NI TREND WATCH 2019

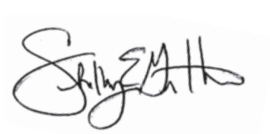
Trends and Challenges in Automated Test
and Automated Measurement

Rethink Megatrends to Secure Your Future

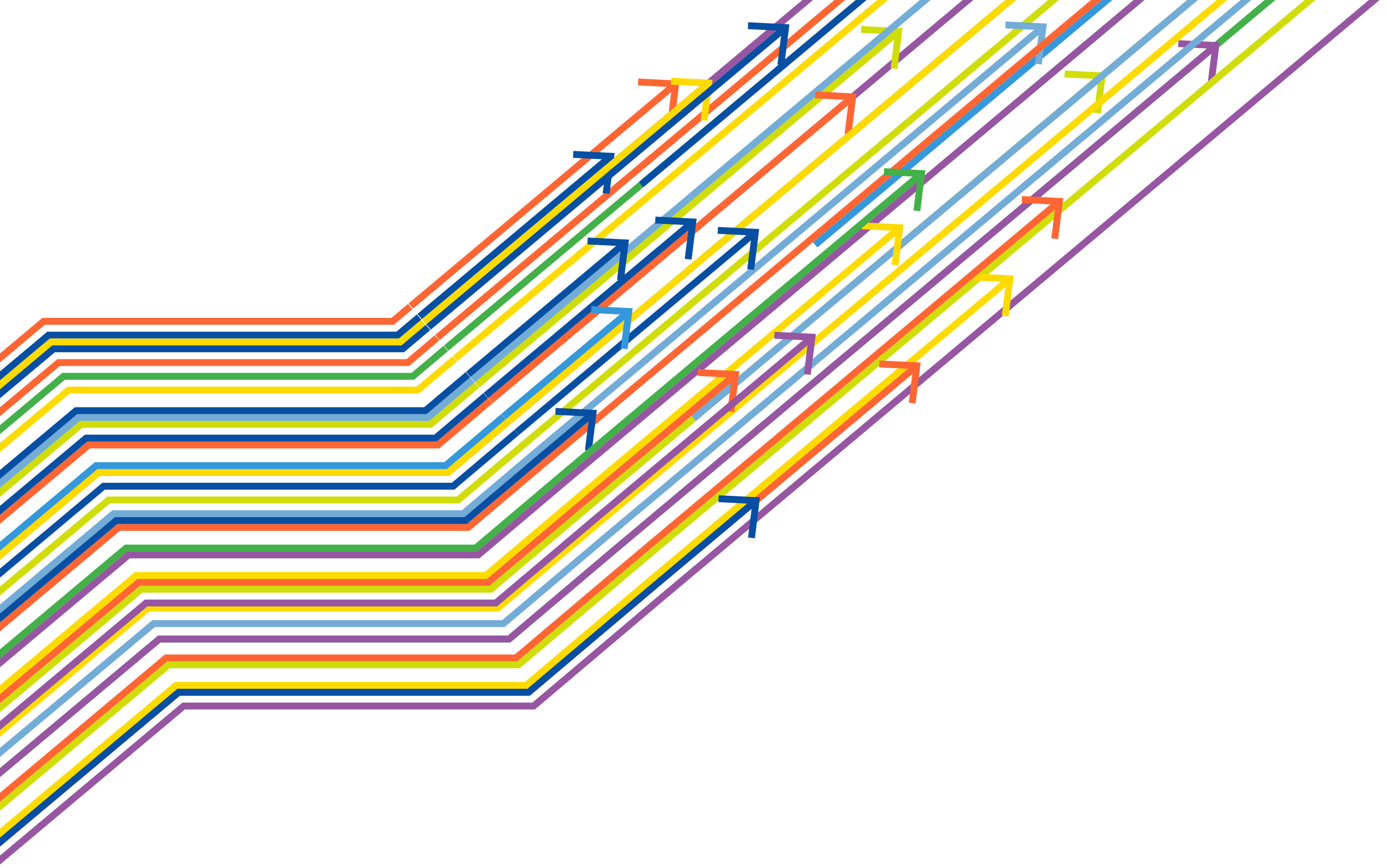
Engineering megatrends are profoundly transforming industries, product testing, and the companies trying to monetize the trends. The proliferation of the Internet of Things, the progression of 5G technology from prototyping to commercial deployment, and the journey to autonomous driving for the masses present large and complex challenges, but they also give us the opportunity to innovate in ways we never could've imagined.

Truly realizing the benefits of these megatrends requires a fundamental shift in our approach to automated test and automated measurement. To be successful, we must think differently, act purposefully, and make the critical shift toward software-defined systems. That's where Trend Watch comes in.

Trend Watch provides insights into the most crucial engineering trends and challenges of our ever-changing technology landscape. I think you'll find it helpful in your efforts to accelerate full force ahead into the future.



Shelley Gretlein
NI Vice President of Global Marketing



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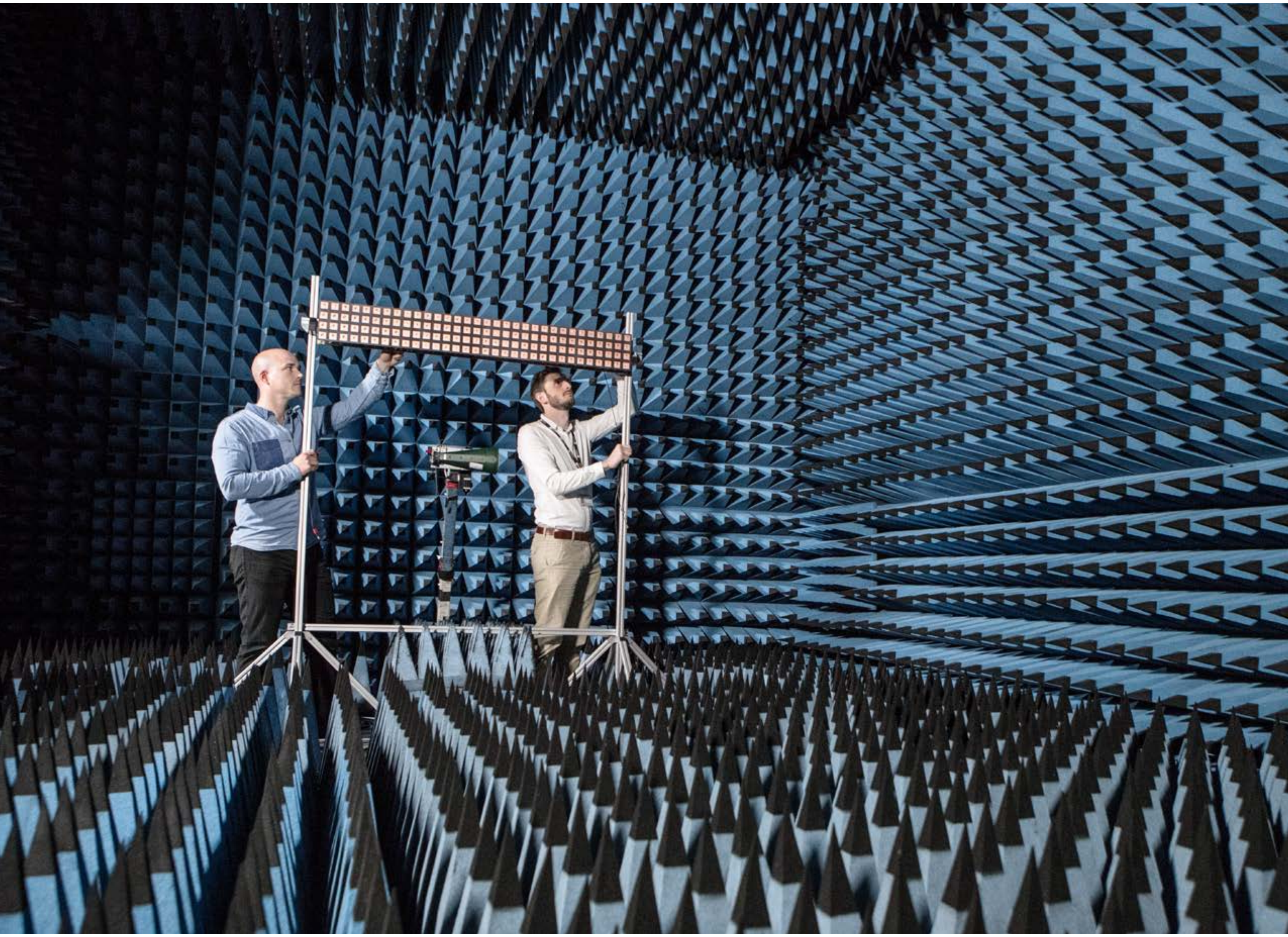
→ Refer to the urgency meter in each article to prioritize these trends for your organization.



ACT PLAN MONITOR

Charles Schroeder
NI Business and Technology Fellow

5G Ushers in a New Era of Wireless Test

- The promises of 5G come with the cost of added complexity.
- New techniques must be developed to test 5G.
- New, lower cost over-the-air test will be required.

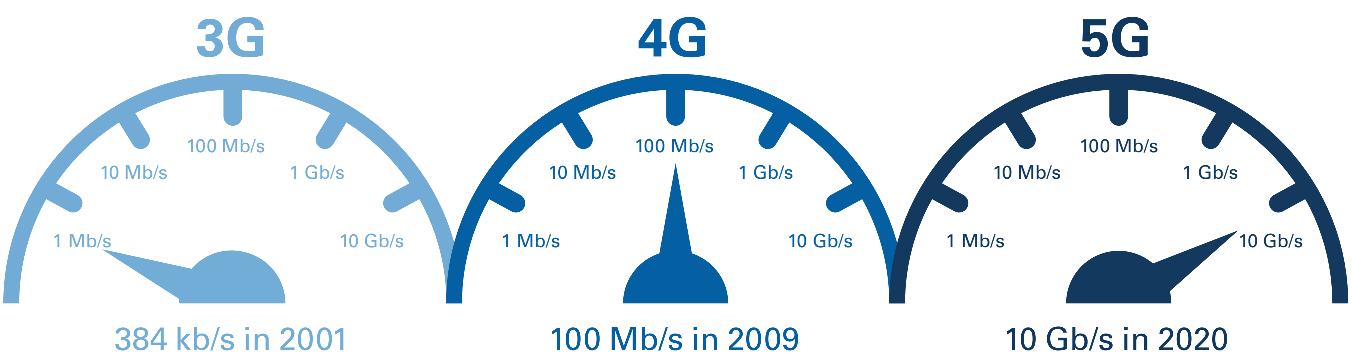
Since the beginning of cellular communication, test engineers have been iterating on an accepted set of measurements and techniques to test wireless communications technology in high volumes, from RF semiconductors to base stations and mobile handsets. But with 5G, the technology inside these wireless devices will be more complex, and the highly optimized techniques that have been used to test previous generations will need to be rethought. Testing 5G components and devices with over-the-air (OTA) methods instead of the cabled methods currently in use will be necessary to validate the performance of 5G technology. As engineering leaders, we need new test methods to ensure the viable commercialization of 5G products and solutions across many industries and applications.

Boosting Bandwidth

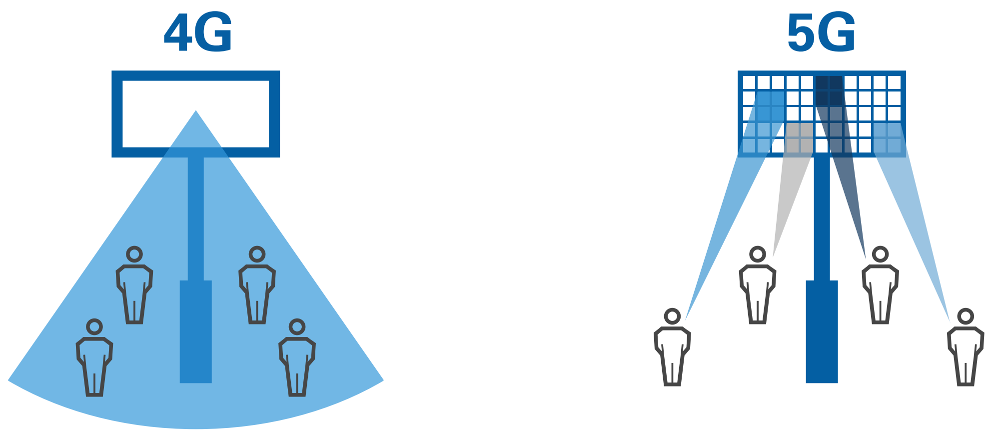
One of the key goals of the 5G standard is to significantly increase data capacity as user data demands continue to rise, but to achieve the target peak bandwidth of 10 Gb/s per user, new technologies are being introduced. First, the 5G spec includes Multiuser MIMO (MU-MIMO) technology that allows users to simultaneously share the same frequency band through beamforming technology that creates unique, focused wireless connections for each user. Second, the 5G standard adds more wireless spectrum, expanding into centimeter and millimeter wave (mmWave) frequencies.

Physical implementations of both the MU-MIMO and mmWave technologies use significantly more antenna elements than previous generations of cellular standards. The laws of physics dictate that signals at mmWave frequencies will attenuate considerably faster as they travel through free space than signals at the current cellular frequencies. So, for a similar transmitted power level, mmWave cellular frequencies will have a much smaller range than current cellular bands.

To overcome this path loss, 5G transmitters and receivers will utilize antenna arrays working simultaneously and using beamforming technology to boost the signal power instead of the single antenna per band in current devices. Though important for increasing the signal power, these same antenna arrays and beamforming techniques are crucial to implementing MU-MIMO techniques.



5G INTRODUCES CELLULAR MU-MIMO CAPABILITIES WITH ACTIVE ANTENNA ARRAYS



How will we fit all these antennas into tomorrow's cell phones? Luckily, the antennas at mmWave frequencies will be much smaller than the cellular antennas used for current standards. New packaging technologies, like antenna in package (AiP), will ease the integration of these antennas into the small space constraints of the modern smartphone, but the arrays of antennas may be completely enclosed without any directly contactable test points.

Using OTA to Address New Challenges

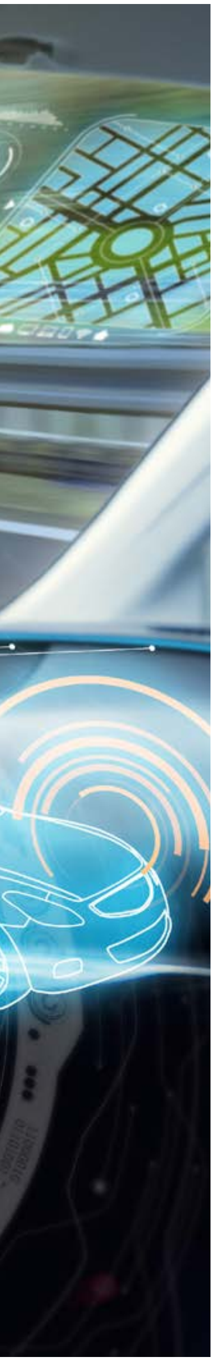
For test engineers, the increased frequencies, new package technologies, and greater antenna counts will make it difficult to keep quality high while limiting increases in both capital costs (cost of test equipment) and operating costs (time to test each device). New OTA techniques can help with these, but they present challenges as well.

First, measurement accuracy will be challenging. Unlike cabled tests, when making OTA measurements, test engineers will deal with the additional measurement uncertainty that comes with antenna calibration and accuracy, fixturing tolerance, and signal reflections. Second, brand new measurements must be integrated into device test plans for anechoic chamber integration, beam characterization, optimal code-book calculation, and antenna parameter characterization. Third, as RF bandwidths continue to increase, the processing needs for calibrating and making measurements on these wide bandwidths increase as well, which adds to test time concerns. Finally, test managers must make additional business considerations to ensure product quality while minimizing the impact to time to market, capital cost, operating cost, and floor space (to accommodate the OTA chambers). Over the next few years, the test and measurement industry will be rapidly responding to these challenges with many new innovations. Test groups should consider highly flexible, software-defined test strategies and platforms as a way to ensure their capital expenses today can keep pace with this rapid cycle of innovation.

Though OTA presents challenges, it also offers benefits. First, OTA is the only option for AiP technologies because the antenna arrays are integrated inside a package with no way to directly cable to the array elements. Even if test engineers could contact individual antenna elements using conducted test methods, they face the difficult choice of testing them in parallel (at the capital expense of needing more instruments) or testing them serially (at the operating expense of test time and throughput). Many technical issues still need to be solved, but OTA test offers the possibility of testing the array as a system instead of a set of individual elements, which could lead to the greater efficiency promises of system-level test.

In the past, test equipment suppliers and test engineers have risen to the challenge of testing increasing performance and complexity while minimizing time to market and cost of test, and they'll do it again for 5G. Though the challenges of testing 5G look complex today, engineers around the world are already developing the new test instruments and methods, like OTA, that are necessary to make 5G a commercial success.


48
mph
MENU
INFORMATION
Autonomous
Mode
NETWORK
DRIVER
Data
Location
/Autonomous
/Sensing
/Communication
/Battery
/Navigation
/Mirrorless
/Ecology



Jeff Phillips
NI Head of
Automotive Marketing

Imminent Trade-Offs for Achieving Safe Autonomous Driving

- Autonomous driving will challenge the cost ratio for sensor redundancy to ensure overall safety.
- A software-defined test platform will be critical to keep pace with the evolution of processor architectures.
- The semiconductor and automotive industries are converging as requirements for autonomous driving are impacting microprocessor architectures.

According to the World Health Organization, every year more than 1.25 million lives are cut short because of traffic crashes, and these crashes cost governments approximately 3 percent of GDP. Though the potential impact of autonomous driving is pervasive, extending into personal, economic, and political domains, the potential life savings alone mean autonomous driving could be the most revolutionary invention of our time.

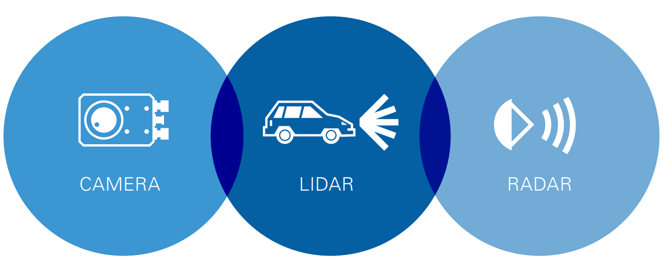
Advanced Driver Assistance Systems (ADAS) are a convergence of sensors, processors, and software to improve safety and ultimately deliver self-driving capability. Most of these systems today use a single sensor, such as radar or camera, and have already made measurable impact. According to a 2016 study by the IIHS, automatic-braking systems reduced rear-end collisions by approximately 40 percent, and collision warning systems cut them by 23 percent. Still, the NHTSA reports that 94 percent of serious car crashes are caused by human error. To move from driver-assist to Level 4 or 5 autonomy and take the driver from behind the wheel, the auto industry faces significantly more complicated challenges. For instance, sensor fusion—the combining of measurement data from many

sensors to drive outcomes—is required, and it demands synchronization, high-power processing, and the continued evolution of the sensors themselves. For automotive manufacturers, this means finding the appropriate balance across three critical trade-offs: cost, technology, and strategy.

Cost: Redundant Versus Complementary Sensors

The standard for Level 3 autonomy says the driver does not need to be actively paying attention if the car stays under predefined circumstances. The 2019 Audi A8 will be the world's first production car to offer Level 3 autonomy. It's equipped with six cameras, five radar devices, one lidar device, and 12 ultrasonic sensors. Why so many? Simply put, they each have unique strengths and weaknesses. For example, a radar shows how fast an object is going but not what the object is. Sensor fusion is needed here because both data points are critical in anticipating the behavior of the object, and redundancy is necessary to overcome each sensor's weaknesses.

LIDAR ADDS REDUNDANCY



Ultimately, the goal of processing sensor data is to create a fail-safe representation of the environment surrounding the car in a way that can be fed into decision-making algorithms and that can keep costs down so the final product is profitable. One of the most significant challenges in accomplishing this is choosing the right software. Consider three examples: tightly synchronizing measurements, maintaining data traceability, and testing the software against the infinite number of real-world scenarios. Each of these is uniquely challenging; autonomous driving will require all three, but at what cost?

Technology: Distributed Versus Centralized Architectures

ADAS processing capabilities are based on multiple isolated control units; however, sensor fusion is driving the popularity of a singular centralized processor. Consider the Audi A8. In the 2019 model, Audi combined the required sensors, function portfolio, electronic hardware, and software architecture into a single central system. This central driver assistance controller computes an entire model of the vehicle's surroundings and activates all assistance systems. It has more processing power than all the systems in the previous model of the Audi A8 combined.

The primary concern with a centralized architecture is the cost of high-power processing, which is exacerbated by needing a secondary fusion controller somewhere else in the

> "[Helmut Matschi, member of the Executive Board, Interior Division, at Continental] said it all comes back to software engineering . . . With widespread use of high-performance computers in vehicles early next decade, development projects might direct as much as 80 percent of their budgets to software, he predicts."
>
> —— *Automotive News*, "Continental Bracing for a World of Bugs," 2018

car as a safety-critical backup. Preferences will likely alternate between distributed and centralized architectural design over time as the controller and its processing capabilities evolve, which means a software-defined tester design will be critical in keeping up with that evolution.

Strategy: In-House Versus Off-the-Shelf Technology

To achieve Level 5 autonomy, the microprocessor for autonomous vehicles needs 2000X more processing capability than the current microprocessors on controllers; therefore, it is quickly becoming more expensive than RF components in mmWave radar sensor systems. History has shown that an increasingly expensive capability that's in high demand draws the attention of leaders in adjacent markets, which drives competition among market incumbents.

As one data point, UBS estimates that the Chevrolet Bolt electric powertrain has 6X to 10X more semiconductor content than an equivalent internal combustion engine car. The semiconductor content will only continue to increase, and market adjacencies will provide invaluable off-the-shelf technology improvements. For instance, NVIDIA has adapted its Tegra platform, initially developed for consumer electronics, to target ADAS applications in automotive systems. Alternatively, DENSO has started designing and fabricating its own artificial intelligence microprocessor to reduce cost and energy consumption, and NSITEXE, Inc., a subsidiary of DENSO, has plans to release a dataflow processor, a next-generation processor IP called DFP in 2022. The race is on.

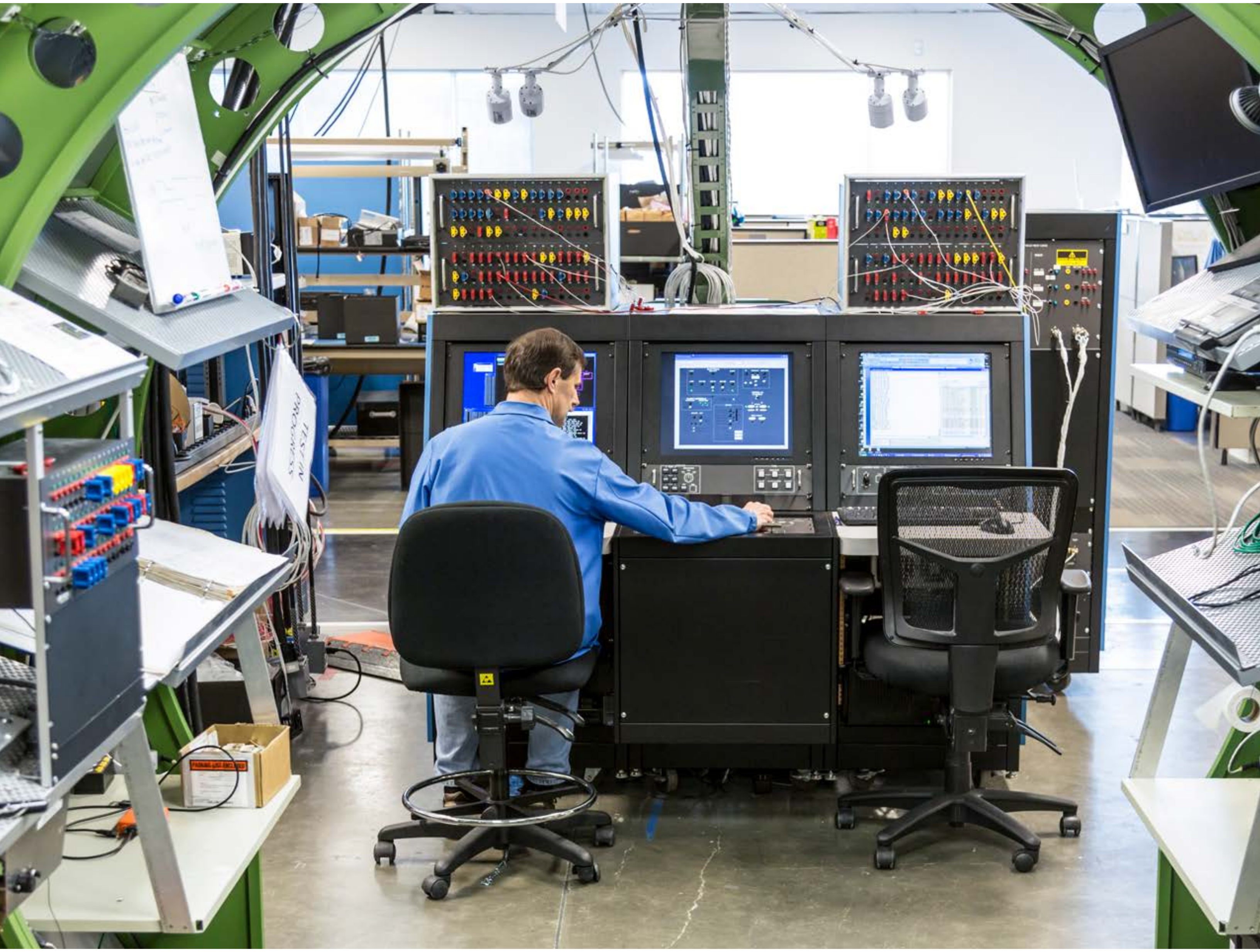
Optimizing the Trade-Offs

Decisions on these trade-offs will have a tremendous impact on time to market and differentiating capabilities throughout the supply chain. The ability to quickly reconfigure testers will be critical in minimizing validation and production test costs and times, so flexibility through software will be key. In an interview excerpt published March 4, 2018, on bloomberg.com, Dr. James Kuffner, CEO of the Toyota Research Institute-Advanced Development, said, "We're not just doubling down but quadrupling down in terms of the budget. We have nearly $4 billion USD to really have Toyota become a new mobility company that is world-class in software." This sentiment is not uncommon in automotive. There's no clear answer on these trade-offs yet, but, just like past industrial revolutions empowered people to afford new technologies through a higher productivity gain, increasing efficiency in software development will be integral to the autonomous driving revolution.

REDUNDANT VERSUS COMPLEMENTARY SENSOR CONSIDERATIONS

Good ● Better ●● Best ●●●

SPECIFICATIONS		CAMERA	RADAR	LIDAR
DISTANCE	RANGE	●●	●●●	●●●
	RESOLUTION	●●	●●●	●●
ANGLE	RANGE	●●●	●●	●●●
	RESOLUTION	●●●	●	●●
CLASSIFICATION	VELOCITY RESOLUTION	●	●●●	●●
	OBJECT CATEGORIZATION	●●●	●	●●
ENVIRONMENT	NIGHT TIME	●	●●●	●●●
	RAINY/CLOUDY WEATHER	●	●●●	●●



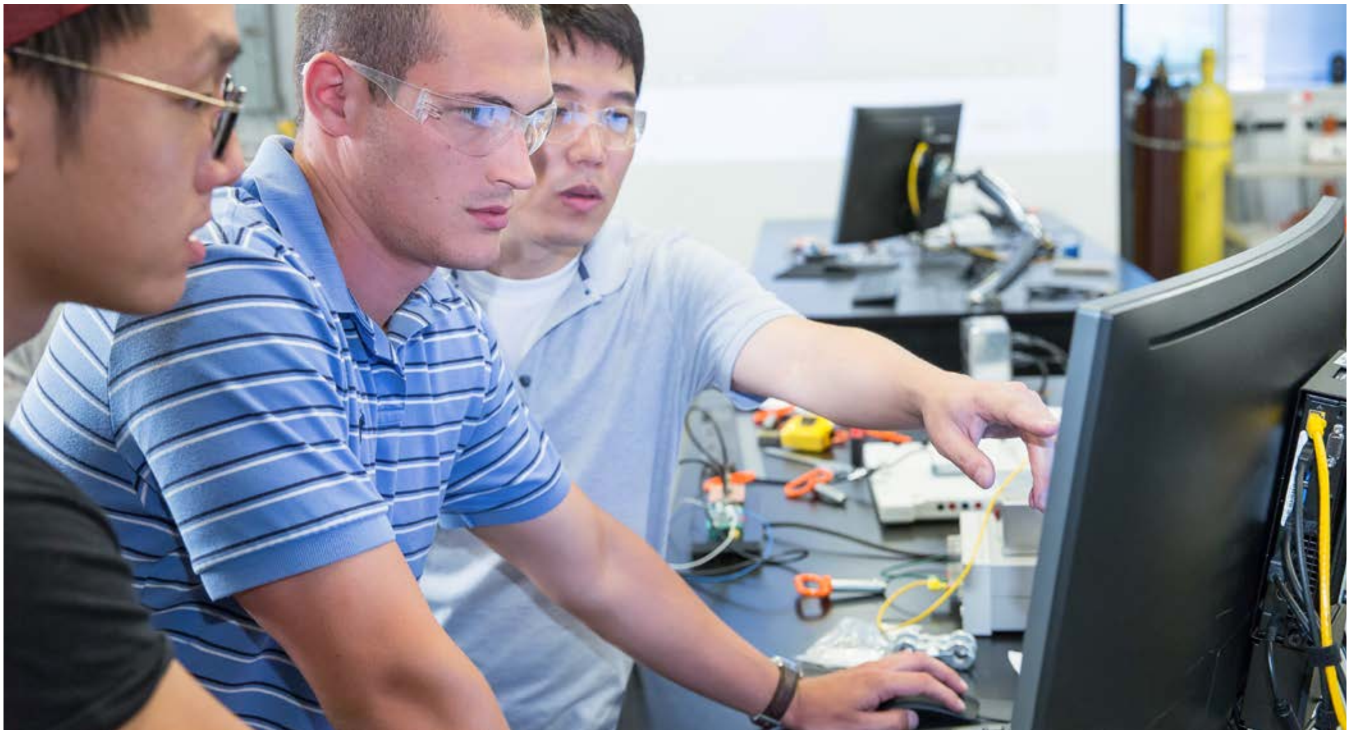
Nicholas Butler
NI Head of Aerospace
and Defense Marketing

Keep Pace With a Standardized Development Process

- Early standardizations focused on hardware abstraction, but modern technology is built on software.
- Iterative software development processes are getting better products to customers faster.
- Test organizations must move to standardized methods of iterative software development to remain competitive.

Standardization has been an aspirational objective in test organizations for decades. In 1961, D.B. Dobson and L.L. Wolff of Radio Corporation of America (RCA) published *Standardization of Electronic Test Equipment*. The paper presents the principles, criteria, and techniques used in the investigation and prototyping of multipurpose missile system test equipment.

The goal of most early technology standardization efforts was to limit the variety of test equipment used in test solutions across the organization. The key objective RCA achieved was the design and deployment of a modular hardware set. Modular hardware leads to higher equipment reuse, more integrated test solutions, fewer obsolete components, and an easier process for technology replacement.



With a large mix of products and assets that can stay in service up to 50 years, test groups in the aerospace and defense industry stand to benefit most from test systems that are more maintainable and reusable.

Security requirements and fast-paced changes are compelling modern test organizations to go far beyond just hardware standardization. They're now focusing on both software layers and the practices used to develop them. Test engineering teams must begin the process of adopting and standardizing on iterative software development to keep pace with product development teams and maintain project schedules in an industry that is quickly modernizing.

Software as the Backbone of Standardization

The RCA paper describes the process of identifying shared inputs and outputs across multiple functional components and missile programs to define the requirements of its modular hardware system. That process of identifying and separating common elements that can be addressed together is the basis of abstraction. Larger instrumentation standardization efforts and a move toward commercial off-the-shelf technology have led to modular hardware standards like VXI, PXI, PXIe, and AXIe that are used in test organizations across many industries. Standard modular hardware platforms abstract redundant elements like power supplies, cooling, and user interfaces to single points within the system.

In the report *Design and Acquisition of Software for Defense Systems*, the Defense Science Board (DSB) states, "many of the capabilities provided by our weapons systems are derived from the software of the system, not the hardware. This shift from hardware-enabled capabilities to software-enabled capabilities is increasing quickly." Modern instrumentation increasingly includes processors and software-defined components like FPGAs. To get the most out of these modern test solutions, defining measurement systems in software is not only beneficial but necessary.

The best test software engineering teams are building abstracted test software that delivers even more benefits than abstracted hardware provides. An abstracted software platform comprises layers that perform specific functions. This allows teams to repair and upgrade each module individually while isolating other layers by maintaining the same inputs and outputs. "With dozens of legacy business lines, software standardization has to address the history of each group," said Mark Keith, chief engineer at Honeywell Aerospace. "The purpose [of abstraction] is to minimize or eliminate the need for software modifications when that obsolete hardware is replaced."

> "With the rate of change in technology today, 30 years can feel like an eternity. Sometimes the best-in-class approaches of today just aren't compatible with the best-in-class approaches of the past."
>
> Mark Keith, Chief Engineer, Honeywell Aerospace

Modern Software Development for Test

At the pace new products and features are released in today's market, just organizing a test software architecture properly is no longer enough. The test software organization must implement practices that drive faster and more flexible delivery to manufacturing and the customer. To deliver all the demanded features, modern software engineering teams are moving to continuous iterative software development practices like Agile.

As stated in the DSB report, "The main benefit of iterative development is the ability to catch errors quickly and continuously, integrate new code with ease, and obtain user feedback throughout the development of the application." Iterative software development is now an industry-standard practice, and it "will help the [Department of Defense (DoD)] operate in today's dynamic security environment, where threats are changing faster than Waterfall development can handle."

Standardizing on Iterative Development

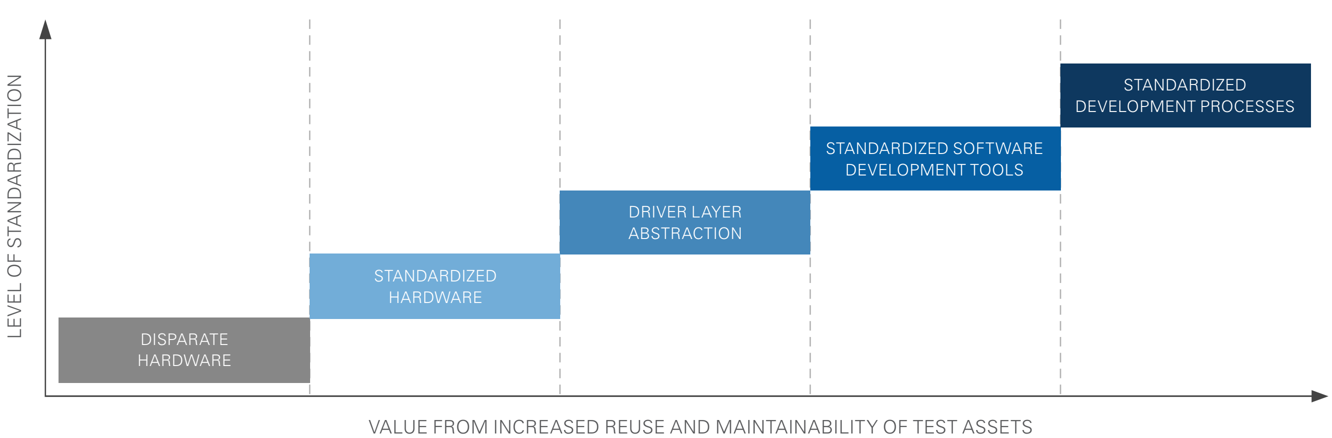
Iterative software development requires a well-orchestrated team that works cooperatively and, much like the abstraction of hardware platforms and software architectures, includes shared and repeated concepts and tasks.

Teams that collaborate on code bases must agree and standardize on tools for source code control, unit test frameworks, code analysis, work management, and deployment. A growing additional concern is cybersecurity. The DSB states, "Checking a software system's code base daily keeps manageable the number of changes required to comply with a large base of cyber rules."

In the report *Contracting Strategy for F-22 Modernization*, the Inspector General of the DoD states, "According to a Program Office official, the DoD is at risk of losing its technological edge against US adversaries and it needs to find innovative ways to bring capabilities to the warfighters faster." Aerospace and defense is not the only industry in which test teams are struggling to deliver better technology to market faster. Iterative development is a proven method for accelerating technology development across multiple industries.

While test engineering teams have been focusing on hardware standardization and tiered software architectures, R&D organizations have moved toward iterative product development. All aspects of standardization are important and valuable to test organizations, but standardization must be refined to work with the engineering practices under development today. Test organizations that adopt Agile software development practices are poised to capitalize on this approaching opportunity.

INCREASED VALUE OF STANDARDIZATION




IDT

Mike Santori
NI Business and
Technology Fellow

Making the IoT Work for Test

- The IoT and IIoT are making test more complex.
- IoT technologies can help address automated test challenges.
- Engineers need to understand and focus on the use cases with the most business value.

Internet of Things (IoT) devices and Industrial IoT (IIoT) systems are increasing in complexity, from semiconductors to electronic subsystems to the smart machines at the heart of Industry 4.0. Test is a hidden but critical function in this product chain, and increasing IoT device complexity is, in turn, increasing test complexity. The IoT can also greatly enhance automated test. Applying IoT capabilities such as systems management, data management, visualization and analytics, and application enablement to the automated test workflow can better equip test engineers to overcome the challenges of the IoT.

Managing Test Systems

Connected, managed devices are fundamental to the IoT and IIoT. Many test systems, however, are not connected or well managed, even as they become more distributed. Often, test engineers have difficulty tracing the software running on any given hardware or just knowing the whereabouts of systems, much less tracking performance, utilization, and health.

Fortunately, most modern test systems are based on a PC or PXI and can directly connect to the enterprise, which enables additional capabilities such as managing software and hardware components, tracking usage, and performing predictive maintenance to maximize the value of test investments.

Ingesting and Managing Data

The business value of the IoT derives from massive amounts of data generated by connected systems. Consuming test data is difficult, though, because of the many data formats and sources, from raw analog and digital waveforms in time and frequency to parametric measurements often gathered at significantly higher rates and volumes than from consumer or industrial devices. To make matters worse, test data is often stored in silos with little standardization. Consequently, this data is "invisible" to a business, making it easy to miss out on valuable insights at other phases of the product life cycle. Prior to implementing a comprehensive, IoT-enabled data management solution, Jaguar Land Rover (JLR) analyzed only 10 percent of its vehicle test data. JLR Powertrain Manager Simon Foster said, "We estimate that we now analyze up to 95 percent of our data and have reduced our test cost and number of annual tests because we do not have to rerun tests."

Applying IoT capabilities to automated test data begins with ready-to-use software adapters for ingesting standard data formats. These adapters must be built with an open, documented architecture to enable ingestion of new and unique data, including non-test data from design and production. Test systems must be able to share their data with standard IoT and IIoT platforms to unlock value from data at the enterprise level.

Visualizing and Analyzing Data

Using general business analytics software for test data can be difficult because this data is often complex and multidimensional. Also, typical business charting capabilities don't include common visualizations in test and measurement, like combined graphs of analog and digital signals, eye diagrams, Smith charts, and constellation plots.

> "It will soon become standard that our customers require the management and maintenance of test assets from around the world. We must reshape our test architectures to integrate IoT technologies, especially to evolve configuration management and data analytics and support the digitalization of our business for Industry 4.0."
>
> Franck Choplain, Digital Industry Director, Thales

Test-oriented schemas with appropriate metadata enable tools to provide visualization and analysis for test data and correlate it with design and production data. Well-organized test data allows engineers to apply analytics from basic statistics to artificial intelligence and machine learning. This enables workflows that integrate and leverage common tools, like Python, R, and The MathWorks, Inc. MATLAB® software, and generates greater insights from data.

Developing, Deploying, and Managing Test Software

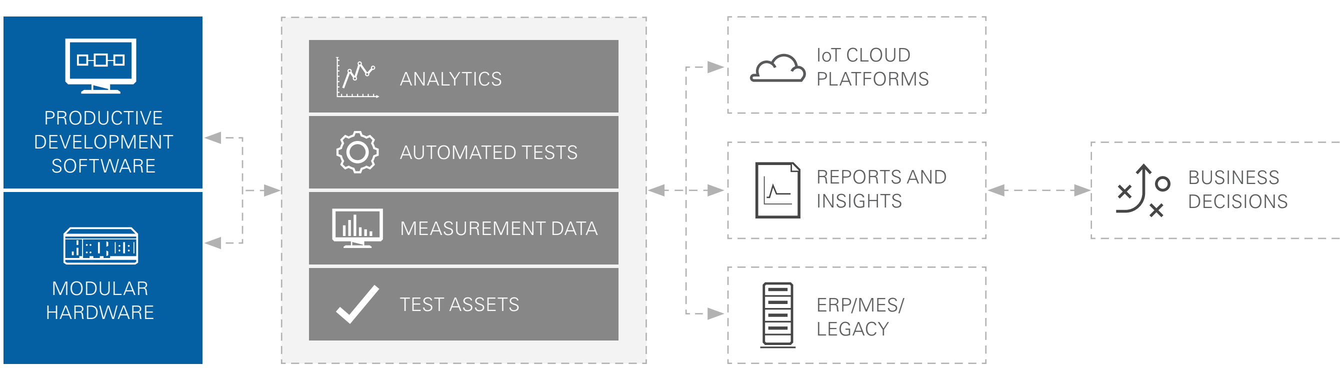
The world is moving from exclusively using desktop applications toward augmenting with web and mobile apps. This transformation can be difficult to realize for test. Computing at the device under test (DUT) is needed to process large amounts of data and make real-time pass/fail decisions, and local operators need to interact with the tester and the DUT. At the same time, companies want to remotely access testers to see results and operating status such as utilization. To address this, some companies have built one-off architectures to manage software centrally, and they download software to testers based on the DUT. But because of this, they must maintain their custom architecture, which requires additional resources that could be applied to activities with higher business value.

Higher level test management is a good candidate to move from the local tester to a cloud deployment. Web-based tools allow for viewing tester status, scheduling tests, and examining test data pushed to a cloud or server. Higher level management capability complements existing test systems built with common tools like NI LabVIEW, Microsoft .NET languages, NI TestStand, and Python. A modular test software architecture (test management, test code, measurement IP, instrument drivers, hardware abstraction layers) enables companies to evaluate the trade-offs of moving different software capabilities from local to server or cloud-based execution. As more of the test software stack moves to cloud deployments, companies will realize the benefits of cloud computing for data storage, scalable computing, and easy access to software and data from anywhere.

Taking Advantage of the IoT for Test

Leveraging the IoT for test is not a futuristic idea; it can be done today. An organization's ability to do so depends on its current automated test infrastructure and most pressing business needs. Some common areas to consider are improving test system management, increasing test equipment utilization, gaining better insight from test data, and remotely accessing shared test systems. A software-defined approach with a high degree of modularity allows businesses to focus on the areas of greatest value without having to make an all-or-nothing decision.

CONNECTED INTELLIGENCE FOR AUTOMATED TEST



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Luke Schreier
NI Vice President of Product
Management for Automated Test

Multi-Industry Convergence Disrupts Test Strategies

- Technologies and processes are crossing industry boundaries, creating both pain and potential for test leaders.
- Test strategies built on closed and proprietary methods put organizations at risk.
- Partnerships with multi-industry companies provide the insight needed to adapt test organizations in time.

Industry convergence is not a new concept; it may actually be one of the oldest. As markets interact, they naturally exchange ideas, processes, and technologies, which makes them grow more intertwined. Agriculture and trade collided to create banking. More recently, the overlapping potential of healthcare and consumer electronics created wearables. Our globally connected society is only increasing the speed and scale with which convergence opportunities present themselves.

The commentary on multi-industry convergence is vast. Blogs, articles, and analyst reports have noted that the acceleration from the digital revolution is upending long-established industries. But they rarely touch on how convergence will disrupt test organizations.

Companies are feeling its effects every day as a dichotomy of threat and potential. Best-in-class organizations are tackling convergence directly by leveraging multi-industry test platforms and partnering with and learning from other organizations with multi-industry exposure.

Creating Test Innovation

The often-cited 2014 Gartner report, *Industry Convergence: The Digital Industrial Revolution*, claims that "industry convergence represents the most fundamental growth opportunity for organizations." For test organizations, this opportunity will come through learning and leveraging from other industries and pooling resources to accelerate innovation.

Convergence at its core is centered around idea sharing. The concept of leveraging and learning from other industries to avoid wasting time and effort on creating something that already exists is often discussed in the context of product innovation, but the same can be applied to test strategies. Functional safety is a great example. Over decades of learning, and motivated by the safety-critical nature of its products, the heavy manufacturing industry developed a process for proving out the functional safety of its embedded electronics: IEC 61508. As other industries like rail and automotive added safety-critical embedded systems to their architectures, they extended and adapted IEC 61508 for their industries with EN 50126 and ISO 26262. Learning from experts in these standards can save time when adding functional safety testing to test strategy if and when it becomes necessary.

Multi-industry resource pooling is a less obvious benefit of convergence. As industries move closer together, their functional needs align more closely. This allows vendors that serve these industries to increase investment because the market for that need is now larger. In test, platform-based vendors can increase their industry-agnostic investment in things like processors or analog-to-digital converters to provide better quality products at lower prices to all industries. When investments are made in hardware, software, or services for test, multi-industry solutions, as opposed to single-industry options, maximize the opportunity for technology leverage.

> "Industry convergence represents the most fundamental growth opportunity for organizations."
>
> *Industry Convergence: The Digital Industrial Revolution*, Gartner, 2014

Overcoming the Cost of Convergence

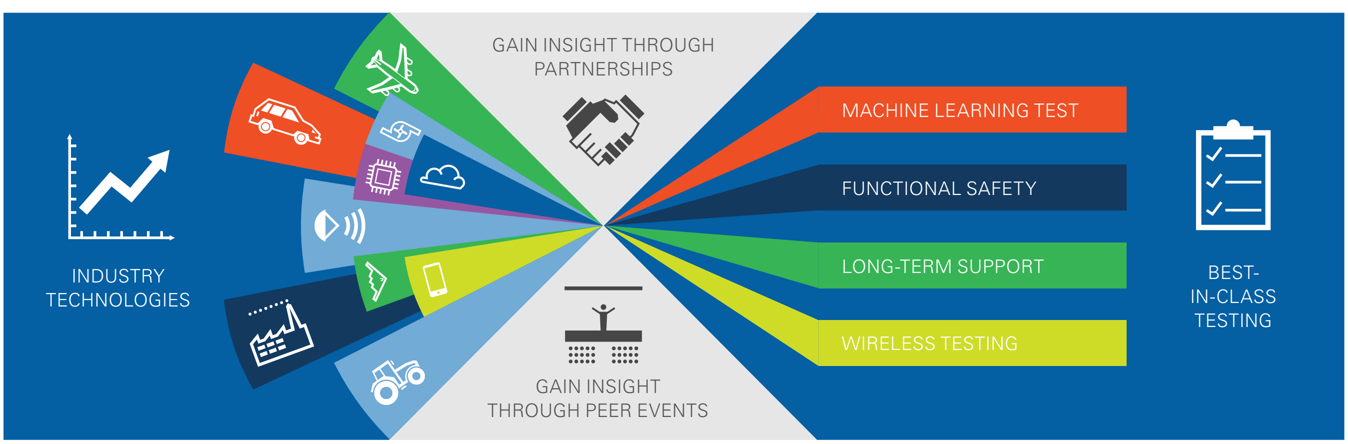
IBM's 2016 *Redefining Boundaries* study of C-suite professionals revealed that "industry convergence clearly eclipses any of the other trends they anticipate in the coming three to five years." Despite its potential upside, convergence tends to raise more concern than excitement, though. For test managers, it adds complexity and demands more adaptable test platforms and even more flexible organizations.

As industries adopt technologies from one another, they need testing and expertise in these new technology domains. Automotive hybrid powertrains, for example, now require systems that can test controls, mechanics, thermodynamics, electronics, software, and even battery chemistries. This has made test systems from even a few years ago obsolete if they were built on inflexible, closed, and proprietary platforms. Instead, test systems should use open and modular hardware and software that work across I/O types, programming languages, and vendors, along with well-defined APIs and interoperability standards.

This is even more challenging when organizations don't know what's next. In the age of convergence, the future is much hazier. Companies, test strategies, and test platforms should be designed to quickly adapt to whatever the future may hold. For example, aerospace companies, which have historically moved very conservatively and relied on long product life cycles, now need to be nimbler as their supply chain grows more closely tied to that of consumer electronics. As a result, aerospace test organizations need their testers to keep up with a much faster technology refresh rate, and designing test architectures with this adaptability is critical. Attending cross-industry networking events and monitoring other industries' trade publications can help educate teams on the latest trends.

Even better, collaborating with organizations that have multi-industry experience can help companies absorb unforeseen circumstances more effectively and leverage best practices from other industries. These companies can outsource their biggest problems to third parties that have already solved them or look for strategic partnerships in other industries around imminent trends like 5G and IoT. NVIDIA and Audi partnering to accelerate technology development or Boeing and Embraer collaborating to take market share from competitors are just two of the many examples of how this type of cooperation can lift organizations above their industry peers. Reevaluating where test happens in the supply chain and reviewing suppliers are also smart tactics. By being proactive, organizations can be prepared for what's next and maybe even influence it.

LEVERAGE CONVERGING TECHNOLOGIES FOR A BEST-IN-CLASS TEST ORGANIZATION



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