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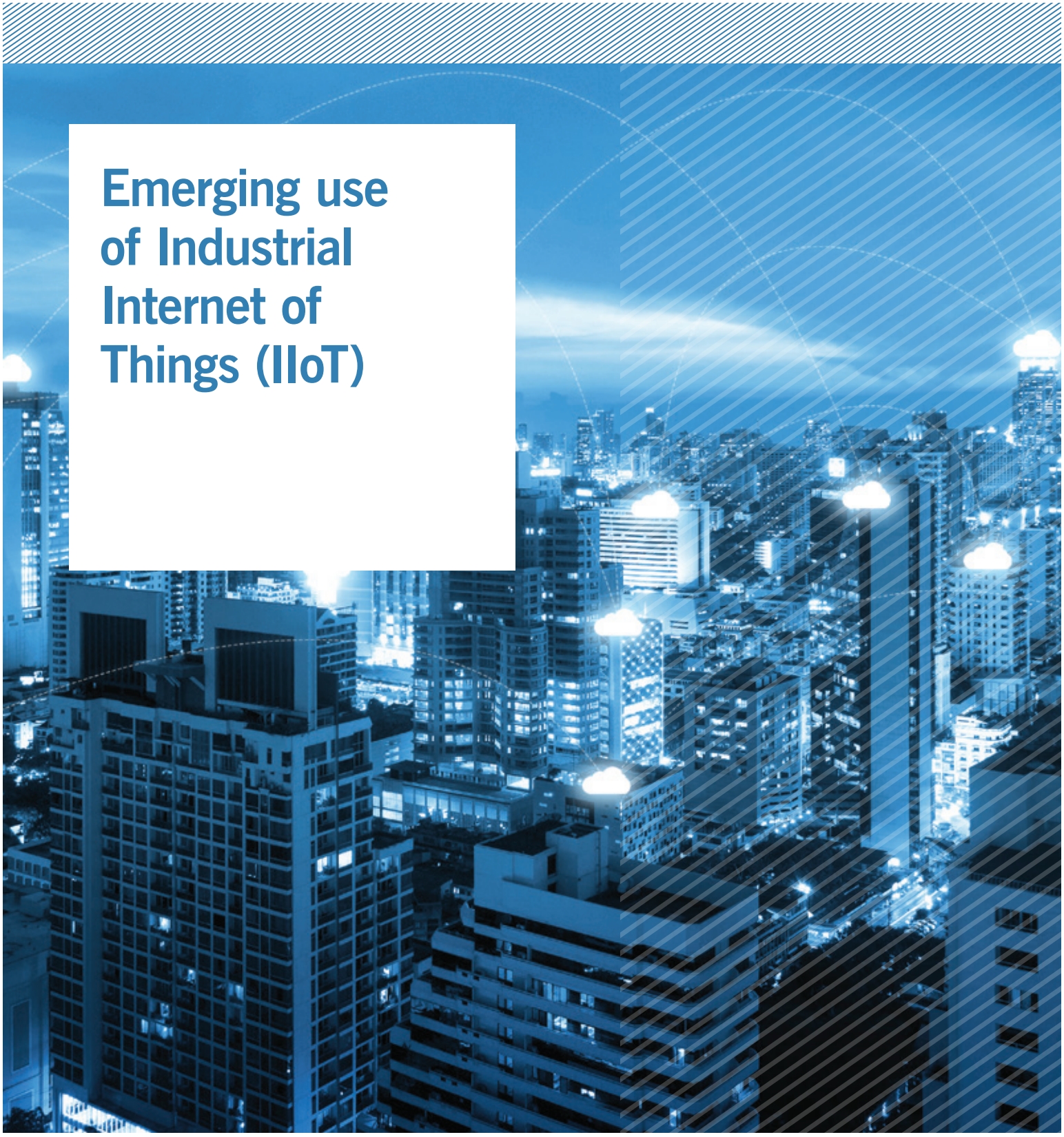

Emerging use of Industrial Internet of Things (IIoT)

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Gilbert Kamieniecky joined Investcorp in 2005. He leads Investcorp Technology Partners, which recently raised a $400m Fund IV to invest in lower mid-market technology companies with a specific focus on Data/ Analytics, IT Security and Fintech/ Payment.

Gilbert is on the board of Ubisense, Contentserv, softgarden, Impero, Ageras, Calligo, OpSec and eviivo. Past board positions include TDX (sold to Equifax), Skrill (Paysafe, publicly listed), Dainese and Asiakastieto (publicly listed).

Prior to Investcorp, Gilbert worked with Morgan Stanley in the Leveraged Finance Group, the Global Industrials Group and Firm Management. Gilbert graduated as Valedictorian from Cass Business School (City University) with a BSc in Business Studies and also holds an MSt in International Relations (History, Politics) from Cambridge University.

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Julian Bennet joined Investcorp in 2016 after three years in the technology team of HGCapital in London. Prior to that, he spent three years at Augusta & Co, a mid-market UK corporate finance boutique and two years at Morgan Stanley, primarily in their technology M&A team, in both London and Dubai. Julian currently serves on the board of Ubisense, Impero and Ageras.

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Kajetan Betz joined Investcorp in 2018. Prior to that, he was an Associate at Lazard based in Frankfurt.

Kajetan currently acts as a board observer at Ubisense and Contentserv.

Kajetan holds a Master in Finance from IE University in Madrid, and a BA in Business Administration from University of Mannheim.

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EXECUTIVE SUMMARY

The advent of increased connectivity, the contribution of major technological advances and the ability to aggregate and analyze massive amounts of data has led to a sea-change in the potential contribution that the Internet of Things ("IoT") will make to 21st Century society. The value enhancements to be gained from connecting devices and locations, instantly analyzing data and taking automatic (and recursive) 'smart' action are hard to quantify, but some industry experts reckon that the total economic impact of the Internet of Things will be somewhere between $4 trillion to $11 trillion by 2025; and indeed a further contributing factor – the ever-increasing pressure on manufacturers to maximize efficiency and continuously improve their manufacturing processes – means that the Industrial sector is poised to take the lion's share of this impact, at an estimated $1.2 trillion to $3.7 trillion.[1] Indeed, IoT's role within Industry has led to what many commentators are referring to as the 'fourth industrial revolution': the industrial Internet of Things or 'Industry 4.0'.

Investcorp has been investing in technology companies whose business models are underpinned by the generation, implementation and analysis of big data for 20+ years, and has had success in this space: most notably the investment into fleet-tracking company Fleetmatics,[2] which IPO'd on the NYSE in 2013. The mission critical nature of these offerings, coupled with high levels of recurring revenue, often make these ideal candidates for investment, and the team has developed significant expertise in this space.

Taking these two factors together, Investcorp identified Industry 4.0 as a key investment theme a number of years ago, and has undertaken a great deal of research to uncover interesting assets in the space. There are several reasons why Industry 4.0 offers investors an exciting opportunity:

- Large and growing end market, which has a great deal of whitespace potential and is currently underserved;
- To remain competitive, manufacturers must invest in solutions that either a) maximize efficiency, b) minimize downtime, or c) increase throughput – solutions providing these factors are absolutely mission critical;
- Many companies in this space are IP-led, and thus have significant barriers to competitors;
- Customer Return on Investment is tangible, easily demonstrable, and often significant in terms of size;
- Solutions are usually scalable and can be modularized easily.

Through this research, Investcorp has identified a number of interesting subsectors: Inspection Technology, Predictive Maintenance Technology, and Real-Time Location Solutions ("RTLS") Technology, amongst others. This paper seeks to inform readers about Industry 4.0's increasingly prevalent role in modern manufacturing, and the value an RTLS solution can bring to its customers: our recent investment in Ubisense, driven to date by its RTLS location-tracking product SmartSpace, is underpinned by all of the factors mentioned above. Ubisense is a platform that will form the bedrock of RTLS solutions and process efficiency in the manufacturing environment going forward.

"Ubisense is at the heart of an industrial revolution, and our location-aware technology is already a mission-critical component of the operations of leading manufacturers like Daimler, BMW and Airbus. We've satisfied some of the world's most demanding customers, giving me great confidence in our team and products, and in future, we'll bring our vision of smart spaces to a range of other markets beyond manufacturing."
Clare Colhoun, CEO, Ubisense

Economic impact of Industrial IoT:
$1.2-3.7tr

[1] McKinsey global institute – The internet of things: Mapping the value beyond the hype
[2] Details on all trades for the past 12 months are available upon request

Industry 4.0

Fourth industrial revolution

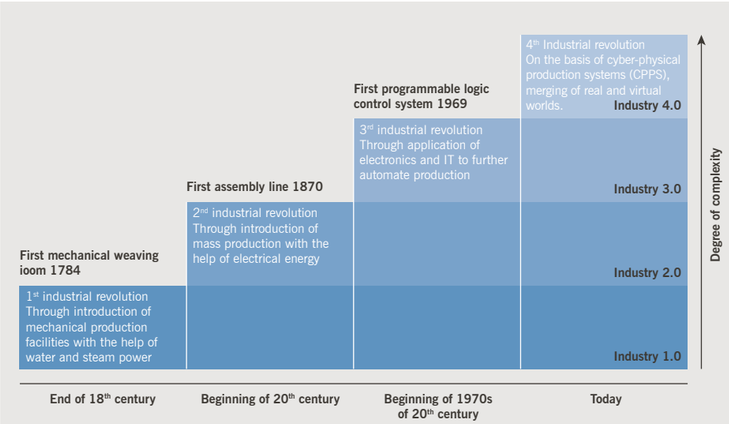
INTRODUCTION TO INTERNET OF THINGS (IOT)/INDUSTRY 4.0

Key terms and definitions

The marriage of advanced manufacturing techniques with information technology, data, and analytics is driving another industrial revolution, one that invites manufacturing leaders to combine information technology and operations technology to create value in new and different ways. Industrial IoT or "Industry 4.0" connects embedded system production technologies and smart production processes to pave the way to a new technological age which will radically transform industry and production value chains and business models. The new era of interconnectivity and digitalization provides manufacturing leaders with the opportunity to explore new means to achieve their business objectives.

The term Industry 4.0 refers to a further developmental stage in the organization and management of the entire value chain process involved in the manufacturing industry. Another term for this process is the 'fourth industrial revolution'. The concept of Industry 4.0 is widely used across Europe, particularly in Germany's manufacturing sector. In the United States and the English-speaking world more generally, some commentators use the terms the 'internet of things', the 'internet of everything' or the 'industrial internet'. What all these terms and concepts have in common is the recognition that traditional manufacturing and production methods are in the throes of a digital transformation. For some time now, industrial processes have increasingly embraced modern information technology (IT), but the most recent trends go beyond simply the automation of production that has, since the early 1970s, been driven by developments in electronics and IT (Figure 1).[3]

Figure 1: **Industrial Revolutions Throughout the Years**[4]



[3] Deloitte Research: Industry 4.0 – The birth of the smart factory
[4] Deloitte Consulting Research

However, throughout this paper we will mostly refer to IoT as opposed to Industry 4.0. There are several definitions of the IoT in technical literature and popular media. We follow definitions that in some form include the following elements:

The IoT is a suite of technologies and applications that equip devices and locations to generate all kinds of information – and to connect those devices and locations for instant data analysis and, ideally, "smart" action. Conceptually, the IoT implies physical objects being able to utilize the Internet backbone to communicate data about their condition, position, or other attributes.[5]

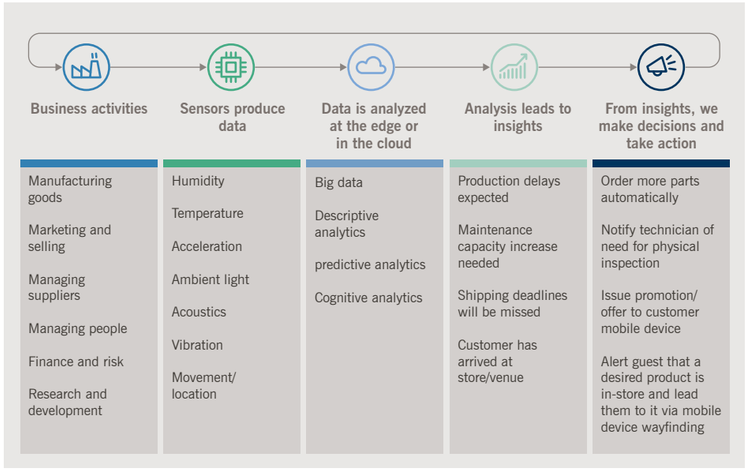
The Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.[6]

IOT AND THE INFORMATION VALUE CYCLE

The IoT focuses on the aggregation and use of information from several sources. Information, however, creates value only when it is structured and utilized for modifying future action and behavior in beneficial ways. Ideally, this modified action gives rise to new information, allowing the learning process to continue and, if necessary, pivot on an ever self-correcting and self-learning path. Information, then, can create value not in a linear value chain of process steps but, rather, in a never-ending, self-correcting process. One way of capturing this process is as an Information Value Cycle (IVC) with discrete but connected stages (Figure 2).[7]

Unceasing self-correction and self-learning

Figure 2: **IoT Information Value Cycle**[8]



[5] Surabhi Kejriwal and Saurabh Mahajan, Smart buildings: How IoT technology aims to add value for real estate companies, Deloitte University Press, April 19, 2016
[6] Gartner
[7] Deloitte Insights – The Internet of Things
[8] Deloitte Consulting Research

For information to complete the cycle and create value, it passes through the cycle's stages, each enabled by specific technologies. It starts with everyday business activities that generate data. This data is captured by sensors (attached to devices, tools, products or workers), creating information as a result, along an array of dimensions such as location, temperature, vibration, humidity, movement, etc. Such information is communicated via a network, aggregated and analyzed over time, leading to insights. These insights – also called "augmented intelligence" – may then either enable automated and pre-defined actions or influence iterative human decision making ("augmented behavior") in a manner leading to improved, more competitive business operations, thereby completing the cycle.

KEY IOT END MARKETS

Generally, such an information cycle can be found in any businesses across different sectors. However, IoT market segments can be largely divided into three broad categories: enterprise/industrial, consumer, and services/public sector. Each of these segments is marked by distinct characteristics and market opportunities (Table 1).

Table 1: **IoT Market Structure**[9]

	Enterprise/Industrial	Consumer	Services/Public sector
Representative value opportunities	• Planning and inventory • Factory and operations • Supply network and logistics • New business models • New products and products development • Asset management	• Customer experience • Channel connectivity • Aftermarket support • New products and extensions • Lifestyle enhancement	• Health care delivery • Commercial building energy management • Public sector safety • Public sector traffic management • Crop yield management
Representative use cases	• Demand and supply synchronization • Quality sensing and prediction • Condition-based monitoring • Dynamic routing and scheduling	• Smart homes • Remote appliances • Connected cars • Personal lifestyle monitoring • Personal asset tracking	• Smart buildings • Smart cities • Smart irrigation • Patient surveillance • Smart law enforcement
Additional features	• Manufacturing operations and product driven • Private cloud primarily • Hybrid architecture • Fewer devices • Relatively complex data sets • B2B channels	• Customer and product driven • Public cloud primarily • Millions of devices • Simpler data sets • B2C channels	• Public sector, services driven • Public/private cloud mix • Variable data set complexity • Medium number of devices • B2B2B, B2B, B2C channels
Projected global IoT spending share by 2020	50-60%	20-25%	20-25%

[9] Deloitte analysis

The enterprise/industrial segment involves relatively complex and rich data sets and far fewer devices relative to the consumer segment. The enterprise/industrial segment tends to also be driven by manufacturing operations and product development within a relatively private cloud environment. There is tremendous potential for demonstrable ROI (cash and non-cash) such as reduced throughput time, improved quality and reduced fault rates, direct/indirect labor cost savings, etc.

In contrast, the consumer segment is typically rooted in customer experience and a more public cloud environment. With interconnected products that are "talking" to each other, manufacturers have the unique opportunity to create their own platform that in addition to the traditional hardware also sells software to the customers, increasing engagement and overall stickiness of the applications. The continuous consumer engagement through such platform also allows for collection of insightful and invaluable consumer data and behavior over time.

The services/public sector segment is generally something of a hybrid between the other two segments in terms of richness and complexity of data, number of devices, and a bias toward a particular cloud environment, although it tends to bear a closer resemblance to the consumer segment in terms of experience-driven use cases.

A large number of IoT/ICT players have now developed an established industrial approach and extensive offering with dedicated divisions and high-level managers in place. Examples include AWS, Telenor, Microsoft, and Cisco. The industrial segment is clearly maturing, now often being mentioned as a top 3 vertical for many vendors, compared to a secondary focus just a few years ago. Specialized vendors are also developing dedicated industrial technology suites.[10] The enterprise/industrial sector is projected to capture slightly more than half of global IoT spending by 2020. A particularly strong driver of growth in IoT spending within that segment is digital supply network (DSN) applications. Traditionally, supply chains are linear in nature, with a discrete progression of design, plan, source, make and deliver. Today, however, many supply chains are transforming from a static sequence to a dynamic, interconnected system – the digital supply network (DSN) – that can more readily incorporate ecosystem partners and evolve to a more optimal state over time. Digital supply networks integrate information from many different sources and locations to drive the physical act of production and distribution.[11] While there are numerous DSN use cases driving IoT spending within the enterprise/industrial segment, four seem to stand out in particular:

1. **Condition-based monitoring/predictive maintenance:** Monitoring and continuously evaluating key performance parameters of capital assets and, in the process, leveraging advanced analytics to predict failures before they occur
2. **Asset tracking:** Tracking location and movement of assets, products/materials, tools and workers using location-based sensors, enabling real-time reporting and optimization of system performance
3. **Dynamic routing and scheduling:** Enhancing the productivity of both individual units and broad networks using deep and broad insights derived from aspects such as visibility on conditions and performance in real time
4. **Asset and process optimization:** Evaluating and monitoring operational data and ambient conditions of critical assets and processes in real time to optimize performance and safety

Key driver: demonstrable ROI

Key driver: consumer engagement

Key driver: experience-driven, data rich use cases

[10] ABIresearch: The Industrial Revolution – The Top Trends and Takeaways from Hannover Messe 2019
[11] Brenna Sniderman, Monica Mahto, and Mark Cotteleer, Industry 4.0 and manufacturing ecosystems: Exploring the world of connected enterprises, Deloitte University Press

Manufacturing is a substantial driver of spending within the enterprise/industrial IoT space as well as overall IoT spending. This may be attributed to Industry 4.0 and the ensuing wave of digital transformations that will likely drive significant demand for IoT capabilities across a broad spectrum of services within manufacturing. Other key sectors driving enterprise/industrial IoT include industrial manufacturing, automotive, oil & gas, power & utilities, life sciences/healthcare as well as transportation.[12]

HOW THE IOT IS RESHAPING FUTURE PRODUCTION SYSTEMS AND THE SMART FACTORY

For decades, many of the world's most renowned manufacturing companies have used their production systems as a source of sustainable competitive advantage. However, such systems are not just about good performance, with fast, efficient manufacturing processes and consistently high-quality output. What differentiates benchmark organizations like Daimler or Toyota is their ability to improve those operations continuously, at a pace their competitors struggle to match. Additionally, well-functioning and strong production systems have other powerful benefits. They give companies a clear, precise picture of their own performance, allowing direct comparisons among plants and encouraging internal competition to improve overall profitability and streamline processes. They provide a common culture, vocabulary and tool set that facilitates the sharing of best practices while minimizing inefficiencies and fault rates. By developing the skills of existing staff and creating an attractive environment for talented new hires, they help people contribute to the best of their ability. The best production systems are simple, flexible, well-structured and built around a company's specific strengths and challenges. That requires a good deal of self-knowledge. A company must not only understand what it wants to achieve but also identify the methods, resources, and capabilities it will need to get there. Ultimately, a good production system is a unique, bespoke management approach that's difficult for competitors to copy. The IoT, with its various use cases, can help even the highest-performing companies to boost their performance still further. Especially in mature industries, such as industrial manufacturing, margin improvements are crucial to again become/stay competitive with lower cost (and not always lower quality) production facilities in China/Asia. The disrupting and technology-driven opportunity is based on the ability to create, structure and interpret huge volumes of data on processes and performance generated by new generations of network-connected devices. However, to successfully capture the opportunity that the IoT brings, companies must revisit and reassess many of the processes and principles that have been so successful for them in the past.[13]

> "For us at Daimler it is beyond question that the digital transformation will lead to fundamental changes in our industry. This applies to the methods we use to develop, plan and produce our vehicles. It also relates to the ways in which we make contact with our customers. And, not least, we will be able to experience the digital transformation in our products themselves."
> *– Markus Schäfer, Member of the Divisional Board of Mercedes-Benz Cars, Production & Supply Chain Management*

[12] Deloitte Insights – The Internet of Things
[13] McKinsey Research: How the Internet of Things will reshape future production systems

> "IoT has helped Toyota improve their response time to quality issues. For example, when the company has a field issue, it can trace a particular part back to its manufacturing conditions and try to understand if there's something in the manufacturing process that is out of control."
> *– Jeff Makarewicz, Group Vice President of Vehicle, Quality & Safety Engineering at Toyota Motor North America*

> "The assembly process involves drilling, riveting and then applying sealant to prevent corrosion. These are the most critical activities in assembly. At the end of the day, humans are not predictable. They take a decision that will have an impact further down the production line."
> *– Sébastien Boria, Mechatronics and Robotics Technology Leader at Airbus*

INTRODUCTION AND DEFINITION OF THE SMART FACTORY

The strive for automation has always been a part of designing and improving factory layouts and manufacturing lines to some degree, and even high levels of automation are nothing new. Lean manufacturing (Kanban) and error-preventing (Poka Yoke) manufacturing systems to ensure Just in Time (JIT) production are well established across all industries in every factory around the world. However, the term "automation" as well as all previously designed manufacturing system suggests and assume the meticulous performance of a single, discrete task or process. Historically, situations in which machines have made "decisions" have been automation-based and linear, such as opening a valve or turning a pump on and off based on a defined set of rules. Through the application of artificial intelligence (AI) and increasing sophistication of cyber-physical systems that can combine physical machines and business processes, automation increasingly includes complex optimization decisions that humans typically make. Finally – and perhaps most crucially – the term "smart factory" also suggests an integration of shop floor decisions and insights with the rest of the supply chain and broader enterprise through an interconnected informational/operational technology landscape. This can fundamentally change production processes and enhance relationships with suppliers and customers – a smart factory goes beyond simple automation.

The smart factory is a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time and autonomously run entire production processes based on large amounts of data. Smart factories can operate within the four walls of the factory, but they can also connect to a global network of similar production systems, and even to the digital supply network more broadly.

Smart Factory: Recursive integration of data throughout supply and manufacturing chain

The smart factory represents an ongoing evolution, a continuous journey toward building and maintaining a flexible learning system – rather than the factory modernization approach of the past. The true power of the smart factory lies in its ability to evolve and grow along with the changing needs of the organization. That includes shifting customer demand and variations in capacity, expansion into new markets, development of new products or services, more predictive and responsive approaches to operations and maintenance, incorporation of new processes or technologies, or near-real-time changes to production. Due to the development of more powerful computing and analytical capabilities (and decreasing costs of such systems), combined with broader ecosystems of smart, connected assets – smart factories can enable organizations to adapt to changes in ways that would have been difficult, if not impossible, to do so before.[14]

KEY FEATURES OF THE SMART FACTORY

As many manufacturers grapple with the myriad organizational and ecosystem-wide changes exerting pressure on their operations, the smart factory offers ways that can successfully address some of those issues. The ability to adjust to and learn from data in real time can make the smart factory more responsive, proactive and predictive, while enabling the organization to avoid operational downtime and other productivity challenges.

Key drivers and coinciding benefits of high(er) degrees in automation include, amongst others, lower lead times for customers, lower overall production costs (due to reduced input factors), along with production capacity improvement and fewer defective products.

Figure 3 depicts the smart factory and some of its major features: connectivity, optimization, transparency, proactivity, and agility. Each of these features can play a role in enabling more informed decisions and can help organizations improve the production process. It is important to note that no two smart factories will likely look the same and manufacturers can prioritize the various areas and features most relevant to their specific needs as they design the layout or improve the current set-up. Most notably, smart factories allow for subsequent optimization and adoption of new technologies as they are built on a modular basis compared to traditional more inflexible factory layouts.

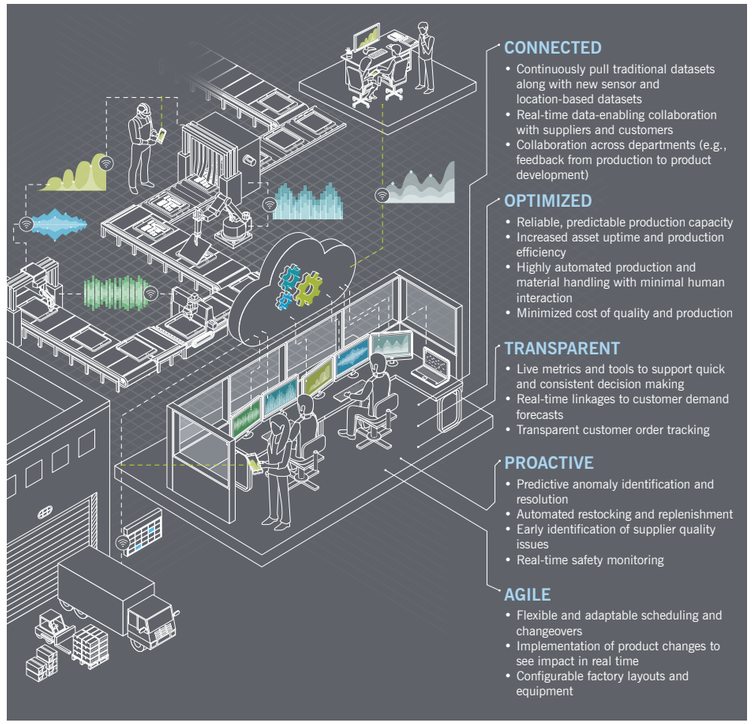
SMART FACTORIES

Smart factories capture massive amounts of data and use it to maximize efficiency, minimize downtime and increase throughput.

This results in lower costs, higher revenues and potentially – the holy grail – happier and more satisfied customers.

[14] Deloitte University Press: The smart factory

Figure 3: **Five Key Characteristics of a Smart Factory**[15]



FOUR DIMENSIONS OF THE IOT'S IMPACT

The advent of IoT technologies – and the more general move to digital tools that support operations, communication, analysis and decision making in every part of the modern organization – will not change the fundamental purpose of production systems. It will, however, transform the way they are built and run, offering improvements across four main dimensions:[16]

- Connectivity
- Speed
- Accessibility
- Anchoring

[15] Deloitte University Press: The smart factory
[16] McKinsey Research: How the Internet of Things will reshape future production systems

Connectivity enables communication, which, in turn, enables continuous measurement and decision-making – all underpinned by powerful software platforms

CONNECTIVITY

Traditional production systems embody a collection of separate tools bound together loosely by the rules governing their application. Usually, these rules are at best defined only on a paper document or a corporate intranet site. In future, such links will be much tighter and more automated, and fast digital connections will allow the whole system to operate as a seamless, cohesive whole. Different end-points will be able to communicate through a highly complex, automated rules engine – a software layer that sits above the value chain – that will allow for a high degree of automation and modular flexibility.

In addition, higher degrees of integration will change production systems in two ways. First, performance measurement and management will be based on precise data. Sensors will monitor the entire production process, from the inspection of incoming materials through manufacturing to final inspection and shipping. Companies will store the output of those sensors in a single, central data cube, together with a host of additional data from other internal sources, as well as external ones (supplier specifications, quality indicators, weather and market trends). All these data pools will combine to set the production system's targets and measure its performance continually, so the staff will be able to see, at a glance, if the system is performing as it should.

Second, connectivity will support better fact-based decision making. Access to comprehensive, up-to-date production information, together with a complete historical picture, will take the guesswork out of changes and improvement activities and reduce iterations. As the collection and reporting of data are increasingly automated, frontline operators and managers will play a larger role in solving problems and improving processes. Root-cause problem solving will be easier, aided by advanced analytical techniques, staff will be able to identify the changed operating conditions that precede quality issues or equipment failures. Furthermore, stored information about similar issues solved elsewhere will help identify appropriate solutions. As an example, a plant manager will be able to share data and potential layout-improvements with other plant managers around the world within the organization and even across the value chain with suppliers and customers to collectively improve (cost and time) efficiencies.

Real-time data collection and analysis leads to rapid responsiveness and accelerated improvement

SPEED

Today's production systems are necessarily retrospective. While they aim to maximize responsiveness by emphasizing discipline, standards and right-first-time practices, the reality falls short. Manual measurement and management mean that most opportunities for improvement cannot be identified until a shift ends, and the numbers come in. In cases of continuous flow production lines, especially seen in pharmaceuticals and automotive, with minimal default rates and down time, new production layouts can rarely be changed and tested which naturally prolongs the phases of change and improvement. With the introduction of comprehensive, real-time data collection and analysis, production systems can become dramatically more responsive and change can be implemented more gradually and quicker. Deviations from standards can immediately be flagged for action. The root causes of those deviations can therefore be identified more quickly, as will potential countermeasures. The entire improvement cycle will accelerate. It isn't just the management of day-to-day operations that will get faster. Capability building will, too, thanks to focused,

online training packages customized to the specific needs of individual employees. Finally, IoT technologies will speed improvements in the production system itself – for instance, by automatically identifying performance gaps among plants or updating processes throughout the company whenever new best practices are identified.

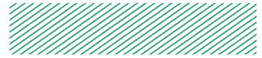
ACCESSIBILITY

Back-end data storage isn't the only thing that will be unified in the production systems of the future. So will access. Staff at every level of the organization will get the tools and data they need through a single application or portal. That portal will be the organization's window into the system's dynamic elements – especially minute-by-minute performance data – as well as more static parts, such as standards, improvement tools, and historical data. These portals – with responsive, customized interfaces ensuring that the right employees get access to the right information and tools at the right time – will simplify and accelerate the operation of the production system. If it identifies a deviation on a production line, for example, it will be able to alert the team leader, show current and historical data on that specific process, and offer appropriate root-cause problem-solving tools, together with a library of solutions applied elsewhere. Using secure and tightly controlled interfaces, the production-system portal will also be accessible beyond the organization's boundaries: it will allow suppliers to track consumption and quality issues in materials, for example, or external experts to review current and historical performance to find improvement opportunities. Using online support and predictive analytical tools, manufacturers of equipment will increasingly operate, monitor, and maintain it remotely. The portal will even allow companies to benchmark their own performance automatically against that of others.

Information flows to the right people at the right time

ANCHORING

One of the most powerful effects of IoT and digital technologies, we foresee, will be to anchor the production system in the organization's psyche. This will overcome the most critical challenge many companies struggle with today: sustaining change, so that the organization improves continually. That anchoring effect will be achieved in several ways. First, the unified data, interface, and tool set will not only help enforce the adoption of standards but also ensure that the right way of doing things is the easiest way. Staff won't need to improvise production plans or override machine settings if the optimum settings are just a button click away. Second, future production systems will help the organization to collaborate more effectively. An end-to-end view of performance will break down barriers among functions and ensure that decisions reflect the interests of the business as a whole. The communication and sharing of information will be greatly enhanced, since a central knowledge hub and social-media tools will let staff in one area access support, ideas, and expertise from another. Finally, future production systems will make performance far more visible: when the whole leadership can see the direct link between operational performance and profitability, for example, the production system will no longer be considered the concern solely of the COO. Digital dashboards on computers, mobile devices, and even smartwatches will show staff in every function and at every level exactly how the organization is performing, as well as the precise value of the contribution of their businesses.



Organizational alignment around central tenet of success

INVESTING IN THE IOT SECTOR

Assessing the market potential

As of today, the IoT sector is still a fairly new market with great potential for rapid mid- to long-term growth. Reasons for this strong growth trajectory include:

Market:

- Large and growing addressable end-markets (Figure 4) with ample white space potential and fragmented competition in local markets
- At-scale adoption of IoT solutions through market-leading corporations across the globe with dedicated budgets and headcount, with increasing confidence in demonstrable and long-term ROI from such investments
- Supporting ecosystem fueling IoT innovation with incubators/accelerators and government grants becoming available as well as rapidly growing appetite from VC, PE and increasingly strategic buyers seeking to diversify technology risk and build alliances

Technology:

- Decreasing cost and improving quality of technology – especially sensors
- Rapidly improving network quality with the advent of 5G, allowing higher quality communication between devices
- AI technology and Machine Learning are improving rapidly, helping companies to truly leverage the full value of massive data pools generated by IoT

Similar to game-changing technology advancements in previous industrial revolutions, today IoT has the potential power to fuel the fourth industrial revolution, driving increases in productivity, transforming business models and redefining the way that organizations relate to and interact with their customers and suppliers. However, this time the impact is set out to be bigger and more pervasive than those that have gone before as the technological advancement is multiplied by the sheer number of devices/ endpoints affected – 500 billion connected IoT devices by 2030.[17] It is not surprising that this market is and will continue to be one of the fastest growing technology sectors. McKinsey expects the overall IoT market to generate between $4tr and $11tr in economic value by 2025.[18]

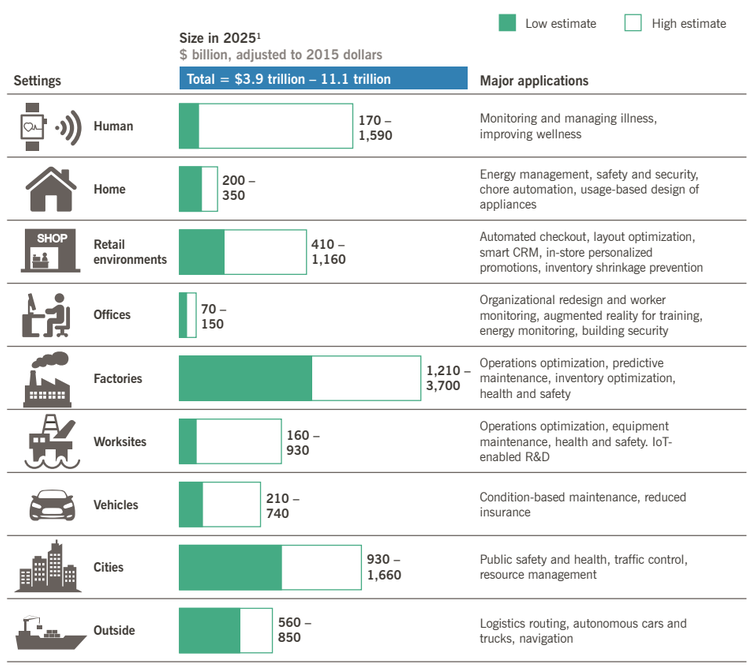
Generally, we found that Business-to-Business (B2B) applications are likely to create more value than consumer facing solutions. Even though consumer solutions generate most of the attention and are a great promoter of IoT in general, it is estimated that the vast majority of potential ROI and value will come from B2B applications (70% of overall generated value enabled by IoT). Based on McKinsey research, the largest economic impact will come from the optimization of operations in factories ($1.2tr to $3.7tr).[19] This process will include tremendous data generation, aggregation and interpretation from sensors throughout manufacturing lines thereby gradually replacing human judgement/error with data-informed machinery and workflow adjustments. Other key ROI drivers will be predictive maintenance, inventory tracking/optimization, quality control as well as health and safety. Naturally, many of the machines currently in use will need to be upgraded or replaced to fully facilitate the use of IoT sensors implicating a sizeable investment requirement for manufacturing companies over the next years.

4th Industrial Revolution – huge market potential

Industrial IoT is driving several investible themes – particularly B2B apps

[17] Cisco – Internet of Things At a Glance
[18] McKinsey global institute – The internet of things: Mapping the value beyond the hype
[19] McKinsey global institute – The internet of things: Mapping the value beyond the hype

Figure 4: **Potential economic impact of IoT in 2025 is $3.9tr to $11.1tr**[20]



1 Includes sized application only.
NOTE: Numbers may not sum due to rounding.

CASE STUDY: ACQUISITION OF UBISENSE[21]

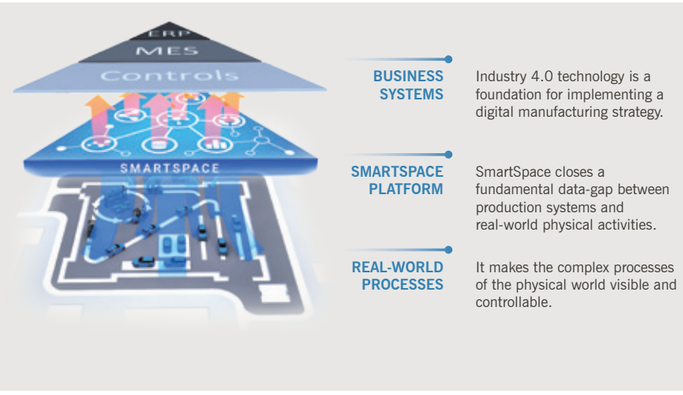
Company overview

Founded in 2002, Ubisense – through its SmartSpace platform – provides a digital twin, in real-time, of the production environment, by generating and interpreting massive amounts of unstructured location data to maximize efficiency and improve decision making. With this Real-Time Location System (RTLS), the company intends to close the data-gap between established business systems – Enterprise Resource Planning (ERP) systems and Manufacturing Execution Systems (MES) – and real-world processes (Figure 5).

Ubisense: a live, virtual map of a production process – "Digital Twin"

[20] McKinsey global institute – The internet of things: Mapping the value beyond the hype
[21] Details on all trades for the past 12 months are available upon request

Figure 5: **Ubisense closes the data-gap between business systems and real-world processes**[22]



> "In dynamic manufacturing environments, data managed by existing Systems of Record like MES and ERP systems can rapidly become stale. IOT platforms build on universal device connectivity and sensing to continuously update established systems with live information from the shop floor. In particular, the Ubisense SmartSpace platform builds a real-time digital twin of the physical space from location sensor data, letting other business systems make decisions based on this up-to-date view of factory operations and unlocking value for manufacturers." – *Andy Ward, CTO, Ubisense*

Scalable, configurable, and sensor agnostic platform

Blue chip customers

The location data is generated through any location sensor technology such as ultra-wideband (UWB; Ubisense's own hardware sensors as well as third party providers), Bluetooth, GPS, barcode scanning, optical sensors or any other shop floor system. The company offers a configurable and sensor-agnostic software platform, as well as its internally developed sensor system, for hyper-accurate real-time tracking that is market-leading in terms of accuracy compared to other players in the space. Applications include process optimization, work-in-progress (WIP) and critical asset location, dynamic process and location control, process flow monitoring as well as process analytics. Scalability and real-time performance lie at the core of the SmartSpace platform, allowing users to build applications that scale from micro-installations (small control systems running on a single machine) through to large sites with several servers and thousands of sensors, devices, people etc., all with predictable performance.

Customers include the Who's Who of global automotive (Daimler, BMW) and aerospace (Airbus, Safran) manufacturers, commercial vehicle producers (John Deere, Paccar) as well as logistics (Kuehne + Nagel) and public transport companies (MetroTransit Minneapolis, and New York Transit). Most recently, Ubisense has also moved into the healthcare sector helping track medical equipment in hospitals/elderly homes and patients in different wards (Veteran's Administration hospital in Tampa).

[22] Ubisense company information

Ubisense – Driving Efficiency

Process optimization lies at the heart of Ubisense and its SmartSpace platform.

Maximizing efficiency, minimizing downtime and increasing throughput generates tangible and significant Customer ROI, time and again.

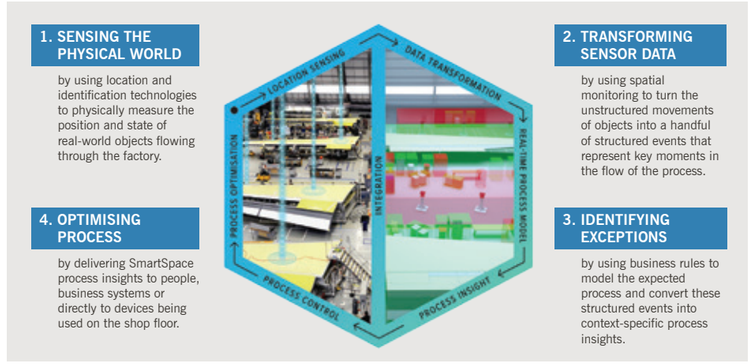
Company structure

The company has four business segments:

- **Software**: The sensor-agnostic Dimension4 location software is a modular software platform including sensor firmware and server-based software components required to configure, coordinate and manage the Dimension4 RTLS, interpret massive amounts of data and enable better decision-making
- **Hardware:** Ubisense has developed two UWB sensor systems that offer unique capabilities addressing various requirement across the different end markets
  - Ubisense Dimension4 is a best-in-class precision real-time location system. It consists of hardware, firmware and server-based software components that together have helped D4 become the most widely deployed, highly accurate and production-proven location system in the world
  - Ubisense AngleID is a next generation RFID solution that can detect tags entering and exiting user defined zones using a single sensor. Simple to set up, it can be deployed in under 10 minutes in industrial environments. Flexible configuration provides up to 8 different detection zones per sensor which can provide precise real-time knowledge of tag location
- **Labor and Maintenance & Services** are support functions that offer installation and other services to the customer to ensure to establish an error-free and highly flexible manufacturing layout

The overall target of the SmartSpace solution is process optimization at the customer, leading to improved efficiency and quality and reduced downtime. Ubisense works closely with its customers throughout the implementation phase to identify the core problem and offer tailored solutions for every manufacturing line layout following the steps outlined in Figure 6.

Figure 6: **Optimizing processes with SmartSpace**[23]



[23] Ubisense company information

A platform providing intrinsic value

Product overview and use cases

The SmartSpace platform has been built for fast and efficient development of new location-aware applications, allowing anyone configuring SmartSpace to quickly prototype ideas, implement designs and deploy new solutions. The combination of highly accurate sensor technology with a modular and individually configurable software layer introducing process logic and spatial modelling allows to create a digital copy - or digital twin - of highly complex processes (Figure 7).

Figure 7: **Building SmartSpace applications with a software and hardware platform**[24]

An example would be a production line: Ubisense Dimension4 tag transmitters might be attached to products on the manufacturing line (i.e. cars, airplanes, etc.), mounted on tools used to perform certain steps of the manufacturing process, and carried by workers. Ubisense Dimension4 sensor receivers (Figure 8) are installed throughout the factory building at strategic locations and detect the tag signals, allowing the tag locations to be computed and therefore the locations of the tagged objects to be found. The real-time location data thus generated forms the input for the SmartSpace location platform software that sits on top of the hardware sensors and generates a spatial model that allows the monitoring of production progress while adding further process logic (e.g. a car cannot move to workstation B if it has not successfully passed through workstation A first; or, a particular tool cannot be used unless the worker holding it has been suitably trained).

[24] Ubisense company information

Figure 8: **Dimension4 sensor (left picture) and various tag options (right picture)**[25]

Industry-leading and has the highest mission-critical reliability (six-sigma) and accuracy in noisy, obstructed and reflecting environments

Ubisense's internally developed RTLS platform is industry-leading and has the highest mission-critical reliability (six-sigma) and accuracy in noisy, obstructed and reflecting environments. These are turnkey products that allow for high scalability and control-ready real-time performance with very low total cost of ownership (TCO), as battery lifetimes are incredibly long (up to 15 years), and proven 24/7 operation for over ten consecutive years. Ubisense's Dimension4 tags come in various sizes and forms to cover a range of tracking needs in harsh environments.

Ubisense sells its hardware/software solution based on demonstrable return on investment (ROI) for its customers, and the company has identified many areas that allow for tremendous savings potential in modern highly complex manufacturing/assembly lines, as shown in Figure 9. For example, in a modern car production line, multiple vehicle models with potentially millions of product option combinations share the same production line. When a tool is used on a car at a certain point of the assembly process, it must be configured with the right settings for the individual car on which it is being used. SmartSpace facilitates this control by monitoring the locations of cars and tools on the assembly line, and automatically and instantaneously configuring the tools when workers move them to begin work on individual cars. By taking the human out of the configuration loop, product quality is improved because the room for human error is greatly reduced, and the worker saves time during each operation. Another very striking ROI can be demonstrated through asset and work-in-progress (WIP) localization. An example would be an overhaul factory site that services and maintains turbine engines of passenger planes. The engine is disassembled and parts are spread out throughout the site/yard. Once each part has been serviced and checked the process of reassembly begins. Without the Ubisense solution the search for parts was done manually and could take up to several working hours for the respective employee. With the technology in use, parts will be tagged when disassembled and can then be easily identified and tracked down when needed thereby drastically reducing reassembly times.

[25] Ubisense company information

Figure 9: **Selected SmartSpace solutions that help systems and workers make informed decisions**[26]

Solution	Description	Effect
Tool control	Instantly and automatically adapt tool setting based on proximity and interactions between tools and assets	Eliminates time for manual tool configuration
Assets & work in progress localisation	Location visualisation of and guidance towards assets and/or work in progress	Reduces search times
Process flow monitoring	Monitoring movements of assets through the area of interest	Identifies logistic bottlenecks
Location-based device control	Context-aware tablets and other mobile devices	Makes the employee more efficient in its task
Just in time logistics	Coordinate supply and production in such a way that hardly any stocks in a company are needed	Reduces inventory costs

Looking at the customer ROI and the various use cases, naturally the customer feedback has been very positive throughout our diligence process and beyond:[27]

> "The system is a key enabler of Industry 4.0. They are absolutely mission critical" *– BMW*
>
> "I see our relationship progressing into the future: …everyone has seen what it can do and so we are expanding the number of parts of plants and the number of plants we use it for" *– Daimler*
>
> "SmartSpace is by far the most advanced company in this field; we did look at competitors but it isn't a level playing field they are way ahead" *– Aston Martin*
>
> "It is not only a matter of improving ROI, it also improves operators' working conditions improving the quality of their job and the quality of the vehicles" *– Toyota*
>
> "We've reviewed many detection systems, but Ubisense is special: very precise, very accurate; it's essential for us to use the digital twin and their accuracy allows us to do that" *– IHI (MRO Operator)*

Given the current state of the technology and the overall sector, the best way to continue to develop top quality products is by talking to the customer and listening to the potential use cases that arise every day. There are no limits to the uses to which the location data can be put to optimize manufacturing, services and other value creating processes. The Company has most recently identified the healthcare sector as a potentially lucrative new vertical. Ubisense's SmartSpace technology could help with location tracking of high value medical equipment as well as patients in different wards.

[26] Roland Berger commercial diligence report
[27] All quotes from customer calls related to the acquisition of Ubisense (conducted by Roland Berger)

Addressable sectors in the IoT and smart factory

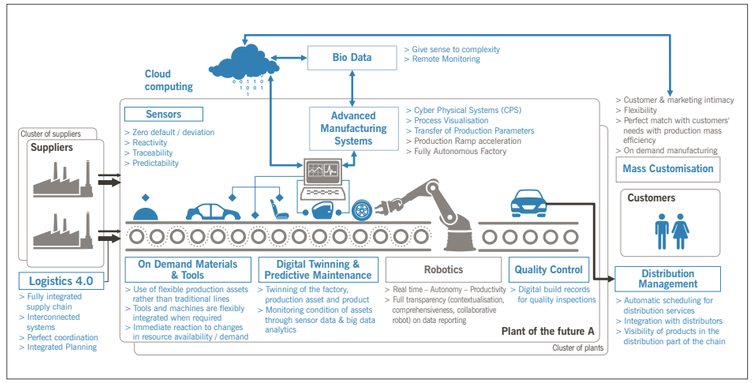
The SmartSpace solution has many touch points in the IoT space and will underpin the smart factory of the future. It is blazing a trail in Industry 4.0 and is profiting from key market drivers in the sector – especially the reduced cost in sensor technology. At the center of the solution sits the connection of the "physical world" with the "cyber world". The process of replicating the real world in a digital model has been called Digital Twinning or Digital Twin. That process can have three main distinct applications:

- **Product twin:** Digital representation of a physical product to model product behavior in a cost-effective way
- **Development twin:** An alternative or addition to physical prototyping in order to test new products/technologies
- **Production twin:** Virtual plant simulation, including process layout, material flow, etc. to simulate and optimize production by identifying impact of changes

SmartSpace falls into the third category – production twin – and thereby has several relevant touchpoints in the continuous process automation and optimization described earlier in this paper. As with many other IoT solutions in a smart factory, SmartSpace has implications for the direct value creation of a customer but also impacts supplier and customer relationships as well as the overall data pool, continuously feeding into big data storage (Figure 10, blue shaded areas denote relevant touchpoints). As this data pool grows, the SmartSpace solution will become exponentially more valuable.

It is blazing a trail in Industry 4.0 and is profiting from key market drivers in the sector

Figure 10: **Overview of the smart factory**[28]



[28] Roland Berger commercial diligence report

Key investment highlights

Ubisense is a company that fully fits into the previously outlined intersection of the most attractive market segments of IoT-driven, B2B, mission critical, smart factory applications with a high, demonstrable customer ROI. Fueled by key market and technology drivers, we believe that Ubisense has enormous growth potential by rolling out and increasing penetration of the SmartSpace solution across existing/new customers and existing/new verticals. Throughout our diligence on the technology and on the sector, Investcorp has identified the following key themes:

Mission critical solution with blue chip client base:

- Improving efficiency and reducing downtime is top of mind for all high value manufacturers as outlined previously in this paper. SmartSpace has excelled at this and generated long (10+ years) track records with industry-leading reference customers (Daimler, Airbus, Safran, John Deere etc.)
- Customer interviews reinforce mission criticality and quality of product, and emphasize strength of relationships with SmartSpace. Ubisense is able to offer a customizable solution that evolves with changing customer requirements over time

Large (multi-billion dollar) and growing market with ability to cross verticals

- Ubisense targets the largest market segment with the highest market potential within the IoT space – factories. Strengths currently exist in auto and aerospace but Ubisense has successfully generated revenue in transport logistics, healthcare and agricultural machinery, with other verticals targeted
- For the SmartSpace product alone, the auto and aero market alone are estimated at £2 billion with significant unquantified upside from Tier 1 suppliers and adjacent verticals (e.g. transport, agriculture machinery) offering the potential for an attractive growth trajectory in the future

Compelling customer ROI enables successful sales model and underpins "land and expand" deployment

- Ubisense excels with its real time offering providing customers demonstrable ROI. Some clients have been able to demonstrate a "payback period" for the investment in the SmartSpace solution of as quickly as 75 days
- As mentioned earlier, at-scale adoption of IoT solutions through market-leading corporations with increasing confidence in demonstrable and long-term ROI are on the rise and should allow Ubisense to grow quickly
- Roland Berger estimates that Ubisense has only penetrated ca. 2-3% of its target market in automotive and aerospace – the remainder of which is predominantly "white space" and seemingly unaddressed by anyone. We see considerable headroom for potential growth by focusing on segments the company already knows well and has excellent references in

Industry-leading data management and interpretation abilities – deep (and impressive) tech offering

- With its real time data analytics, edge processing and the ability to handle enormous data volumes at sub-second speeds Ubisense demonstrates technological strength, which should mean a high barriers to entry for competitors
- Future potential to leverage access to data with existing strong analytics platform and machine learning/artificial intelligence opportunities to drive predictive solutions for new use cases, especially in the healthcare sector

Scalable asset with industry-leading levels of reliability

- A very low failure rate of the SmartSpace solution (fewer than 1 in a million data events is incorrect) means it is "best in class" product for a demanding customer base

SUMMARY

In conclusion, we have seen the impact that the Internet of Things has had, and will increasingly continue to have, upon all facets of modern society: (i) in the public sector in applications as varied as healthcare delivery, public safety, traffic management, and the eventual construction of smart cities; (ii) in the consumer space for lifestyle enhancement, entertainment, connected cars, smart homes; and, possibly most valuably, (iii) in the industrial space for location tracking, demand and supply synchronization, dynamic routing and scheduling, predictive maintenance, inspection technology and so on.

In the industrial segment, the Internet of Things can help even the highest-performing companies to boost performance: the RoI to a customer of a good product can be over a matter of months or even weeks. Leaders in Industry are rallying to this maturing technology, and such investment drives the creation of exciting and new solution sets, and the 'Smart Factory' is the beneficiary. This new, 'fourth industrial revolution' is perhaps better termed an evolution: incremental improvements and the recursive use of massive amounts of data have enabled continuous, flexible learning, and the ability to adjust to conditions and variations in real time. Location-tracking is a significant feature of this new 'real-time' learning.

In the field of Real Time Location Solutions, Investcorp identified Ubisense as what it considers to be a stand out leader. The Company has a strong position in a growing end market, and they have truly blazed a trail, securing a position as one of RTLS' leading solution providers. Ubisense's success with international, blue-chip customers across a range of different end markets – from automotive to aerospace to logistics and transportation – has proven out the efficacy of the product, and we remain excited to see how far this innovative, ground-breaking company will go in the future with continued support and investment from the Investcorp team.

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Investcorp is a leading global manager of alternative investments. Led by a new vision, Investcorp has embarked on an ambitious, albeit prudent, growth strategy. The Firm continues to focus on generating value through a disciplined investment approach in six lines of business: private equity, real estate, absolute return investments, infrastructure, credit management and strategic capital.

As at June 30, 2019, the Investcorp Group had $28.2 billion in total AUM, including assets managed by third party managers and assets subject to a non-discretionary advisory mandate where Investcorp receives fees calculated on the basis of AUM.

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