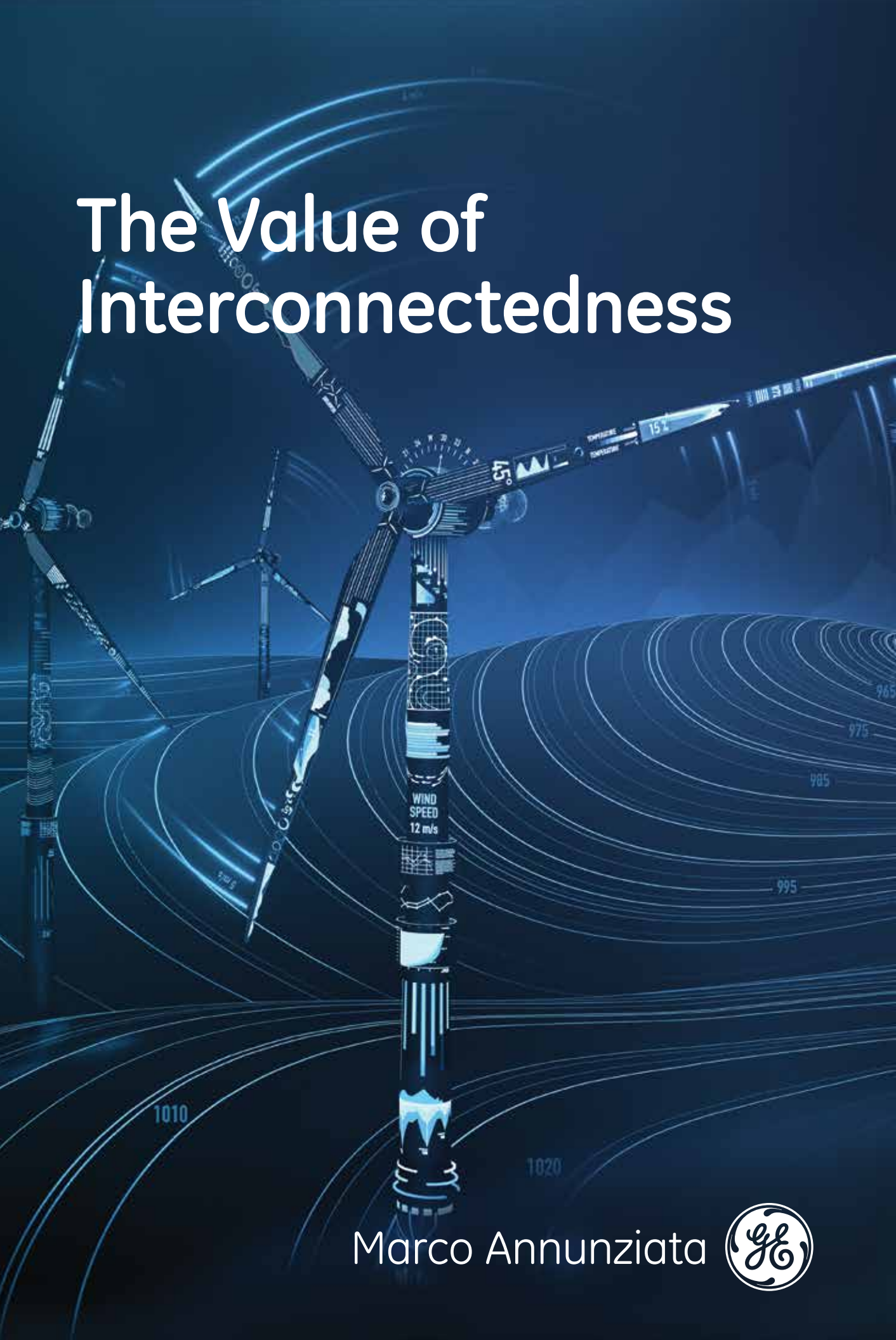
The Value of Interconnectedness



Marco Annunziata

The Value of Interconnectedness: Toward a new kind of industrial company

The convergence of the digital and the physical in the industrial world is a profound transformation that is far from fully appreciated. A connected device or machine becomes something entirely new. A smart phone, for example, still performs its original function; it allows you to make and receive telephone calls. But interconnectedness has rendered this a secondary function. The smart phone has new ways to make us more connected and informed (video chat, social networks, e-reader, and news and weather alerts). It is our concierge (restaurant reviews and bookings, taxi caller, online shopper). It is our entertainment system (music, TV, and games). It controls our thermostats, alarm systems, cars and more. A smart phone today is a fundamentally different object.

Cars are undergoing a similar transformation. Self-driving cars are already a reality. They can guide us on the most efficient route through web-enabled navigation systems and find the nearest gas station or restaurant; thanks to sensors, they can watch out for us, warning us if we stray from our lane, if we are about to turn when someone is in our blind spot, if we are at risk of hitting a pedestrian. In a Tesla, some technical problems can be fixed remotely by a technician at a computer hundreds of miles away. A car today is a fundamentally different object.

In a similar way, a company producing interconnected industrial devices becomes a fundamentally different company.

We have argued in previous work that the Industrial Internet and Advanced Manufacturing are not only transforming individual machines and systems, but they are also changing the nature of economies of scale, transforming the economic landscape and blurring the lines between manufacturing and services. In a similar way, industrial companies that combine the digital and the physical open entirely new dimensions in the way they operate and in the value they can provide to customers and shareholders.

Connecting the digital world of research, design, engineering and manufacturing enables a company to drastically reduce the time to introduce new products, leading to faster responses to customer needs and higher engineering productivity. Translating real-time factory and supply chain data into insights makes those factories and supply chains able to respond much faster to shifts in customer needs and external shocks. Linking engineering, supply chain operations, and services data through the cloud means operators can optimize factories and products in real time and continuously improve them throughout their lifecycle. As a result, machine uptime, throughput, and inventory turnovers increase. Higher responsiveness leads to higher sales.

Combining deep expertise in both digital technology and industrial machines is not easy. Both fields require complex and sophisticated domain expertise, and are experiencing fast-paced innovation. To be successful, a digital-industrial company must keep ahead of the curve on both fronts and be able to merge them seamlessly

[1]Marco Annunziata and Peter Evans, "Industrial Internet: Pushing the Boundaries of Minds and Machines" ; and Marco Annunziata and Stephan Biller, "The Future of Work".

in a way that maximizes value. Just like innovation, design and manufacturing need to be closely intertwined to learn from each other and adapt to each other, so digital technologies and industrial manufacturing need to be melded to learn from each other and spur each other to reach higher levels of performance. Software development must be guided by the industrial machines' purpose, potential and limitations—and vice versa.

GE has achieved this combination by establishing a new Software Center of Excellence (COE) in San Ramon, Calif. With an investment of $1 billion in software and analytics over three years, GE has become one of the major software companies in the world with the San Ramon Center and regional software centers in Europe and China. GE now employs 14,000 software engineers.

More than 1,000 of these software and data science experts are concentrated in the San Ramon COE, working seamlessly with their counterparts in the company's industrial divisions from Oil & Gas to Transportation, from Aviation to Healthcare. Combining the software skills of the COE's experts with the sectoral experience of data scientists and data engineers in the industrial businesses is essential—both to maximize the joint value of digital and physical as well as to ensure the compatibility and adaptability of software solutions across industries.

Creating value: The platform and Industrial Internet solutions

Platforms

Platforms are essential to enable and monetize the value of interconnectedness. Interconnectedness is all about communication, collaboration and compatibility, including for big industrial equipment, and it all starts with platforms. The power of platforms has been abundantly demonstrated in the digital world; just think of the burgeoning range of increasingly powerful apps on our smartphones. A powerful platform can facilitate the compatibility of applications, delivering a number of benefits:

i. collecting and analyzing data from a larger set of different industrial assets, creating a deeper and more informative information set that delivers more effective insights;

ii. enabling the interoperability of a wider range of assets within an industrial operation or system, boosting operations optimization;

iii. allowing applications to be adapted and adopted across different industrial sectors;

iv. making it easier for developers, engineers and data scientists to collaborate on a wider range of industrial solutions, leveraging the Global Brain to the maximum effect.

Most engineering and manufacturing system design tools, as well as factories and supply chains, have a plethora of data sources that are often neither connected nor integrated. To unleash the power of data integration and **systems-level** analytics and optimization in manufacturing, it is critical to ensure interoperability between data sources.

Much effort has recently been expended in integrating the data of design, product engineering, and manufacturing engineering through product lifecycle management (PLM) tools. But we have yet to reach the stage where a change in design automatically propagates through all virtual validation tools, such as robot and controls emulation, throughput and process simulation, and productibility and model-based manufacturing tools.

In factories and supply chains, it is not uncommon to find **20 or more separate data collection systems,** from Enterprise Resource Planning (ERP) to Manufacturing Execution Systems (MES) to energy management and homegrown quality systems. In fact, from a data collection perspective, every machine or controller might generate megabytes of data that often are not used to their fullest extent.

Integrating and fusing those data into one interoperable platform allows engineering, factory and supply chain leaders to gain visibility over their functions and to understand the system-level trade-offs of their decisions. Furthermore, the interoperability platform enables the development and implementation of generic engineering, factory, and supply chain tools that require only minor customization for different businesses and plants. These tools will unleash the power of analytics, simulation, and optimization providing leaders with (1) visualization of key performance integrators, (2) real-time decision support, and in some cases, (3) optimization and automation of decisions allowing them to focus on strategy and 'exception management' rather than day-to-day operations.

Platforms will play a key role in accelerating the growth and unleashing the value of the Industrial Internet, and the Future of Work more broadly. GE has developed Predix, our proprietary software platform for the Industrial Internet. Predix is designed specifically to meet the requirements and characteristics of industrial systems: it guarantees data security as well as mobility, it is optimized for machine-to-machine communication, and it supports distributed computing and big data analytics. Predix will support the rapid development of a growing number of applications for asset and operations optimization for a wide range of industrial sectors.

GE's Industrial Internet solutions

In previous papers we highlighted how the Industrial Internet can increase efficiency and productivity, eliminating unplanned downtime of machines like power turbines and locomotives.[2] Industrial Internet solutions are now being developed and applied in a range of industrial sectors, including those that play a pivotal role in driving economic growth. In this section we provide selected examples of GE's Predictivity services—productivity-enhancing solutions developed across different sectors—to give a fuller sense of the range of potential applications.

Transportation

The transportation network is the backbone of the economy, and inefficiencies in transportation translate to higher costs for business and ultimately in slower growth in output and incomes at the national level. In the railways sector, efficiency and productivity can be increased by raising the velocity at which the railway network operates, and by reducing the "yard dwell time" that trains spend idle in a railway yard. Dwell time is closely and inversely linked to operating margins.

To improve performance, GE has developed the RailConnect 360 solution, which provides comprehensive support to rail mechanical and transportation departments on locomotive health, maintenance and repairs. The system collects and analyzes performance data during locomotive operations, provides automating diagnostics and root cause analysis. This allows railway managers and technicians to schedule preventive, conditioned-based maintenance and repairs, maximizing reliability and availability. Software modeling can guide an optimal reconfiguration of network and yard operations—along the logic of the digital thread in advanced manufacturing. Similarly, it enables advanced planning of resources and materials.

GE's Movement Planner software has already achieved 10 to 20% increases in velocity and a 50% reduction in the need to change crews, substantially improving asset productivity. Similarly, our Trip Optimizer solution for railways has already delivered a 10% reduction in fuel consumption.

Aviation

The top priorities in aviation are clear: maximizing safety and minimizing delays, limiting cancellations and reducing fuel consumption. Intelligent Operations services, developed by the Taleris joint venture between GE & Accenture, use proprietary algorithms to monitor data collected from aircraft equipment and airline systems to predict, prevent, and recover from operational disruptions. The system has already proved capable of spotting and flagging issues not detected by traditional diagnostics, preventing operational disruption and lost revenue. For an average U.S. domestic airline (14 million passengers, 85,000 flights per year), Intelligent Operations services could prevent 1,000 delayed departures and flight cancellations each year, helping more than 165,000 passengers get to their destinations on time.

Another Predictivity solution, Flight Efficiency Services (FES), collects real-time data generated by an aircraft and applies proprietary techniques that provide business intelligence and actionable insights to significantly improve an airline's overall efficiency. FES uses smart software tools and analytics algorithms to help airlines achieve higher levels of efficiency in four areas: fuel management; flight analytics; navigation services; and fleet synchronization.

[2]See "Industrial Internet: Pushing the Boundaries of Minds and Machines" and "The Future of Work"

Health Care

Health care touches everyone, and the value of improving the quality and speed of health care outcomes is readily apparent. But health care also has enormous economic significance: better health care translates into higher economic growth , and cost effectiveness in health care services is an increasingly pressing priority in both advanced and emerging economies.

GE has developed a range of Industrial Internet solutions for health care. Centricity 360™ is a secure and reliable cloud-based platform that helps teams of physicians and caregivers work together in a clinical community—where they can quickly confer on patient cases, simultaneously access images and reports, and collaborate on diagnoses and treatment plans. It helps reduce duplicate tests and patient transfers, while yielding improvements in imaging costs and system maintenance.

Hospital Operations Management (HOM) integrates bed assignment, departmental workflow, patient flow, and equipment management to reduce wait times, optimize utilization of equipment and beds, and enable more efficient quality care to be delivered throughout a patient's stay, from admissions to discharge. It reduces bed turnaround time and patient wait times.

DoseWatch gives hospitals a Web-based radiation dose monitoring system that tracks a patient's exposure to radiation from any imaging device. This means clinicians can reduce the cumulative radiation dose produced by a series of imaging procedures, while still delivering the high image quality needed to diagnose and treat cancerous diseases.

Energy

Maximizing efficiency in power generation and distribution is essential not just to enable economic growth, but to do so in a way that improves environmental sustainability, especially as global growth raises standards of living—and desired energy consumption levels—across emerging markets. There are a number of Industrial Internet applications that are helping raise efficiency in this sector.

Wind PowerUp is a perfect example of the combined joint power of software and hardware. The software analytics allow wind farm operators to optimize the performance of the turbines, based on environmental conditions. Raising the turbines' efficiency can increase the wind farm's annual energy output by up to 5%, which translates in a 20% increase in profitability. Wind PowerUp is already in operation on nearly 500 wind turbines, delivering an additional 86GWhr in annual power generation.

GE has developed a similar blend of software and hardware solutions for gas-power generation: the FlexEfficiency Advantage Advanced Gas Path solution (AGP). AGP combines sophisticated software with an upgraded hardware design enabled by the use of new materials. Based on 100 million hours of real-world operating data already, the flexibility of this system allows power generation plants to prioritize increased output, more efficient load responsiveness, reduced emissions, more robust start ups

[3]See for example David E. Bloom, David Canning and Jaypee Sevilla (2001), "The effect of health on economic growth: Theory and evidence", NBER Working Paper n. 8587.

or lower turndown capability. Thanks to this flexibility, plant operators can quickly react to changing market conditions by maximizing output or reducing operating costs, and to possible changes in emissions and power grid regulations. On one combined-cycle power generation plant with a net output of 525.2 MW, these solutions can reduce annual carbon dioxide emissions in an amount equivalent to that of 2,200 cars.

Lighting

You don't need to be as large as a jet engine or a gas turbine to be brilliant. GE has developed a smart LED light bulb as well. It is an interconnected light bulb, which allows you to connect your home's lighting system from any location, and can sync with other connected devices thanks to the "Wink" application. This solution helps reduce energy consumption, resulting in cost savings at the individual home level, and corresponding sustainability benefits at the macro level. The system is flexible and easy to install and use—requiring only the Wink app, the light bulbs and a base station, without any additional infrastructure.

The benefits of interconnected lighting, however, will be even more powerful at the commercial level, and herald a profound transformation in cities as ecosystems. Once interconnected, lighting becomes a city's nervous system. It is intrinsically linked and crucial to the functioning of every element of a city, from a major infrastructure like highways, subways and power grids to parking lots, streets and public buildings. Once interconnected, it becomes a platform that can make cities truly smarter, and enormously more efficient.

We have already developed monitoring and control management systems which allow for real-time visibility of efficiency levels of individual fixtures as well as fault alerts. This enables cities to optimize the management of their lighting systems, maximizing energy efficiency, optimizing asset management, and yielding maintenance costs savings. San Diego, California, the first city to adopt GE's Lightgrid Outdoor Wireless Control System, estimates it will save more than 250,000 dollars each year with this GE technology. As cities adopt these systems at scale, the energy savings will be substantial, and interconnected lighting could translate into a precious boost to local authorities' budget and a strong improvement in their eco-sustainability.

Even more importantly, interconnected lighting can become the platform linking together different aspects of the life and functioning of a city - exactly like the nervous system in a human body. Interconnected lighting could link together a city's transportation system, helping optimize traffic flow; it could collect data on air quality and meteorological conditions, noise levels and foot traffic; and link to portable interconnected devices to collect and distribute information. The benefits could extend from adapting lighting intensity to traffic conditions on streets and in shopping areas to helping schedule preventive maintenance on city infrastructures in a way that minimizes disruptions - improving the quality of city life at lower cost.

Commercial and industrial systems also stand to benefit greatly from interconnected lighting. Commercial establishments will leverage the interconnected lighting infrastructure to improve customer experience while reducing costs; and in

industry, interconnected lighting will be an integrant part of the digital thread that improves communication, workflow and efficiency on factory floors as well as through supply and distribution networks. Again, the benefits in terms of lower costs and greater sustainability will be substantial.

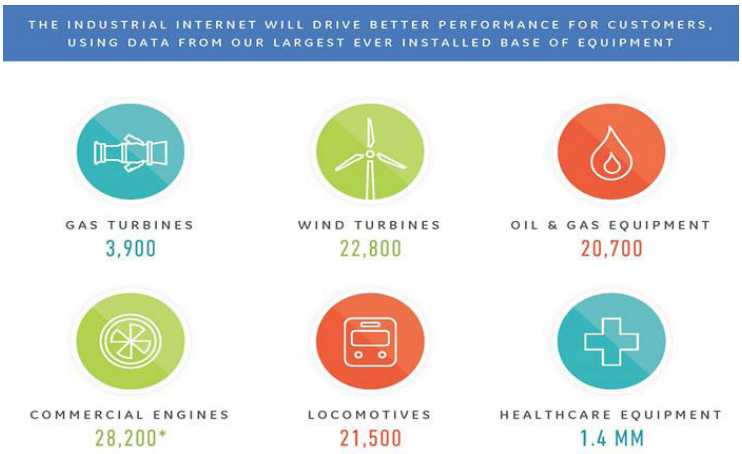
The Industrial Internet is making lighting truly brilliant.

A closer relationship

The examples above represent not just the new value that a digital-industrial company can provide, but also how this transforms the relationship between a solutions-provider and its customers. These solutions are developed through a much closer relationship with customers, which lead to a much deeper understanding of their needs, priorities and constraints. Developing these solutions, in fact, requires internalizing the customers' own objectives and value propositions. This requires a more intimate understanding of the customers' relationship with their customers, which, in turn, could be transformed as the reach of the Industrial Internet extends directly to the consumer—think of the relationship between utilities and households, and the additional role that Wink plays in it.

Installed base: the importance of industrial scale

Just as a powerful platform is essential to unleash the power of Industrial Internet solutions, so the software platform itself needs to be deployed across a large hardware base to quickly deliver benefits and rapidly trigger network effects. Given GE's position as a leading industrial hardware manufacturer, the solutions described above can be scaled across a global industrial system, reaching a massive installed base of industrial assets: more than 28,000 commercial jet engines; 21,500 locomotives; nearly 23,000 wind turbines; 3,900 gas turbines and 20,700 units of oil and gas equipment; and 1.4 million pieces of health care equipment.



This is only a portion of the universe of industrial assets that will be impacted by the Industrial Internet revolution. These numbers summarize GE's footprint in the key industrial sectors where the company operates, but the Industrial Internet will affect all key assets and equipment across all industrial sectors. These numbers, however, already give a powerful sense of the scale of this transformation.

They also underscore the point raised at the beginning of this paper: that a company producing interconnected devices—in this case interconnected industrial assets—

becomes a fundamentally different company. In particular, **the simultaneous development of interconnected hardware and an enabling software platform under the same roof redefines the very nature of a company, transforming it from a traditional industrial equipment producer to a full-range customer solutions provider, able to maximize customer outcomes and profitability.**

Valuing interconnectedness: Financial impact

The Industrial Internet solutions described above have started to deliver greater efficiency and productivity, higher "uptime" of assets, and reduced energy and water consumption to companies operating in aviation, energy, transportation, mining and other sectors, as well as to cities and hospitals. **What are the implications for the new breed of industrial companies that can deliver these solutions?**

While we are still in the early phases of the Industrial Internet, Predictivity solutions are already beginning to show a meaningful impact on GE's top line: For 2014, GE is on track to record more than $1 billion in revenues from Predictivity solutions. **While the process is just at the very beginning, there are several reasons to believe that this area will be characterized by especially fast revenue growth.**

- **First, the merging of the digital and the physical brings the benefits of Moore's Law to the industrial world.** Physical machines are subject to physical laws, and will therefore not enjoy the full exponential improvement in cost-adjusted performance typical of software. But as the digital becomes closely interlinked with the physical, it will accelerate the pace of performance improvement in a way that has hitherto not been possible.

- **Second, as the Industrial Internet platform takes hold, it will trigger network effects** that will allow more companies and individuals to participate in the Industrial Internet innovation process and will accelerate both the pace of such innovation and the speed at which additional benefits can accrue.

- **Third, the economic incentive to adopt efficiency-enhancing Industrial Internet solutions is extremely strong across all industrial sectors.** This is due in some cases to external pressures, such as the need to contain costs growth in the healthcare industry or improve margins in the mining industry given weaker commodity price dynamics. But it is also driven by competitive pressures, as the efficiency gains that Industrial Internet solutions can deliver could quickly change the competitive landscape. For companies in sectors impacted by the Industrial Internet, the cost of doing nothing is simply too high.

It is worth noting that software and other mature tech companies are able to achieve operating margins well in excess of 30% given the near zero marginal cost of incremental sales of digital products and solutions. This compares high-teens operating margins for best-in-class traditional industrial equipment manufacturers.

[4]Data based on publicly listed companies on the major world stock markets.

Market valuations currently indicate strong investor confidence in the ability that software-driven companies have to create value, especially when compared with traditional industrial companies. Price to sales multiples are in a relatively tight 1-1.5x range for traditional companies such as industrial conglomerates (1.1x), industrial machinery (1.3x), oil and gas equipment and services (1.5x), electrical components and equipment (1.3x) and aerospace and defense (1.1x). Only health care equipment fares better, with 3.0x.

By contrast, multiples for software-driven industries average around 5x, with internet software and services (5.7x) and healthcare technology (5.0x) at the top, followed by application software (4.5x), systems software (4.3x), data processing and outsourced services (3.2x), life sciences (3.1x); biotechnology is the outperformer with 10.5x. The Operating Margin for the second group is more than double that of traditional industries (24% vs 11%); and these new industries combined have a nearly identical market cap to that of traditional industries, even though their sales are only one quarter of the traditional group.

The higher multiple is a testimony to market expectations of faster growth, higher margins and greater capital efficiency in the new, digital-driven industries. **Companies that position themselves at the intersection of digital and physical within industry should see their valuations move closer to those of software-driven companies,** as the additional value and greater growth potential of Industrial Internet solutions becomes apparent. As argued above, the intrinsic limitations of physical machinery could cap the pace of improvement in the industrial world compared to the full power of Moore's law; on the other hand, the huge installed base of industrial assets provides an enormous base of economic value that can be leveraged and boosted by the merger of the digital and the physical.

An example of this trend can be seen in Tesla, a car maker that trades at a price-to-sales multiple of 13.0x, well above that of even established digital players such as Google (6.2x) and Apple (3.4x). Markets are clearly looking at Tesla as a fundamentally different kind of car maker: a company that produces interconnected cars. And this is in an industry where digital services are (at this stage) limited to the new cars it produces; they cannot be applied to a new car company's existing installed base of assets, as is the case for other industrial sectors. Yet the example of Tesla suggests that it is possible in principle that "new generation industrial companies" that leverage the merger of digital and physical could attract even stronger market interest and valuation than segments of the digital industry.

Conclusion

The marriage of the digital and physical world brought by the Industrial Internet and augmented by advanced manufacturing and the global brain is bringing a profound transformation to industry. At the same time, it is redefining the nature of industrial companies. Those that position themselves at the intersection of digital and physical become fundamentally different from traditional industrial companies—just like interconnected devices are fundamentally different from their non-connected versions.

Industrial Internet solutions are beginning to deliver substantial benefits to companies operating in aviation, energy, transportation and other industrial sectors, as well as

[5]Multiples as of 02 October 2014.

to cities and hospitals. While we are still at the beginning of this process, Industrial Internet solutions are already having a meaningful impact in terms of revenue generation for a company like GE. Revenue and margin growth in these services should be considerably higher than in traditional industrial solutions, thanks to the accelerating power of digital technologies, network effects, and powerful economic incentives for adoption. For companies, the cost of doing nothing is simply too high.

As these benefits unfold, "new generation industrial companies" will also be seen by markets as fundamentally different, with a revenue growth and margin potential closer to that of software-driven companies than traditional industrial companies. This should translate in the strengthening of key market valuation metrics.

Compared to software-driven companies, these "hybrid" industrial companies have one disadvantage: the physical limitations of hardware will cap the exponential improvement potential of the embodied digital technologies. However, they have the comparative advantage of a large installed base of industrial assets, which enables the new Industrial Internet solutions to be readily leveraged across a huge range of economic activities to maximize their overall value-creating potential.

Platforms will play a crucial role in accelerating the growth of the Industrial Internet, and in allowing companies to monetize the resulting benefits. Developing a platform establishes a keystone position within the Industrial Internet ecosystem: the company that owns the platform can leverage a broader and deeper pool of distributed expertise, and capture a share of the value that third parties create on the platform. Capitalizing on this role as an ecosystem hub requires the ability to move fast, keeping ahead of the curve, and rapidly adapting to the faster market changes spurred by the digital-industrial innovation.

As communication and collaboration accelerates, the industry will need supportive common standards and communication protocols, as well as continuous strengthening of cyber security safeguards. To this end, GE is a founding member of the Industrial Internet Consortium, a partnership of industry, government and academia aimed at sharing best practices and shaping global development standards to accelerate the growth of the Industrial Internet in the most efficient and open way possible.

The new wave of innovation spurred by the Industrial Internet is bringing about an unprecedented transformation. As software-driven performance improvement reverberates through the world's massive installed base of industrial machinery and gets embodied in new investment, it will reshape industry, reshuffling the competitive landscape. Mastering both the digital and the physical is the key to accelerating value creation in this new industrial world.

WEATHER CONDITIONS
SSURE FLOW ANALYSIS