NI Trend Watch 2018

FUTURE FASTER

Future Faster

We're almost 20 years into the 21st century and, from self-learning robots to affordable genome sequencing and ubiquitous data storage, it's undeniable that technology has never advanced faster. At this pace, we need to think critically about where we're headed and how we'll get there.

Shelley Gretlein
Vice President
Corporate Marketing
National Instruments

Some of the most exciting recent advancements include artificial intelligence and cloud computation outperforming a human 10 years sooner than predicted, and silicon-germanium heterobipolar transistors setting new speed parameter standards. Additionally, the NIO EP9 electric supercar set a record by autonomously completing the 3.4-mile Circuit of Americas track in 2:40:33 at 160 mph, and a prototyped hyperloop system promises to propel passengers to their destinations at an average speed of 600 mph. With this momentum, 2018 will undoubtedly be another banner year for technical progress.

The coming year will also generate new business insights with Big Analog Data™ solutions and increasingly capable machine learning. We'll continue to experience major milestones for connected vehicles and smart factories, see significant decreases in test times of increasingly complex semiconductors, and witness exciting progress in 5G for communications and connectedness.

As we all race into the future, NI will keep its customers one step ahead with an open, software-centric platform designed to accelerate the development of any user-defined test, measurement, or control system. Are you ready for the future?

Articles

3 Mandates for Successfully Managing Your Things

The proliferation of smart and connected “things” in the Industrial Internet of Things (IIoT) provides tremendous opportunities for increased performance and lower costs, but managing these distributed systems is often an overlooked challenge.

5G Progress Set to Disrupt Test Processes

5G innovation doesn’t stop at design. Test and measurement solutions will be key in the commercialization cycle, but 5G requires a different approach to test than previous wireless technologies. Find out what it’s going to take to make 5G a reality.

Breaking Moore’s Law

The constant pace of innovation has tracked remarkably close to Moore’s law for decades, despite a few minor revisions and much talk of its death. But now, the more than 50-year-old observation is facing health challenges again. Learn what that means for the future of the semiconductor market.

Vehicle Electrification: Disrupting the Automotive Industry and Beyond

The vehicle electrification trend goes deeper than a global shift from internal combustion and hybrid vehicles to fully electric powertrains. Consider implications beyond the increasingly complex vehicle itself, including new demands on supporting infrastructure.

Automating Engineering Insights With Machine Learning

Intelligent systems create and rely on data, but the ever-increasing quantity of data exacerbates the Big Analog Data™ challenge. Discover how machine learning addresses the problem head-on, so engineers can focus on finding and solving the next grand challenge.

3 Mandates for Successfully Managing Your Things

The Industrial Internet of Things (IIoT) has quickly evolved from concepts and pilot projects to fleet-wide deployments with impressive returns. These returns are based largely on the actionable, data-driven insights that have equipped forward-looking companies, such as Jaguar Land Rover, China Steel, and Duke Energy, to maximize uptime, boost performance, and drive future product innovation. Industry is evolving to become smarter and more connected. Late adopters of the IIoT risk losing market share and incurring unnecessary costs by not keeping up with the pace of innovation. In fact, "95 percent of business leaders expect their company to use the IIoT within the next three years," according to Accenture's Connected Business Transformation report from March 2017.

With today's edge node hardware and analytics software, it's fairly straightforward to extract business benefits from small-scale IIoT pilots for predictive maintenance and connected smart machine control. Technologies are readily available today to enable a growing volume of connected systems and uncover engineering and operational intelligence management challenges that will define the continuing evolution of the IIoT. Attention and investment are now shifting toward the next challenge: scaling and managing large IIoT deployments, including remote systems management, software configuration management, and data management.

1. **Remote Systems Management**
   With reduced operational technology costs, systems that monitor and control critical assets have become prevalent. Asset and maintenance managers now face the challenge of implementing cost-effective strategies to manage those operational technologies and minimize asset downtime. Companies can harness the flexibility cloud-hosted technologies offer to implement remote system management solutions that provide useful insights into the state of multiple connected systems.

   Successful remote system management solutions will need to address system aspects such as provisioning, configuration, diagnostics, and edge device administration. Remote system management capabilities often include monitoring system parameters, such as memory and CPU usage, networking, and I/O statistics, at the task or process level to help minimize the impact of downtime due to software bugs and discover potential security breaches.

> "Ninety-five percent of business leaders expect their company to use the IIoT within the next three years."
>
> —Accenture, 2017

2. **Software Configuration Management**
   The IIoT market is setting high expectations for continuous delivery and improvement. Increasing pressure to get to market quickly demands flexibility from software to fix bugs, modify functionality, and respond to security vulnerabilities. Failing to implement effective software management strategies can lead to systems running outdated software, which can impact asset performance, security, and reliability. IIoT companies can implement proven frameworks and best practices to avoid the costs and inefficiencies of manual software distribution.

Effective software configuration management strategies in industrial settings will operate in highly dynamic, heterogeneous environments where system availability and network stability are variables. A high mix of systems from multiple vendors operating at different levels of the IIoT network will require technologies capable of tracking and controlling granular software changes at the application and firmware levels of each system. Going forward, companies will need to transition to platforms that incorporate software configuration management best practices to navigate the often-blurry boundaries between operational technology (OT) and mainstream IT solutions without impacting the business.

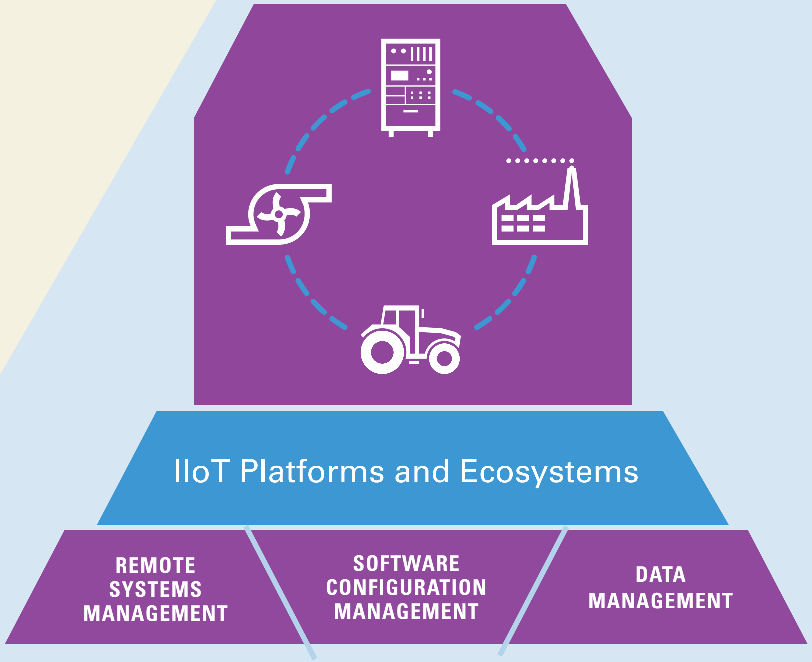
3. Data Management

IIoT systems can generate massive amounts of data in the order of terabytes and potentially exabytes. Managing this amount of data to obtain actionable insights is a vector of differentiation that companies must address to understand their business and implement improvements. Valuable information is hidden in the oceans of data produced by IIoT systems, and these insights can be unlocked using intelligent and advanced signal processing. As data management technologies become more accessible, companies have a range of options to manage their data and obtain insights across all levels of the organization.

Data management strategies need to include analysis features that operate at both the edge and enterprise levels. According to "IDC FutureScape: Worldwide Internet of Things 2017 Predictions," by 2019, at least 40 percent of IoT-created data will be stored, processed, analyzed, and acted upon at the edge. An effective data management solution needs to incorporate data from multiple distributed sources and produce different levels of insights to get the right information in front of the right people so they can translate raw data into informed decisions.

The Time Is Now: The Power of Platforms

Building IIoT solutions today represents an opportunity to develop a competitive edge and avoid getting left behind as the market continues to embrace available solutions. Companies across all industries are adopting a new breed of disruptive platforms and ecosystems that will transform businesses into engines of innovation and growth by exploiting intelligent technologies such as sensor-driven computing, industrial analytics, and intelligent machine applications. With IIoT technologies, we can harness the benefits of these state-of-the-art platforms to ultimately reduce maintenance costs and improve asset utilization.



5G Progress Set to Disrupt Test Processes

5G signifies a generational transformation that will profoundly impact businesses and consumers across the globe. It promises a revolutionary untethered experience with much faster data, shorter network response times (lower latency), instant access anywhere and everywhere, and the capacity for billions of devices. We're not just talking about being able to download a video to your phone faster. Unlike 3G and 4G, 5G looks to expand far beyond our mobile devices and into applications that touch all facets of our lives. From enabling the Industrial Internet of Things to ensuring the safety of autonomous vehicles, 5G will change our lives in ways that are hard to even imagine.

> "Ten years from now, we're going to look back and say that 5G was one of the most important pieces of technology ever. It enables everything we see today that's emerging, whether it's self-driving cars that talk to each other or just having the most amazing video experience."
>
> —Patrick Moorhead, President and Principal Analyst, Moor Insights and Strategy

The Road to 5G

The 3GPP standardization body is furiously marching toward defining 5G, but the real work is just beginning. Companies specializing in semiconductor, network infrastructure, cloud, software, manufacturing, and test technologies must now design, develop, test, and deliver solutions that take advantage of these new wireless capabilities. This is no easy task.

5G features new technologies such as Massive MIMO and mmWave. Both technologies use multiple antennas and beamforming, which is a huge departure from current and previous wireless architectures. 5G also includes new wireless control mechanisms that split the control and data to facilitate the concept of network slicing, which scales the level of service to an individual user device.

In addition, the standards proposed for 5G are far more complex than 3G and 4G standards. 5G will transform our networks, so the industry must transform the way these systems are designed, developed, and tested. For algorithm design, simply modeling systems without any real-world validation has not been enough for an idea to advance from concept to production. For test, traditional methods that focus on an individual component will not be able to account for the overall impact to the system.

A Platform-Based Approach

Wireless researchers across the world quickly discovered that the only path to success is via a platform-based approach to 5G with software at the core. Nokia introduced the first mmWave 5G prototype at 73 GHz and broke the record for mobile access data rates using mmWave spectrum. Lund University developed the first Massive MIMO prototype, and researchers at the University of Bristol and Facebook extended their Massive MIMO prototypes to achieve unprecedented spectrum efficiency milestones.

These system prototypes have already played an important part in the 5G technology evolution. The platform-based design approach used in these examples takes full advantage of software defined radios (SDRs) to tackle system challenges and reduce time to results. SDRs for design and prototyping will continue to evolve as the software changes. We can even envision more capable SDRs with software extending beyond the physical layer to leverage the vast ecosystem of open source software. This will enable researchers to address both the upper layers and the network to further decrease time to adoption and shatter the siloed approach to design.

5G Innovation Doesn't Stop at Design

Test and measurement solutions will be key in the commercialization cycle. Test systems must expand beyond the physical layer to quickly and cost-efficiently test these new multiantenna technologies with controllable/steerable beams. Additionally, these systems must address the new mmWave-capable devices with extremely wide bandwidths. These test solutions must not only be able to test the important parameters of a device but also be cost-effective for 5G to reach its potential and achieve widespread adoption.

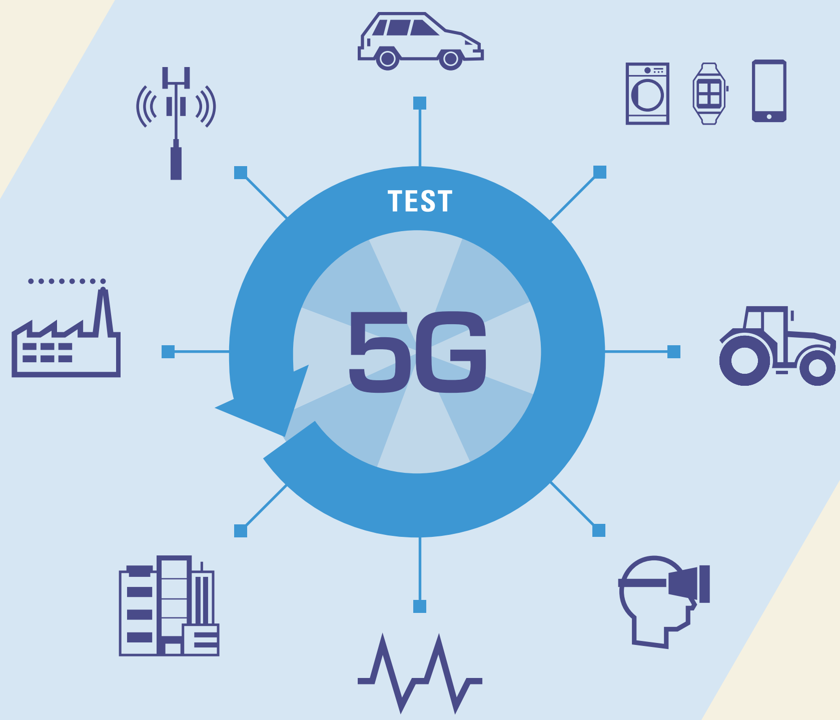
With these characteristics, 5G requires a different approach to test for wireless devices and systems. For example, system-level over-the-air (OTA) test must become standard in the 5G ecosystem. OTA test presents several challenges but perhaps the most daunting pertains to the environment in which the test equipment and the device under test must coexist. Air is an unpredictable medium, and the channel itself varies over time and environmental conditions. Wireless test engineers must isolate the channel in the OTA scenario and control the device on a per beam basis to effectively "test" the device.

In addition, companies like Intel have introduced early phased array antenna modules featuring an antenna attached directly to the RF front end to minimize system losses. Because access to the device is limited, the test equipment must step up in frequency to the mmWave bands and characterize key performance metrics beam by beam.

Finally, whereas bandwidth is a familiar test challenge, the tested bandwidth of 5G is expected to increase by 50X over a standard LTE channel. At these bandwidths, test systems must not only generate and acquire wider bandwidth waveforms but also process all that data in real time.

What's Next

Wireless researchers have embraced a platform design approach using SDRs to expedite the early research phase of 5G, and they have delivered. Now, test solution providers must do the same. 5G presents a paradigm shift the likes of which we've never seen before, and a platform-based approach that is flexible and software configurable will be essential to the development of this ecosystem.



Breaking Moore's Law

Much has been published recently on the death of Moore's law. Though the more than 50-year-old observation is facing health challenges again, don't start digging the grave for the semiconductor and electronics market. Gordon Moore, cofounder of Intel, famously observed the rate at which transistors on a semiconductor doubled, initially every 12 months and then approximately every 24 months. Despite a few minor revisions, semiconductor processing has tracked remarkably closely to that observation for decades. This "free" scaling allowed similar architectural designs to be reimplemented, which provided the lower costs, lower power, and higher speeds expected from the growing curve. Does the disappearance of this free scaling signal the end of advancements in computing? Though this threat is serious enough to inspire DARPA to increase funding for researching a post-Moore's law world, scientists and engineers have a history of overcoming the scaling hurdles, and some innovative alternatives to pure semiconductor scaling paint a bright and interesting future. "The end of Moore's law could be an inflection point," said Dr. Peter Lee, corporate vice president of Microsoft Research, in the March 2016 Technology Quarterly by *The Economist*. "It's full of challenges—but it's also a chance to strike out in different directions, and to really shake things up."

> "The end of Moore's law could be an inflection point. It's full of challenges—but it's also a chance to strike out in different directions, and to really shake things up."
>
> —Dr. Peter Lee, Corporate Vice President, Microsoft Research

History of Breaking the Law

Moore's law specifically relates to the number of transistors on a semiconductor device, but it is often confused with the other benefits of semiconductor scaling such as higher speed and lower power. These expected benefits of scaling held true for decades but are no longer easy or expected. Processor cooling stalled the exponential rise of processor frequency technology, but this apparent "wall" spurred innovations that made the multicore processor commonplace. Though core frequency growth has been limited, PC system performance has continued to scale with the addition of multiple cores and special vector processing units that speed up graphics, games, and video playback. These additions created new challenges in developing software models to best use these new processing blocks. Along with generating processing architecture changes, high-speed transistors have been applied outside the CPU to the I/O subsystems that feed the processors with higher bandwidth from networks, cameras, and data collection. Applications of high-speed signal processing to wireless and wired standards have created a growth in I/O bandwidth that has exceeded simple transistor frequency scaling.

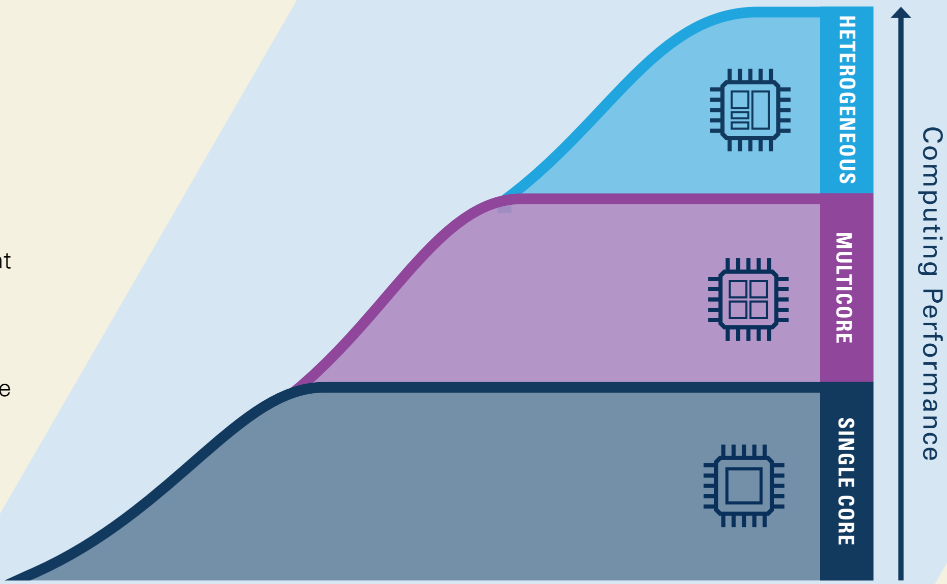
Using the Third Dimension

Previous predictions of the end of Moore's law have been met with breakthroughs in chip design. The current techniques to better leverage the third dimension by stacking chips and transistors will continue to increase density, but they may create new design and test problems. For example, the spiraling cost of smaller transistors has required new chips to combine more system functions to justify the higher price. This advanced "system on a chip" approach is demonstrated by the evolution of the FPGA from a simple array of logic gates into a high-performance I/O and processing system that combines processors, DSPs, memory, and data interfaces into a single chip. Many of the emerging options to scale chip density rely on using a third dimension in both how transistors are built and how 3D-IC technology can be used to combine existing chips into a single package. Though these systems on a chip are more complex to design and test, they were created to lower the end-system design cost with their high level of integration. Even with this benefit, chip stacking involves new complexities that present new challenges. As more systems rely on 3D scaling, the debug and test challenges will become more obvious, and more silicon area will be used to provide integrated debugging and test features.

New Computing Architectures

History has shown that previous scaling problems have encouraged novel architectural improvements that better leverage silicon technology. The latest challenges created the purpose-built computing era for which multiple, unique computing architecture types are combined and applied to problems. This trend grew popular with graphics processors that complement general-purpose CPUs, but that technique is rapidly expanding with custom-built computing acceleration using FPGAs, vector processors, and even application-specific computing blocks. These speed-up techniques, like those used for machine learning, will become the next standard blocks added to the system on a chip of tomorrow. The key to leveraging these mixed-processing architectures is software tools and frameworks that help users design with a high-level description for deployment to a variety of processing engines for acceleration. The initial struggle to exploit parallelism in the multicore chips will repeat as heterogeneous computing becomes the option for scaling.

And though the viability of the venerable Moore’s law is being threatened again, market needs such as machine learning and autonomous driving will require continued scaling in processing capability and I/O bandwidth, which presents a fresh opportunity to drive new architectural innovations.



Vehicle Electrification: Disrupting the Automotive Industry and Beyond

Around the globe, governments are announcing mandates that will bring about the demise of the internal combustion engine. China has led the charge by requiring 8 percent of new vehicles on the road to be "new energy" or zero emission vehicles in 2018, a huge growth over the current 2 to 3 percent on the road today. Similar strong government regulations limiting the future of the internal combustion engine have passed around the world, and the importance and growth of the hybrid and fully electric automobile industry can't be overstated. Volvo has possibly taken the strongest stance of the automotive manufacturers by pledging to make only hybrid or fully electric cars by 2019 and committing to sell more than 1 million electric vehicles by 2025. "This announcement marks the end of the solely combustion engine-powered car," said Hakan Samuelsson, president and CEO of Volvo, in a July 2017 statement.

> "This announcement marks the end of the solely combustion engine-powered car."
>
> —Hakan Samuelsson, President and CEO, Volvo

More Than Just EV/HEV

The move from internal combustion to hybrid and then fully electric power plants represents only the most visible portion of the aggressive growth of power electronics systems in vehicles. Electrification applies just as significantly to vehicle subsystems. As recently as 10 years ago, a fully mechanical coupling between the steering wheel and the front wheels was not unusual. The steering wheel connected to a shaft that connected to a rack-and-pinion system that turned the wheels, and even a more efficient hydraulic version of the system still maintained a mechanical coupling between the steering wheel and the tires. The story is similar for the accelerator pedal and manual transmission.

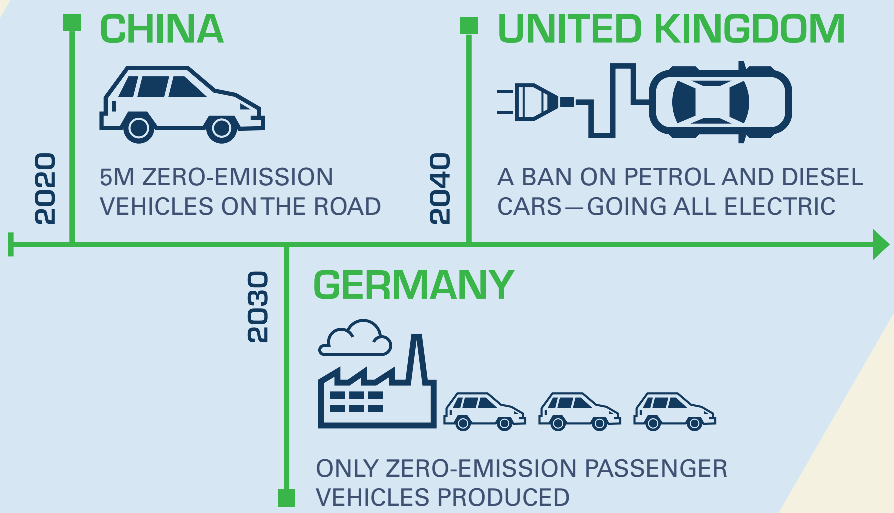
The explosion of drive-by-wire technology throughout the modern vehicle has changed this paradigm. A sensor, a remote actuator, and multiple control systems have replaced the mechanical linkage. Instead of a direct connection between the steering wheel and the front tires, a sensor on the steering column now measures the angle of the wheel. An embedded controller then translates that measurement into an angle and sends the value to the vehicle's communication bus. Elsewhere on the communication bus, another controller picks up the value, translates that into an angle of the wheel potentially based on vehicle speed and driver settings, and then commands an actuator to move the wheel to a desired angle. In many vehicles, a safety system sits in the middle of this drive-by-wire steering system to make sure the vehicle stays in the traffic lane and avoids obstacles in the roadway. As the number of power electronics subsystems in the vehicle grows, the automobile itself begins to look like an electrical microgrid with a common power bus connecting a growing list of sources and sinks of power, each managed by an independent embedded control system.

The Broader Impact

Taking a slightly broader look at the implications of government automotive mandates, the exponential growth in electrification and the impending end of internal combustion engines represent a radical change in the infrastructure required to support the shift in vehicle power plants. A car with an internal combustion engine requires roughly 10 minutes at nearly any street corner's gas station to fill up its tank for another 300 miles of driving. However, even with a dedicated supercharger, a similar pit stop requires at least an hour for a fully electric vehicle to charge. Even for the slow recharge associated with a daily commute, the required charging hardware needs some thought. For homeowners, installing an overnight charging station might be as simple as putting in a high-current circuit in the garage, but this becomes more complicated for a renter in a house or an apartment. If a car owner happens to live in a city and parks on the street, the concept of a home-charging station might be completely impossible.

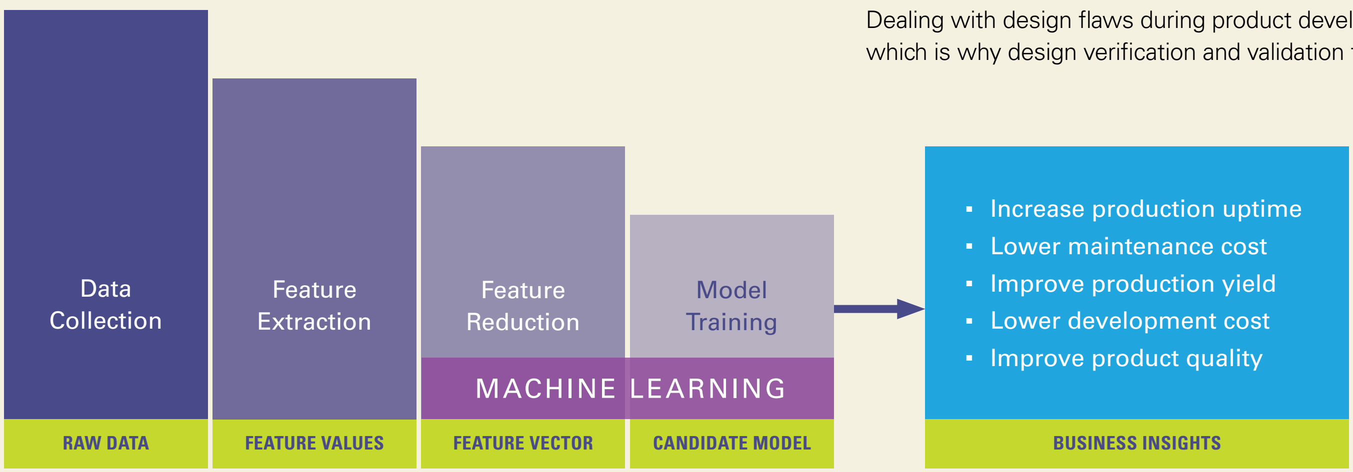
Looking at the future of vehicle electrification from the prospective of the electrical utility, the cyclic demands based on the daily workforce schedule combined with the high-load demands of fast charging present incredible new challenges for the electrical grid. If an entire workforce returns home at 5:00 p.m. and plugs in its electric vehicles around the same time, this shifts the timing of the typical peak demand on the grid and refocuses the regional peak consumption from heating or cooling toward transportation. On the larger scale of a gas station, a collection of the superchargers for fast charging will require an amount of energy similar to that of a medium-sized neighborhood.

The government-mandated trend of electric vehicles directly leads to growth in the complexity of vehicles and indirectly leads to an immediate need for growth in infrastructure. The future of the automotive industry will drive the future of the grid, which will require smarter control systems. Turning this into reality represents a truly interdisciplinary challenge to build safe and reliable control systems among other needs. To get to market quickly, this will require an increased reliance on real-time test, production test, and ecosystem partners who have vertical expertise building tools on top of an industry-leading, flexible, and open platform. With the right tools, engineers can adapt to the disruptive technologies vehicle electrification will require.



Automating Engineering Insights With Machine Learning

Machine learning has already delivered remarkable results in certain niches where pattern recognition is obvious, but it's making even bigger and longer lasting impacts on businesses that demand broad insights and efficiencies in their industries. The investments of tech giants in machine learning applications are drawing a lot of attention. Google's largest collection of developers outside its US headquarters is a research group dedicated to machine learning. Microsoft open sourced CNTK, Baidu released PaddlePaddle, Amazon decided to support MXNet on AWS, and Facebook created two deep learning frameworks. The wave of machine learning applications in the consumer space will spill over into industry, which will help engineers and managers improve business operations with automated data analysis. In addition to driving innovation, machine learning offers practical, here-and-now business improvements such as operational uptime, production yield, and engineering efficiency.



Machine Learning Feeds on Data

The ability to network intelligent systems to improve data visibility is well-documented as both an Internet of Things (IoT) benefit and a Big Analog Data™ challenge. ABI Research (QTR 1 2017) says sensor and machine data from industrial equipment is expected to top 78 exabytes by 2020, and somewhere among all that data will be evidence of a machine failure, manufacturing defect, or critical validation test missed by today's technology. Vast data sets will help train better models from machine learning algorithms and yield faster results, but only if they're available. Today's system designers need to view organized data collection as the first step to implementing machine learning technology and develop more comprehensive DAQ and management strategies for connected systems.

Driving Innovation

Dealing with design flaws during product development can be expensive, which is why design verification and validation test receives so much time, attention, and budget. Before machine learning can help focus costly engineering time on the product areas that need the most test and validation, historical test data needs to be organized and accessible.

Improving Yield

Most manufacturers today screen for pass/fail conditions and save data for forensic analysis, calibration records, and genealogy. Some manufacturers use more advanced automated test methods, but machine learning models can help them screen for product defects regardless of root cause. Did the silicon-level components on the current build come from a new fab? Does the design include counterfeit components? Is the wave-soldering temperature off because of a faulty sensor? Endless anomalies can cause defects, so setting up test limits for all of them is not practical (or possible). Machine learning technology will alert manufacturing test engineers to defects missed in the design and test phases of product development.

Increasing Uptime

Many companies in process manufacturing or other process industries have extensive databases of maintenance and operational data for their industrial assets. Maintenance engineers manually work with this data today, but future machine learning methods will process this data to classify operational states and detect anomalies. Properly trained systems will identify irregularities that need attention and alert maintenance personnel for troubleshooting.

Taking Advantage of the Edge

In many ways, the stage is already set for machine learning. The convergence of rugged processing and sensor fusion with machine learning will help engineers build better systems that can interpret data at the edge without needing to communicate with the enterprise stack. Some technology can already train and run models at the edge to give engineers the following system architecture options: model training and deployment in the cloud, at the edge, or both. Pushing intelligence to the edge with real-world signals reduces the latency of decisions and the need for costly infrastructure, which helps as billions of new devices come online and compete for limited bandwidth.

Platforms Will Harness the Power of Machine Learning

One key element to watch for is the incorporation of machine learning in technology platforms that help developers focus on new problems, save time stitching together adjacent technologies, and avoid getting lost in middleware. Engineers rarely want to spend time dealing with questions that have already been answered or deemed necessary only because of toolchains. What cloud analytics are supported? Whose cloud? Are there RTOS compatibility issues when deploying the models? Integrating machine learning into cloud, software, and hardware platforms will provide precurated technology stacks so engineers can focus on new challenges.

> "Huge opportunities exist to extract insights hidden in the disparate business information systems most businesses have today. A machine learning platform can quickly pull this data together along with newly acquired IoT sensor data. Let the platform do the non-value-add work so the business can focus on deriving actionable insight."
>
> —Andy Timm, Chief Technology Officer, PTC

Machine learning applications today can impressively find pictures of a dog in a photo album, but business leaders are looking to engineers, platforms, and the next wave of machine learning to help find uptime, yield, and efficiency in a sea of Big Analog Data.

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
ni.com/trend-watch