



NI Trend Watch 2015

Technology Trends That Accelerate Your Productivity

Technology Trends in 2015: The Platform is King of the IoT Era

The next time you walk down the street, pause for a moment and look around. I bet the majority of people you see are using a device to talk, text, tweet, or connect with someone else. The world has long been composed of systems that are connected or intelligent but not both (think HVAC units, automobiles, or electrical grids).

Connected systems like telephone lines and light switches can transmit information or state but offer little to no intelligence. Intelligent systems such as engine control units and thermostats have onboard processing intelligence, but they can't communicate outside the closed circuit. Today, the people you see connecting around you are using systems that marry the two concepts to become both intelligent and connected. What you see on your walk is the Internet of Things (IoT): a convergence of systems that have traditionally been disparate.

This connectedness, particularly in the industrial and consumer spaces, increases the demands on traditional design and manufacturing test systems. Once popular options like fixed-function, black-box instrumentation and turnkey data-logging software can't keep up with the number of standards, protocols, and functionalities that modern business demands. These systems of systems require software that meets key requirements like prototype to deploy, flexibility, and decision making at the node. If you are building a system today, you need a foundation to stand on that adapts to and even anticipates changing system requirements. We think that foundation is a platform-based approach.

In their book, *The Power of Product Platforms*, Meyer and Lehnerd define a framework for developing product platforms. They said that instead of building each product from the ground up for a specific application, you should invest in a set of common building blocks that you can aggregate in different ways to create a product platform and specific applications. Software programmers are similarly taught to modularize their code to optimize its reuse across projects. Though there is certainly R&D leverage for the vendor, the value for the end user is rapid innovation. You can develop "common" functionality such as licensing, data communication protocols, and data visualization as core building blocks, so the development team can focus on segmenting functionality such as unique design flows, IP, or target connectivity.

Consider Black and Decker's reusable battery design. This common functionality means the saw team and the leaf blower team aren't independently investing in battery architecture; instead, a core team provides best-in-class battery reuse and the saw team can focus on value specific to the saw.

The fundamental case for a platform-based approach and what originally defined "virtual instrumentation" revolved around the use of a standardized platform (PC) to automate the collection of data from benchtop instruments. The current platform-based design strategy is defined by the combination of modular hardware components that you can program using compelling, configurable software to define functionality that best suits the needs of your application.

As market leaders, NI is committed to staying ahead of the technology curve, thinking beyond the current challenges, and providing flexible solutions and technologies with a platform-based approach for software to design for the unknown future. You can't build future systems based on the energy infrastructure of today or on the wireless standards we currently understand. We innovate for the future based on system architectures we don't yet understand, technologies not yet finalized, and communication protocols not yet approved.

To do that, we must read and understand today's trends as more than just flash-in-the-pan, vogue technologies. We must learn the trend and apply it, to shape the trajectory of that trend in our favor. This report focuses on the IoT and other trends that a platform-based approach to engineering will impact.



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5G: The Internet for Everyone and Everything



With the introduction of the smartphone, wireless data has become an indispensable part of everyday life for many. Few actually acknowledged the transformational impact of the “mobile Internet” as Apple and others introduced highly functional smart devices. We simply reveled in all of the new and useful things we could do with our mobile devices. For many, wireless data and the mobile Internet simply equate to streaming YouTube videos anytime, anywhere, but they have changed our lives much more than that.

Though today’s 4G networks incorporate the latest technologies and continue to offer faster data access, the road beyond LTE and LTE-A is far from clear. The rapid consumption of wireless data continues to outpace the industry’s ability to meet demand. However, faster data and greater access are only part of the story. The mobile Internet has painted a picture of continued innovation and inspired researchers all over the world to think beyond faster data and greater capacity. These new networks, referred to as fifth generation or 5G, may transform our lives yet again and unleash enormous economic potential.

What is 5G?

It is clear: 5G networks must accommodate many more users and devices while delivering more data to each user at any instant in time. Since the dawn of digital communications in the 1990s, the cellular technology roadmap has followed a rigid path focused on increasing capacity and data rates to ultimately arrive where we are today. Now that the mobile Internet is a reality, a new vision has been cast. Researchers envision not only a 5G network with unprecedented data rates and mobile access but also an opportunity to redefine the network to accommodate a wealth of new and diverse connected devices. 5G also presents researchers with a challenge to improve more known, but no less important, issues such as the coverage uniformity across a served region and more energy-efficient networks.

1,000X Faster Data Rates

5G targets peak data rates per user in the range of 10 Gb/s (over 1,000X 4G). To provide a frame of reference, a user can download an HD video in 40 minutes using the highest speed networks in good conditions. With 5G, a user can download this same video in a matter of seconds.

Faster data access is certainly exciting, but there are challenges to achieving this. The spectrum that service operators paid governments billions of dollars to acquire has simply run out. Today’s networks use spectrum anywhere from 700 MHz to almost 3 GHz, and a variety of public and private entities already claim this spectrum. This challenge

can be met in two ways: (1) explore new spectrum or (2) develop new technologies to send more bits to users in the currently allocated spectrum.

Billions of Connected Devices

By 2020, industry analysts predict 50 billion devices will be connected to mobile networks worldwide, and these aren’t just devices connected to a human hand. Embedded devices sending bits of information to other devices, servers, or the cloud will account for a large percentage of the devices.

The explosion of devices connected to the Internet has been dubbed the Internet of Things (IoT). These devices may incorporate sensors to measure pressure, temperature, or stress and perhaps include actuators to turn on and off devices or make adjustments in real time.

One example is traffic lights that are not just timed but connected and controlled remotely so that traffic congestion sites are immediately known and offloaded. If vehicles were connected directly to a traffic controller, then traffic lights may not even be necessary.

Buildings, bridges, and roads could be monitored continuously for structural

health. Corporations and governments could use air-pollution monitoring data to regulate emissions and apply corrective action. Patient vital sign data could be logged and monitored to better understand the cause and effect of certain health conditions. The possibilities are endless.

The 5G systems needed to turn these possibilities into realities are composed of heterogeneous devices encompassing both low and high bandwidth, which presents significant design challenges. To unlock the potential of IoT, 5G must address network response times (latency). Control without deterministic response times limits the utility and adoption of these technologies. It’s estimated that latency on current networks is on average in the tens of milliseconds range with a very wide standard deviation. If researchers succeed in reducing latency and improving determinism, then control applications—that is, connected

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devices with sensors, actuators, and so on—could be controlled and operated remotely or autonomously in the cloud.

5G on the Horizon

With fixed spectrum allocations below 3 GHz, researchers are investigating waveforms that make better use of the existing spectrum to essentially increase the number of bits through a given amount of spectrum. Current standards based on orthogonal frequency-division multiplexing require more frequency to separate transmit and receive data with sufficient efficiency. New 5G waveforms attempt to address spectrum efficiency using the existing network infrastructure to accommodate more users and devices and to squeeze out more bits per hertz. The Technical University in Dresden (TU-Dresden) has prototyped one of these new waveforms called generalized frequency-division multiplexing and prototyped a complete link. TU-Dresden realized 30 percent improvement in data rates compared to 4G.

Another option is densification, which means increasing the number of access points, including macro cells, small cells, and pico cells, deployed in a geographic region. Densification relies on the theory that adding more access points to a served area divides the spectrum by geography rather than the spectrum itself. In addition to densification, new network topologies such as Cloud RAN or C-RAN enable service operators to locate their equipment in the cloud, which significantly reduces the heating and cooling costs of locally deployed equipment as well as the power consumption of a network. A critical challenge of distributed network control is latency. Researchers in the Connectivity management for eneRgy Optimised Wireless Dense (CROWD) networks project, which is funded by the European Union, have shown successful prototypes with these new architectures. This indicates that distributed control within a dense network is possible.

New base station technologies such as massive multiple input, multiple output (MIMO) promise more bandwidth and energy efficiency. Massive MIMO base stations incorporate hundreds of antenna elements to focus the energy per user, which increases data rates and improves the quality of the communications link particularly at the cell edges. Recent experiments by Lund University in Sweden indicate that massive MIMO can increase data rates by 100X or more.

New spectrum frontiers in the millimeter wave (mmWave) frequency range are being explored around 28 GHz, 38 GHz, and the 71 GHz to 76 GHz range. These frequency bands are “lightly” licensed and offer plentiful high-bandwidth spectrum. In the past, communication at these frequencies was thought impossible due to the propagation characteristics of electromagnetic waves and the cost of developing and implementing networks in these bands. But NYU WIRELESS has conducted channel-sounding measurements, and the channel profiles indicate that mmWave communications may in fact be feasible. Nokia Networks has prototyped a mmWave communication link and is achieving data rates 100X above current 4G rates with deterministic latency.

Making the Vision a Reality

5G will happen and its impact will be transformational, but researchers need the tools and technologies to design and rapidly prototype their concepts faster to expedite the time to market and, ultimately, the time to deployment. New 5G waveforms, network densification, massive MIMO, and mmWave communications may be incrementally deployed along a time curve and as such are not mutually exclusive and may be complementary. These 5G technologies are moving forward, and the vision of an Internet for everyone and everything comes closer to reality every day.

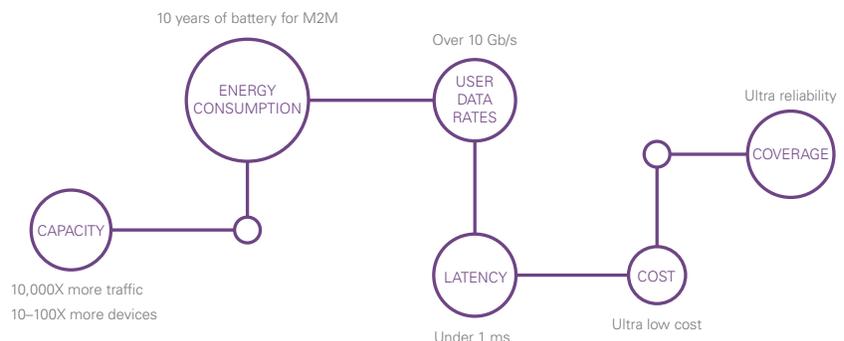


WIRELESS TO COME
 Watch as 5G expert, Prof. Fettweis, summarizes the wireless solution engineers must create to match the needs of today’s tactile Internet world.

[youtube.com/nationalinstruments](https://www.youtube.com/watch?v=NationalInstruments)

NAVIGATING 5G TECHNOLOGY CHALLENGES

The mobile Internet paints a picture of continued innovation and inspires researchers to think beyond faster data and greater capacity. These new networks, referred to as 5G, may unleash enormous economic potential.



When Exposed to IoT, Big Iron ATE Will Rust



When the first “smart” refrigerators were released in the early 2000s, consumers weren’t sure what to do with them. When Nest released the smart thermostat, though, a revolution happened. Humans were taken out of the loop because the thermostat learned on its own about desired temperature and how quickly it could cool or heat a house. And it could synchronize all of this better than a human could schedule it. Consumers began to understand what a smart device could do. Though creating smart devices is left to inventors and designers, the test engineer must ensure that they function safely and reliably while meeting the requirements of a disruptive business model.

It could be argued that the Nest thermostat was the first instantiation of the original goal of the Internet of Things (IoT), but we all know it will not be the last. In fact, Gartner estimates there will soon be more connected devices than humans on the planet, and by 2022 each household could contain more than 500 connected devices. As society continues to reap the benefits of connecting devices and freeing up humans to do more productive things than optimize their thermostats, automated test will continue to be challenged to keep pace economically.

Traditional automated test equipment (ATE) was optimized to test technology that harnessed the power of Moore’s law—mostly digital, increasing transistor count, decreasing footprint—and it does this very well. But over the past few decades, a subtle shift to integrate more analog technology into ICs has resulted in a test challenge that is much more than Moore. Innovation for the IoT has tasked test engineers to verify mixed-signal systems that include both digital signals and analog signals from sensors, RF antennas, and more—all at consumer volumes and for the lowest price possible. For the testing challenges of tomorrow, traditional ATE falls short. Test engineers need smart ATE for the smart devices of the IoT.

Same Instrumentation From Characterization to Production

Every week counts in the customary 12-month design cycle of an IC, which makes data correlation a costly exercise for test engineers. Test engineers must conduct data correlation because of the often isolated nature of the characterization and production tests implemented at different locations by different teams in different setups.

Characterization typically is conducted in a laboratory using an array of fixed-functionality instruments, whereas the production tester is a large “test head” filled with proprietary instrumentation that is suspended by a manipulator. Each setup has different instrumentation from different

vendors, different connectors, and different cables at varying lengths. The end result of these combinations is an endless permutation of variables that could cause misalignment in measurements between characterization and production test.

IoT innovators have three options to reduce the variables in the equation. First, they can move the production tester into the characterization lab; this requires additional capital investment in the most expensive equipment. Second, they can take the pile of box instruments into the

production line for testing, but this cripples the measurement throughput, which results in a testing bottleneck. The last option is to invest in a smarter ATE platform that gives test engineers the flexibility to have the same instrumentation in different form factors for characterization and

production testing. Though data correlation concerns are never completely eliminated, test engineers can use the ATE platform’s modularity to simplify this process as the IoT squeezes time to market and cost of test.

Test Equipment That Scales With Product Innovation

When the end goal is to sense, compute, communicate, and connect everything, smart devices built for the IoT must evolve at a grueling pace. According to teardown.com, when Samsung released the Galaxy S5 smartphone, the company decreased the cost of test by \$0.09 compared with the S4 and added five new sensors (humidity, infrared, proximity/gesture, heart rate, and fingerprint). How is this possible? One approach is to build a test strategy on open standards with maximum interoperability.

In a platform-based, modular approach to smarter test equipment, test engineers can construct a system from commercial off-the-shelf instrumentation for their initial requirements. This gives these engineers

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the flexibility to select instrumentation from a variety of specialized vendors, but it also requires interoperability between platform elements and places a high value on software—the ultimate source of “smartness” in test system design. Nevertheless, with this approach, engineers can scale up the capability of a tester by adding modules when necessary, which eliminates the high cost of retooling the hardware or rewriting the lowest levels of software.

Regardless of the approach, cost and time to market are the driving factors when choosing the platform for test equipment in the IoT. Certain companies, such as those that test memory and microcontrollers, are satisfied with fixed-functionality “big iron” testers. But as companies innovate and rapidly evolve the functionality of their devices, they need a smarter ATE platform that can productively scale with that innovation.

Future-Proofing Test Equipment With Software

When the Federal Aviation Administration recently decided to allow airline passengers to use their handheld electronics so long as they were in airplane mode, it did not require everyone to send their phones in to have hardware swapped out—it was a software fix. When Tesla Motors discovered that its car was riding a little too close to the ground at higher speeds, it did not force a recall; instead, Tesla sent out an over-the-air firmware update to stiffen the suspension of the car at higher speeds. Users were once forced to purchase a new device to gain new functionality. Smartphones, televisions, computers, and now even automobiles take

advantage of reprogrammable firmware technology to extend or improve the functionality of hardware devices after initial release.

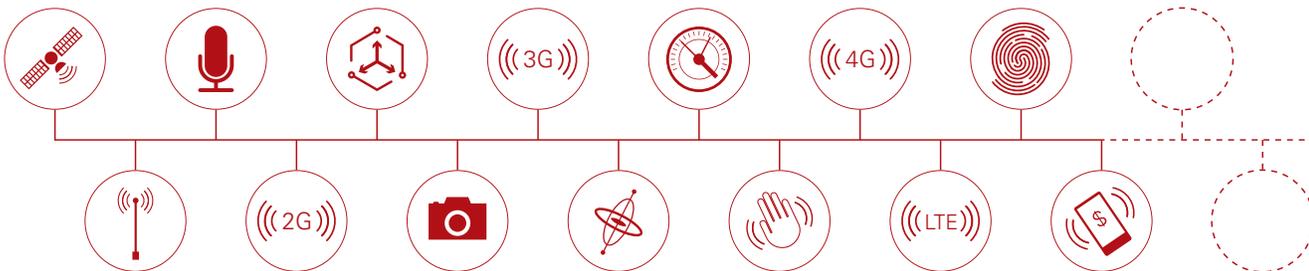
As the market continues to evolve and grow in complexity, we will be forced to embrace change and expect the unexpected. And just as these smart devices increase situational intelligence through upgradable software, so should the test equipment. With software-defined test equipment, organizations can invest in a platform that meets the test challenges of today but also adapts to new requirements while mitigating capital expenses. Modular hardware definitely plays a role in this approach, but software is what ties everything together in a platform-based, smart ATE approach.

Each year, a company similar to Nest or Tesla will revolutionize a market and change the way that we interact (or do not interact) with a device. Each year, additional sensor technology will be created to give us insight into the world around us. Each year, a new communication protocol will be defined that allows us to embed more data in fewer bytes. And each year, test engineers will be required to validate that all of these new devices deployed into the IoT are working safely, reliably, and cost-effectively. More and more companies have adopted a smarter, platform-based approach for their test equipment to address these challenges. As cost and time to market are continually reduced, innovative companies cannot afford to have their devices outsmart their ATE.



FUTURE-PROOF
 See how IDT reduced the costs of “big-iron ATE” through trial and error by first building their own systems and then looking to a modular solution.

[youtube.com/nationalinstruments](https://www.youtube.com/watch?v=...)



Smarter ATE enables test engineers to anticipate and economically incorporate technology advances into their test systems through an open-platform of modular hardware and scalable software.

The Industrial Internet of Things



The idea of a smarter world where systems with sensors and local processing are connected to share information is taking hold in every single industry. These systems will be connected on a global scale with users and each other to help users make more informed decisions. Many labels have been given to this overarching idea, but the most ubiquitous is the Internet of Things (IoT). The IoT includes everything from smart homes, mobile fitness devices, and connected toys to the Industrial Internet of Things (IIoT) with smart agriculture, smart cities, smart factories, and the smart grid.

The IIoT can be characterized as a vast number of connected industrial systems that are communicating and coordinating their data analytics and actions to improve industrial performance and benefit society as a whole. Industrial systems that interface the digital world to the physical world through sensors and actuators that solve complex control problems are commonly known as cyber-physical systems. These systems are being combined with Big Analog Data solutions to gain deeper insight through data and analytics.

Imagine industrial systems that can adjust to their own environments or even their own health. Instead of running to failure, machines schedule their own maintenance or, better yet, adjust their control algorithms dynamically to compensate for a worn part and then communicate that data to other machines and the people who rely on those machines. By making machines smarter through local processing and communication, the IIoT could solve problems in ways that were previously inconceivable. But, as the saying goes, "If it was easy, everyone would be doing it." As innovation grows so does the complexity, which makes the IIoT a very large challenge that no company alone can meet.

By making machines smarter through local processing and communication, the IIoT could solve problems in ways that were previously inconceivable.

The IIoT Challenge

This challenge becomes even more daunting and complex when comparing the requirements of the industrial internet to those of the consumer internet. Both involve connecting devices and systems all across the globe, but the IIoT adds stricter requirements to its local networks for latency, determinism, and bandwidth. When dealing with precision machines that can fail if timing is off by a millisecond, adhering to strict requirements becomes pivotal to the health and safety of the machine operators, the machines, and the business.

Adaptability and Scalability

As the IIoT comes to fruition, it will be a big change for historical industrial systems. The traditional design and augmentation of industrial systems are characterized by either (1) designing a proprietary or custom

end-to-end solution or (2) adding functionality by repeatedly tacking on vendor-defined black boxes. The tack-on solution can be quick to implement, but at what cost? One of the biggest advantages of the IIoT is that data is easily shared and analyzed for better decision making. For example, in a vendor-defined condition monitoring solution, the data being acquired and analyzed is not easily available; the system is limited to sending simple alarms to prevent a catastrophic failure. Data may be available after an event to analyze and determine what went wrong, but by then, time, money, and more may have been lost. If the condition

monitoring data is not continuously analyzed and made available through an open, standardized interface, there is no possibility of adjusting control algorithms based on the data collected or correlating the collected data to control events to improve efficiency or prevent system downtime.

The opposite is true for end-to-end solutions. All of the components and the end-to-end solution can work in harmony, but the underlying issue still remains. When an end-to-end solution is built, the communication protocols are uniform and data can be shared easily. But at that point, the solution itself essentially becomes the black box due to proprietary communication protocols. As soon as an update is required, the engineer faces the dilemma of tacking on a solution that may not communicate well with the whole system or of starting the process over and creating a new end-to-end solution. IIoT systems need to be adaptive and scalable through software or added functionality that easily integrates into the overall solution. When the entire system is a black box, this cannot occur. There has to be a better way to integrate disparate systems and reduce system complexity without sacrificing innovation.

Security

Adaptability and scalability are only the first of many challenges presented by the IIoT. Systems management and security are also paramount. As massive networks of systems come online, these systems need to communicate with each other and with the enterprise, often over vast distances. Both the systems and the communications

need to be secure, or millions of dollars' worth of assets are put at risk. One of the most prevalent examples of the need for security is the smart grid, which is on the leading edge of the IIoT. As information on the grid becomes more accessible, so does the damage a security breach can inflict.

Maintenance and Updates

In addition to being secure, these systems need to be continually modified and maintained to meet ever-changing functionality and system-maintenance requirements. As more capabilities are added, software updates are needed or more systems must be added. Soon a tangled web of interconnected components starts to form. The new system has to integrate not only with the original system but also all of the other systems. Imagine modifying and updating thousands or millions of systems located all over the world, including some in remote locations.

The IIoT Investment

Developing and deploying the systems that will make up the IIoT represent a massive investment for decades to come. The only way to meet the needs of today and tomorrow is not by predicting the future but by deploying a network of systems flexible enough to evolve and adapt. The way forward involves a platform-based approach; a single flexible hardware architecture deployed across many applications removes a substantial amount of the hardware complexity and makes each new problem primarily a software challenge. The same principle must be applied to software tools to form a powerful hardware-software platform that creates a unified solution. An effective platform-based approach does not focus on hardware or software but instead on the innovation within the application itself.

Platforms to develop the IIoT exist today. The platforms that system designers choose need to be based on an IT-friendly OS so they can be securely provisioned and configured to properly authenticate and authorize users to maintain system integrity and maximize system availability. These platforms can achieve this through an open OS that helps security experts from around the world unite and develop the latest in embedded security. These platforms also need to be based on standard Ethernet technologies and incorporate evolving standards to enable a more open and deterministic network that meets IIoT latency, determinism, and bandwidth requirements while maximizing interoperability between industrial systems providers and the consumer IoT. Organizations like the Industrial Internet Consortium (IIC) document use cases and ensure interoperability, and IEEE has formed the Time Sensitive Network task group to evolve IEEE 802.1 to meet these requirements.

The ongoing design of the IIoT represents a massive business and technology opportunity for all of us. Organizations like the IIC, IEEE, and AVnu are working hard to define the IIoT. They are actively gathering use cases to better understand how best to enable more innovation. Engineers and scientists are already implementing systems on the leading edge of the IIoT, but they still face many unknowns and much work ahead. Start concentrating on a platform-based approach and become part of the IIoT generation by getting involved with these bodies to define the future and ensure that businesses focus on innovation and not simply integration.

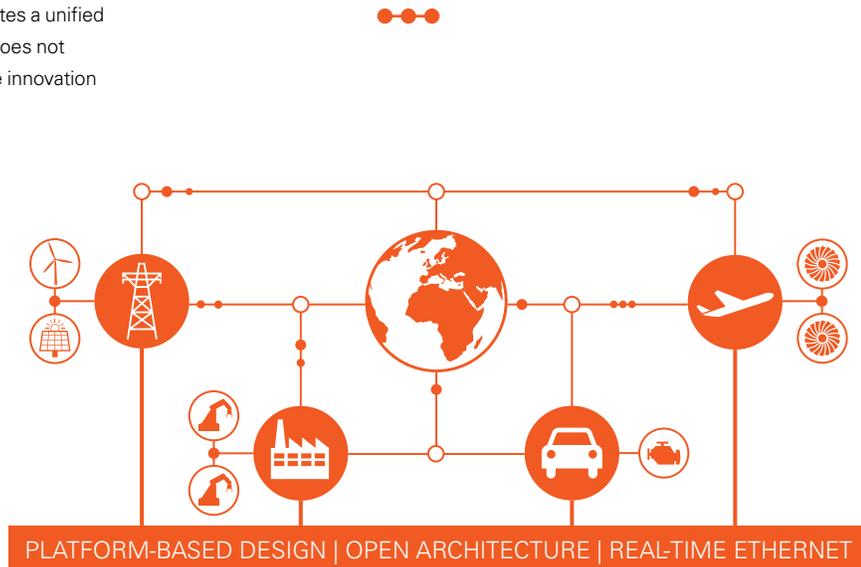


THE SYSTEMS AGE

How many friends do your machines have? Hear from GE about the interconnected nature of today's machines.

youtube.com/nationalinstruments

To adapt to changing requirements, devices that power the IIoT will need to be built on an open, integrated hardware/software platform and a real-time network that can scale with new technologies.



The World Is Ours to Make: The Impact of the Maker Movement



The maker movement is driving engineering into the mainstream. Makers around the world are inspiring each other to create (or “make”) smart gadgets, robotic gizmos, autonomous drones, and wearable devices. These innovations are no longer monopolized by multimillion dollar companies. Instead, makers work in home garages and collaborative workspaces with their peers. More importantly, they openly share their inventions online to inspire new innovations from other makers. This type of grassroots “viral innovation” is disrupting the status quo. Is this the beginning of the next industrial revolution?

The Homebrew Computing Club was founded in the 1970s by a small group of hobbyists building personal computers in their garages. They met regularly in Silicon Valley to share inventions and discuss new ideas. None of the members understood the historical implications of the meeting when two members of the club, Steve Jobs and Steve Wozniak, presented their new computer. It was the Apple I, and it helped deliver PCs to the masses and propel us into the information age.

Modern-day makers are the same as the hobbyists of the 1970s, just on a much larger scale. Nearly 200,000 of them attended the two flagship Maker Faire events, also known as the “Greatest Show and Tell on Earth,” last year in San Francisco and New York. The Internet is fueling a maker community orders of magnitude larger than what was possible in the 1970s. As the maker movement continues to grow and garner worldwide attention, it is important to assess the impact it will have on innovation, economic growth, and our future generations.

Consumer-Driven Innovation

The PC created a new generation of software developers who could innovate in the digital world without the limitations of the physical world. Through its inherent nature of virtually no marginal cost, software has become the great equalizer for innovation. It provides an open canvas for creativity that empowers individuals to make highly valuable products with the ability to disrupt corporate-driven products and business models. At no other time in history has it been easier for an idea to originate in the imagination of a single individual and spread to a mass market.

Advances in 3D printing and low-cost microcontrollers as well as the ubiquity of advanced sensors are enabling makers to bridge software with the physical world. Furthermore, the proliferation of wireless connectivity and cloud computing is helping makers contribute to the

Internet of Things (IoT). IoT describes a world of interconnected devices that use sensors to interact with the people, environment, and other devices around them. This interconnection adds functionality and greater insight into an unlimited number of existing and new devices. By combining hardware and software, the maker movement will advance the IoT much like the open platform for mobile app creation has developed a new economy around smartphones. Examples such as an automated cat feeder, a smart air conditioner that

learns from your living patterns, and an umbrella that alerts users based on the local weather report showcase the lifestyle improvements and niche solution development that the IoT will provide.

As machines replace humans for manual and procedural work, education systems around the world need to shift focus from one-way lectures and rote memorization to collaborative, creative problem-solving environments. Learning by doing, iterating on ideas, and collaborating with peers are the hallmarks of the maker movement.

Democratization of Entrepreneurship

The Pebble E-Paper Watch raises \$10M. The LIFX smartphone-controlled LED bulb raises \$1.3M. What do these products have in common? They both secured funding through Kickstarter, a crowd-funding website that is changing the game for entrepreneurs. Both products were created by makers who seek to commercialize their inventions. These “startup makers” iterate on prototypes with high-end tools at professional makerspaces such as TechShop and FabLab. There, engineers and artists collaborate to create products that not only use advanced technologies but also feature polished aesthetics. They then secure funding through crowd-sourcing sites where success is based on

the mass consumer valuation of the product instead of the assessment of a few venture capitalists.

The maker movement is a catalyst to democratize entrepreneurship. For companies to remain competitive, they need to embrace the maker movement or leave themselves open for disruption. GE executives recently launched FirstBuild, a makerspace to engage students, entrepreneurs, and makers to co-create appliances of the future. FirstBuild has already generated new projects such as instrumented refrigerators, quiet-close microwave doors, and a smart water pitcher that automatically refills when it is in the refrigerator. By embracing the ingenuity of its own employees and the public, GE is enabling a new process of product development and capturing the creative energy surrounding its products.

Education Transformation

"Tell me, I forget. Show me, I remember. Involve me, I understand."—Chinese Proverb

As machines replace humans for manual and procedural work, education systems around the world need to shift focus from one-way lectures and rote memorization to collaborative, creative problem-solving environments. Learning by doing, iterating on ideas, and collaborating with peers are the hallmarks of the maker movement. This philosophy is exactly what we need to improve our education system. In fact, many parents have engaged in the maker movement with their kids because they know that the education system is not adequately preparing their children for the 21st century.

Education is ripe for transformation. PCs, the Internet, and mobile devices have changed every aspect of our lives except education. Technology adoption by schools has not changed the lectures and multiple-choice tests that make up the fundamental way we teach and assess our students; however, we have begun to see the first signs of a global trend in education. Schools at all levels are transforming traditional classrooms and libraries into collaborative makerspaces. MIT recently began accepting maker portfolios in its admissions process, UC Berkeley created a makerspace for students to collaborate, and nonprofit organizations such as the Maker Education Initiative provide blueprints for grade schools looking to implement maker-like learning environments. And this is just in the formal education system. Online education portals such as Coursera and edX offer free classes so anyone with Internet access can learn and build projects at home. Perhaps a cultural shift to the maker movement values will finally fuel a significant transformation of our education system.

The Future Impact

Humans are genetically wired to be makers. The maker movement is simply the result of making powerful building and communication tools accessible to the masses. It is a grassroots subculture that is enabling engineering innovation on a global scale. By democratizing the product development process, helping these developments get to market, and transforming the way we educate the next generation of innovators, we will usher in the next industrial revolution. The world is ours to make.

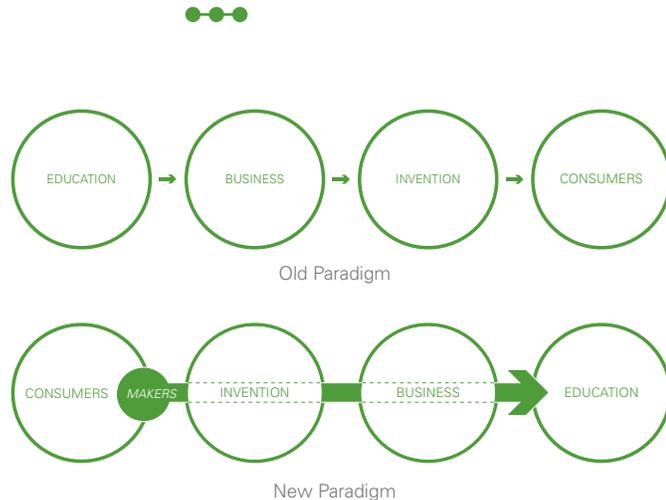


BOOM! THE IMPACT OF THE MAKER MOVEMENT

"When you create inside of a community, not only do you achieve your objective, you exceed it." Hear from TechShop CEO Mark Hatch as he discusses today's maker community.

[youtube.com/nationalinstruments](https://www.youtube.com/watch?v=nationalinstruments)

Historically, the education system has produced graduates that went on to work for companies where new products were invented, then pushed to consumers. Today, consumers are driving the innovation process and demanding education, business and invention to meet their requests. Makers are at the center of this innovation transformation.



ni.com/trend-watch

