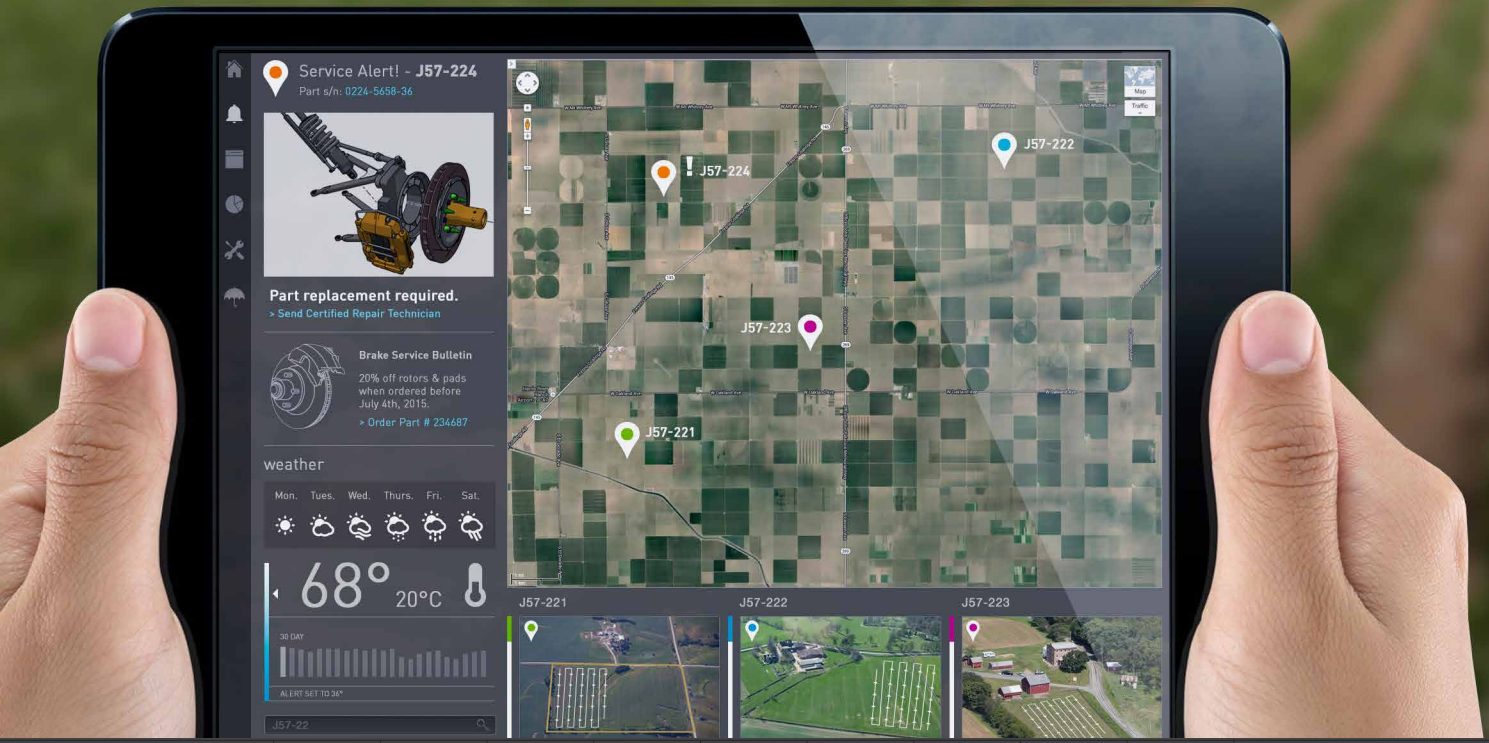
The Internet of Things

How a world of smart, connected products is transforming manufacturers



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We live in a smart, connected world. The number of things connected to the Internet now exceeds the total number of humans on the planet, and we're accelerating to as many as 50 billion connected devices by the end of the decade[1]. For manufacturers, the implications of this emerging "Internet of Things" are huge.

According to a recent McKinsey Global Institute report, the Internet of Things (IoT) has the potential to unleash as much as $6.2 trillion in new global economic value annually by 2025[2]. The firm also projects that 80 to 100 percent of all manufacturers will be using IoT applications by then, leading to potential economic impact of as much as $2.3 trillion for the global manufacturing industry alone.

The rise of the IoT has been driven by the convergence of market forces and parallel innovation of enabling technologies. Products have evolved from purely physical components to complex systems combining processors, sensors, software, and digital user interfaces that are now connected to the Internet and each other. As their definition has evolved, product capabilities have multiplied, creating new forms of value and even doing things well beyond their primary function.

The impact is a fundamental transformation of how manufacturers create and exchange value with customers. This transformation is shifting the sources of value and differentiation to software, the cloud, and service, and spawning entirely new business models.

To capture this great wave of value creation opportunity, manufacturers have an urgent need to rethink nearly everything — from how products are created, sold, operated, and serviced. Those who don't place their current competitive advantage at risk.

FORCES OF TRANSFORMATION

We're at the early stages of a fundamental transformation, marking what could be one of the most significant disruptions since the Industrial Revolution. How did we get here? PTC has identified the key Forces of Transformation, some of which are long-standing while others are more recent. Individually, any one of these forces is disruptive. Together they are completely transformational and have driven us to a world of smart, connected products in the IoT.

DIGITIZATION

Replacing analog product and service information with a fully accurate virtual representation that can be easily leveraged across the value chain (engineering, factory floor, service).

As manufacturers digitize product and service information and leverage the Internet, they reduce geographic boundaries.

GLOBALIZATION

The general shrinking of the world driven by technology that eliminates economic and geographical divisions and opens new markets.

As manufacturers design, build, sell, and service globally in the pursuit of new markets, they are confronted with increasing regulation.

REGULATION

Enforcement of governmental rules, non-governmental organizational policies, and industry standards related to environment, health, safety, and trade.

As manufacturers seek to differentiate across global markets, they are driven to offer greater customer choice at scale.

PERSONALIZATION

Efficiently tailoring products and services to accommodate regional and personal preferences, the growing influence of consumers, and the consumerization of IT.

As manufacturers seek to more efficiently meet the growing diversity of customer demand, they are increasingly turning to software.

SOFTWARE INTENSIVE PRODUCTS

Integrated systems of hardware and software capable of sophisticated human-to-machine interaction, diagnostics, and service data capture with additional value delivered through software enhancements.

As manufacturers deliver ongoing value through smart products, new service-centric business models have emerged.

SERVITIZATION

Fundamental business model shift in which products evolve to integrated "bundles" of services capable of delivering new value continuously throughout the customer experience lifecycle.

As manufacturers seek to unleash greater value from their increasingly smart products, they are adding connectivity to those products.

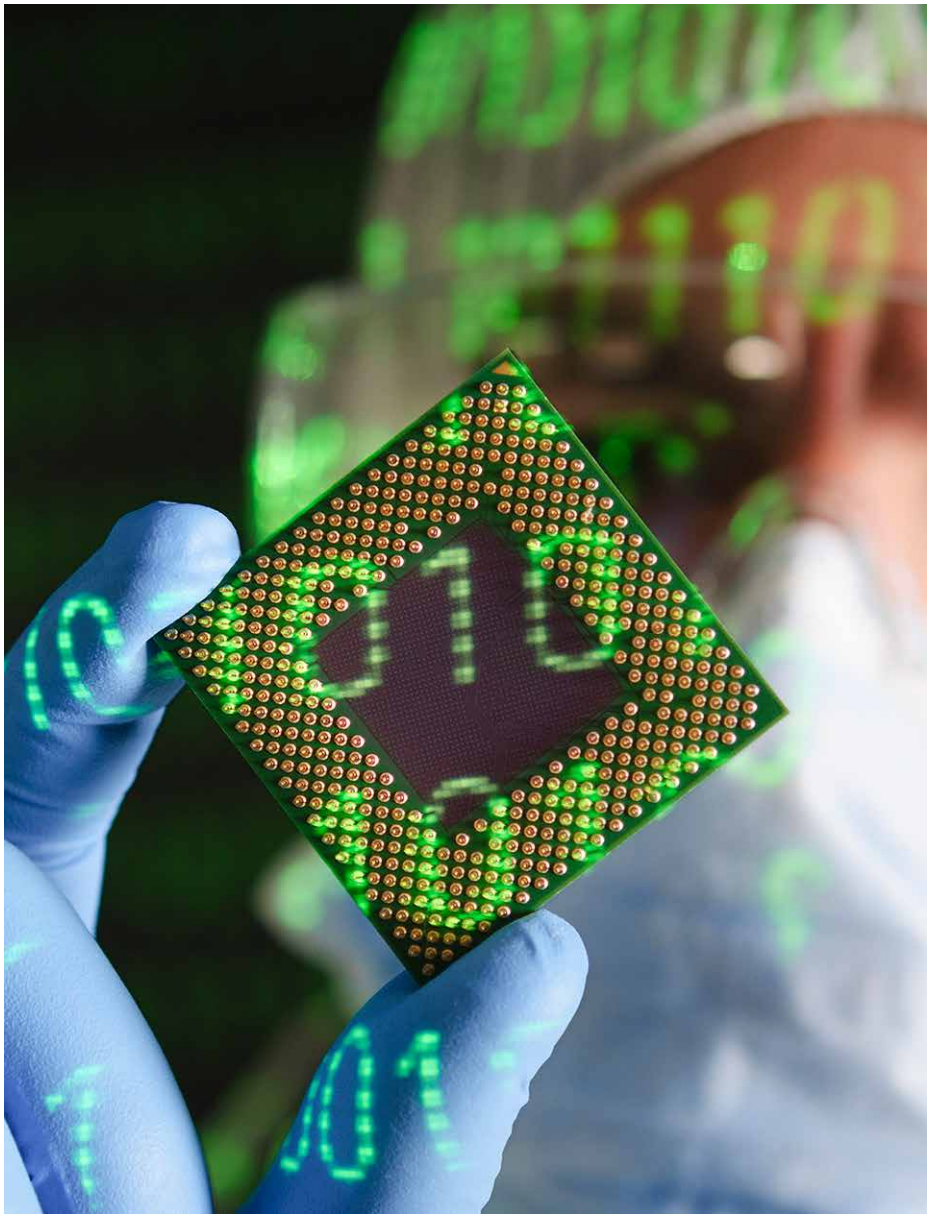
CONNECTIVITY

Pervasive networks of Things embedded with sensors and individually addressable to enable sophisticated monitoring, control, and communication.

ENABLING TECHNOLOGY

Against the backdrop of these Forces of Transformation, the world has seen a series of technology innovations that make the IoT both technologically and financially feasible today. Technology innovations across computing and communication infrastructures , as well as the things themselves, have converged — after all, the Internet now connects the car, the home appliance, and the office building.

- **Computing Infrastructure:** Data capture and analytics tools and new business and software applications create new forms of value
  - **Expanded Data Storage Capabilities:** In 1956, IBM's 305 RAMAC held 5 MB on fifty 24-inch disks, weighed one ton, and cost $3,200 a month. Today, consumers can purchase a 1 TB 3.5 inch disk drive (the size and weight of a small book), for $85. This technical innovation has supported increased data creation. In fact, 90 percent of the world's data has been created in the last two years alone
  - **Increasing Processor Performance/Efficiency:** The innovative Intel Pentium processor was released in 1993 and drew 8 watts with a 75 Mhz clock speed. Today, Intel's Core i7 Haswell processor draws 84 watts with a 3.5 Ghz clock speed. In these twenty years, CPU power consumption increased by 10x while CPU processing performance exploded by 47x
  - **Evolution of Cloud Computing/Big Data Tools:** Gartner projects that the Infrastructure as a Service (IaaS) industry, which includes on-demand computing, storage, and network resources, will grow by 41 percent through 2016 to become a 24 billion dollar industry. Emerging frameworks like Hadoop, a data processing framework and distributed file system, promote efficient analysis of ever-growing data sets

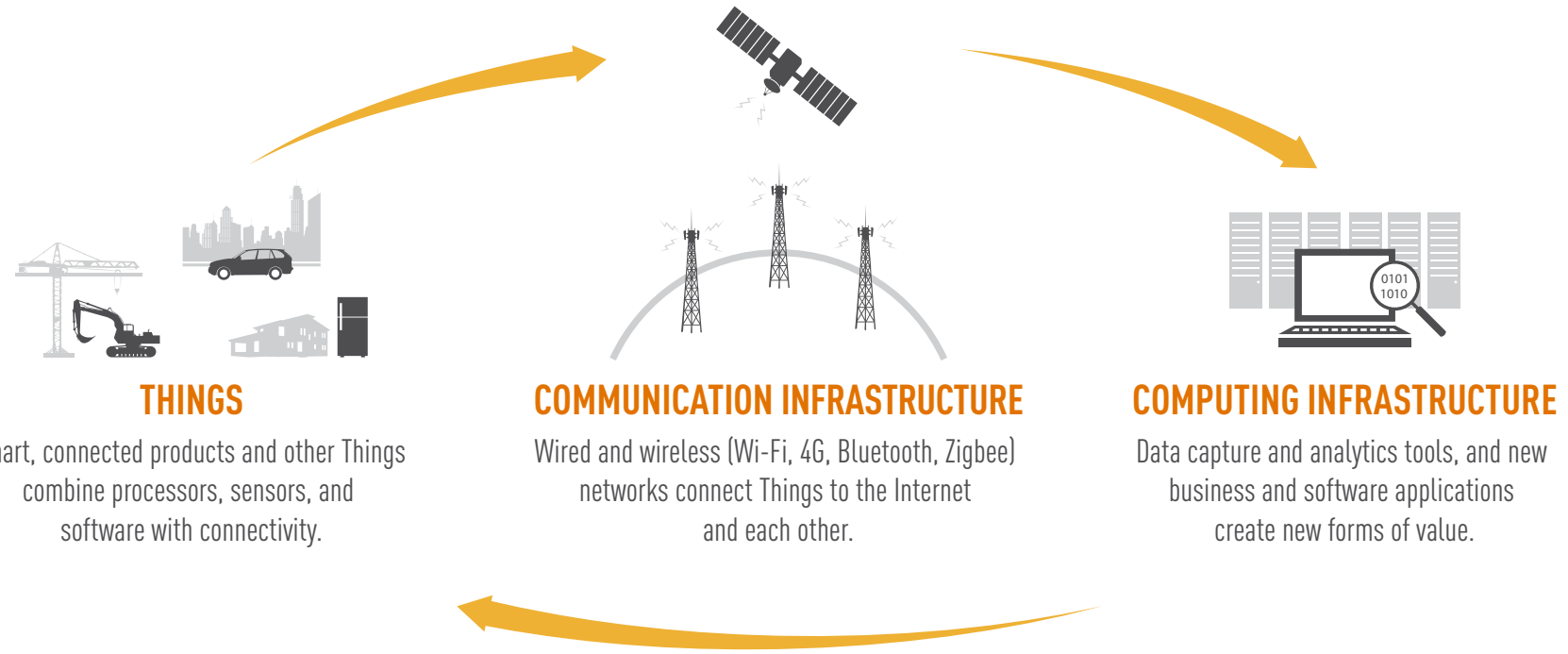


- **Communication Infrastructure:** Wired and wireless (Wi-Fi, 4G, Bluetooth, Zigbee) networks connect Things to the Computing Infrastructure and each other.
  - **Evolution of Connectivity:** The expanding 4G LTE wireless broadband network has 100 Mbps downstream and 50 Mbps upstream rates, while emerging wireless technology standards, such as ZigBee, enable cost and power efficient wireless networking over long distances through mesh networks
  - **Introduction of IPv6 Address Scheme:** In response to the need for an address pool to support the exponential growth of Things connecting to the Internet, the IPv6 was created. The now broadly accepted 128-bit Internet scheme offers about 3.4×1038 (340 trillion trillion trillion) unique addresses to accommodate the requirements of the IoT
  - **Ubiquity of Connectivity:** Chipmakers are now designing connectivity directly into the hardware, (e.g., SSL encryption), reducing the demands on software code. Also, while a fragmented assortment of wireless communications technologies still exists today, they are growing. For example, public Wi-Fi hotspots are expected to grow 350 percent by 2015[3]
- **Things:** Smart, connected products and other Things combine processors, sensors, and software with connectivity.
  - **Miniaturization and Efficiency of Components:** Advances in production technology and chip architecture enable manufacturers to embed components without diminishing the user experience. System-on-Chip solutions host all components of an electronic system on a single 28nm-48nm chip, and low power 32 bit microcontrollers allow devices to run on single AA batteries for years
  - **Declining Prices of Processors, Sensors and Components:** Economies of scale — from production of devices such as smartphones, for example — have depressed the cost of sensors and processors. From 2012-2015[4] Gartner forecasts the cost of most technology components will continue to fall by between 15 and 45 percent
  - **Software Development Frameworks:** Demand for software delivered inside and alongside the product and the business applications needed to deliver value-add solutions is increasing dramatically. Rapid application development tools, development communities, and reuse have simplified and accelerated software and application development and innovation

THE INTERNET OF THINGS (IoT)

The IoT is comprised of the three core components: A collection of smart, connected products, product systems, and other Things connected through an Internet-like communication infrastructure to a computing infrastructure that are creating new forms of value. Data from the product condition, operation, and environment are delivered in real-time enabling capabilities to control, service, and upgrade the product and system performance.

For manufacturers (i.e., those in the Things business), these innovations not only have the potential to generate incredible amounts of new value, but also to disrupt the status quo. The capabilities created and data generated by this new generation of smart, connected products requires new thinking about the enterprise applications and the connected ecosystem to optimize current business processes, drive better decision-making, and expand areas of innovation.



THINGS

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COMMUNICATION INFRASTRUCTURE

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COMPUTING INFRASTRUCTURE

Data capture and analytics tools, and new business and software applications create new forms of value.

CAPABILITIES OF SMART, CONNECTED PRODUCTS

Smart, connected products in the IoT blur the line between products and services and enable an entirely new set of capabilities that create value for both manufacturers and their customers. There are six unique categories of capabilities that manufacturers must consider and adopt strategically:

- **Personalize/Customize:** Products can be efficiently tailored by the end user or manufacturer before or even after a product is sold
  - **Example:** The Ford Model T was infamously available in any color as long as it was black. A century later, Motorola's Droid Maxx is similarly limited in its physical diversity, but is infinitely customizable through the Android™ mobile platform and apps that can be added and configured to create a truly personalized product at the cost of a mass produced product
- **Monitor Condition/Operation:** Products can assess their own condition, performance, and the operator's inputs and status
  - **Example:** John Deere's WorkSight technology connects its equipment to monitoring dashboards so company managers can see where an entire fleet of vehicles are at any time, and evaluate the performance of that equipment in real-time. Diagnostic data flows wirelessly to a technician who may show up at a worksite with a replacement part before a driver has even noticed a problem
- **Monitor Environment:** Products can assess the external environment through sensors and data sources
  - **Example:** Auto-industry supplier Continental AG makes windshield-wiper systems with rain-sensors and software that control how rapidly the wipers sweep the windshield depending on the volume of rain. Continental also lets car makers connect the sensors to vehicle-control systems that tell the car to roll up the windows or close the sunroof when rain starts

- **Remote Control:** Products can be operated remotely in real-time
  - **Example:** The General Atomics MQ-9 Reaper is an unmanned aerial vehicle capable of remote controlled or autonomous flight operations. They provide troops with a 24-hour "eye in the sky" seven days a week. Each aircraft can stay aloft for up to 17 hours at a time while the trained crew located safely at a base steer the craft, analyze the images, and act on what they see. In addition, they are about 1/10 the cost of traditional war planes
- **Service/Upgrade:** Products can be serviced, updated and enhanced instantly and from anywhere
  - **Example:** Trane, a maker of heating, ventilation, and air conditioning (HVAC) systems that is part of Ingersoll-Rand Corp, makes systems that contain extensive digital sensors connected to its Intelligent Services Center. Trane Intelligent Services are able to resolve 30 percent of HVAC problems remotely without sending a service truck. Some 40 percent of problems are diagnosed in 30 minutes or less. This allows Trane and its customers to reduce costs and improve equipment up-time
- **Autonomous:** Products are capable of self-operating, learning, updating, and correcting by analyzing real-time data
  - **Example:** Google first revealed that it had been working on self-driving cars in 2010. Since then, Google's vehicles have logged hundreds of thousands of miles on public roads, and data now shows that autonomous cars drive more smoothly and more safely than human drivers. Expanding connectivity to include other systems will also make it possible for cars to send hazard warnings to each other, adapt based on traffic and weather information, and even interact with signals as they approach intersections

IMPACT OF THE INTERNET OF THINGS ON MANUFACTURERS

While product and service capabilities have multiplied, the sources of value and differentiation have shifted. Manufacturers now have opportunities to create new sources of competitive advantage, but only if they heed the three essential value shifts:

- **Value is Shifting from Hardware to Software:** Products have evolved from purely physical components to complex systems combining processors, sensors, software, and digital user interfaces. As manufacturers seek to accelerate product innovation and efficiently meet the growing diversity of customer demand and regulation, they increasingly turn to software. One example, the automobile now has on average 100 million lines of code to enable variable driving modes, various engine and emission configurations, adaptive cruise control, and hands-free commands
- **Value is Shifting from Product to Cloud:** While smart products have enabled new capabilities, there is a limit to the incremental value that can be generated from within the product. Connecting smart products enable a digital component of the product in the cloud to extend capabilities within the product and deliver entirely new capabilities alongside the product. Manufacturers are also finding that moving product capabilities to the cloud accelerates service, enhancements, and innovation. For example, Wi-Fi music systems shift core functionality from the product to the cloud to dramatically simplify the product design, improve user experience, and better integrate with other apps and services
- **Value is Shifting from Product to Service:** Market forces and competition have diminished the viability of product-centric strategies that maximize returns at the moment of sale, and led to a burgeoning business model shift. Products are integrated with services that deliver new value throughout the entire product lifecycle or simply deliver the desired outcome via an on-demand service. One example, aircraft engine manufacturers sell hours of flight instead of engines, driving manufacturers to optimize product up-time, develop value-add services, and enable operators to better manage costs

These three essential value shifts have created new sources of competitive advantage, but also require new skills, infrastructure, cultural norms, and operational models. For manufacturers that transform to meet the demands of a smart, connected world, this combination of software, the cloud, and services will be the crucible of innovation and the basis for differentiation, new business models, and disruption. Those who don't place their current competitive advantage at risk.

RESPONDING TO THE INTERNET OF THINGS

Manufacturers must begin to transform existing business processes and fundamentally rethink how they create, operate, and service smart, connected products in the IoT. For those that get it right, the future represents a huge opportunity to create product and service advantage:

- **Transform How Products are Created**
  - Manufacturers must plan and design flexible platforms that enable personalization, value added services, and product enhancements to be delivered remotely before and after the product is in the market
  - Manufacturers must design out the complexity created by combining processors, sensors, software, digital user interfaces and connectivity, and deliver a simple user experience
  - Manufacturers must incorporate product usage data into R&D processes and drive new functionality, define specifications, and increase customer intimacy
- **Transform How Products are Serviced**
  - Manufacturers must plan and deliver remote software and service updates in real-time, with minimal customer disruption, and at minimal marginal cost
  - Manufacturers must plan and optimize product and service parts management and inventory control by tracking assets and analyzing real-time product usage data to predict parts needs
  - Manufacturers must plan and optimize field service management processes by bundling proactive and reactive maintenance and providing technicians with information in advance to increase first time fix rate
- **Transform Business Models**
  - Manufacturers must rethink business processes and business models to maximize returns across the entire useful life of the product, and not just up to the point-of-sale
  - Manufacturers must plan for increased complexity of expanded partner and supplier ecosystem, and consider the opportunities and threats they create
  - Manufacturers must capture and analyze product data to anticipate product service needs and user desires for additional services and capabilities

To learn more visit PTC.com, or contact PTC to discuss how PTC can help your company transform for the IoT.

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