# AUTOMOTIVE JOURNAL

# Connect through Collaboration

The New Year often symbolizes a fresh start, a new beginning full of promise and hope and not yet exposed to the practicalities of the real world. It's the "fresh" and not the "start" that's so intriguing. While it's true that I am starting a new chapter leading NI's Transportation business and furthering our mission to help you move faster toward Vision Zero, it's the "fresh" that excites me.

Fresh air from zero emissions cars. Fresh ideas in a culture of high innovation and intense problem solving. Fresh approaches to meeting incredibly complicated technical challenges. Fresh thoughts about sustainability of our planet.

At NI, we transform test from a necessary evil to a key enabler of performance and differentiation. To do so, we enable innovators to digitally transform product development and manufacturing, significantly improving time to market and quality and operational efficiency.  We do this by providing insights throughout the product life cycle using analytics on all product data (including test) and by seamlessly integrating automated test into their engineering and manufacturing workflows.

There are no shortcuts on the path to Vision Zero, but there is a better way. Let us show you.

DRITA ROGGENBUCK
SENIOR VICE PRESIDENT AND GENERAL MANAGER
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# Considering EVs? Consider Them Faster.

For me, electric vehicles (EVs) have felt like a luxury—and a risk—rather than an everyday tool. Between my range anxiety and my inexperience with EVs, I've deemed myself a potential late adopter of EV technology. This means I can still take my time considering a switch to EVs, right? Maybe not.

Automakers are making it very hard to wait, and that's a good thing. For example, General Motors announced that its Cadillac lineup will be all electric by 2030. In addition, Honda said it will sell only EVs and hybrids in Europe after 2022 and phase out all gas cars by 2040. [1] Also, just from CES 2022, I counted no fewer than six big announcements related to new EVs hitting the road soon. Those are big commitments considering that EVs don't have a century of iterative innovation like combustion cars and that regulations and technology are constantly evolving.

In this uncertain environment, automakers are, at different degrees, managing to meet the accelerating pace by making these firm, public commitments and investing accordingly. But ramping up new EV technologies, implementing faster product development cycles, and maximizing quality take more than commitment and investment.

This sprint to meet EV production targets involves the race to produce the best battery in terms of safety and performance. Battery manufacturers who want to claim the longest range and fastest charge need to conduct extensive testing to reach these goals.

## How Hard Can Battery Test Be? Very.

Consider an EV manufacturer with massive walk-in chambers to house the batteries during validation. Its engineers test for capacity, peak power, thermal runaway, overcharge, temperature cycling, protection systems, hipot (high potential), pressure decay, imbalance charge, short circuit, and dozens of other variables over multiple temperature ranges. At the same time, they test for compliance with IEC 62660, SAE J2464, and other standards. Managing the list of tests to perform is already a big challenge by itself.

This manufacturer falls somewhere in between the Complex Test Cell and the Multicell Lab (`FIGURE 01`) categories. One of its main concerns is scaling while managing the megawatts of power, multiple batteries running different tests, high-channel counts, test cell control, the data from results and the facility, and the coordination of test execution (which sometimes runs continuously for as long as six months) for all the packs and modules. Its engineers faced questions such as the following:

- How do we scale from a single test cell to large, multisite, complex test laboratories?
- Do we have the right level of test-result traceability for analytics and decision making?
- Is our test repeatable to the point that we can rerun it, even years later?
- Can we efficiently reconfigure our test cells for new batteries or for more of them?
- Are we working as efficiently as possible, or are we hindered by our existing technologies and processes?

With current time-to-market and EV scrutiny conditions, the way companies and engineers approach test can separate the winners from the losers. Unfortunately, many companies are forced to persist through testing with disparate, disconnected tools that, at best, are cumbersome and time-consuming to manage.

[1] EVERY AUTOMAKER'S EV PLANS THROUGH 2035 AND BEYOND. FORBES, OCTOBER 4, 2021.
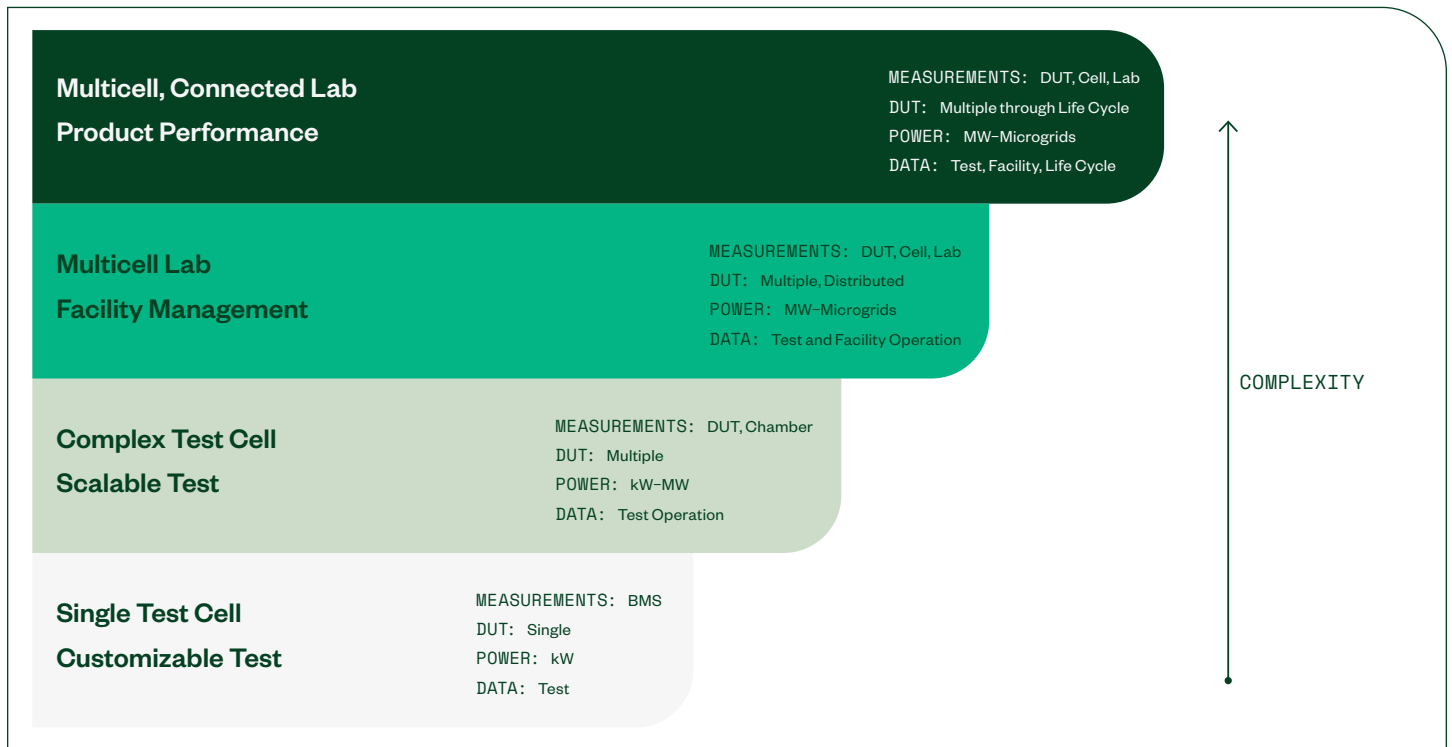
**Multicell, Connected Lab**
**Product Performance**

MEASUREMENTS: DUT, Cell, Lab
DUT: Multiple through Life Cycle
POWER: MW–Microgrids
DATA: Test, Facility, Life Cycle

**Multicell Lab**
**Facility Management**

MEASUREMENTS: DUT, Cell, Lab
DUT: Multiple, Distributed
POWER: MW–Microgrids
DATA: Test and Facility Operation

**Complex Test Cell**
**Scalable Test**

MEASUREMENTS: DUT, Chamber
DUT: Multiple
POWER: kW-MW
DATA: Test Operation

**Single Test Cell**
**Customizable Test**

MEASUREMENTS: BMS
DUT: Single
POWER: kW
DATA: Test

COMPLEXITY

**FIGURE 01**

Scalability is a multidimensional, interdependent problem that disparate, disconnected technologies cannot solve.



In-Chamber Measurements

Environmental Chamber

DUT

Chiller

Battery Test Software
Battery Data Analytics

Battery Cycler        Measurement Rack

**FIGURE 02**

A typical battery test lab setup includes the cycler, chamber, measurements, chiller, and software.

# It Can Get Easier

At NI, we understand this almost impossible situation, and we're making our own commitments so automakers can meet theirs. One such commitment is to connect their test in multiple dimensions.

The typical battery lab setup in FIGURE 02 features multiple components that need to operate in a coordinated way. Tasks as simple as charging and discharging the battery with the cycler need to perfectly synchronized with the conditions inside the environmental chamber, the test procedures, the data capture, the measurements, and the communication with the battery management system (BMS).

For example, NI's Battery Test System (BTS) works as a measurement rack and as the software-connected orchestrator of the test to enable customization and automation. NI SystemLink™, BTS software, and data analytics tools work together to ensure test-result traceability, test repeatability, and proper management of the whole test-cell operation. From the battery cycler to the measurements on the pack/module, running tests with NI's software helps catch defects before they become catastrophic issues, improves product design, and ensures safety and quality.

To offer a more complete solution to the market, we've expanded our portfolio of EV power-level test solutions that provide our customers with critical power-level test capabilities. The expansion came about in multiple ways, one of which was the acquisition of NH Research Inc. (NHR).

Through NHR, NI added capabilities for battery test, battery emulation, grid simulators, and AC/DC loads and sources. NHR's power test equipment performance, modularity, safety, flexibility, and scalability complement NI's existing battery test solutions in a way that addresses most of the challenges stated above.

Because NI already offers the measurement capabilities and software for automating and customizing test and data analysis, the integration of NHR completes the power electronics required to test battery or battery-related systems in a fully software-connected toolchain for applications such as:

- HIGH-POWER BATTERY MODULE AND PACK TESTING—By precisely handling power to and from the battery (cycling), engineers can test batteries as if they were in operation. Following profiles of acceleration, braking, charging,

environmental conditions, and more, engineers validate their batteries' range and performance down to the last mile. They also test for algorithms that improve the safety and performance of the whole EV drive train.

- BATTERY EMULATION—Engineers can test how well their battery, inverter, motor, onboard charger, or even full drive unit meets control, safety, and durability requirements using power electronics devices to emulate the battery behaving any way they need in order to run the test.

The combination of NI's flexible, software-connected EV test platform with the power conversion and electrification test systems expertise of NHR facilitates rapid responses to changing test needs while maintaining quality and empowering engineers to overcome their test challenges. Our goal is to help EV automakers accelerate product development to deliver their products to market faster so they can meet their own goals and commitments.

We believe in the long-term benefits EVs offer, and, just like the automotive companies out there, we invest accordingly to make them a reality. In other words, we want to make it easier for automakers to get to market and make it harder for people like me to wait before going electric.

# Author

ARTURO VARGAS MERCADO
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EV BATTERY TEST, TRANSPORTATION, NI

# How do we prepare for the increasing complexity of testing the ever-changing technology for building a car?

Managing the data life cycle across 30,000 parts is a huge challenge; without a data and analytics infrastructure, you may hit blind spots that affect performance, quality, and profitability.



**1 CAR**

**30,000**
PARTS

**40M**
LINES OF CODE
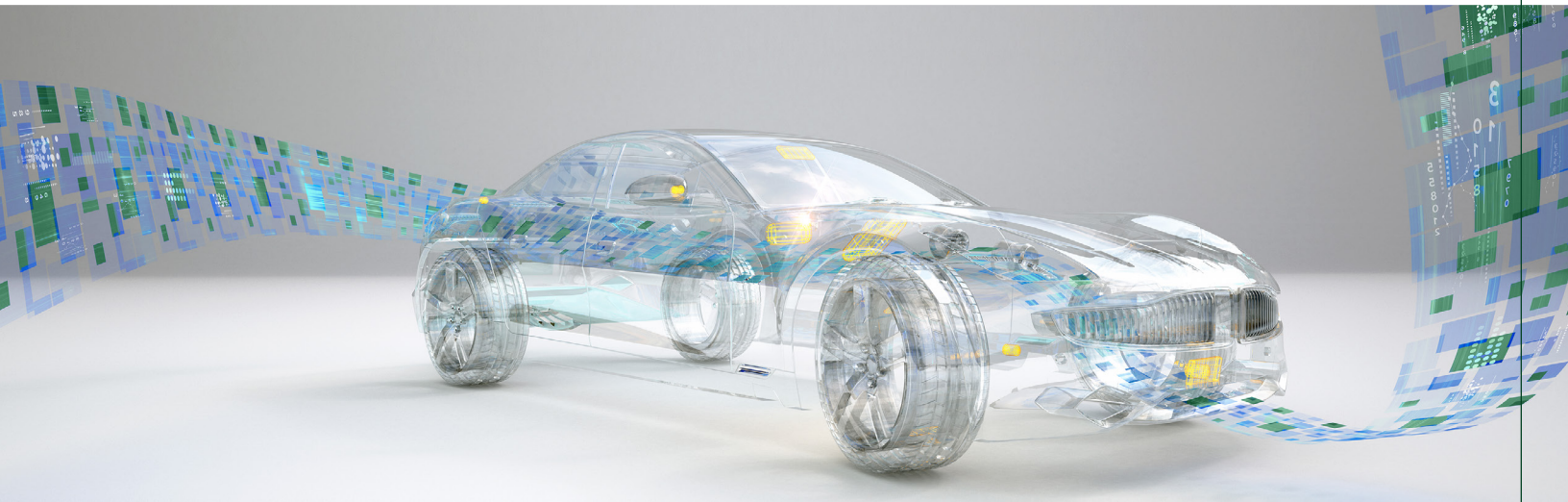
**20**
DIFFERENT COUNTRIES FROM WHICH PARTS CAN ORIGINATE

**1,000s**
OF MACHINES TO CONSTRUCT A SINGLE CAR

A SMART FACTORY ASSEMBLING A CAR MAY GENERATE

**1M GB**
OF DATA PER DAY

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## According to a Leading Automotive Company

**7,000**
SEMICONDUCTOR DEVICES WITH

**~1**
PART/MILLION FAIL RATE

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**4,000**
CARS ASSEMBLED DAILY

**28**
CARS FAILED OFF THE PRODUCTION LINE

## There are no shortcuts on the path to Vision Zero.

NI is already helping automotive innovators deliver results.

**TIER 1 AUTOMOTIVE SUPPLIER**
**50%**
REDUCTION IN TTM[1] ON NEW ADAS AND INCREASED PRODUCT HOMOGENEITY

**TIER 1 AUTOMOTIVE SUPPLIER**
**6 MONTH**
REDUCTION IN DEVELOPMENT TIME AND $800K SAVED IN ONE YEAR

**AUTOMOTIVE OEM**
**96%**
ACCURACY IN PREEMPTIVELY DETECTING FAULTY SENSORS

**ASIAN OEM**
**90%**
REDUCTION IN TEST TIMES AND ¥100 MILLION+ SAVED PER YEAR

[1] TIME TO MARKET

# Virgin Hyperloop: The Future of Transportation

Imagine a world where cities are connected as easily as metro stops. A world where you can travel from Las Vegas to Los Angeles in the same amount of time it currently takes you to drive across town. A world where you can travel 670 mph without polluting the air or harming the environment.

That's the future envisioned by Virgin Hyperloop, and with the help of NI, they're making it happen. Virgin Hyperloop is presently driving a radical transformation in the transportation industry through hyperloop technology: a new mode of transportation designed to eliminate the barriers of distance and time for both people and freight.

We had the chance to sit down with Trevor Hanken, a member of the test automation team at Virgin Hyperloop, and Alexander Wolpe, who manages the test software group, to talk about what Virgin Hyperloop's journey has looked like thus far, how NI empowers the team to achieve their goals, how partnership opportunities enabled by NI are driving innovation, and what the future of mobility will look like.

## The Future of Mobility

Virgin Hyperloop is on a mission to create fast, effortless journeys that expand possibilities. How are they planning to do that? With the introduction of hyperloop, the Virgin Hyperloop team is transforming the way we think about mobility and creating viable, sustainable alternatives to modern transportation.

Currently, professionals working in large metropolitan areas are faced with challenges ranging from heavy traffic during lengthy commutes to added time spent away from loved ones as a result of living outside the city. These issues not only negatively impact these individuals and their families but also pose greater environmental challenges in the form of traffic congestion and energy consumption.

Transportation that operates at unprecedented speeds is exciting for everyone, whether you're tired of commuting or simply passionate about traveling and exploring. The introduction of hyperloop would also open doors for new possibilities of accessibility by stimulating new economies and creating opportunities for people to live and work in areas that would otherwise be unattainable. The benefits of this transformational innovation in the transportation industry are far-reaching.

## What Is Hyperloop?

Expected to provide direct and on-demand transportation, the hyperloop system consists of vehicles called "pods" that travel in a near-vacuum tube at speeds that can reach approximately 670 mph, or 1080 km/h. The novel experience that results from this new mode of transportation is one that is people-first and focuses on safety, comfort, and convenience.

One of the reasons that Virgin Hyperloop can achieve such high speeds is the utilization of magnetic levitation in tandem with near-vacuum tubes. As you might expect, there are many teams working together to ensure the success of this project, from building individual components to managing the control systems that levitate and guide the pods themselves as they move through the tube.

Both Hanken and Wolpe are core members of the test software group, with Hanken specifically working in test automation. He and his team are responsible for testing the behavior of hardware components that make up a hyperloop system, as well as sub-systems that are composed of both controllers and the

associated hardware. Essentially, this team writes software to both control the stimulus to the device under test (DUT), and log any feedback from the DUT and attached sensors.

Every hardware component and test system, as well as their supporting software, come together to create a system that reinvents mass transportation as we know it. While developing this revolutionary system presents unlimited opportunity, there's also a responsibility that is thrust upon the Virgin Hyperloop team.

Thus, this project is driven by a few key pillars:

- SPEED—Hyperloop is set to transport people and products 3X faster than high-speed rail and more than 10X faster than traditional rail
- SUSTAINABILITY—This transportation system joins the fight against climate change by creating a more efficient and conscientious travel system
- SAFETY—Extensive testing is done to ensure dependable and reliable transportation for every passenger and every ride
- EXPERIENCE—This new state-of-the art transportation system warrants a one-of-a-kind travel experience that revolutionizes modern transportation

Hyperloop is trailblazing the transportation industry, and it will ultimately minimize congestion, accelerate travel speeds, reduce energy consumption, and create a more sustainable travel economy.

## Achieving Vision Zero

At the heart of conversations surrounding the future of mobility is the responsibility we have as human beings to, as we like to say here at NI, engineer a healthy planet. Fortunately, NI and Virgin Hyperloop share a common goal of accelerating the path to Vision Zero, which calls for zero emissions, zero collisions, and zero congestion. Between traffic congestion, accessibility limitations, and pollution, we're ready and hopeful for a new era of transportation that's able to sustain humanity for the next 100 years.

We are dealing with the effects of pollution and congestion, and with hyperloop, we can create a new standard for what 21st century travel looks like: One that is going to get us where we want with airline speeds and with zero direct emissions.

**Trevor Hanken**
Test Automation Engineer, Virgin Hyperloop

> "By working closely with NI, we have been able to find the right subject matter experts and partners to help us in building out our many test systems in such a short time."
>
> **Alex Wolpe**
> Software Test Team Manager, Virgin Hyperloop

Embracing an efficient and environmentally friendly future of mobility presents its own set of unique challenges but is absolutely necessary to drive the movement toward Vision Zero. Hyperloop sets out to tackle this challenge head-on with plans to have a lower environmental impact than other modes of transportation and an emphasis on zero direct emissions, as it is 100% electric.

With the ability to travel at airline-like speeds for long distances in a fully autonomous capacity, which may eliminate human error and avoid weather hazards, the future of mobility is looking bright. From professionals yearning to reduce the carbon footprint garnered by long commutes to the wanderlust-stricken people hoping for faster and more efficient methods of travel, everyone can celebrate this transition to a renewable energy-powered future.

## NI Is Connecting Experts with Each Other

Beyond providing hardware and software support to Virgin Hyperloop, NI's partner network has been pivotal in helping the team achieve its vision. Truly, one of the most valuable and important cornerstones of NI is our ability to connect companies with experts and technology to transform transportation, inspire innovation, and drive performance.

Specifically, Virgin Hyperloop has benefited greatly from working alongside Genuen, a team historically known for creating test systems and simulated, real-world environments that produce the data needed to create reliable products or meet imperative regulations.

Virgin Hyperloop selected Genuen to help them build out their flight control's hardware-in-the-loop (HIL) system, which enables the Virgin Hyperloop team to verify and validate the embedded software as implemented in the embedded hardware design. According to Wolpe, Genuen has been very essential in helping the Virgin Hyperloop team design an HIL system system that can meet the demanding requirements of the flight control team and their simulation environment.

## Using NI Test and Methodology

Testing hyperloop pod components and embedded control systems can be time-consuming without a simulation environment. That's where the HIL side of things comes into play. The HIL team at Virgin Hyperloop is responsible for testing the behavior of controllers by integrating models into HIL systems. This allows the team to test out the "real life" behavior of controllers without needing to have the fully assembled product. Using traditional methodology could be both cost-prohibitive and time-restraining.

Part of the verification and validation process involves getting as much reliability and robustness through a simulated environment as possible. In fact, collaboration with NI was crucial in creating an HIL system system capable of emulating all controllers of a hyperloop pod, all built on the same platform, NI VeriStand.

The value of the multi-year journey Virgin Hyperloop has sustained with NI is underscored by the openness and scalability that our platform provides the team, especially in adhering to timelines. The

team agrees, "Having all components of these systems seamlessly integrate with each other has dramatically reduced our turnaround time for creating such a system. Additionally, it makes it much easier to maintain and adapt to new requirements and test cases."

The HIL system is just one example of the way this team has pushed the boundaries of what they are able to accomplish. Virgin Hyperloop has also utilized NI hardware and software applications like CompactRIO systems and LabVIEW software technology to accelerate timelines and drive optimal performance.

## Expanding Possibilities

From the test software side of things, one thing is certain: Virgin Hyperloop plans to continue working with our team here at NI for all testing needs as they continue to trailblaze the transportation industry and redefine 21st century travel.

Thus far, our test technology has played a crucial role in supporting the commercialization process as Virgin Hyperloop develops and begins to bring its product to market. As Hanken points out, it's clear that moving from research and development efforts to prototype testing to fully-developed-system testing to manufacturing and end-of-line testing for quality requires extensive testing at each step of the product life cycle.

From hardware and software to partnerships and continued support, we are beyond excited to be a part of Virgin Hyperloop's journey to bring forth the future of mobility.

So, what's next for the Virgin Hyperloop team? Well, after the success of the team's first-ever hyperloop test in November 2020, where passengers traveled 100 mph in only six seconds, they plan to continue leveraging NI's evolving test technology and test solutions to support their plans for reinventing mass transportation and executing their bold vision. Stay tuned and keep up with the Virgin Hyperloop team to witness innovation and performance at its finest.

## Authors

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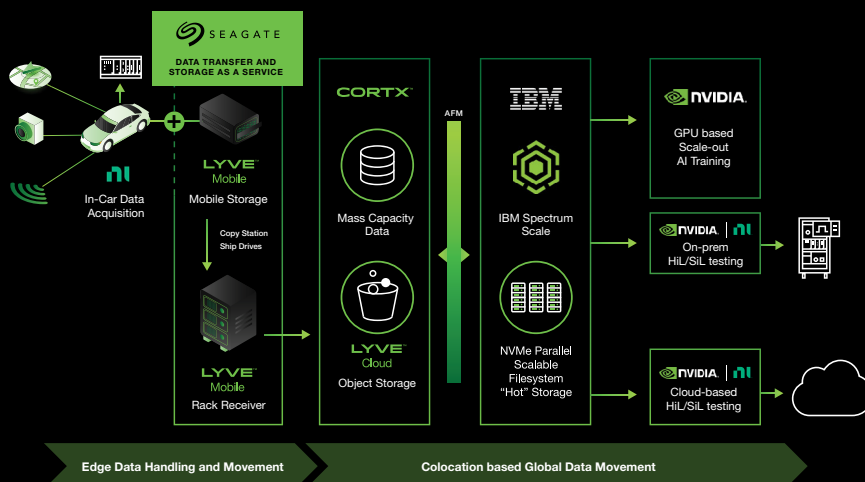TEST AUTOMATION ENGINEER III, VIRGIN HYPERLOOP

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# How Do We All Collaborate Together to Reach Vision Zero?

NI Partners and customers know that reaching Vision Zero is not just an objective—it is the only objective.

The new NI as a Service Series examines the different approaches NI and its partners use to help customers tackle challenges, make good decisions, and put into practice the optimal processes to achieve Vision Zero.

In the automotive industry, only the companies that continue to optimize and adapt to change will survive. At NI, our mission is to support our customers through these changes.

Understanding the areas our customers want to improve helps us translate requests and needs into viable project plans and delivery. This is how NI Professional Services add value, from providing guidance on technical approaches to delivering complete system solutions.

Three of our services are specifically targeted to improve development processes, generate higher added value, and accelerate goal achieving to help our customers reach Vision Zero.

## Resident Engineering Services

Our resident engineers (REs) are dedicated technical professionals who work daily alongside your staff at your location. They act as partners and advisers as they study your organization's processes, requirements, strengths, and limitations. They deliver high business value, ensure seamless transitions, and accelerate development.

Christine Brandewie, an NI RE working with Rivian for the last six months, has one goal for her project at the electric SUV and pickup truck manufacturer. Brandewie's main purpose is to decrease the time Rivian's engineers spend customizing NI solutions to their needs by incorporating real and direct feedback that shortens goal-achieving time schedules. Access to firsthand feedback that can be used right away is one of the main advantages of working as an RE.

Brandewie's project at Rivian focuses on hardware-in-the-loop systems, which involve many different technical components communicating with each other and working together in synergy. As she said, "These are not simple to make or test!"

A large part of her job on-site is troubleshooting and resolving issues with software configurations that are slowing down development. The immediate feedback she receives from Rivian's engineers helps her find and resolve problems quickly.

## Methodology Consulting Services

When best-in-class companies need help developing test strategies to drive business insight, NI works to connect people, ideas, and technology. This is the main job of Stephen Channon, senior consultant for NI Methodology Consulting Services. With more than 25 years of experience in the automotive field, Channon can assess the industry as a whole and better understand customers' needs and points of view.

According to Channon, a key element in collaborating with our customers has been their interest in how we can help them determine and implement a new workflow, for example, the use of continuous integration and continuous deployment (CI/CD). They want strategies to better manage their software and test configurations to accelerate their test processes. For example, a customer asked us to help refactor its test bench software into smaller elements to reduce future qualification workload and to speed up test development time. That is exactly what we did, because at the end of the day, it really is all about digital transformation, enabling our customers to be more efficient.

Channon added that some of the most important assets we can leverage on the path to Vision Zero are the new capabilities NI has gained through acquisitions and the significant role that NI has been playing in the test data field with SystemLink™ software and the O+ platform. These continue to resonate more in the industry and show their value.

## Integration Engineering Services

Through NI Integration Engineering Services, we are working together with our extensive network of partners to provide a wide range of options that can assist customers with designing, developing, and deploying the most complex systems.

David Pratt, senior product manager for NI Professional Services, said that he actively collaborates with his team and NI Partners to produce comprehensive solutions that deliver desired outcomes to customers. These solutions provide unique value by combining technical offerings with professional service capabilities specifically packaged to overcome the challenges customers face.

The NI Professional Services team is excited to align the delivery of our services with customers' workflows and expectations, and to coordinate with our transportation-focused partners across the industry to help one another. Our flexibility and customization to meet customers' needs helps them achieve their goals at a variety of levels.

Ultimately, our colleagues', partners', and customers' feedback has given us unprecedented visibility into their challenges and enables us to build a clear picture of how we can work together to achieve the Vision Zero objective faster without compromising safety.

Change remains constant (see Q4 2021 *Automotive Journal*), so adapting to these changes, emphasizing flexibility, and developing new and better strategies for our customers' upcoming challenges are the keys to success.

Do not miss next quarter's NI as a Service Series article! We will explore different projects designed to reach Vision Zero.

## Author

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# A Connected ADAS and AD Workflow: No Longer a Dream

In the Q4 2021 *Automotive Journal*, we dived into how mastering the advanced driver assistance systems/autonomous driving (ADAS/AD) validation workflow relates a lot to solving puzzles, competing in sports, and participating in the rush for gold and oil (see "Solving the ADAS and AD Puzzle Together"). This is NI's view, but some of our strategic partners, Ansys, Foretellix, Konrad Technologies (KT), and Seagate Technology, are sharing their perspectives on this with us as well.

**JEFFREY PHILLIPS**
DIRECTOR, GO-TO-MARKET STRATEGY, TRANSPORTATION, NI

**JEFFREY PHILLIPS: WHO ARE YOU AND WHAT IS YOUR SUBJECT MATTER EXPERTISE?**

**Eric Bantegnie:** Ansys is the global leader in engineering simulation. Through our strategy of Pervasive Engineering Simulation, we help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and create products limited only by imagination. In my position as vice president, I am currently acting as a special adviser to the CEO and as CTO of Ansys Europe.

**Roy Fridman:** Foretellix provides a test management, verification, and validation platform for ADAS/AD systems. Our platform orchestrates, manages, and analyzes the massive scale of meaningful tests and edge cases required to ensure that these systems have been tested successfully in all the relevant scenarios. In my role as vice president of business development and sales, I help my team drive the company's growth from direct sales and partnerships such as ours with NI.

**Michael Konrad:** KT is a global supplier of automated test equipment in multiple markets including consumer electronics, automotive, medical, and aerospace/defense. We've been an NI Partner since 1996. I am the founder and CEO of the company.

**Melyssa Banda:** Seagate Technology is a world leader in mass-data storage infrastructure solutions. My role in leading our Lyve Mobile Solutions is to help businesses mobilize their massive data sets and maximize the value and insights they're able to gain from their data. This includes providing enterprises in the ADAS/AD space with in-vehicle storage capacity, modular edge solutions to off-load data and an agile, affordable, and secure architecture.

JP: WHAT TRENDS AND CHALLENGES DO YOU FORESEE IN ADAS/AD?

EB, Ansys: Products and systems are becoming increasingly complex, interconnected, and interdependent. Projects also run the risk of cost and schedule overruns and product failure while losing to the competition on superiority and time to market. To meet these challenges, there is a strong industry focus on implementing a model-based systems engineering (MBSE) approach that creates a digital thread that can be shared, continually improved, and managed throughout the product life cycle. MBSE enables our customers' digital transformation journeys with the digital thread providing the framework for continual feedback and incremental opportunities to model, simulate, refine, and validate throughout the product life cycle—from design and development through operation.

RF, Foretellix: Modern vehicles have become complex digital products, but their development and testing tools and methodologies have yet to undergo their own digital transformation. Most of the tools lack scale and automation and are not suitable to meet the challenges of these complex digital products. The industry is shifting to massive scale virtual testing, automation, and advanced analytics.

MK, KT: Key trends for the automotive market are the increasing adoption of ADAS/AD capabilities, a greater need for reliable test methods, and an ever-decreasing time to market for these new features. Primary challenges are evolving standards for ADAS/AD performance, new and evolving sensor capabilities, and an archaic and insufficient multiyear development process.

MB, Seagate: ADAS/AD customers are experiencing challenges with the explosion of data volume. Data collected from vehicles' sensors, including cameras and lidars, has seen a more than five-fold increase in just a few years, and will continue to grow exponentially. There is an increase in artificial intelligence (AI)-based algorithms involved in the perception systems. The validation of these ADAS/AD engine control units (ECUs) will be mandatory with each feature update—even when only a few lines of software code are changed. More and more data will be in the loop for testing. All this data needs to be captured, moved, and analyzed with workflows that control cost, quality, and time to data.

JP: WHAT'S YOUR PERSPECTIVE ON A DATA- AND SOFTWARE-CONNECTED WORKFLOW?

EB, Ansys: MBSE is a key driver for digital thread and digital transformation initiatives. Our customers, including large automotive, aerospace and defense, and high-tech OEMs, contractors, and Tier 1 suppliers, are switching to an MBSE methodology within the different life-cycle phases and functions, and will eventually expand to the digital thread that spans from design and development through operation.

RF, Foretellix: As cars become more digital, they depend on data, create data, and basically become data centers on wheels. This data can be utilized in many ways to drive new approaches to monetize the car, increase safety, and much more. It is our goal to provide a platform and tools that help development teams test these complex digital systems with advanced automation. We also offer strong analytics tools that help reduce cost, decrease time to market, and ensure safety.

MK, KT: A connected workflow is necessary to optimize designs at each step of the development process and share key attributes across these steps to reduce overall development time. Data-driven and analytics-based development efforts are necessary for successfully deploying safety-critical ADAS/AD functions, and a data- and software-connected workflow will offer such capability.

MB, Seagate: In recent years, we have seen a major disruption in the automotive software space. Due to the need to continually evolve the vehicles' perception and decision-making capabilities, the vehicle's software architecture has been altering. From AUTOSAR to real-time operating systems (RTOSs), this architecture expands into Linux, open-source software, and AI that enable the growth of the vehicle's code and capabilities, and data is essentially the fuel of this process. The more data captured in real-life scenarios, the better the vehicle's logic and decision-making capabilities will be.

JP: HOW DOES A DATA- AND SOFTWARE-CONNECTED WORKFLOW HELP ADDRESS THESE TRENDS AND CHALLENGES?

EB, Ansys: As AI systems in autonomous vehicles increase in design complexity, siloed tools for information sharing, such as paperwork and spreadsheets, break down. That's where MBSE comes in. It allows for work from end to end—from concept to certification—and starts to become the only way to handle autonomous vehicle development to safety-critical standards.

RF, Foretellix: The ability to collect, share, and analyze data at scale from physical and virtual sources (real
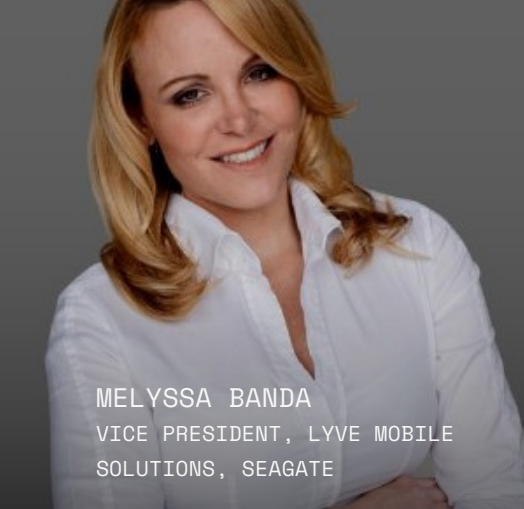
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driving, simulation, and so on) is key to properly testing and deploying ADAS/AD functionality. Companies such as NI and Foretellix drive data collection, generation, analytics, and insight.

**MK, KT:** A connected workflow will enable reuse of best practices and data at different phases to shorten development cycles and time to market. It will also provide incremental improvements in software design to accommodate developing standards and changing sensor specifications and create higher quality designs for prototype development.

**MB, Seagate:** We are helping the industry by enabling carmakers and suppliers to free their cash from storage and IT infrastructure and focus it on the goals that matter most to them: evolving and accelerating their novel technologies and IP around ADAS/AD and securely connected services. Together, NI and Seagate are providing an innovative ADAS record offering that allows OEMs and suppliers to modernize their data storage strategy from self-managed to storage as a service (StaaS). This leads to reduced costs and efficient storage throughout the entire data flow and accelerates customers' access to data and ability to innovate.

**JP: HOW AND WHY DOES AN ECOSYSTEM OF SUBJECT MATTER EXPERTS MAKE A DIFFERENCE?**

**EB, Ansys:** As MBSE becomes more prevalent, being able to connect simulations to physical hardware is of the utmost importance. Without this connection, true verification and validation of systems cannot take place. Due to this connection, Ansys and NI can shorten complex product development cycles and ensure that components behave as designed. Together, both

companies will help solve the complex challenge of re-creating real-world simulations to validate sensors and inject data into software and hardware under test in real time. This shared focus will provide customers with critical insights into how products will perform in the market by bridging the worlds of simulated and physical test with more precise outcomes.

**RF, Foretellix:** The challenge of automated driving is an ecosystem challenge. No company can solve it alone. Alliances of companies providing best-in-class tools and methodologies to support safer ADAS/AD features are crucial for the broad deployment of these systems.

**MK, KT:** Working with subject matter experts and platform providers like NI ensures a consistent understanding of the challenges and a productive experience for our common users and partners in the ecosystem. For a smaller company, it also presents an opportunity to work on bigger projects within the automotive ecosystem.

**MB, Seagate:** To provide the best solutions for OEMs and suppliers, it takes the world's leaders in respective specialties. With NI's long-standing reputation and expertise in automotive testing, as well as Seagate's expertise in mass data storage, we are building a comprehensive portfolio of solutions, allowing OEMs to share data more efficiently among endpoint, edge, cloud, or any locations. With that, we help to reduce development time and cost.

**JP: WHAT HAS BEEN THE FEEDBACK FROM CUSTOMERS SO FAR ABOUT THE COLLABORATIVE ECOSYSTEM WITH NI?**

**EB, Ansys:** We have heard from customers at joint engagements that the openness of the collaborative

ecosystem compared with being locked into a unique solution by a vendor is very much appreciated. Some key benefits mentioned are ease of reuse and flexibility as well as the cost-effectiveness of the solution.

**RF, Foretellix:** We get a lot of positive feedback on the joint toolchain proposed by NI and Foretellix. Customers prefer strong alliances with companies that are able to work together and streamline the massive amounts of data needed to validate the ADAS/AD algorithms in an efficient way.

**MK, KT:** The feedback on offering new test capabilities and services to the automotive ecosystem has been positive and optimistic. It is seen as encouragement for Konrad Technologies to participate in a wider range of automotive applications.

**MB, Seagate:** Today's Level 3+ campaigns generate about 100 TB of data from each vehicle every day. Customers are running on at least three continents and requiring captured data to be validated and available in the cloud within days. We are talking about 1 PB that needs to flow into our customers' core (cloud) daily. This is no task for niche vendors. Seagate's Lyve Mobile Solutions are designed to help our customers rethink the entire data flow and find a new way to manage their data.

JP: THANK YOU FOR SHARING YOUR PERSPECTIVE. 2021 HAS BEEN A GREAT START TO ESTABLISHING ALL THESE STRATEGIC PARTNERSHIPS. IN 2022 AND BEYOND, WE ARE LOOKING TO EXTEND OUR COLLABORATION EFFORTS FURTHER WITH YOU. NO SINGLE ENTITY WILL ACHIEVE AUTONOMOUS DRIVING ALONE, BUT AN ECOSYSTEM WILL!

# 5G V2X Map-Based Hybrid Channel Model Implementation

With the increasing maturity of 5G V2X technology, the wireless channel model based on stochastic behavior is unable to conduct accurate channel emulation for a specific scene, which makes the current communication on-board unit (OBU) performance evaluation of advanced driver assistance systems (ADAS) system difficult. As a deterministic modeling method, raytracing (RT) can theoretically achieve accurate simulation based on a digital map. However, due to its high computational load, it cannot simulate vehicular networking channels, especially in multi-user/link scenarios. In recent years, graph theory, as an effective and accurate semi deterministic model, has offered the characteristics of high computational efficiency and modeling accuracy. This paper introduces a new multiusers V2X channel simulator based on a digital map using graph theory. In the end, we present some test results to verify the system.

## Index Terms−V2X, Channel Emulator, Map Based, 5G

With wireless network evolution, a cellular network provides increasing capacity to support more vehicle communication function. In recent years, the design goal of the 5G vehicle-to-everything (V2X) standard has been to solve the multiple communication mechanisms brought by autonomous vehicles. It is very important to introduce a channel model that can be used to verify V2X performance.

Current wireless channel models can be classified as stochastic or deterministic models. The widely used stochastic channel model is known as the geometry-based stochastic channel model (GSCM). According to the cluster modeling method, the GSCM can be further divided into Winner type and COST type. The former includes the 3GPP spatial channel model (SCM), extended SCM (SCME)[3], Winner, Winner II[4], Winner+ (WIM+), and QuaDRiGa [5]. The latter is COST-type GSCM[7].

The main problem with stochastic models is that they cannot perform accurate channel analysis for the specific scenario. To solve the problem, a map based deterministic channel model is taken into consideration.

In the past few years, deterministic channel models such as ray tracing (RT) have been used increasingly.

The main problem of ray tracing is using it to model the accurate power delay spectrum (PDP) [1],[2]. This is mainly because

the calculation of scattering scenes based on RT will lead to a significant increase in the calculation of time.

Recently, a new geometric−stochastic channel modeling approach based on graph theory has been proposed, which can simulate multiple-bounce scattering to several interactions in a very efficient way. In graph theory channel models, propagating paths are represented as sequences of branches (edges) connecting nodes (vertices, representing scatters) [8].

In this paper, we propose a graph theory-based channel model implementation for V2X. The channel emulator can realize the emulation of specific channels for multiple users which makes it easy to be integrated into the vehicle scene test for verification of communication performance.

## Channel Model Implementation

### Overall architecture of the channel model

Generally, the emulator is divided into two parts: software and hardware.

In the software, the channel emulator mainly realizes the process of user settings, channel coefficient calculation, and hardware access control. In the hardware, the channel emulator completes multiuser CIRs reloading, real-time tapped delay line (TDL) channel filtering, and some hardware accelerating.

## The main software

The core tasks of the software for the channel emulator includes parameter setting, geometric path calculation, propagation coefficient calculation and CIR acquisition.

The simulator setup module includes a map-importing section, a V2X scene setup for a typical V2X scene type, and wireless channel setting which including wireless channel type, frequency, antenna attributes, number of users, and path or location planning for each user and roadside facilities.

After the parameters setting is complete, the system software discretizes the building surface according to the input digital map and abstracts it as vertex sets. The software records the coordinates of each vertex set and the normal direction of the surface.

When the vertice sets are accomplished, visibility analysis among different vertices is dynamically generated based on the position of the vertices and the movement trajectory of the communication transceiver terminal. The visibility of each pairs of two nodes is realized by detecting whether the vector connecting the two nodes intersects the surface according to their position and the position of the surface. After finishing visibility analysis, the propagation diagram has now been established.

After the geometric propagation path is determined, the propagation coefficient　of each available link is calculated, and matrices D(f) R(f) T(f) and B(f) at a specific frequency are calculated. During the calculation of matrix T(f) and R(f), the antenna radiation patterns are also embedded into calculation.

When D, T, R, and B sub matrices are generated, the matrix inverse can be calculated, and the channel transfer function can be achieved.

Finally, after Fourier inverse transformation (IFFT) to the transfer function, the final CIR is obtained.

The CIRs of multiple users will be stored in the corresponding storage space, and the CIRs reloading and hardware emulation will be conducted based on the fact that the schedule controller will download the corresponding CIR to the hardware part of the channel emulator at the corresponding sending time of the user.

## The main hardware

The solution uses NI software defined radio (SDR) hardware.

The PXIe-8135 PXI Controller is an industrial-grade embedded controller featuring Windows OS. The PXIe-5646 PXI Vector Signal Transceiver (VST) executes AD/DA conversion as well as RF upconversion and downconversion as the core components of the channel emulator. PXIe-7965R FPGA Modules are the coprocessor of the VST that add channel fading to input signals in baseband by the Xilinx Virtex-5 FPGA in the module. Multiple PXIe-7965R FPGA Modules form a computation pool, which processes the data from all VST channels linked by the PXI Express bus. All these components are integrated in a PXI Express bus via the PXIe-1085 PXI Chassis.

The embedded controller completes the software part of the channel emulator and the configuration of different RF hardware resources, including the real-time reloading of multiuser CIR coefficients and the selecting and switching of RF channels. In the FPGA module, a finite impulse response (FIR) filter is used with the overloadable CIR coefficient to realize the updated channel TDL model. At the same time, some matrix operations and inverse fast Fourier transform (IFFT) operations are implemented in the FPGA to optimize computing efficiency.
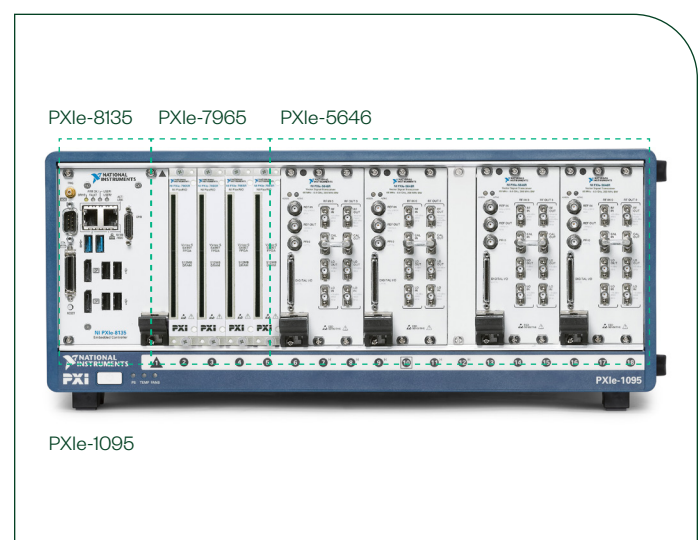


PXIe-8135　PXIe-7965　PXIe-5646

PXIe-1095

FIGURE 01

Hardware Solution with PXIe-5646 PXI Vector Signal Transceiver

| PARAMETER | VALUE | COMMENTS |
|---|---|---|
| Multi-Channel | 4x1x1 | 4 channels synchronization processing. Each one is 1x1 |
| Maximum RF Bandwidth | 200 MHz | 200 MHz |
| Tapped-Delay-Line Sampling Rate | 200 MSPS | PXIe-5646 ADC and DAC have 16-bit resolution |
| Delay Resolution | 5 ns | This is currently implemented as a sample-based tapped delay line. Fractional delay filters would not use. |
| Maximum Delay | 20.6 µs | Maximum tap delay |
| Power Normalization | | Power normalization of all paths |

TBL
01 | Hardware System Specifications

# Conclusion

In this paper, a new channel simulator based on graph theory is proposed, and the reliability of the system is verified by some test results. In the future, this system will further optimize for the multi-user V2X scenario.

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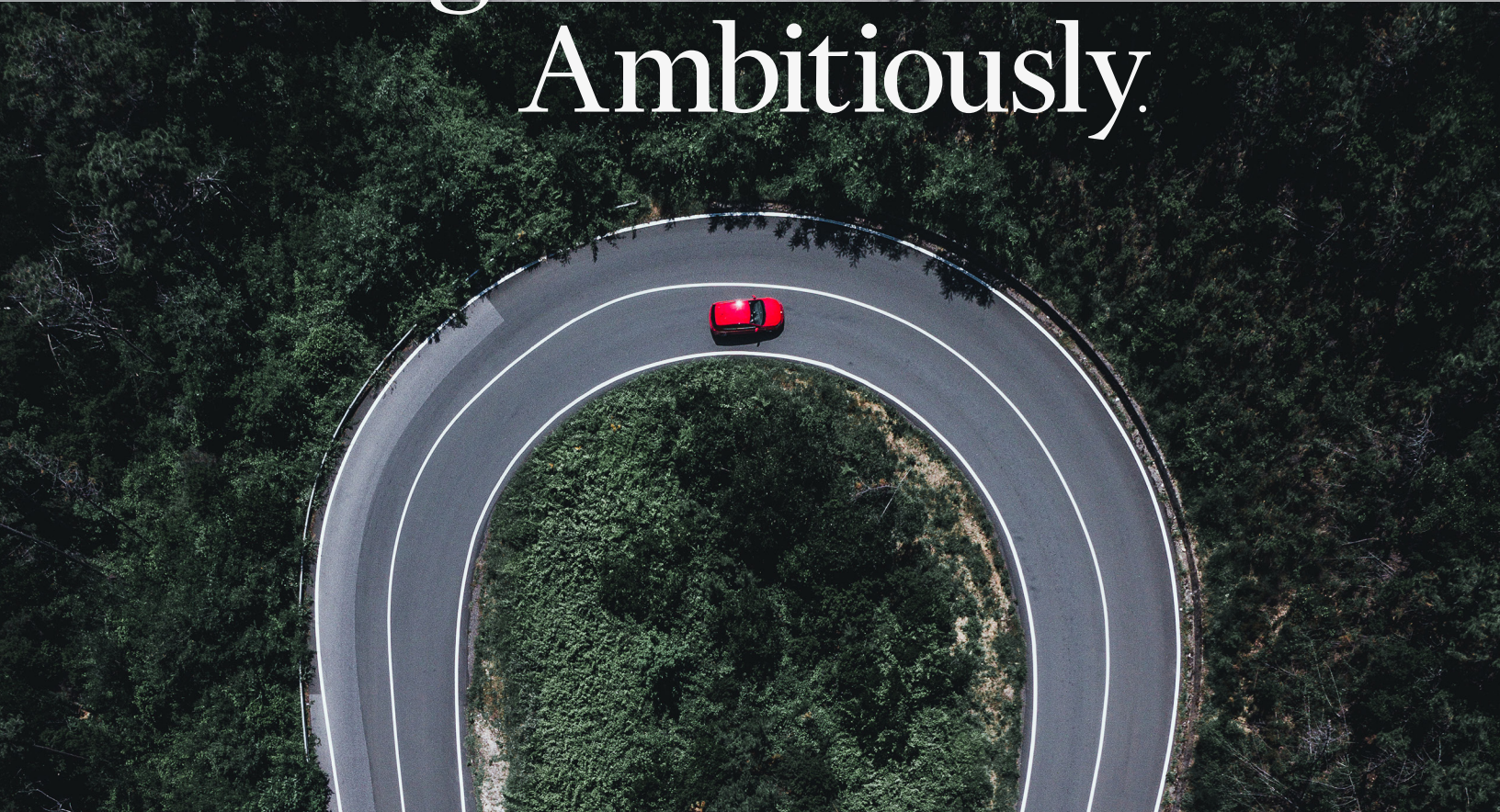800.553.2255 or email sales.na@electrorent.com.

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