Next time we will continue with the third obvious spec, which is storage. Again, it is about throughput and most importantly about write speeds. But there is more than meets the eye here, too. Afterward, we will check out additional parameters like modularity and flexibility to adapt to changes for external loggers and data reduction including compression and triggering, as well as data tagging and labeling. Lastly, we will investigate internal data loggers (ECUs) and start to compare the pros and cons of both approaches to close out road testing as a whole.

This concludes the first 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. This is just the very beginning of the AD data and software workflow. It is NI's goal to enable organizations through a set of software and hardware solutions to help complete this complex puzzle (Figure 02). NI aims to make sure its customers and partners can accelerate development and turn test into a strategic advantage that will unlock greater product performance.

Author and Co-Author

Daniel Eaton
Chief Field Application Engineer, Transportation, NI

Daniel Riedelbauch
Chief Solutions Marketing Manager, ADAS & AD Test, NI

NI Recognized for Innovation in the Automotive Industry

During the recent Battery Innovation Center (BIC) annual industry luncheon, NI was the recipient of the Charged for Innovation award which recognizes a company with fielded technology whose magnitude is amplifying and sustaining the automotive industry. NI was honored to be recognized amongst industry peers by one of the nation's leading battery research initiatives. Our team, along with BIC, continues to push the envelope of testing to enable automotive companies to develop safe and reliable energy storage systems. Special thank you to the team at BIC for the recognition, and for hosting NI at your annual luncheon.

2023 Event Schedule

MAY 23–24

NI Connect
Austin, Texas

NI Connect will focus on technology innovations that continue to redefine product and operational performance and how we're working with innovators like YOU. Join fellow engineers and leaders of industry who are passionate about accelerating the development of innovative technology that performs flawlessly. **Register here.**

MAY 23–24

Vehicle Electronics Connected Services
Gothenburg, Sweden

Vehicle Electronics and Connected Services in Gothenburg is all about the autonomous and electric future of transportation. Meet with us there to talk about the complete ADAS workflow—from Record to Replay and HIL. **More info.**

MAY 23–25

The Battery Show Europe
Stuttgart, Germany

The Battery Show Europe brings together experts from all domains around battery testing. NI will show how our battery test approach helps customers scale up battery production. **More info.**

MAY 24–26

Automotive Engineering Exposition
Yokohama, Japan

The largest exposition in Japan for automotive engineers and the opportunity to discover the latest technologies and products. Meet NI experts to talk about Battery Test and complete ADAS workflow. **More info.**

JUNE 13–15

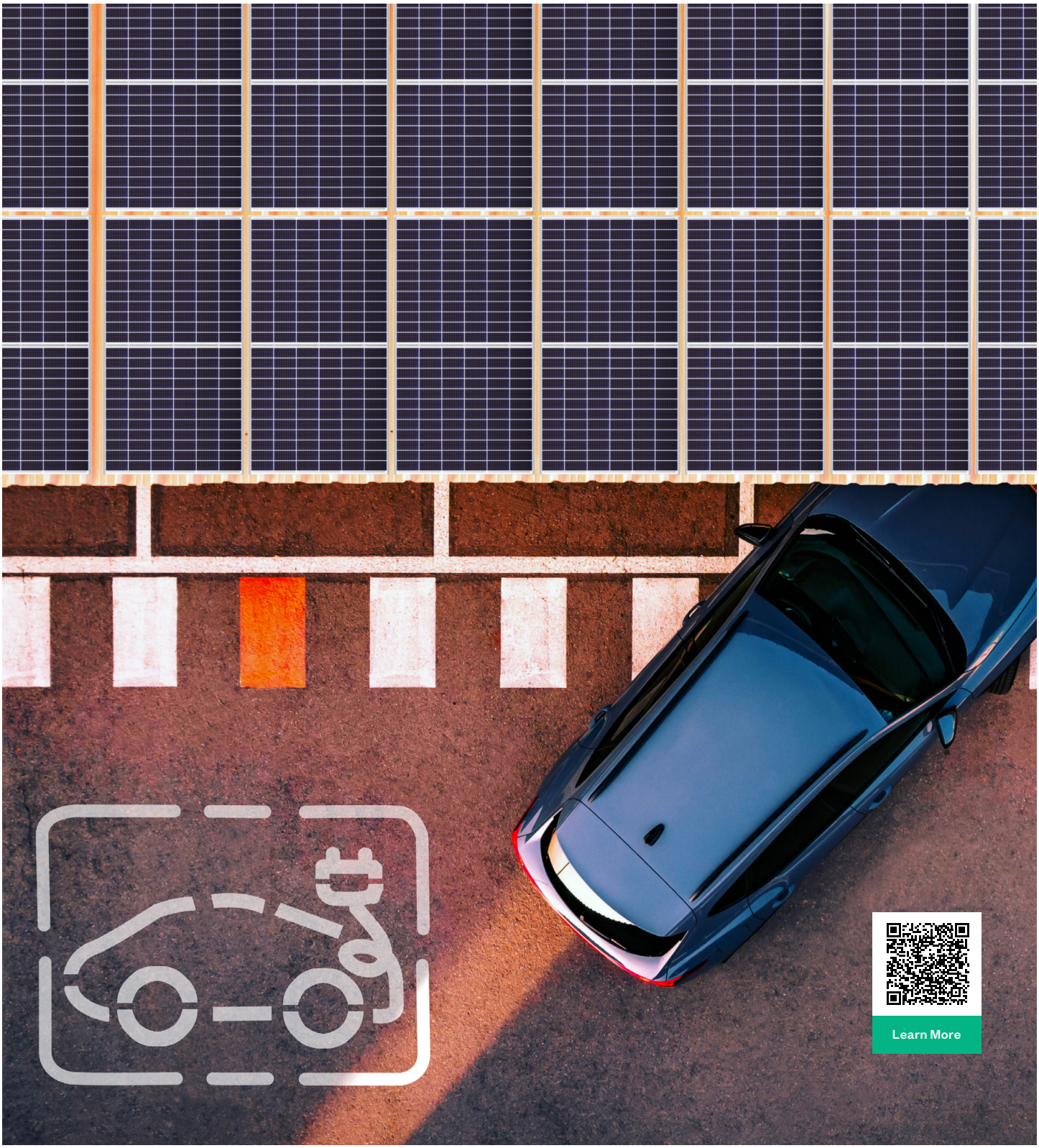
Automotive Testing Expo Europe
Stuttgart, Germany

Automotive Testing Expo is the world's leading international expo for every aspect of automotive testing. Meet our experts to talk about everything automotive, from testing and validating various ECUs to the latest news in ADAS/AD, Battery Test, and Electric Drive Test. **More info.**

JULY 5–7

Automotive Engineering Exposition
Nagoya, Japan

The largest exposition in Japan for automotive engineers and the opportunity to discover the latest technologies and products. Meet NI experts to talk about Battery Test and complete ADAS workflow. **More info.**



US CORPORATE HEADQUARTERS
11500 N MOPAC EXPWY, AUSTIN, TX 78759-3504

T: 512 683 0100
F: 512 683 9300

INFO@NI.COM

NI.COM/GLOBAL – INTERNATIONAL BRANCH OFFICES