Modernizing Machine-to-Machine Interactions

A Platform for Igniting the Next Industrial Revolution

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Machine intelligence is evolving to meet the needs of the 21st century industrial company. These increasingly intelligent devices need a safe, secure, and highly functional way to talk to each other, and to the rest of the industrial world.

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Executive Summary

A new industrial revolution is at hand. Led by advances in technology and global business practices, the industrial world is fast becoming the domain of advanced forms of machine intelligence and machine-to-machine communications. At the center of this change is a new generation of intelligent devices that are self-aware, able to adapt their behavior to new or changing circumstances, and can be managed and reprogrammed to meet rapidly changing business and technology requirements.

The intelligence in these devices can be delivered at all levels of industrial infrastructure, from an individual controller on a wind turbine or manufacturing shop floor to an entire fleet of aircraft or network of industrial machine assets. This intelligence is bi-directional—machines can be the source of massive quantities of data in support of advanced analytics, or they can operationalize changes in industrial asset functionality that result from the analytics enabled by these intelligent machines and their data.

These new machines are social, able to sense each other's presence and interact with one another. And they are secure, able to support a high degree of interoperability and interaction while still meeting the industrial world's strict requirements for safety and data privacy.

These intelligent machines can also leverage important new technological advances in virtualization, connectivity, cloud computing, user interface design, and advanced analytics, simultaneously bringing industrial companies into the 21st century while protecting their investments from the 20th century.

What's needed now is a platform that can make this opportunity a reality across the entire industrial world. This platform must be cost-effective and scalable, leverage existing and emerging technologies, and provide industrial companies and their partners with the means to develop and deploy the machine apps that will deliver this new industrial revolution in a safe and secure way. Such a platform will be the catalyst for a broad ecosystem of technology and equipment vendors, service providers, and other players with a stake in enabling the new industrial revolution.

This new industrial platform is here today. And with it has come the opportunity to effect a broad-based change across the industrial world. The time to start is now.

Introduction: The Industrial Internet in the 21st Century

This is the revolution of machines—machines that are self-aware, that can connect and interact with other machines and their human operators.

The concept of machine-to-machine (M2M) communications has a rich history in the industrial world, and many technologies and standards exist that provide the foundations for a high degree of functionality across a broad range of industries.

However, advances in computing, software development, networking, analytics, and security have made it possible to extend the concepts inherent in over five decades[1] of machine-to-machine interaction to a new level of functionality and efficiency. These advances are already beginning to ignite a new industrial revolution.

This is the revolution of machines—machines that are self-aware, that can connect and interact with other machines and their human operators, that can be provisioned, managed, upgraded and decommissioned remotely, that can function safely and securely, and that can dramatically improve industrial operations at all levels of the global economy.

This revolution is not happening in vacuum. A number of important steps have already been taken that are ensuring a standard approach to developing and deploying the machine software, communications systems, and user experiences that can deliver a scalable, safe and secure environment for the next industrial revolution. This in turn is allowing a standard, repeatable way to build and manage new operational, management, and analytical software. And with those developments has come an ecosystem of companies, products, and services to bring to market the software and hardware that can help realize this new industrial world. The result is a more productive, efficient, and secure industrial world, one that is poised to translate these opportunities into savings in industrial efficiency that range from $320 billion to $640 billion annually.[2] And that new world starts now.

[1] http://energy.sandia.gov/?page_id=6972

[2] *Industrial Internet, a Key Growth Initiative for GE.* Bank of America Merrill Lynch Global Research. Sept., 2013.

The Changing Needs of the Industrial World

The state of the art in machine-to-machine communications and machine intelligence provides a high degree of functionality, but it's insufficient to deliver the enormous gains in efficiency that are possible in industry. Industrial companies need to move their operations into the 21st century, and in the process put to use recent innovations in communications, analytics, computational power, sensor technology, virtualization, software development, and cloud technologies.

In the short term, modern industrial companies need a data analytics and operations-driven approach to their businesses that allows them to collect and deliver the right data, from the right end points, in the right velocity and quantity to a wide set of well-designed analytics. These analytics in turn provide new insights and support more efficient operations at all levels, as well as enable new business processes and opportunities.

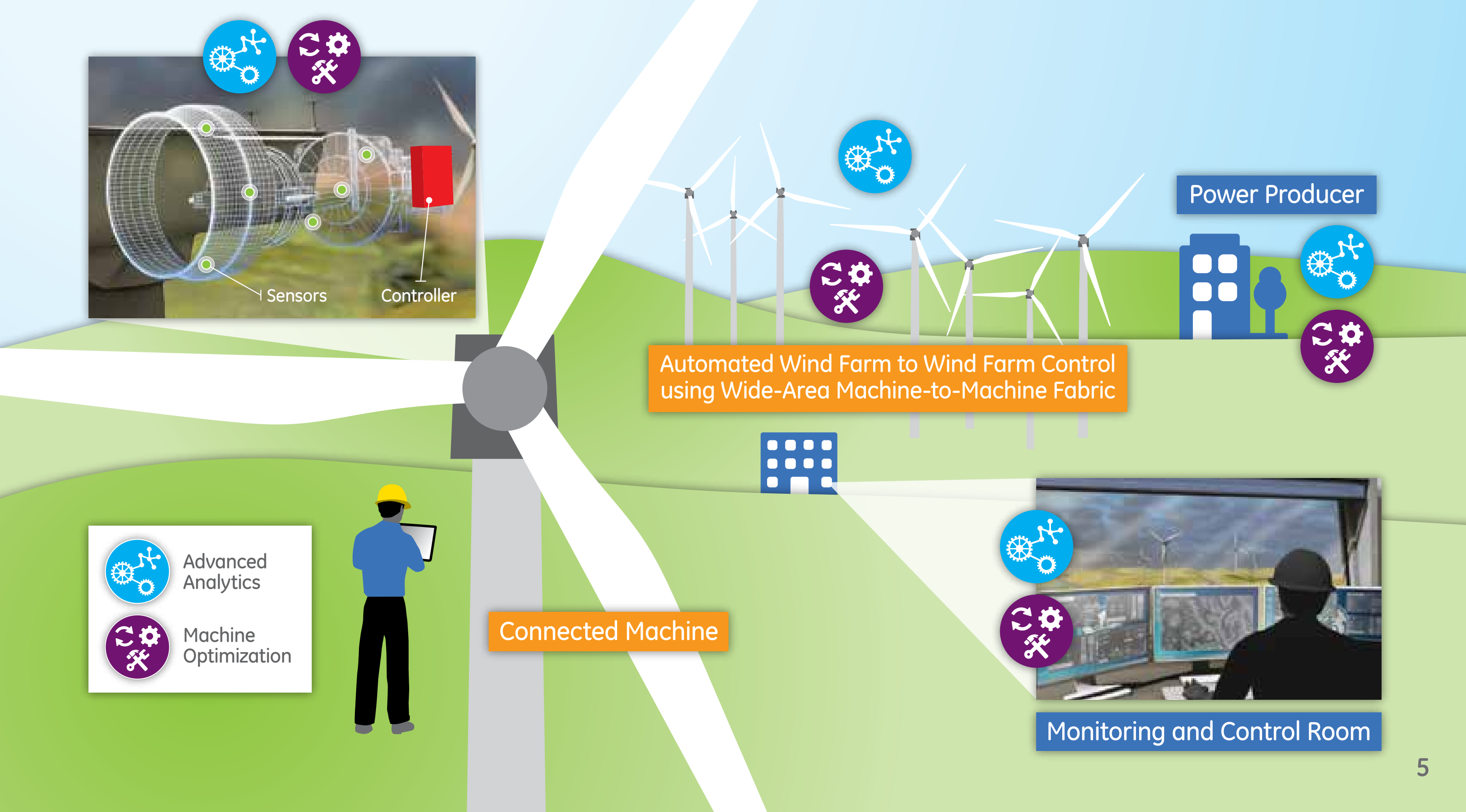
In the longer term, industrial companies need a real-time, wide-area control environment that allows them to safely and securely deploy, manage, upgrade, and decommission an increasingly intelligent set of assets in a controlled, deterministic manner, whether the asset is a single device or an entire fleet or plant full of assets. This capability will create enormous efficiencies and savings across a wide range of industrial companies and their business processes.

However well-developed industrial technology may be, these short-term and long-term imperatives cannot be realized using today's technology alone. The software and hardware in today's industrial machines are very interdependent and closely coupled, making it hard to upgrade software without upgrading hardware, and vice versa. This limits the ability of companies to use embedded virtualization, multi-core processor technology, advanced communications, and the cloud to automatically and remotely upgrade and manage industrial machines.

Also lacking are standards and best practices that support agile development and deployment, as well as the reusability, scalability, interoperability, and portability required to leverage the modern industrial enterprise. For example, the limits of current industrial technology mean that upgrading software in an existing machine—something every smart phone user has experienced as a simple and quick process—remains a difficult and costly drain on operational and capital expenses.

What is needed is the technology and best practices that support a modern industrial environment, one that is data and analytics driven and based on machine-centric distributed computing models designed specifically for industrial settings. This technology platform will set the stage for the next industrial revolution—the one driven by intelligent machines and even more intelligent industrial operations and processes. A platform that can help deliver the hundreds of billion dollars in efficiency waiting to be tapped by the industrial world.

Wind Power Generation in The New Industrial World



Modernizing the Industrial World: The Industrial Internet, Brilliant Machines, and the Changing Face of Industrial Operations

The components that make up the modern industrial enterprise—devices, machines, businesses and people—are deeply connected, instead of the silos that were part of the previous generation of industrial enterprise.

On the surface, the modern industrial world looks similar to the industrial world of the recent past. At the heart of the industrial company in both worlds are sensors, controllers, devices, machines, and networks. People are also central in both worlds, and the places where people, devices, and machines work are largely unchanged: airplanes, factories, hospitals, and wind farms, among others.

Under the covers, however, today's modern industrial world is very different. The many components that make up the modern industrial enterprise—devices, machines, businesses, and people—are deeply connected to each other, instead of the silos of operation that were part of the previous generation of industrial enterprise. This is because the modern industrial enterprise is based on an updated *Industrial Internet* that supports new kinds of intelligent devices: over 50 billion such devices will be connected by 2020, according to published reports.[3] This Industrial Internet in turn enables new applications, and operational, analytical, and business models as well as supporting existing operations and legacy technologies.

This new industrial world scales from the individual sensor, wind turbine, jet engine, or medical device to an entire industrial plant, hospital, fleet of aircraft, or power grid. And at every level of operations, the modern industrial company can deploy advanced analytics that support operations and business processes at all levels of the company, in a role and context-based manner.

These capabilities also set the stage for the wide-area control, in real time, of industrial assets from a "single pane of glass" that can greatly improve operational efficiencies at all levels of the company. Real-time wide-area control will allow groups of devices or assets to be deployed, managed, upgraded, and decommissioned in a more centralized and efficient manner, allowing industrial companies to deliver new business models and levels of service that simply have not been attainable to date. Software changes can be pushed out simultaneously to an entire network of devices—much like what is done with smart phone apps today—instead of laboriously upgrading each machine's software, and often its hardware as well, on a machine-by-machine basis.

New Technologies, New Capabilities

Several key technologies come into play to support this new industrial world. Virtualization and agile development and deployment methodologies that have seen great success in enterprise IT are now being put to use in the industrial world. Industrial companies are taking advantage of advancements in processor technology, including multi-core implementations and hardware hypervisor support, as well as new capabilities in networking, storage, and cloud-based computing.

Also at play are new standards and best practices for connectivity and interoperability that allow new and old devices to connect and interoperate, permitting older proprietary systems to co-exist alongside more modern machines and technology.

Key to this new industrial world is the ability to put an unprecedented amount of intelligence and computing power directly on what GE calls "Brilliant Machines" (see sidebar), machines that run advanced machine apps, software and operating systems and can function autonomously and/or connect to other machines in a synchronized fashion. This is more than just a matter of enabling a new generation of sensors to connect to a cloud-centric, distributed environment—this is about putting intelligence and compute power directly on the machine.

[3] http://newsroom.cisco.com/feature-content?type=webcontent&articleId=1208342, 2013

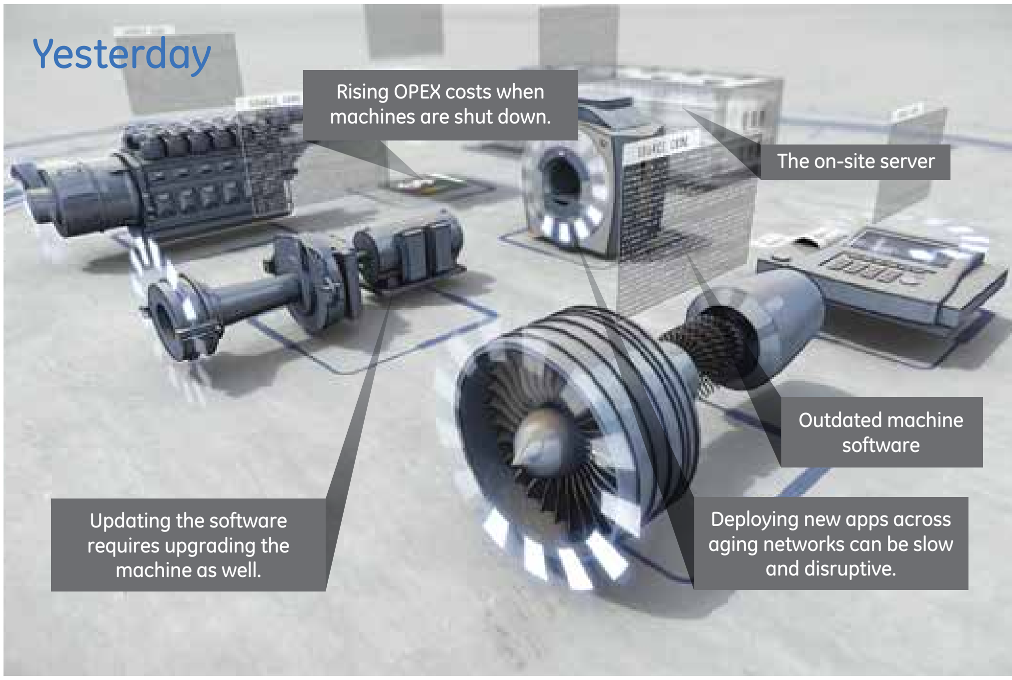
Brilliant Machines and Software-Defined Machines?

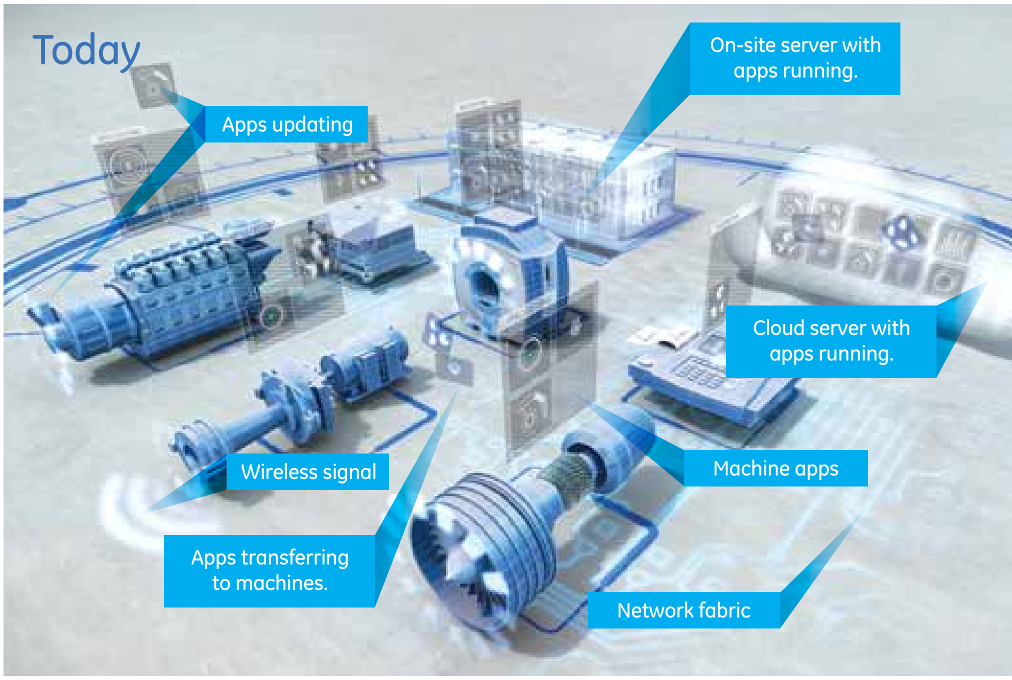
Brilliant Machines are securely managed industrial devices that autonomously connect to the Industrial Internet, execute native or cloud-based machine apps, and analyze collected data and react to changes in those data. They are predictive (anticipating and reacting to state changes), reactive (sensing the environment and acting on it), and social (communicating with each other and other industrial resources).

Brilliant Machines are a key component of the new industrial revolution. Brilliant Machines can be anywhere—inside a jet engine, a medical imaging device, a mining company's grinding circuits—and they can automatically, securely, and safely be connected to the Industrial Internet. Brilliant Machines can support today's advanced operations and analytics requirements as well as the promise of machine-centric distributed computing and real-time, wide-area control. They typically run advanced operating systems that leverage virtualization and multi-core processor technology, and they support a wide range of on-premise and cloud-based applications and processes.

Brilliant Machines allow developers and industrial operators to decouple machine software from hardware, allowing them to be upgraded and maintained without any mechanical modifications or direct human interaction. The software in Brilliant Machines is developed using GE's software-defined machine (SDM) infrastructure: A Brilliant Machine's functionality is defined by the software that runs inside it, software that can be modified and upgraded as changes in technology and business process require. A software developer uses a software-defined machine environment to make the changes in the software that runs the Brilliant Machine, and then pushes those changes out to however many Brilliant Machines need the update.

This software-defined machine infrastructure allows machine functionality to be virtualized in software, providing enormous efficiencies in development and deployment, and enormous savings in provisioning, upgrading, and reusability. As long as the hardware is able to embed the software, the lifespan and usability of a Brilliant Machine is limited only by the intelligence inside it and the creativity of the developer who creates it.





These technological opportunities are already having a profound effect on existing business models, setting the stage for new ways to conduct business and provide high degrees of service as well as new product opportunities. Advanced industrial companies are already improving how they operate and maintain complex industrial equipment and networks of equipment, in sectors such as aviation, energy production, and mining, while increasing the value of existing equipment, personnel, and business relations.

The Modern Industrial World of Today and Tomorrow

> *The data from these devices can be used in a hierarchy of analytical and operational functions, from the individual and her doctor to the researchers and all the way up to the company that makes the device.*

The advances in modernizing the industrial world are not just pipe dreams of the future, many of them are in place and in use today. In domains such as aerospace, transportation, healthcare, and energy production, the transition to the modern industrial company has already started and the benefits are already being realized.

Connected Cardiology

The delivery of healthcare has seen a massive infusion of sensor-based technology in recent years. Much of this technology has been deployed on consumers' wrists and smart phones, allowing individual runners to mark their progress and check their vital signs. Increasingly, these individual devices, and a growing number of other healthcare monitoring devices, are being connected by the thousands into analytical and diagnostic grids. These grids, based on Industrial Internet technology, are providing platforms for new and exciting advances in healthcare diagnosis and delivery.

A major university research project is underway that is collecting real-time data on one million individuals, all of whom are wearing advanced, sensor-based devices—which are actually small, personalized Brilliant Machines—that can transmit data on heart and respiration rates and other vital signs. The data from these devices can be used in a hierarchy of analytical and operational functions, from the individual and her doctor to the researchers and all the way up to the company that makes the device.

At the most basic level, the individual can monitor her cardiac health and make adjustments to her training regimen, and her doctor can receive real-time alerts and updates regarding changes in key vital signs. At the next level, the researchers can collect data from multiple patients and aggregate the data to look for patterns that reveal warning signs of impending illness or ways to improve training and quality of life. Those patterns can then be used to make suggestions on how to improve healthcare delivery.

Further up the analytical chain, other epidemiologists could use the data to look at larger populations in order to determine whether there are correlations between the real-time data and such factors as age, race, and gender. And the manufacturer of the device can look at the data and understand ways to improve the effectiveness of medical devices for individuals as well as doctors, researchers, and others.

This is the reality at present—these kinds of advances in analytical and operational control can be delivered today. And what will happen in the very near future is even more exciting.

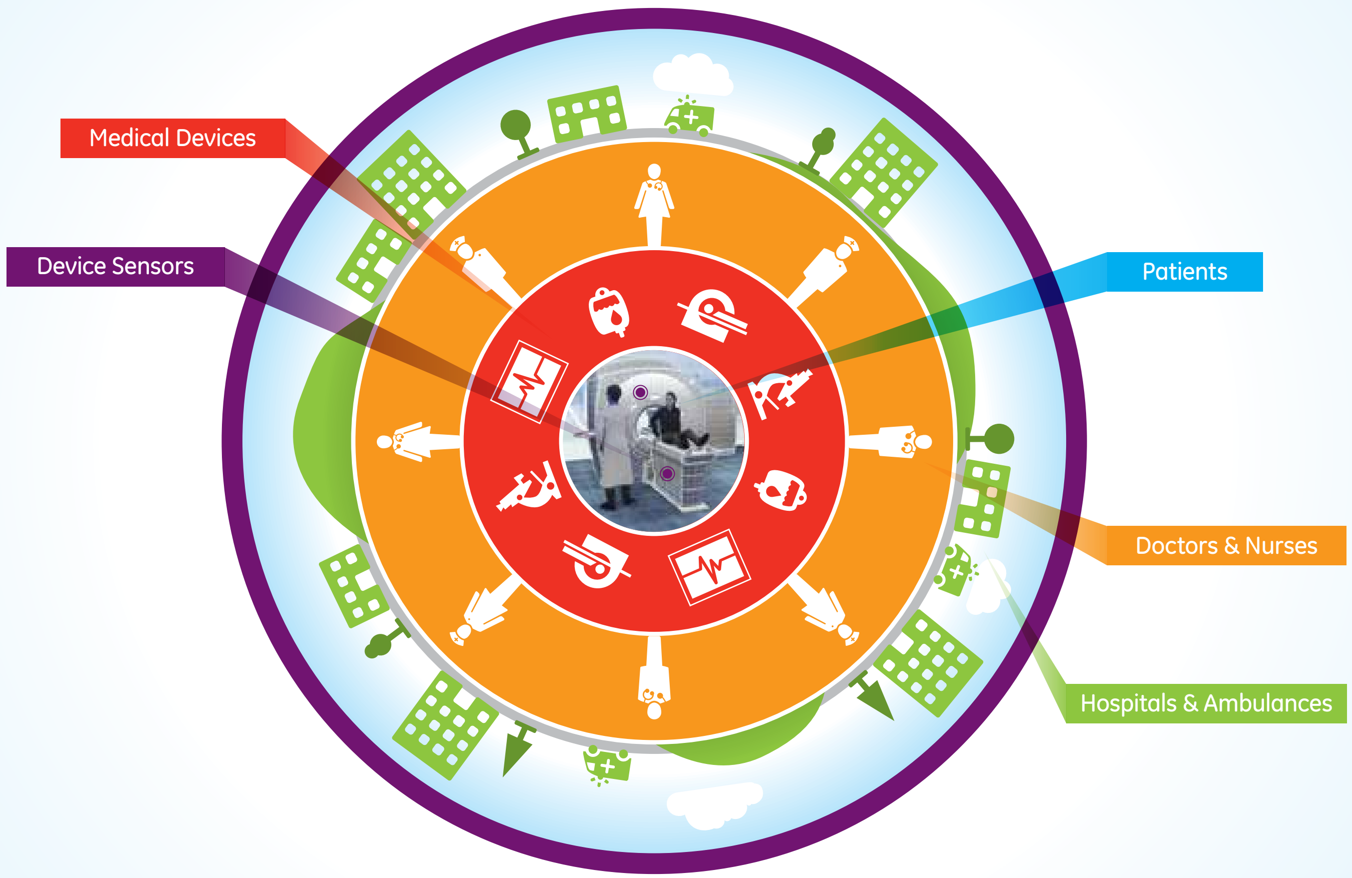
Imagine a healthcare environment where all the medical devices are Brilliant Machines, able to be controlled individually or *en masse* from a single management environment. MRI and other radiographic devices, infusion pumps, laboratory analysis machines, and other equipment can now be part of an advanced networking environment. This HIPAA-secure network not only automatically downloads new scans, test results, and monitors the delivery of treatments, it also monitors the use, location, and maintenance requirements of the different pieces of equipment.

This network of Brilliant Machines is also social: a reading from an oximeter, instead of being interpreted by a nurse and used to adjust a patient's oxygen levels, is communicated directly from the oximeter to the ventilator, which then adjusts the oxygen being delivered to the patient. Using advanced predictive analysis algorithms, the hospital is also able to both monitor and anticipate changes in patients' medical conditions as well as perform preventive maintenance on its equipment, automatically uploading and managing software and other upgrades to the devices.

A healthcare network of Brilliant Machines can also extend outside the hospital. Imagine an ambulance that can communicate with traffic lights, changing the right of way to provide a faster path to the hospital. And on the way to the hospital the ambulance can communicate the patient's vital signs to the hospital and receive information from the patient's healthcare record, allowing ambulance personnel to communicate with the hospital and the patient's personal physician, and to get started on testing and treatment options well before the patient is admitted to the ER.

This ability to manage these valuable assets using the Industrial Internet's wide-area control capabilities can improve the economics and service delivery models of the hospital—and those of the companies that manufacture and service the medical devices—in a significant way. And, most importantly, these capabilities can improve the quality of healthcare delivery to patients as well.

Connected Cardiology



> *A rail operator can embed Brilliant Machines inside the locomotive, the freight cars, the track, the rail yard, and the containers, and improve railroad operations by orders of magnitude.*

The Intelligent Railroad

Using modern Industrial Internet technology to monitor the safety of trains and train tracks is another important way in which the industrial world is already using the concepts of advanced data collection, aggregation, and analysis to improve operations and trim costs.

A major U.S. railroad is using cameras, infrared sensors, and other sensing technology on its over 30,000 miles of track in order to prevent derailments, which can cause loss of life and the release of toxic substances into the environment. The goal is to monitor train tracks, freight cars, and even the wheels of the train in order to detect problems that might eventually lead to a derailment. This is very much a big data analysis challenge: the cameras and sensors capture a terabyte of data every minute—vibration, sound, temperature, position, velocity—which is transmitted via fiber optic cable to a data center, and analyzed using a complex set of algorithms that can detect anomalies in how the trains move over the tracks.

While railroad operations may seem quite different than monitoring patient populations, the use of data and analytics is very similar. The quantity and real-time nature of the data collected by the rail operator means that it can monitor an individual train and react to a sound or vibration that might indicate the imminent failure of wheels or other components. The railroad company can also aggregate the data across its entire network and correlate them to a host of other parameters. Taken together, these data could help improve or optimize track maintenance as well as optimize locomotive and freight car maintenance. These efforts will improve its service levels to its customers. And, as with healthcare delivery, the locomotive, freight car, and track manufacturers can use the data to improve the design and delivery of their products as well.

These parallels extend to the future of real-time, wide-area control as well. A rail operator that can embed Brilliant Machines inside the locomotive, the freight cars, the track, the rail yard, the containers, and even other goods being shipped by rail, can improve the efficiency and effectiveness of the railroad operations by orders of magnitude.

Railroads that have deployed Brilliant Machines in real-time networks can extend the maintenance support model to allow for real-time changes in operations that take into account how slowing down a train or unexpected track conditions will impact the entire network.

Real-time wide-area control also lets the rail operator know where all its rolling assets are, allowing the railroad to provide better support to their logistics customers and partners: Being able to know exactly where a particular shipment is can allow customers to redirect shipments to new destinations based on their own changing market requirements. The opportunities for new levels of service and new levels of customer satisfaction are boundless.

The Intelligent Railroad

Behind the scenes is a set of specialized industrial applications, or machine apps, orchestrated by an advanced Industrial Internet platform—that can monitor existing conditions, predict problems or anomalies, alert maintenance personnel to be ready to repair a specific piece of equipment, and have the spare parts ordered and waiting for a repair that has been scheduled based on the equipment's location and proximity to the rail yard. An entirely new piece of equipment—a new locomotive or freight car—can be queued up and waiting, the data needed for its journey already loaded, so that it can be swapped out and sent on to complete the journey with virtually no delay.

This combination of enabling analytical and operational excellence today, while positioning a company for the real-time, wide-area control of industrial assets in the near future, is being replicated across the industrial world: Aerospace, energy production, mining, and other major industries are able to become modern industrial companies today, while setting the stage for an even brighter future.

What Is Needed to Realize this Modern Industrial World?

The examples above highlight the capabilities—present and future—of the modern industrial world, and help define a critical missing link: an Industrial Internet platform. While many of the fundamental capabilities are already scattered across the market, this new industrial revolution requires them to be anchored in a single platform that can allow industrial companies, their partners, and their suppliers to make use of these capabilities in a unified, efficient, and rationalized manner.

As such, the platform needs to support the following:

Industrial-Class Safety and Security

Industrial companies need a different safety and security regime than has been the norm in enterprise and consumer environments, due to the significantly different impact of a safety or security breach in an industrial setting. In the enterprise or consumer world, a denial of service attack or identity theft is problematic and potentially damaging. In the industrial world, the real-time nature and interdependencies of industrial processes—often extending across corporate firewalls and international borders—requires a much higher level of safety and security. A security breach or denial of service attack in the industrial world could have a massive ripple effect across a global supply chain, disrupting business and delaying the delivery of products and services.

This means that machines are a vital link in the security regime of the Industrial Internet, and therefore need to be made safe and secure from before they are connected and until after decommissioning. This also means that their access is controlled and once online, end-to-end communications between the machines and any other component of the Industrial Internet must be made secure.

Real-Time Control and Data

While individual real-time requirements differ from industry to industry, even very different industries have a broad range of common requirements that can and should be fulfilled by a single M2M platform. Moreover, these requirements cannot be fulfilled using existing commercial and consumer Internet technology. The need to support real-time controls, larger quantities and faster velocities of data, and more rigorous safety and security requirements, as well as different analysis and control requirements, more than justify the need for a distinct Industrial Internet platform.

Machine-Centric Distributed Computing

Support for a scalable machine-centric distributed computing model based on the ability to control networks of resources in real time is another key requirement. With this, every node is a complete point of presence and all nodes collectively operate as one. Industrial platforms will need to include support and interoperability with enterprise networks, as many of the key modern use cases require interoperability between industrial and enterprise systems.

Brilliant Machines and Software-Defined Machines

An important part of machine-centric, wide-area management and control is the support for Brilliant Machines. The proliferation of Brilliant Machines in the industrial world will facilitate the ability of industrial companies to remotely manage and control industrial assets and use them as intelligent devices. This intelligence and innovation can be placed in individual sensors and machines, networks of devices, industrial plants, and entire grids containing hundreds of machines.

Backing up these Brilliant Machines and their machine apps is the software-defined machine (SDM) infrastructure. (See figure.) This infrastructure provides a standard way for developers to abstract the machine software and machine apps from the underlying hardware, shifting software design in the industrial world from hardware-specific to device-agnostic. This allows machine apps to run on secure virtual machines that exist on-premise and/or in the cloud, or anywhere else permitted by the network security model. The SDM infrastructure also supports complex

This new industrial revolution requires a single platform that can allow industrial companies, their partners, and their suppliers to make use of these capabilities in a unified, efficient, and rationalized manner.

modeling and simulation scenarios for developing new capabilities and analytics. This is done by running a simulation of a machine or network of machines in a high-performance compute cloud. The results of these simulations can be encoded in machine apps updates and pushed out to Brilliant Machines.

Next-Generation Machine Apps

Supporting Brilliant Machines requires support for the machine apps that make Brilliant Machines come alive. Using the software-defined machine infrastructure, machine apps provide discrete services to industrial machines, from basic machine identity to performance reporting, advanced services for data visualization, and location-based awareness, among others. They can communicate real-time status and performance data, and leverage cloud-based analytics, prognostics, and relevant historical data about maintenance history, status, and other operational characteristics. These apps are deployed on a variety of devices, from tablets and smart phones to advanced touchscreens and HMI devices, making use of data visualization, location-based awareness, and other capabilities that support a mobile industrial workforce.

Improve the Scope and Quality of Analytics and Operations

Another key capability is to provide an order of magnitude improvement in the scope and quality of analytics and operations. With the speed, quantity, and quality of data in the industrial world significantly greater than what is found in the enterprise, the analytical and operational environment needs to be "upgraded" to reflect a vastly different set of requirements for data governance and analytical and operational excellence.

Industrial-Class Up Time Requirements

The enterprise world sees system up time in terms of five or seven "nines" of availability—meaning that a service is guaranteed to be up and running 99.999% (five "nines") or 99.99999% (seven "nines") of the time. Five nines of availability translates to six seconds of downtime each week, while seven nines is the equivalent of .07 seconds of downtime per week. While these numbers are generally acceptable in an ERP system, the industrial world requires much more stringent service levels: When the safety of an airplane or nuclear plant is on the line, much more than seven "nines" of service availability may be needed.

Device Connectivity, Provisioning, and Decommissioning

Connected industrial devices need to be instantly on and instantly credentialed and authenticated, as opposed to existing models of discovery that may require end-user or field technician interaction. This is a key part of the wide-area control capability discussed earlier: The "single pane of glass" management model requires that assets be brought and up down, upgraded and modified, without physically having to change or configure hardware or software.

Modern User Experience

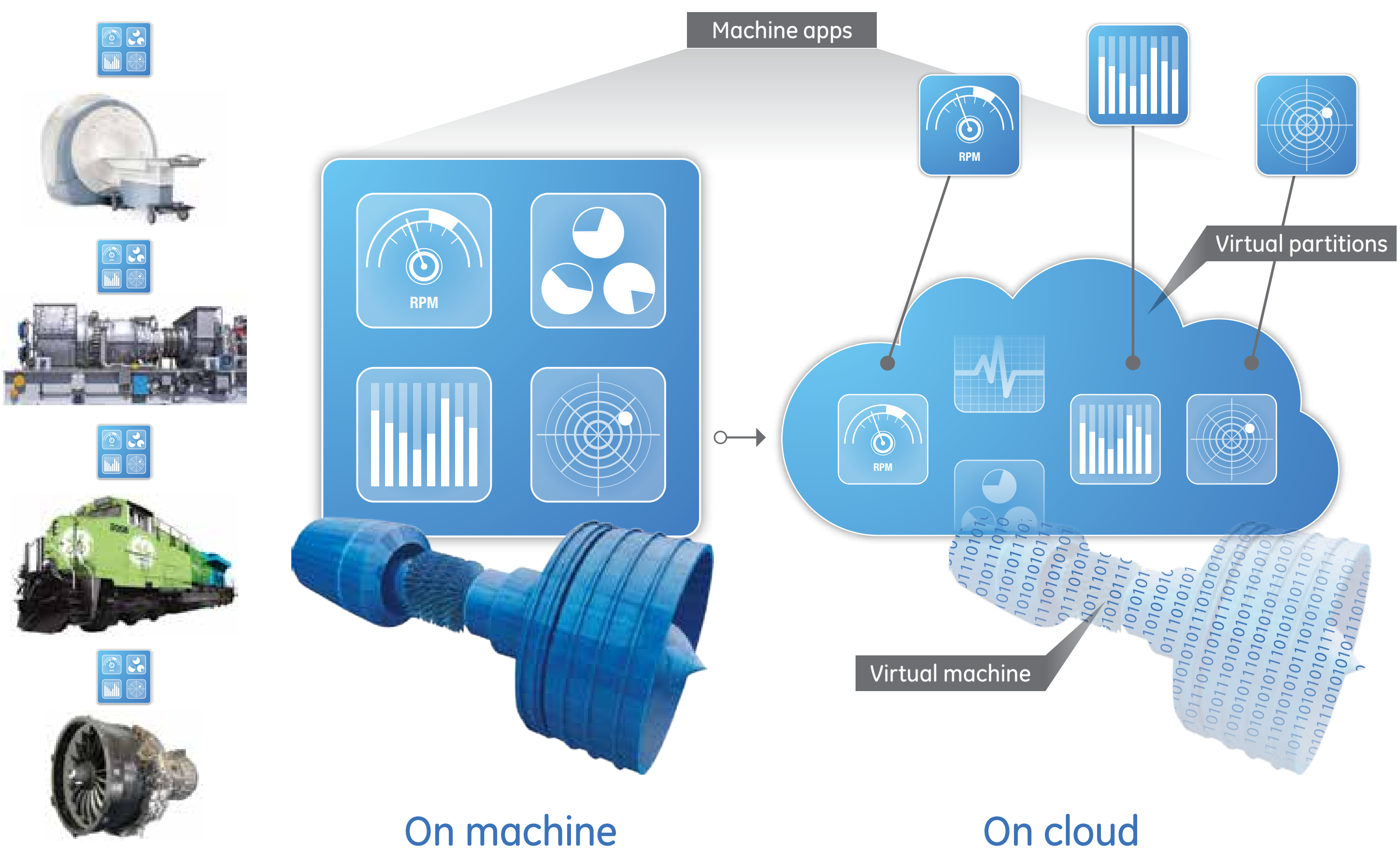
Aligning the industrial user experience with the consumer experience will help drive a broader use base for industrial applications, and it will allow industrial companies, many of which have an aging workforce that will soon retire, to create a user environment that appeals to a new generation of workers. As the quantity and scope of use of industrial data grows, companies will need new ways to turn data into information, and new approaches to user experience design that will filter and deliver context-relevant right information to the right people at the right time.

Interoperability with Existing Industrial and Enterprise IT Technology

Industrial companies also have a broad range of legacy technology that needs to be supported. This means that technology and business change must be managed at a cadence that is appropriate for industrial companies' adoption curves. The Industrial Internet must have the ability to help companies leverage both their existing industrial and enterprise IT investments without forcing them into a costly upgrade cycle. Brilliant Machines allow a degree of analytical and operational management and control that naturally can and should extend to key enterprise applications and functionality such as enterprise asset management, resource planning, supply chain planning and forecasting, and human capital management, among others.

Taken as a whole, these requirements define the specifications for an Industrial Internet platform that can leverage advances in computing, analytics, communications, and the cloud to support a modern industrial enterprise. Most importantly, the first generation of this platform is here today.

Software-Defined Machine



How GE Is Realizing the New Industrial World: The Predix™ platform

Predix™ is GE's software platform for the Industrial Internet. Predix enables industrial-scale analytics for asset and operations optimization by providing a standard way to connect machines, data, and people. Deployed on machines, on-premise, or in the cloud, Predix combines an industry-leading stack of technologies for machine-to-machine communications, distributed computing and big data analytics, asset management, and mobility, delivering on the industry's needs for scalability, extensibility, customizability, and security.

Why Predix?

- **Machine-Centric:** Connect, make machines intelligent, and optimize them from anywhere in the network.
- **Industrial Big Data:** Optimized for real-time, large-scale analytics and asset management.
- **Modern Architecture:** Rapidly deliver consumer-grade Industrial Internet apps with a cloud-agnostic big data platform.
- **Resilient and Secure:** Protect industrial data and control access to machines, networks, and systems.

Predix provides a standard, stable environment that will make it easier to connect, retrofit, and upgrade industrial assets to networks of machines and machine apps, systems, people, and processes, while enabling embedded analytics that can make machines intelligent and self-aware. The Predix platform is also scalable, supporting high-volume analytics, industrial data and operational management, across individual machines and entire networks, on-premise, in the cloud, or in a hybrid environment. And Predix is adaptive, allowing applications to be customized and extended across industries and their assets, data sources, and devices, both mobile and fixed.

GE's approach to developing Predix and bringing it to market starts with an understanding of the rapid changes at work in the industrial world, gleaned from its experience providing advanced industrial equipment and services. With this background, GE realized the need to accelerate the development, adoption, and time to market of modern industrial solutions and reduce the capital and operational cost and complexity of their use. To enable these goals, GE recognized early on the need to support a standard machine app model and a variety of existing and emerging requirements for connectivity, user experience, machine intelligence, analytics, and advanced industrial operations.

It became clear that embodying these concepts in the Predix platform will enable GE, its customers, and partners to accelerate innovation. To this end GE is taking the lead by incorporating Predix into its machines and its Predictivity advanced Industrial Internet solutions. GE is working with a rich ecosystem of technology partners, application developers and relevant standards groups to make Predix broadly available to the market at a rapid pace.

Predix consists of three basic components that underlie the provision of the advanced capabilities we have described above. (For a more complete understanding of Predix please go to: www.GESoftware.com/Predix)

Machines: Predix serves as the enabling platform for the development, deployment, and management of software-defined machines and machine apps. This includes the virtualization of operating environments and the use of embedded hypervisors that can leverage the separation of functionality and services on advanced multi-core processors. This capability enables industrial assets of all kinds to be transformed into Brilliant Machines, including legacy systems and devices, and as such function as components of an advanced operational and analytical environment. Industrial operators can now deploy, update, maintain and improve assets without service interruption.

Networks: Predix enables the real-time, scalability and functionality requirements of the Industrial Internet, and provides a connectivity platform for the analytics, operations, and wide-area control required in the modern industrial company. This means being able to connect all assets—machines as well as people—in a highly safe and secure environment. Deterministic machine-to-machine connectivity, as well as support for legacy connectivity protocols, is enabled by Predix. The platform also supports a consistent performance and user experience environment backed by support for industrial service level and quality requirements.

Users: Providing a modern, consistent user experience was a key design goal for Predix. This includes support for a highly functional and efficient development environment that can deploy software that integrates data and processes from across the Predix world. The development environment also enables the creation of new apps that can leverage mobile use requirements in a hardware and operating system-neutral manner. Most importantly, the Predix user experience supports the interaction of users with Brilliant Machines and other advanced industrial assets, and provides a new user experience that is commensurate with the new functionality that Brilliant Machines and the Industrial Internet can unleash.

Deployed on machines, on-premise or in the cloud, Predix combines machine-to-machine communications, distributed computing, big data analytics, asset management, and mobility, and delivers scalability, extensibility, customizability, and security.

Conclusion: Why Now and Why GE's Predix?

GE has developed the Predix platform and is creating an ecosystem of partners and value-added companies that will help make the Industrial Internet a reality for GE's customers.

The availability of Predix will open up the reality of the modern industrial enterprise to a wide range of industrial companies and stakeholders, from manufacturers and their suppliers to machine users/operators, machine buyers, and, most importantly, the global society in which we all work and live. To that end, Predix will help GE and its partners bring new industrial solutions to market more quickly, and in doing so drive important advances in functionality as well as efficiency and cost-savings.

This is not something GE is doing alone. Standing alongside GE is an ecosystem of partners that will help extend the value of Predix well beyond GE and its customers. These partners—taken from the ranks of industry, technology companies, academia, non-profits, systems integrators, and the financial world—are engaging with GE in establishing standards and driving the knowledge and products needed to make Predix an industry standard in its own right. And GE is already seeing valuable contributions from and collaborations with industrial, enterprise, and developer communities.

The new industrial revolution has already begun. Come join us in this journey.

Predix will open up the modern industrial enterprise to a wide range of industrial companies and stakeholders, from manufacturers and their suppliers to machine users/operators, machine buyers, and, most importantly, the global society in which we all work and live.

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