

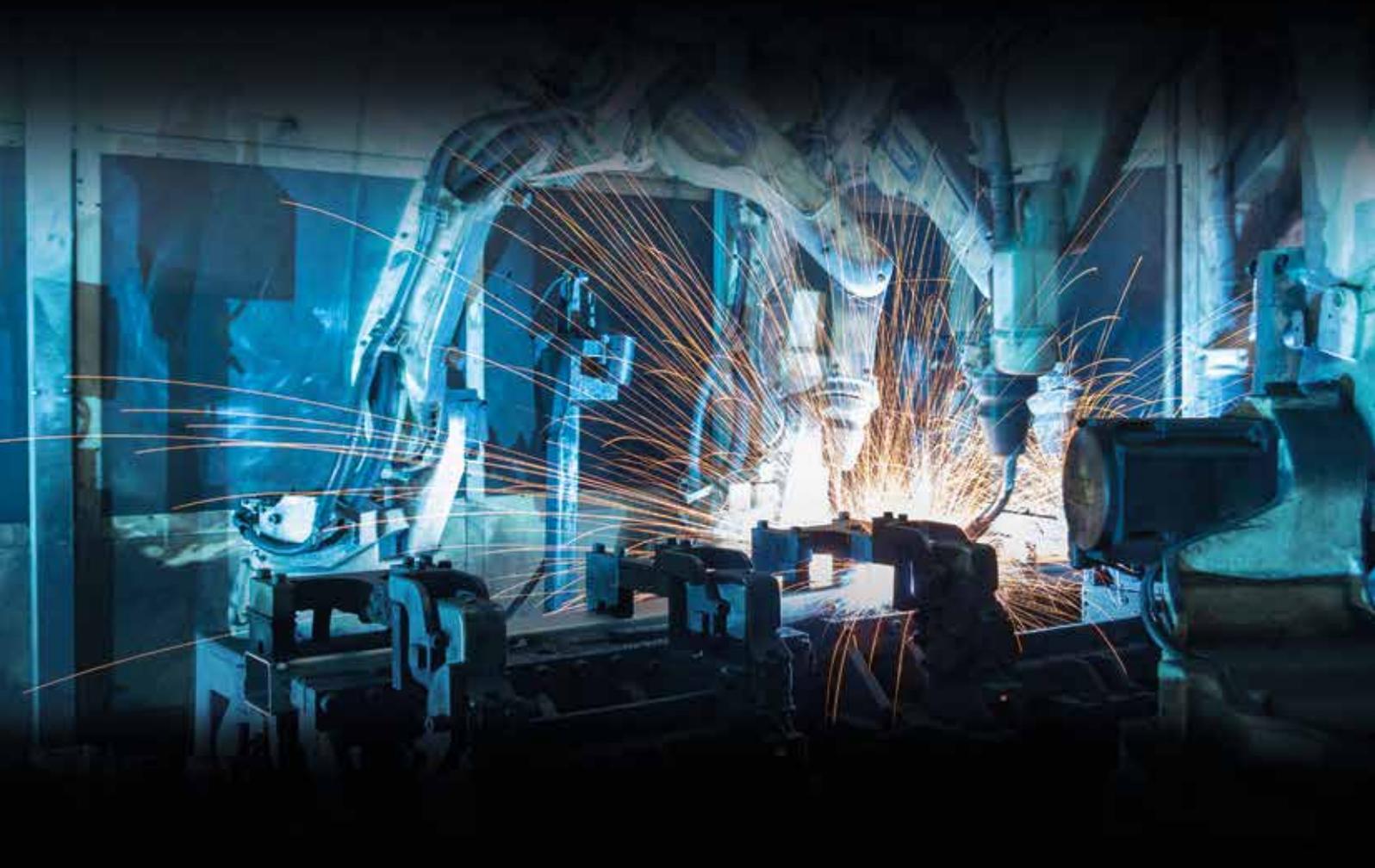


# SMART MANUFACTURING

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## *The Rise of The Machines*

*June 2019*



**GP.Bullhound**

*Dealmakers in Technology*

**Important disclosures appear at the back of this report**

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# THE VIEW

*From GP Bullhound*

**Dr. Nikolas Westphal**  
*Director*

Full automation of human work has been a constant dream (and nightmare) of civilisation. The ancient Greeks already spun myths about Hephaistos' automatons; the ancient Chinese those of Master Yan.<sup>(1)</sup> In 1884, William Morris dreamt of "beautiful factories", in which people worked only four hours per day enabled by machines.<sup>(2)</sup> Today, rules-based automation is already a reality, as commercial robots have been around since the early 1960s and proliferated across various industries.

As software and "intelligent" technology have already revolutionised the way we work and live, they will also fundamentally evolve the way we produce things.

Imagine a shopfloor where machines configure themselves in a process guided by algorithms; equipment that anticipates breakdowns and repairs itself; workers enabled by Augmented Reality to train and work in endless scenarios; and a universal data framework that encompasses everything from demand planning, real-time modelling of the production line as well as design automation, honed into changing market needs.

Any single item in this list will have implications for existing business models and the future of work. One is the shift to Manufacturing-as-a-Service, where OEMs sell a subscription to use a physical product instead of the product itself. Hyperpersonalisation, predictive manufacturing and massive productivity gains will similarly lead to a complete (self-)re-invention of the Capital Goods economy.

The commercial traction that this sector generates is immense. Overall, smart manufacturing companies have received more than €5.9bn of venture and growth funding in 2018, up from only about €0.6bn five years earlier. 2018 combined such rounds as the \$180m seed round of Bright Machines, the \$160m Series E of Desktop Metal, or the \$2.2bn Series C/D of SenseTime. Many of the prominent entrepreneurs and investors in this ecosystem have kindly agreed to contribute to this report, for which I am very grateful.

In *Chapter 1*, we look at the cyberphysical production stack and big-picture industry trends and developments. *Chapter 2* drills down into the virtualised layers of the production stack, using four concurrent trends to emphasise the importance of data as the "new oil". *Chapter 3 and 4* cover the growing transaction activity in this space and show a spotlight on the pace at which certain world regions – namely, the US and China – are charging ahead. *Chapter 5* features some of the key investors and entrepreneurs and *Chapter 6* presents different views on the future of manufacturing specifically and the future of human labour in general.

The digitisation of production will create huge opportunities but also challenges to the societies that it affects. Ultimately, we believe that freeing mankind from repetitive tasks will enable us to concentrate on those qualities that set us apart from machines and algorithms: being and acting human.



Notes:  
(1) Price, Betsy B.: Ancient Economic Thought, Routledge Study in the History of Economics, Vol. XIII  
(2) Morris, William: A Factory As It Might Be, London 1884



# I. MANUFACTURING THE FUTURE

## *Key Trends And Technologies*

GP Bullhound

1

### Smart manufacturing is part of the large, global “Smart Enterprise Wave”

Like the “new enterprise”, smart manufacturing focusses on agile, non-linear processes which are driven by Big Data analytics, constant monitoring and real-time collaboration. The defining feature of these new enterprises is the creation of platforms and the integration of concurrent technology trends.

2

### The smart manufacturing ecosystem spans the entire breadth and depth of the technology stack

Smart manufacturing encompasses all layers of the technology stack, from the highly physical to the highly virtual. We have grouped it across five layers: production, interface, orchestration, design and intelligence.

3

### Device proliferation has reached critical mass, making smart manufacturing affordable and potentially ubiquitous

Device costs between 2007 and 2014 have decreased by more than 95% across verticals. As a result, device proliferation has reached critical mass, enabling ubiquitous application of smart manufacturing technologies.

4

### Smart manufacturing will enable new business models and significant economic efficiencies

By enabling continuous delivery and continuous innovation, smart manufacturing has already started to create the outcome economy, where goods are delivered as a service. In addition, according to Accenture, smart manufacturing could unlock between 9% and 48% of additional value, depending on sector.

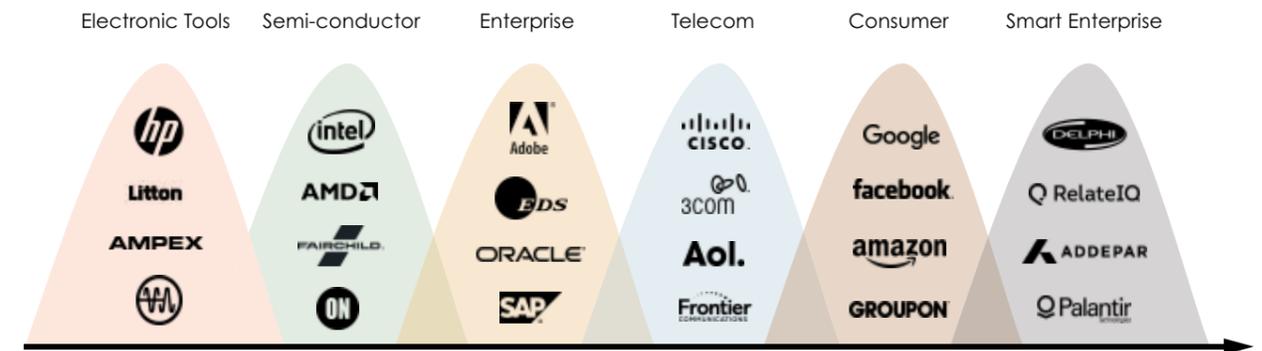
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# THE SMART MANUFACTURING WAVE

## Technology Converging Towards Smart Industry

Silicon Valley Technology Trends



A lot has been written about the fourth industrial revolution as the continuation of previous innovation waves in industrial technology: from the steam engines of the first industrial revolution, via electric power and information technology to finally the cyberphysical production systems of today. Interestingly, however, the fourth industrial revolution is part of a bigger wave that Joe Lonsdale, the founder of Palantir, describes as the Smart Enterprise Wave.<sup>(1)</sup>

While the old enterprise featured well-laid out, linear processes, the new enterprise focusses on agile, non-linear processes which are driven by Big Data analytics, constant monitoring and real-time collaboration. The defining feature of these new enterprises is the creation of platforms and the integration of concurrent technology trends.

This is one of the main differences to the previous "Web 2.0" wave: while Web 2.0 applies linear analysis to problems, the smart enterprise employs a combination of technologies that enable an additional layer of analytics and abstraction.

This additional layer is powered by what Eric Schaeffer calls the "combinatorial effect of technologies".<sup>(2)</sup> In essence, this means that the productivity effects of machine learning, Big Data, IoT, robotics and cloud services grow exponentially as these technologies are combined.

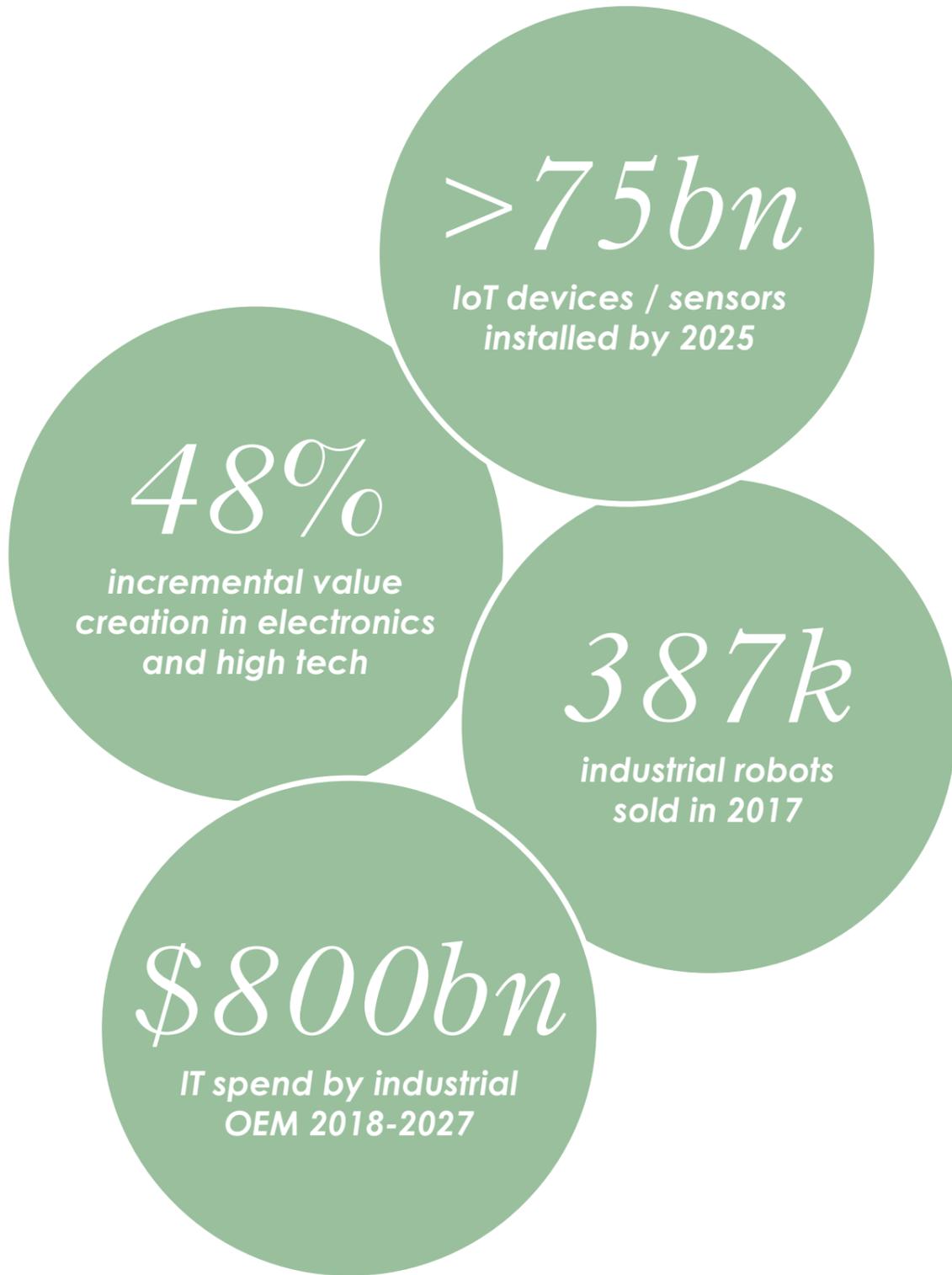
The potential for value creation is indeed huge. On a global scale, McKinsey estimates the shareholder value creation opportunity from smart manufacturing to be in the \$2.0 tn range.<sup>(3)</sup> We will see some more granular examples later in this chapter in the expert view provided by Accenture.

In addition, the upcoming industrial revolution may provide the opportunity for a complete re-invention of the capital goods sector. The first manufacturers are now using their newly found agility to move towards subscription models (we have shown a case study of Rolls Royce's "power by the hour" proposition later on). This will enable continuous upgrades and the creation of product platforms from which the entire economy will benefit.

Notes:

(1) Lonsdale, Joe, Man-Machine Symbiosis and The Smart Enterprise Wave (2) Schaeffer, Eric, Industry X.0

(3) McKinsey / Atluri, Venka et al., The trillion-dollar opportunity for the industrial sector: How to extract full value from technology

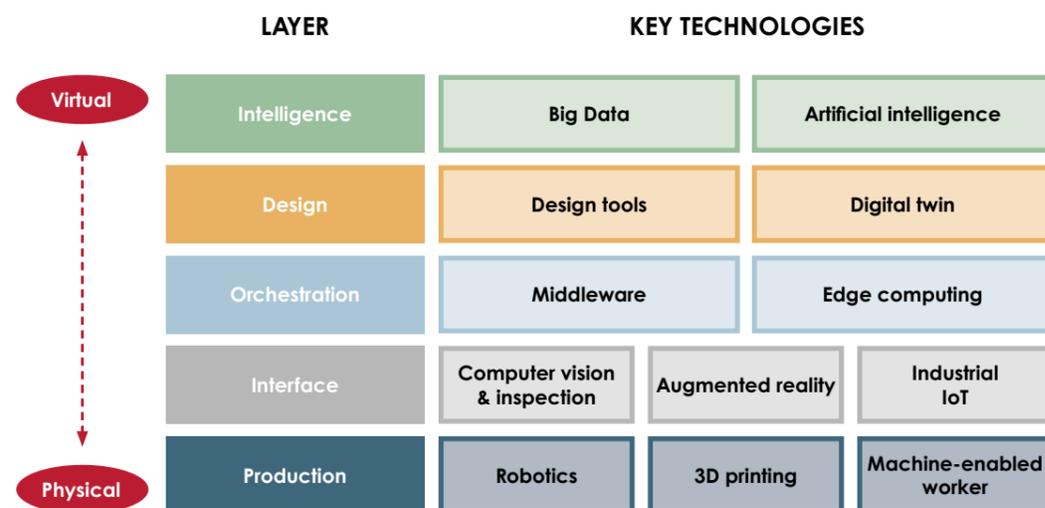




# REVOLUTIONISING THE FACTORY STACK

## How Technologies Combine To Create A Holistic Ecosystem

The cyberphysical production stack



The core of smart manufacturing is the combination of different technologies. In order to better understand the building blocks behind this, we have grouped the most relevant technologies into different layers across the cyberphysical production stack: from the highly virtual to the highly physical.

The basis of our stack is physical production, represented by robotics, 3D printing and augmentation of human workers (e.g. by cobots or AR). These are connected by a layer of interfaces: computer vision, AR platforms and IoT.

Next up is the orchestration layer, consisting of middleware applications as well as edge computing, which enables orchestration on device level.

Moving further towards the analytical layers of the stack, we have grouped design technologies, such as design tools (e.g. CAD) as well as digital twin, which are key to model the impact of design as well as process decisions.

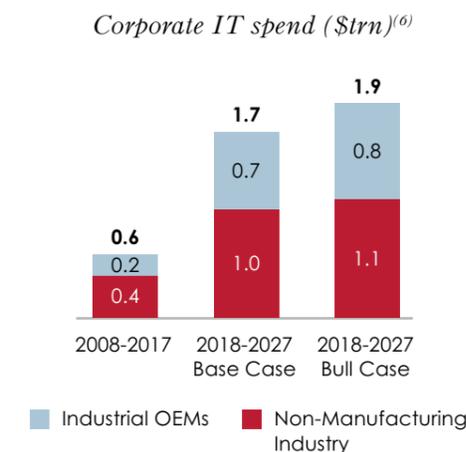
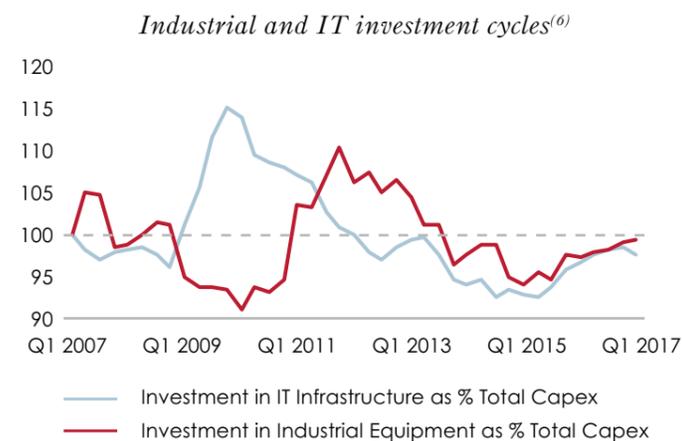
Lastly, the top layer of abstraction in our framework consists of intelligence tools, in particular Big Data and AI. These will enable intelligent control of production itself, but also the planning behind it.

Companies have a choice whether they prefer to position themselves horizontally or vertically across this stack. The major theme across the sector, is however, the creation of platforms, be they horizontally or vertically integrated.

# REACHING CRITICAL MASS

## Investments Accelerating At Decreasing Device Costs

	Industrial robots	Sensors/IoT	3D printing	Drones
Number of devices	387,000 units sold in 2017 <sup>(2)</sup>	> 75bn devices installed by 2025 <sup>(3)</sup>	6.7m units shipments by 2020 <sup>(4)</sup>	> 1m units by 2050 <sup>(5)</sup>
Cost per unit <sup>(1)</sup>	2007 \$550,000 2014 \$20,000	2007 \$40,000 2014 \$100	2007 \$40,000 2014 \$100	2007 \$100,000 2013 \$700



One of the key drivers behind the current investment wave into smart manufacturing is the increasingly widespread availability of cost-efficient devices. For example, the average cost of robot units has decreased from \$550,000 to \$20,000 between 2007 and 2014; for IoT devices, costs have decreased from \$40,000 to \$100 during the same time.

As a consequence, devices are proliferating at an unprecedented scale. It has been forecast, for example, that there will be nearly ten times as many IoT devices as humans populating the planet by 2025.

This coincides with increased investments by industrial OEMs in equipment as well as IT infrastructure at the same time. Since about 2015, both investment categories have been expanding as a percentage of total capex at the same time, indicating a widespread upgrading of facilities by industrial OEMs.

Furthermore, industrial OEMs are forecast to contribute about 40% of corporate IT spend over the next decade, significantly more than in the last ten years. All of this indicates that the market for smart manufacturing is progressing towards critical mass.

Source: GP Bullhound

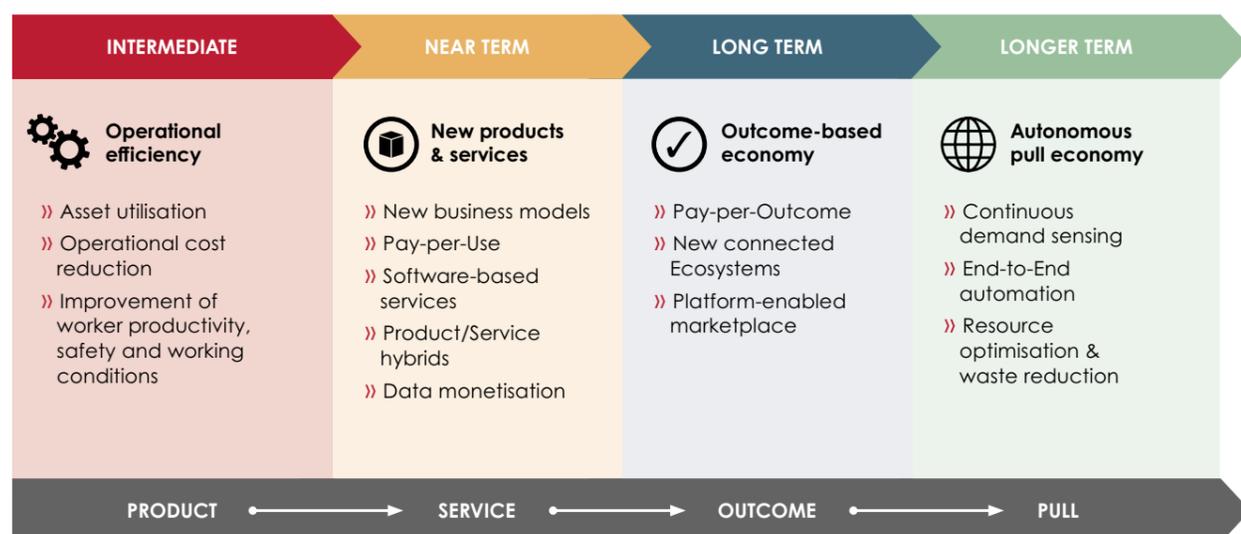
Sources: 1. Statista 2. Statista (IFR), "Worldwide sales of industrial robots from 2004 to 2017" 3. Statista (IHS), "Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025" 4. Statista (Gartner), "3D printers - worldwide unit shipments 2015-2020" 5. BCG, "Engineered products infrastructure machinery components. Drones go work" 6. Morgan Stanley Research, "Tech's Next Big Wave: Manufacturing"



# TRANSFORMING HOW PRODUCTS WILL BE DELIVERED

## Creating The Outcome Economy

From product- to service-orientated manufacturing<sup>(1)</sup>



As the digitisation of the manufacturing sector progresses, it enables previously unknown levels of agility and tractability in the design and running of industrial processes. The end result of this evolution could likely be a complete re-invention of the Capital Goods sector.

In a first step, improved maintenance cycles and the ability to update underlying control platforms "over the air" allow manufacturers to sell their product not as a physical good, but as a subscription service. This has advantages for both sides: the manufacturer can rely on predictable, continuous revenue streams and stronger lock-in, while the customer can channel investments via opex and only pays for actual consumption of

the product. Some industry pioneers adopted this concept some time ago, e.g. Rolls Royce with its Power By The Hour (PBH) concept.

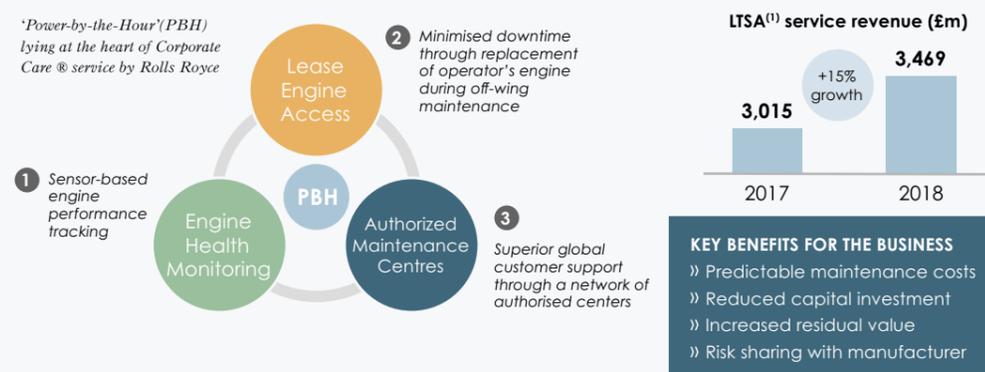
Once capital goods become further digitally orchestrateable, this will enable not just selling these goods as-a-service, but the creation of entire digital ecosystems and marketplaces around product platforms, similar to what we know today in the IT world.

Ultimately, agile and predictive manufacturing will create something that is known as the "pull economy": an end-to-end ecosystem where production is optimised to demand and resources and mass customisation will be the standard.

Sources: 1. Eric Schaefer Industry X.0: Realizing Digital Value in Industrial Sectors 2. Company annual reports and press releases.

## Successful XaaS Models Already Deployed: The Cases Of Rolls-Royce And Kaeser

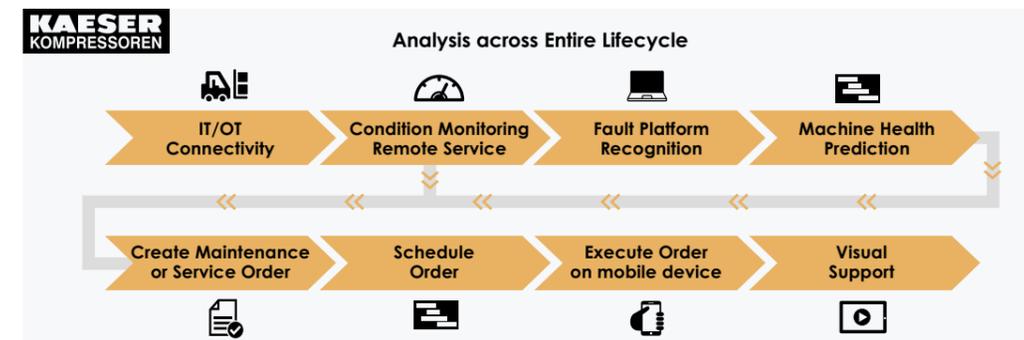
### CASE STUDY: ROLLS-ROYCE'S "POWER-BY-THE-HOUR" (PBH)



- » Invented in 1962, 'Power-by-the-Hour' (PBH) is a pioneering engine maintenance approach at the foundation of Corporate Care service by Rolls Royce.
- » Originally PBH service implied complete engine and accessory replacement on a fixed-cost-per-flying-hour basis and further was expanded with additional services.
- » The concept creates a synergy effect through alignment of interests: manufacturer receives a guaranteed revenue stream while operator pays for well performing engines only.

### CASE STUDY: AIR AS A SERVICE

- » Kaeser equips its compressors with sensors for environmental and performance data
- » This enables predictive analytics and optimized maintenance scheduling, resulting in less down-time
- » Kaeser now sells "air-as-a-service" by the cubic meter through compressors it owns and maintains



Note: (1) Long Term Service Agreements  
Sources: 1. World Finance, 2016. "Rolls-Royce is driving the progress of the business aviation market".  
2. Rolls-Royce, 2012. "Rolls-Royce celebrates 50th anniversary of Power-by-the-Hour"



# TECHNOLOGY CLUSTERS

## The Key To Becoming A Smart Manufacturer

**Raghav M. Narsalay**  
Head of Industry X.0 Research, Accenture

For industrial enterprises, digital transformation often translates into a phrase called Smart Manufacturing. Smart Manufacturing is not only about digitizing the manufacturing function. Rather, it is about using digital technologies to unlock new operating efficiencies during product conceptualization, design and manufacture and towards delivering hyper-personalized experiences to customers across the product lifecycle.

A 2017-Accenture survey of 931 senior business executives spanning 12 industries and 21 geographies reveals that almost all executives want to leverage digital technologies to enhance efficiency of their operations and to drive more personalized experiences for their customers and workforce. However, only 13% of business executives feel confident of achieving this goal. Importantly, 64% believe that failure to drive experiences and efficiencies with digital technologies will cause their businesses to struggle for survival in as short a span of next three years.

Many executives, the research team spoke to, concurred about not knowing where and how to begin their digital journeys. "How do we know which technologies should we invest in to drive experiences and efficiencies? How can we invest in digital technologies at scale when we don't know how investment in these technologies will impact financial performance of a business?", is what a senior executive from a fast-moving consumer goods (FMCG) industry had to say during one of the interviews.

Accenture's research<sup>(1)</sup> provides a starting point.

Using a combination of survey data, published company financials, and econometric tools, this research shares estimates of the top and bottom line impact businesses can achieve by systematically combining digital technologies to deliver efficiencies and experiences. (See Figure 1 and Figure 2)

For instance, companies in the industrial-equipment sector could realize additional cost savings of over 19% per employee if they combined autonomous robots, AI, blockchain, big data and 3D printing. Whereas, chemicals companies can potentially unlock growth of around 25% in their market capitalization by enhancing their ability to create new value with technologies cluster consisting, autonomous vehicles, big data, digital twin, mobile computing and virtual reality.

According to our research, the five percent of businesses in our sample, that combined six technologies—mobile computing, big-data analytics, machine learning, augmented and virtual reality, autonomous robots and autonomous vehicles – lowered their overall costs by 14% between 2013 and 2016. Cost savings for those not combining the six, was a negligible 0.6 percent.

Figure 1: Incremental savings in costs per employee

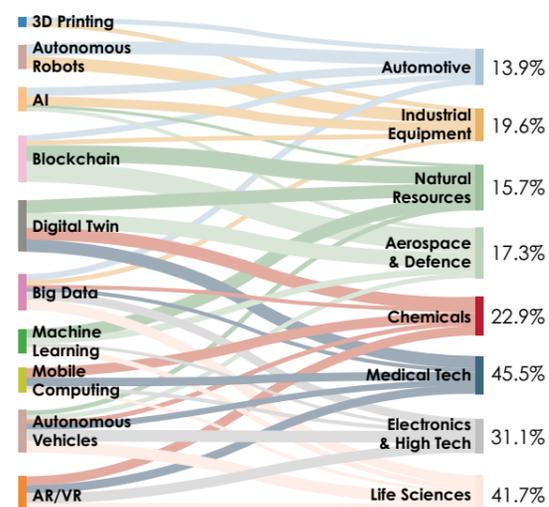
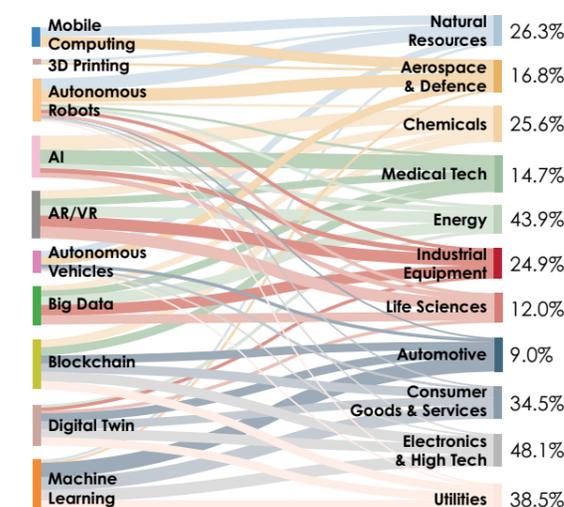


Figure 2: Additional gains in market capitalization



Volvo serves as an excellent example of how companies have already started leveraging the power of technology clusters to become smart manufacturers.

<b>Mobile computing</b>	Volvo's On Call mobile app gives drivers all sorts of information and utility. Volvo owners use the app to see where the car is parked, monitor fuel levels, double-check to see if a window was left open or a door ajar, and even start the engine remotely. <sup>(2)</sup>
<b>Big-data analytics</b>	In collaboration with Teradata, the business-analytics solutions provider, Volvo analyses all user data collected, to find patterns that can make the driving experience of their customers safer and more convenient. <sup>(3)</sup>
<b>Machine learning</b>	Next, Volvo translates trends in the data they collect into something meaningful for everyday operations. Take their ongoing work to be a leader in driverless cars. More than 20 cameras, radars, and laser sensors on board every Volvo vehicle stream real-time data to Nvidia's Drive AGX autonomous vehicle computing platform, which helps the car learn to react to situations on the road. <sup>(4)</sup>
<b>Augmented, virtual and mixed reality</b>	In 2014, Volvo partnered with Google to use the tech giant's Cardboard VR for the launch of its redesigned XC90 SUV. Paper goggles, paired with an Android/iOS app, now allow potential customers to test-drive the XC90 from their home. <sup>(5)</sup>
<b>Autonomous robots and autonomous vehicles</b>	Volvo, for its part, has used robots to make cars for decades. Some processes – such as the welding of metal parts and the measuring, placing, and bolting of doors to its cars – are now completely automated. <sup>(6)</sup> Robots are currently playing an important role in the production of Volvo's popular S60 sedans. Volvo has developed technologies such as adaptive cruise control, autobraking-pedestrian-detection systems, and parking assist. <sup>(7)</sup> Volvo has even launched a large-scale trial of autonomous-driving technology on actual roads.

Surely, how technologies should be clustered or combined will vary across industries and will certainly change over time. But the value takeout associated with their application, regardless of industry, will continue to be significant, is indisputable.

Sources: 1. "Combine and Conquer: Unlocking the power of digital", Accenture (September 2017). Accessed on December 20, 2018 and viewable at: [https://www.accenture.com/\\_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub\\_26/Accenture-Industry-XO-whitepaper.pdf](https://www.accenture.com/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_26/Accenture-Industry-XO-whitepaper.pdf)

Sources: 2. "Volvo On Call", Volvo. Accessed on December 26, 2018 and viewable at: <https://www.volvocars.com/us/own/connected-car/volvo-on-call>  
 3. "Big Data at Volvo: Predictive, Machine-Learning-Enabled Analytics Across Petabyte-Scale Datasets", Forbes (July 18, 2016). Accessed on January 25, 2018 and viewable at: <https://www.forbes.com/sites/bernardmarr/2016/07/18/how-the-connected-car-is-forcing-volvo-to-rethink-its-data-strategy/3/#21f0f9a612d>  
 4. "Volvo's next generation of cars will use Nvidia's self-driving car platform", The Verge (October 10, 2018). Accessed on December 26, 2018 and viewable at: <https://www.theverge.com/2018/10/10/17958980/volvo-self-driving-cars-nvidia-drive-agx-xavier>  
 5. "Volvo is using Google Cardboard to get people inside its new SUV", The Verge (November 13, 2014). Accessed on January 25, 2018 and viewable at: <https://www.theverge.com/2014/11/13/7217397/volvo-is-using-google-cardboard-to-get-people-inside-its-new-suv>  
 6. "Robotics on the rise in manufacturing facilities," Charleston Regional Business Journal (September 2016). Accessed on April 10, 2018 and viewable at: <https://charlestonbusiness.com/news/manufacturing/70567/>  
 7. "Autonomous Driving", Volvo. For more information, please visit: <https://www.volvocars.com/intl/buy/explore/intellisafe/autonomous-driving>



## II. THE POWER OF DATA

*Data And AI In The  
New Manufacturing World*

GP.Bullhound

### 1 Analytics & Foresight

As data generation in the manufacturing sector increases, so does the role of analytics and foresight. From initial design to production and in-life management, smart manufacturing provides unparalleled tools and insights.

### 2 Design & Simulation

Modern design and simulation tools allow production processes and outcomes to be fully understood, simulated and designed in real time and fed back into the real world on a continuous basis. The Digital Twin is the core tool in this concept.

### 3 Intelligent Worker Augmentation

While machines play a crucial role in automation, not all tasks can be taken over by robots. Augmented Reality (AR) and collaborative robots (Cobots), however, can provide substantial productivity gains to a workforce augmented by these tools.

### 4 Software-Defined Manufacturing

Combining all the previous trends stands a concept that promises to create a "lights out" factory, based on disposable robots and machine intelligence. In a few years, manufacturers will be able to feed designs directly from CAD straight to the end of the production line.

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**1,812**  
Petabytes  
manufacturing  
data created

**2.6m**  
Cobots sold  
until 2025

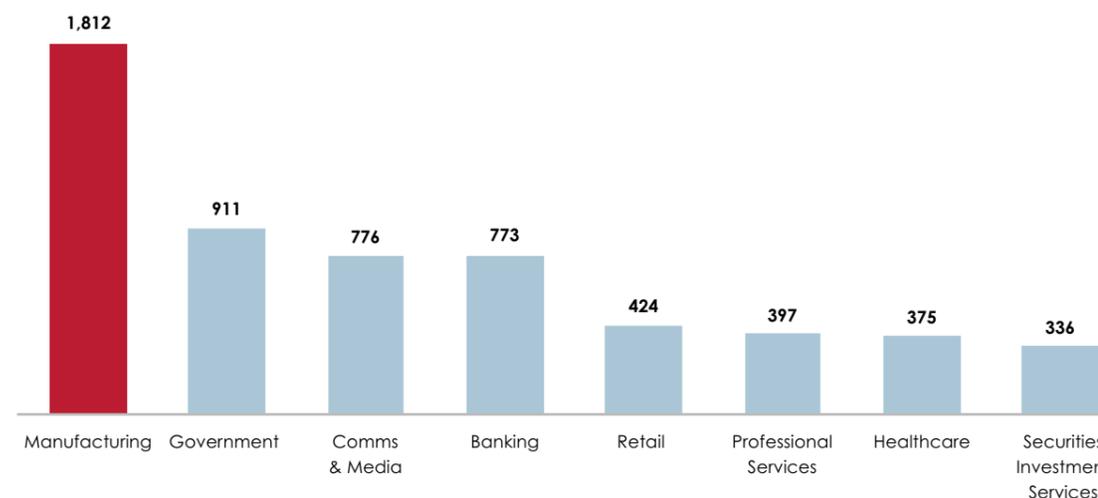
**\$3.8trn**  
incremental Real Gross  
Value Added in  
manufacturing  
through AI

## BUILDING THE INTELLIGENT FACTORY

### *The Importance Of Data In A Smart Factory Environment*



Annual data creation by industry (Petabytes)



The most important factor in creating the smart factory is data. The manufacturing shopfloor is already the most data-rich environment in the world: collectively, it creates 1.8k petabytes of data every year, twice as much as the government sector and by far outstretching communications and media, banking or retail.

Harnessing this extremely data-rich environment is one of the key challenges of industrial transformation. The initial struggle in this process is often to make the data universally available.

Once this has been solved, however, we see an endless possibility of applications, of which we have picked four very promising ones to illustrate the role of data as the "new oil" in a smart manufacturing economy.

*Analytics & Foresight* is one of the highly transformational trends which may ultimately conclude with the creation of fully predictive manufacturing. *Design & Simulation* is already used to great effect in highly automated environments. Closely connected to this is *Intelligent Worker Automation*, e.g. by AR devices or cobots, to increase their productivity.

Finally and lastly, we present a view on *Software-Defined Manufacturing*, where physical factories become as agile and automated as a modern data centre, driven by AI and edge intelligence.

Source: Morgan Stanley Equity Research, "Engineering the 21st Century Digital Factory"



## DATA-DRIVEN INDUSTRIAL AUTOMATION

### *Harnessing Data To Create Actionable Insights*

#### Willem Sundblad

*Founder & CEO, Oden Technologies*

Martin Lorentzon, co-founder of Spotify says, "The value of a company is the sum of the problems you solve." I think it's true for all businesses, but especially true for manufacturers. Manufacturing has always been competitive in nature, but due in part to globalization, the competition has intensified tenfold. Improvement methods such as Lean, Six Sigma, and Kaizen, that emerged as a result of the competitive landscape, are now considered table stakes for everyone, forcing manufacturers to look to a new frontier to gain the competitive advantage. They've found this new frontier in digital manufacturing solutions.

There are two ways that a digital system can deliver value to users. It can help them solve problems faster than previously possible. This has immediate value, given how time consuming the process of solving quality, performance or downtime issues is in manufacturing.

However the second way a digital solution delivers value is more long-term and transformative: it allows users to solve problems they would never be able to solve previously. Take the environmental algorithms we have delivered at Oden Technologies as an example. The factory environment (e.g., temperature, humidity, etc.) plays a sizeable role in material processing. But, in order to understand and adjust process parameters to account for the impact of environmental factors, one has to first analyze an abundance of data. The volume is typically too great for skilled engineers to handle, and since many do not have the experience to train models, the task is nearly impossible. However, digital solutions like Oden have algorithms to analyze millions of historical data points and make recommendations on the optimal settings that will drastically improve quality and output. These trained models do what even your most skilled engineer cannot.

Getting to a Smart Digital Factory is a journey. At Oden, we educate the industry on the four levels to that journey towards data-driven, intelligent manufacturing.

**Level 1 - Almost Accessible Data.** This is where most factories currently sit. Many different siloed systems combined through ad hoc, manual data collection. Extracting value from data is time consuming and reactive, only performed when a 'fire' - an emergency situation - arises.

These factories are leaving a lot of money on the table since there is a tremendous amount of cost reductions and profit in eliminating variability and picking off the low-hanging fruit, like making process improvements that increase capacity. Digital investment in the form of new infrastructure and integration is required to go from a Level 1 factory to a Level 2.

**Level 2 - Instantly Accessible Data.** All production data sources are integrated into one platform, a single source of truth for the entire factory. When the architecture is set up correctly, the right people have access to data and analysis tools that allows them to solve problems in very short order.

While 'fighting fires' is still a reality, identifying the root of those issues takes minutes. It still requires effort from people to engage with the system to be truly proactive with predictive and preventative improvements.

One of our customers saw \$60k return in the first 6 months on just one production line from simple analytics. The faster a manufacturer installs the right architecture the faster they can get to Level 3, since it's all built on the same data.



**Level 3 - Data Finding People.** In a Level 3 factory you have machine learning (ML) models detecting insights and anomalies, surfacing them to the right people. This is where users can start to be proactive and truly prevent problems from happening. You will not need new architecture to go from Level 2 to Level 3, but you do need new tools to build up a robust data science engine.

The architecture itself is very important, traditional automation systems are not built for this volume of data. The data then becomes a depreciating asset, where the more you have the slower the software runs and the more costly it is. If you have the right architecture the data becomes an appreciating asset: the more you have, the more powerful your solution will be. Examples of Level 3 insights that we have delivered are Predictive Quality, Performance optimization models and the environmental analysis previously mentioned.

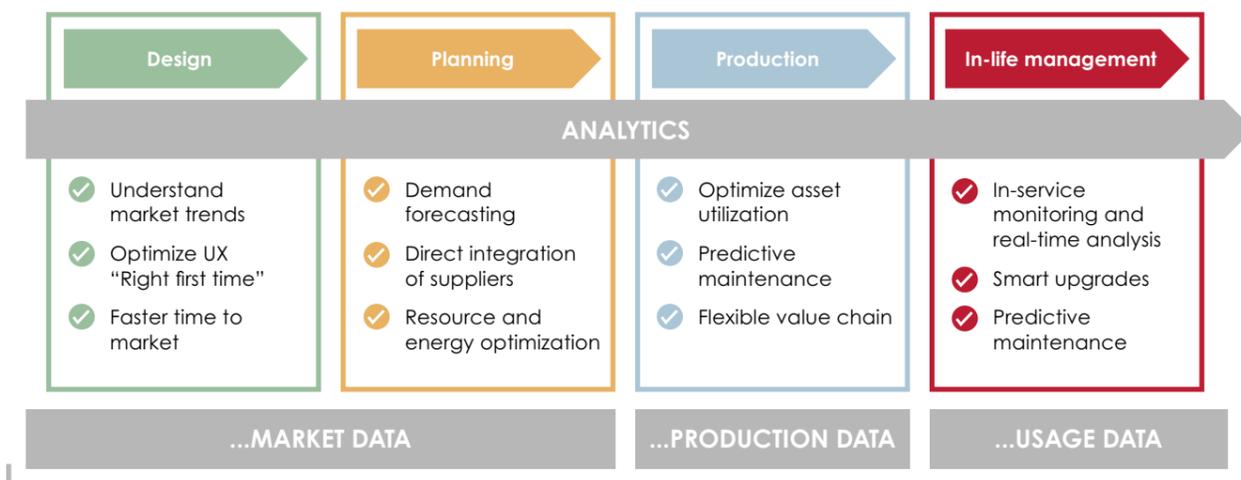
**Level 4 - Data Creating Actions.** In a Level 4 factory a machine learning model makes recommendations for new settings that go directly to the machine to be executed: an intelligent autonomous production line.

We are currently experimenting with an autonomous system, but just like self driving cars it will take a while (and lots of data) before it's ready for commercial use. That is why it is essential for manufacturers looking into digital solutions choose providers that are not just promising ML and AI out of the box, but set your factory on a journey towards intelligent industrial automation with value-added along the way.



# 1. ANALYTICS & FORESIGHT

Impact across the product lifecycle



Holistic data analytics fabric, encompassing:

Jeffrey Immelt, former CEO of General Electric stated in 2014: "If you went to bed last night as an industrial company, you're going to wake up today as a software and analytics company."

This captures the increasing importance of data analytics in a world of faster-turning product cycles and asset subscription models. Equipment may be saturated with devices, but the ability to collect, interpret and predict data from across the entire value chain will be one of the key drivers of industrial success.

As data becomes ubiquitous, platform models are gaining more and more relevance in this area. A horizontal example of this is New York-based Oden Technologies, which provides an intelligent process automation platform that spans the entire shopfloor. Other examples include companies which focus on providing vertical-

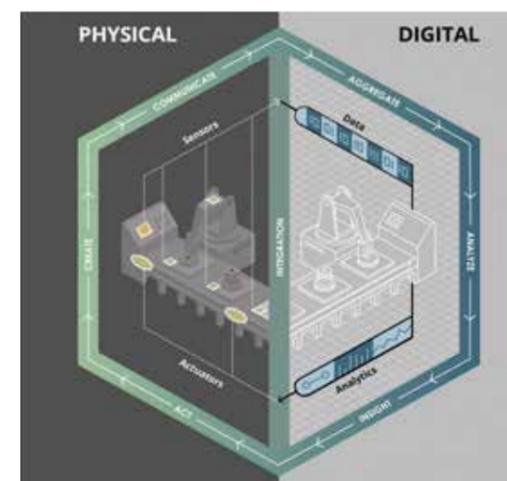
agnostic, but technologically deeply embedded data platforms, such as Munich-based Empolis, which uses semantic analysis technique for error prediction, localisation and fixing or the large data analytics company Palantir, which provides a fully configurable data platform to capture parts, equipment and processes.

Far Eastern start-ups are particularly strong in data analytics and AI – prominent examples include recently IPOed SenseTime and Horizon Robotics, which provide edge computing AI solutions.

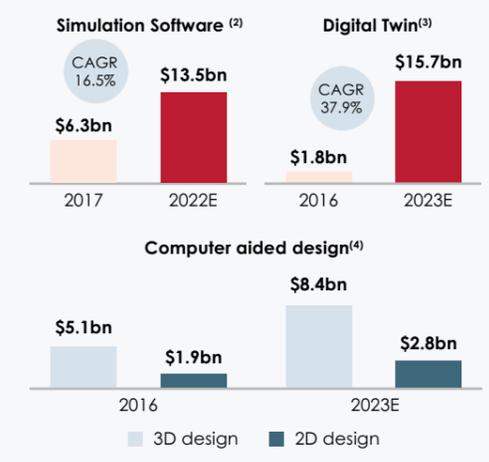
The ultimate end result of these innovations will likely be predictive manufacturing systems, which are not just able to react on their own performance data, but also on usage and market inputs, lifting automation to the next – decision-making – level.

# 2. DESIGN & SIMULATION

Example of Digital Twin in Manufacturing<sup>(1)</sup>



Industrial Design & Simulation Market



Computer-aided design and simulation is not a new concept, with the first CAD programmes available since the late 1950s. With increasing processing power, however, two trends have emerged which are pushing the boundaries of what has been possible before: firstly, the ability to map increasingly complex models in 3D and, secondly, the ability to simulate at scale in real time.

Combining those two trends together yields the real-time digital twin, which enables OEMs to model both their manufacturing line as well as their output and directly simulate outcomes of different decisions and scenarios.

The above chart shows this concept schematically: every single element of the manufacturing line is modelled in a "digital

twin" comprising all specifications and physical properties. Sensors then feed back data into the digital twin, where the data is analysed, new configurations are tested and, once a decision has been made, fed back to the real-world factory line.

One showcase for the real-life use of this technology is Siemens' electronics manufacturing facility in Amberg, where production has now reached a quality level exceeding 99.9989%.<sup>(5)</sup>

The market potential for this technology is indeed huge. Market studies estimate the digital twin market will become larger than simulation software or CAD by 2023; Gartner estimates that by 2021, half of all large industrial enterprises will use the digital twin and those that do will become 10% more effective.<sup>(6)</sup>

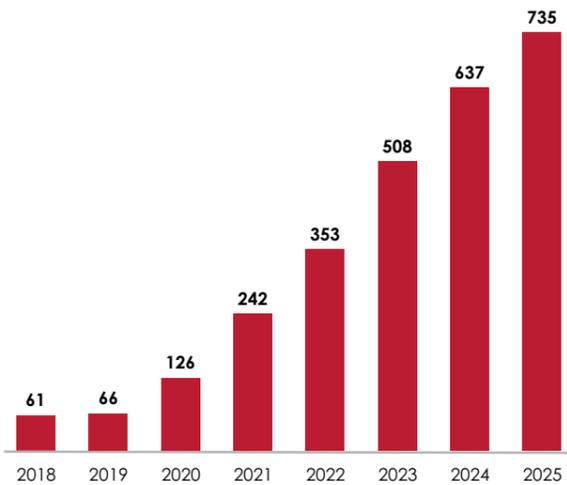
Source: GP Bullhound

Sources: 1. Deloitte University 2. Markets and Markets, "Simulation Software Market by Component (Software and Services), Application, Vertical (Automobile, Aerospace & Defense, Electrical & Electronics, Healthcare, and Education & Research), Deployment Mode and Region - Global Forecast to 2022 3. Markets and Markets, "Digital Twin Market by End User (Aerospace & Defense, Automotive & Transportation, Home & Commercial, Electronics & Electricals/Machine Manufacturing, Energy & Utilities, Healthcare, Retail & Consumer Goods), and Geography - Forecast to 2023" 4. Statista (BIS Research) 5. Siemens AG, "The digital enterprise EWA – Electronic Works Amberg", 2017 6. Gartner, "Prepare for the Impact of Digital Twins", September 2017

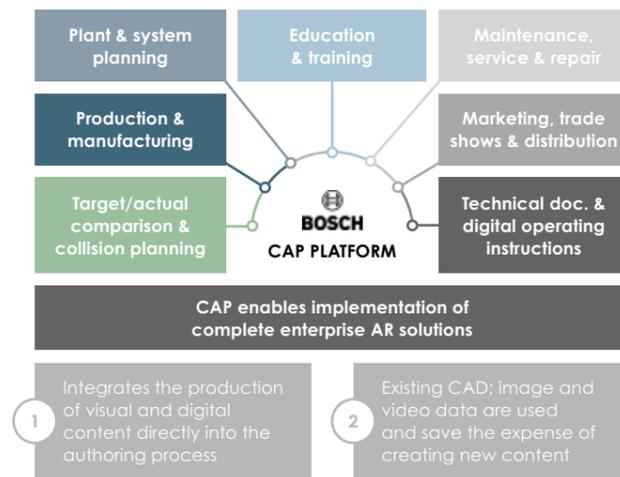


### 3. INTELLIGENT WORKER AUGMENTATION

Cobots: projected sales worldwide (in 1,000)<sup>(1)</sup>



AR in production: the Bosch Common Augmented Reality platform



Creating more autonomous and connected machinery is only one lever of efficiencies in smart manufacturing. Equally promising is to provide the existing human workforce with tools and data to master the challenges of further automation.

There are two technologies, which are particularly relevant in this context: firstly, the real-time provision of data and instructions to human workers via AR devices and, secondly, the adoption of collaborative robots, or "cobots".

Providing real-time instructions via AR devices (goggles or handheld devices) is a key tool to enable workers dealing with the complexities of an automated environment and to "jump start" their training. Bosch is one of the companies which is pursuing this area across several dimensions: the Common Augmented Reality Platform (CAP) provides a platform to collaborate with shopworkers using handheld AR interfaces; at the same time, Bosch is also invested in various AR as well as computer vision start-ups (e.g. Wave Optics, Airy3D, allegro, and Mod.Cam, among others).

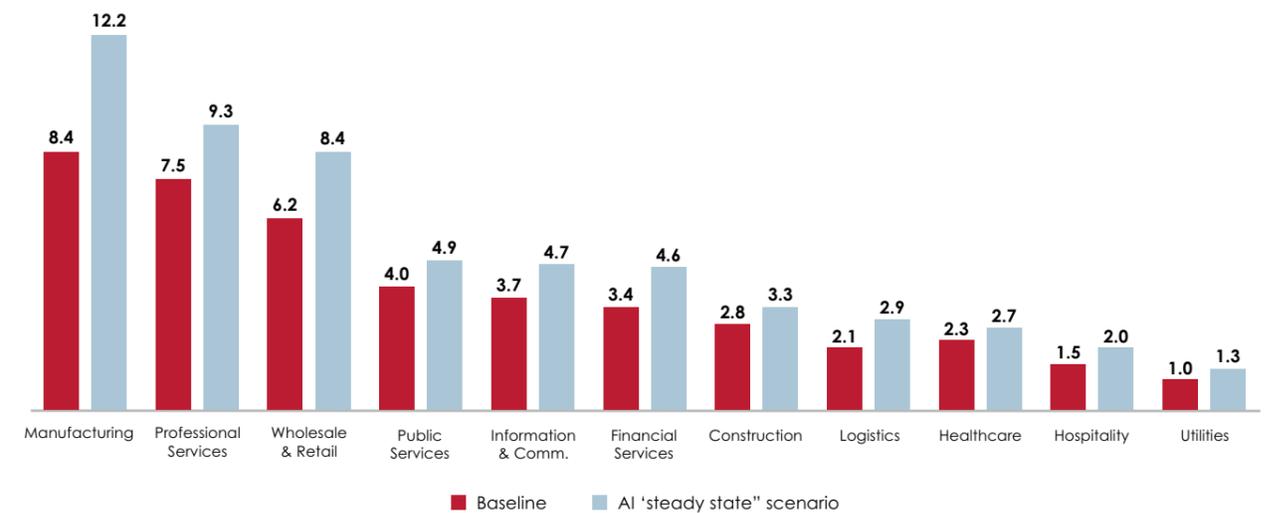
Another way of augmenting workers is by providing them with robotic hardware, i.e. cobots. Cobots address the issue that regular industrial machinery is too large and unwieldy to directly interact with workers. This poses two challenges: firstly, cobots need the physical capabilities to interact with and imitate human movements; secondly, cobots require data and intelligence to understand how and where to move.

The potential size of this market is huge; annual cobot sales are forecast to grow more than ten-fold to nearly 750,000 units over the next five years. While big strategics, as e.g. Hahn Automation (which acquired Rethink Robotics) or Kuka are pushing in this space, full-stack start-ups such as Franka Emika are set to profit from this trend as are platforms that allow robots to learn from humans, as e.g. MicroPsi, 20 Billion or Wandelbots.

Source: 1. Statista 2. GP Bullhound

### 4. SOFTWARE-DEFINED MANUFACTURING

The impact of AI on industry output (Real Gross Value Added<sup>(1)</sup> in 2035 in the USA in \$trn)



The concluding point in our short selection of data-related smart manufacturing trends is what we call Software-Defined Manufacturing. To some extent, this combines aspects of all three previously mentioned trends but also adds new aspects to the combination.

The basic notion of Software-Defined Manufacturing is to create a production line that is orchestrated in real time by software, without any human intervention at all. This will require the integration of strong data analytics capabilities, real-time digital twin, smart up- and downstream capabilities (e.g. smart logistics) as well as simple but new hardware elements for connectivity, computation and execution.

The idea of a fully software-driven, "lights out" factory is only in its early stages, but has

already gained significant traction, especially in the electronics and semiconductor manufacturing space.

One of the notable new companies in this space is Bright Machines, which raised a seed round of \$179m in 2018. Similarly, recently-IPOed Foxconn Industrial Internet has been promoting this idea since its inception in 2016.

New manufacturing companies, that are not saddled with existing infrastructure, such as Tesla or Lillium have been vigorously pushing this agenda over the last couple of years. The economic impact from this could be tremendous. Accenture e.g. estimates that, by 2035, the impact of AI on manufacturing profits could be an uplift of 39% compared to baseline, translating into an additional GVA of nearly \$4 tn.

Source: Accenture and Frontier Economics



## SOFTWARE-DEFINED MANUFACTURING

### *Creating A Fully Autonomous Factory*

#### **Brian Mathews**

*Chief Technology Officer, Bright Machines™*

At Bright Machines™, we have a vision: to transform the manufacturing industry by delivering intelligent, Software-Defined Manufacturing. In this future, new products are deployed to production lines in seconds rather than months, production equipment is fully utilized regardless of product mix or volumes. Yields are increased with automatic data-driven configuration changes. Product design changes can be deployed a dozen times a day without downtime for retooling. Any product issues reported by customers are automatically traced back to the precise factory conditions that created the issue, and software makes recommendations on how to address the issue. When demand increases, the production process running at the primary factory can be digitally brought on-line at other factories worldwide within minutes, where software adapts the product design to site-specific production equipment automatically.

A similar vision has already been realized in the cloud computing world. Modern cloud computing data centers are massive collections of dissimilar production hardware (networking, storage, CPU, GPU, power generation, cooling, etc.) from many different companies all controlled by many different interface "standards". While data centers have existed since the Apollo 11 era, the introduction of software controllable hardware and sophisticated automation software enabled modern cloud computing data centers to house millions of servers. In traditional (self-managed) IT data centers, you had to trade-off speed of innovation against complexity of scale, and reliability. But modern public-cloud data centers automate everything with software: configuration management, integration, deployment, and test. The result has been tremendous increases in the speed of product

innovation and the scale of global operation, while simultaneously increasing reliability and reducing costs. In other words, software automation allowed software companies to change their product more often while increasing reliability.

The manufacturing of physical goods, meanwhile, has yet to realize automation's full potential in this way. When it comes to manufacturing electronics, the front of the line (component placement, soldering, etc.) is already highly automated, but at the end of the line there are millions of human workers doing final assembly and inspection. It often takes dozens of expensive engineers months of effort to design, build and fine-tune automation for these production lines.

Bright Machines is changing that. We are making it just as easy to build physical products as it is to build digital ones. With Software-Defined Manufacturing, we're revolutionizing physical goods manufacturing, just as cloud computing has done with the manufacturing of digital goods. Our software (Brightware™) and robotic cells (Bright Robotic Cells) make software-defined automation accessible by complementing robotics with intelligent machine vision and a dynamic, agile configuration management layer. This enables the manufacturing line to autonomously re-configure as required; the aim is to "automate the automation" by combining capabilities from CAD, simulation, machine learning, computer vision, IoT, and configuration management with an open data platform.

Software-Defined Manufacturing enables manufacturers to create their ideal assembly and inspection Microfactories that automatically re-configure and re-calibrate to different tasks



and different products via computer vision. When computer vision bridges the divide between idealized digital-twin simulations and the imprecise analog reality of factories, it enables the entire CAD-to-Product workflow to be automated.

Once this level of automation has been reached, further "shift left" steps are possible: the engineering and ultimately, the design of the line itself, could be automated. This will enable far-reaching, universal mass customization of manufactured goods.

Today, the first use case we are looking at is "electronics in a box", i.e. the final assembly of electronics devices. The automotive industry looks particularly promising: electric vehicles and autonomous driving features are dramatically increasing the demand for electronics, requiring a complete re-think of how assembly processes are automated. Similar cases can be made for other industries.

Our \$179m seed round, together with the more than 400 manufacturing experts including 100 mechanical, electrical, computer vision and robotics engineers, will enable us to pursue this first milestone in the near future. Our robotic cell hardware is already in use by automotive and electronics customers; and we are building an adaptive, intelligent machine-vision and configuration platform behind it. In the end, our aim is to create the core platform for a new manufacturing ecosystem, bringing the agility of software to the physical world.



### III.

## A FAST GROWING ECOSYSTEM

### *Key M&A And Funding Trends*

GP.Bullhound

1

#### Large, but lumpy M&A and fast, massive growth in venture funding

Smart manufacturing has seen more than \$30bn M&A volume over the last four years as well as nearly \$6bn annual venture funding in 2018. Especially the growth in venture funding has been explosive, with almost no venture funding in 2013 and since then continuously increasing annual volumes.

2

#### M&A is driven by large consolidators, building full-stack platforms

All of the top-15 M&A transactions in the sector in 2013-2018 were large consolidators expanding their footprint or adding new capabilities. Throughout this time period, only 17% of all M&A transactions were buy-outs. M&A in the smart manufacturing space is still largely driven by strategics.

3

#### The large wave of current venture funding has created highly capitalized start-ups across all verticals

All of the top-20 funded start-ups in this sector have received more than \$100m total funding to date, with some of the most prevalent rounds in 2017/2018. Two of them – Sense Time and Magic Leap – have received more than a billion dollar funding.

4

#### In addition to M&A, strategic consolidators are building extensive venture portfolios

Out of the large consolidators, there is none that doesn't hold a VC portfolio. The list is led by GE with 75 investments, followed by Siemens, Intel, Bosch, Alphabet and Cisco, all placing significant bets on new technologies in the smart manufacturing area.

GP.Bullhound

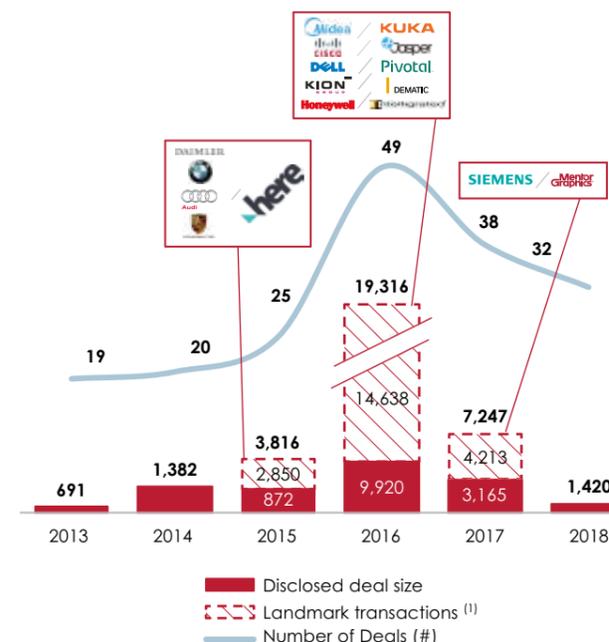


## M&A AND FUNDING ACTIVITY

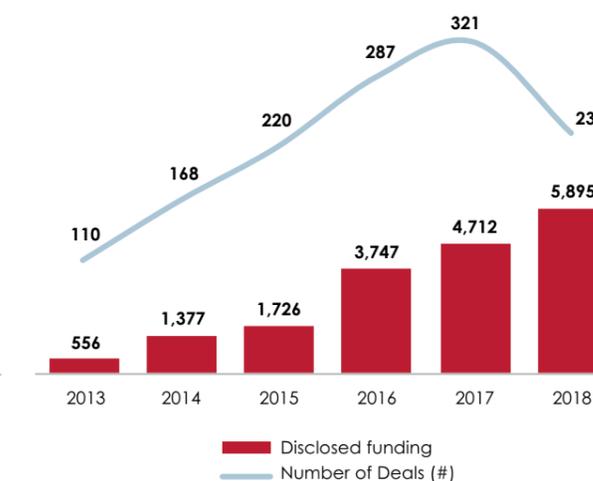
### Increasing Levels Of Activity Across Stages And Categories

#### Key Funding and M&A Trends

M&A transactions by number and volume (EURm)



Venture investment transactions by number and volume (EURm)



As an important part of our research thesis, we have looked at transaction activity in the smart manufacturing sector and compiled a set of 1,578 relevant M&A and VC funding transactions 2013-2018 from a much broader set of transaction verticals.<sup>(3)</sup>

It is notable that M&A volumes in this field are lumpy and dominated by large platform transactions, while venture funding activity has been increasing constantly over the last few years.

Overall, last year saw 32 M&A transactions in smart manufacturing – down from 49 at the peak in 2016, but up considerably from 2013 – as well as 233 venture funding rounds,<sup>(4)</sup> exceeding 2013 by more than double. Essentially, the venture funding statistics speak for themselves. Total funding across all stages and geographies last year stood at an all-time high of €5.9 bn, indicating the current dynamism of this sector as well as a progressively increasing degree of maturity.

Sources: Pitchbook, Capital IQ, target companies and investor's websites.  
 Notes: (1) Landmark transactions included M&A deals for Here Global in 2015, KUKA in 2016 and Mentor Graphics Corporation in 2017. (2) Data on deals covers the period from 01/01/2013 to 31/12/2018, excluding 49 deals with undisclosed deal date. (3) Total number of deals screened: ~ 7,000 (4) One reason for the decline in number of transactions may be a reporting lag of up to 18 months in early stage transactions. See this Dealroom.co blog post: <https://blog.dealroom.co/the-dirty-secret-of-venture-capital-investment-data/>

- €5.9bn venture capital funding in 2018
- €33.8bn M&A transaction volume 2013-2018
- 1,300+ venture capital investments 2013-2018
- 60% annual growth in venture funding 2013-2018
- €16bn transaction volume of top 10 landmark deals

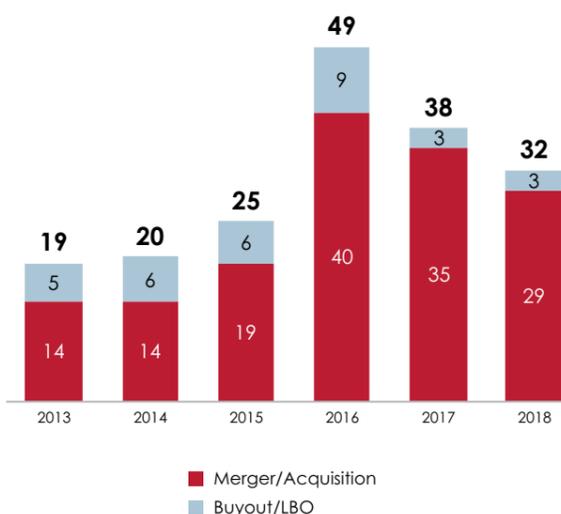


# M&A BY TYPE & VERTICAL

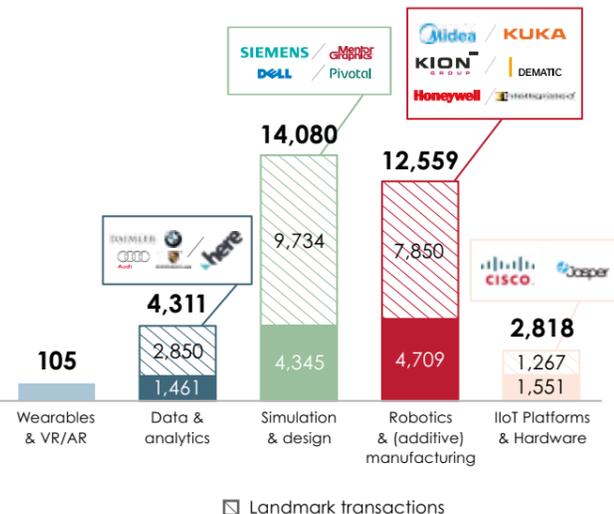
## Sustained Strategic Investor Interest In Platform Acquisitions

M&A by type and verticals

M&A transactions by lifecycle (# deals)



M&A transactions volume by vertical (EURm)



Looking at the deal statistics for M&A in this sector, one characteristic immediately stands out: only 17% of transactions throughout this time period were buy-outs. This is particularly remarkable, as both the software and the industrial sector are prime targets for leveraged buy-outs.

One of the reasons for this could be that, apart from the large, global OEMs, fully-fledged smart industry platforms are still "in the making", as we will see when looking at the venture ecosystem. Indeed, most transactions in this sector are driven by large strategics further building out their platform capabilities.

Most prominently, this encompasses players such as Midea, Siemens, GE, Cisco, big automotive OEMs, Stratasys, Dassault and many more. As we will see on the following

pages, these are also highly active in building out their venture portfolios in order to gain access to new vertical technologies.

Two recent private equity deals highlight the criteria that late stage investors apply to investments in the smart manufacturing area. One of them is Investcorp's investment into Ubisense, a horizontal IoT device and software platform, providing a high degree of product maturity and strong software component. Another example is Summit's investment into OnRobot, which is scaling across collaborative robotics through a buy-and-build strategy. Both are investments with the hope to create strong platforms. We expect LBO activity in this field to significantly pick up once some of the fast-growing companies have reached a more mature stage in their lifecycle.

## Selected Landmark Transactions

Deal Date	Acquirer	Acquirer country	Target	Target country	Amount raised (EURm)
13/07/16	Midea	China	KUKA	Germany	4,570
30/03/17	SIEMENS	Germany	Mentor Graphics	USA	4,213
04/12/15	BMW, Audi, Volkswagen	Germany	here	Hungary	2,850
22/03/16	CISCO	USA	Jasper	USA	1,267
25/01/16	SIEMENS	Germany	3D-Adaptec	USA	896
28/12/16	General Electric	USA	Arcam	Sweden	653
12/12/16	General Electric	USA	CONCEPT LASER	Germany	549
19/06/13	stratasys	USA	MakerBot	USA	454
17/11/17	DASSAULT SYSTEMES	USA	Exa	USA	343
11/06/15	TERADYNE	USA	UR	Denmark	312
15/12/14	KUKA	Germany	swisslog	Switzerland	306
25/04/18	TERADYNE	USA	MIR	Denmark	222
15/07/14	stratasys	USA	SOLID CONCEPTS	USA	218
25/10/18	Munich RE	Germany	relayr.	Germany	216
06/02/14	AUTODESK	USA	Delcam	Germany	209

Vertical ■ Wearables & VR/AR ■ Data & analytics ■ IIoT platforms & hardware ■ Simulation & design ■ Robotics & (additive) manufacturing

Sources: Pitchbook, Capital IQ, target companies and investors' websites. Notes: (1) Data on deals cover the period from 01/01/2013 to 31/12/2018. (2) Significant transactions include KUKA and Mentor Graphics M&A deals in 2016.

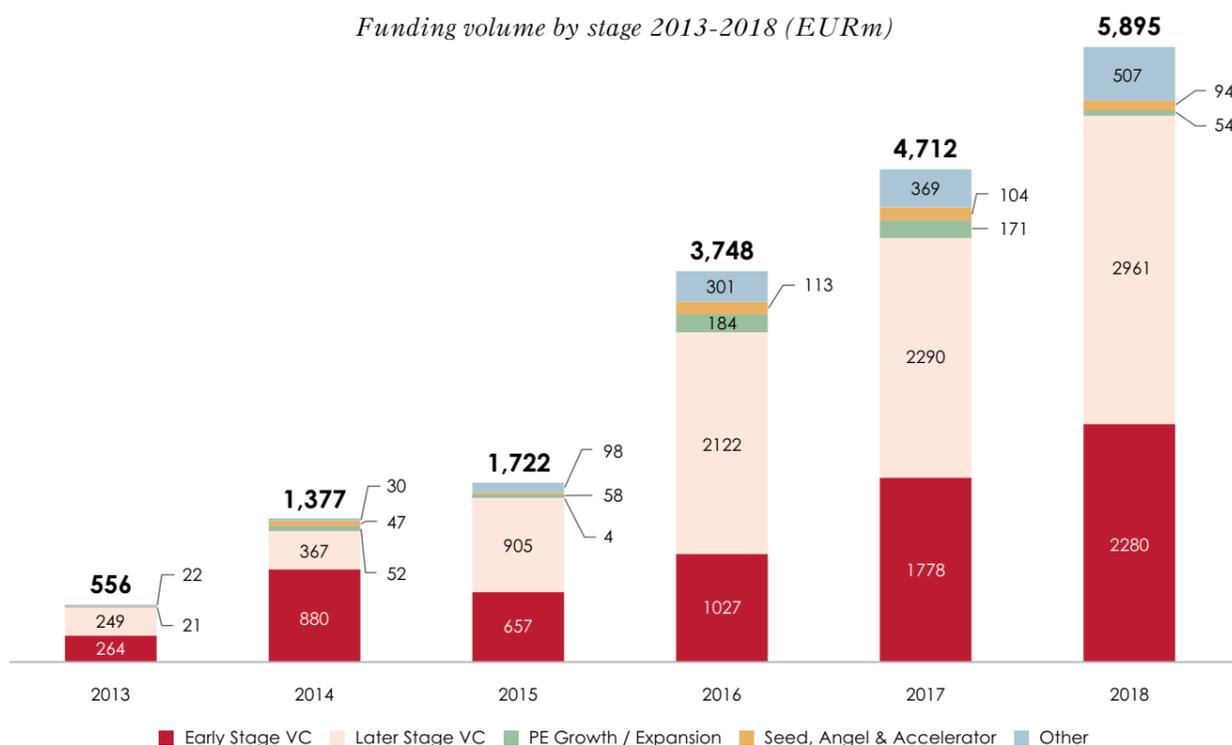
Sources: Pitchbook, Capital IQ, target companies and investors' websites. Note: Data on deals cover the period from 01/01/2013 to 31/12/2018.



# FUNDING TRENDS BY STAGE & INVESTOR

## A Fast Growing And Increasingly Mature Universe

Funding volume by stage 2013-2018 (EURm)



Looking at venture funding in the smart manufacturing space, our data indicates that volumes have increased more than ten-fold since 2013, showing substantial growth across all funding stages. Especially since 2016, volumes have significantly accelerated with new start-ups continuously pushing into this sector and later-stage companies gaining significant traction.

While funding has been driven especially by some large players, such as Magic Leap, SenseTime and Horizon Robotics (whose latest funding round is actually not part of the data set as it closed

in February 2019), it is notable how many well-capitalised firms exist in the \$100-300m range. These cover all verticals, from the production layer up to software and design & simulation. Notable is also the emergence of full-stack start-ups, such as Bright Machines, which strive to address the entire smart manufacturing stack with their platform.

Further detail is provided in Chapter V, where we discuss key investment considerations for full-stack as well as vertically focused solutions.

# Most Funded Companies 2013 – 2018



Vertical ■ Wearables & VR/AR ■ Data & analytics ■ IIoT platforms & hardware ■ Simulation & design ■ Robotics & (additive) manufacturing

Sources: Pitchbook, Capital IQ, target companies and investors' websites. Notes: (1) Data on deals cover the period from 01/01/2013 to 31/12/2018. (2) Other group of transactions includes corporate investments, PIPE, Product Crowdfunding and Grants (3) Transactions include private placement deals and M&As (trade sales and LBOs).

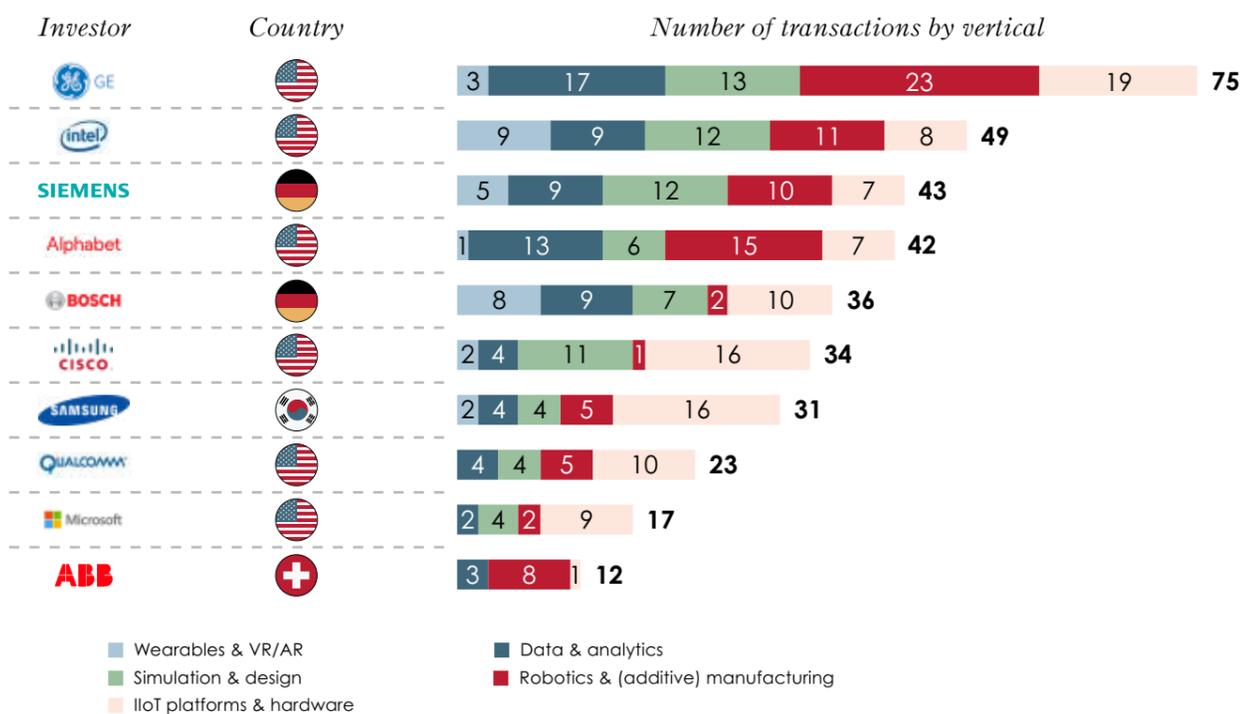
Sources: Pitchbook, Capital IQ, target companies and investor's websites. Note: Data on deals cover the period from 01/01/2013 to 31/12/2018. (1) Horizon Robotics total funding amount includes funding round on 29/02/2019.



# THE ROLE OF LARGE CONSOLIDATORS

## Continuously Expanding Footprint Via Investments And M&A

Selected top 10 strategic investors by number of transactions

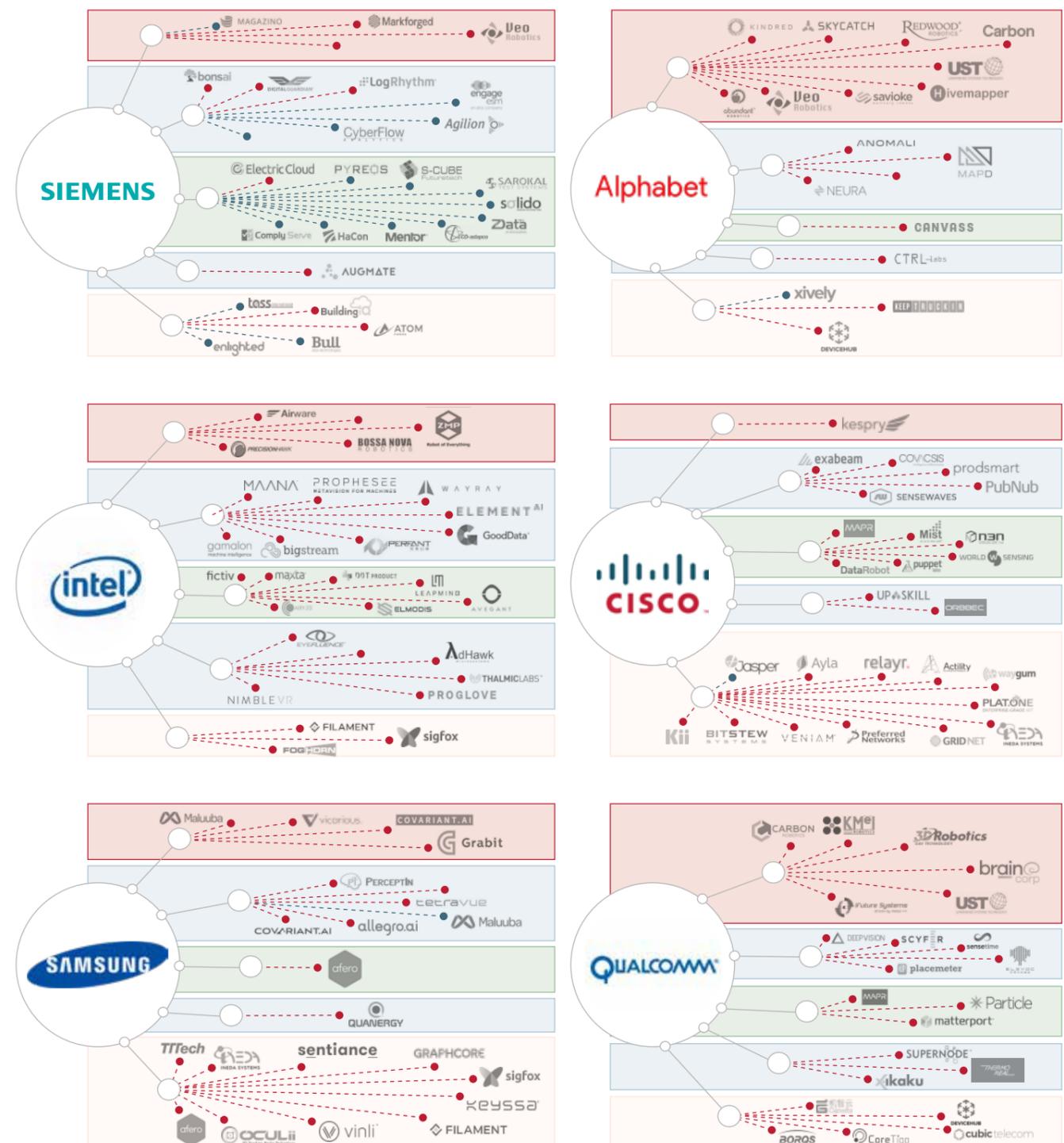


Similar to M&A, venture funding in the smart manufacturing space is also to some extent driven by large strategics intending to complete their platforms by gaining access to additional vertical and horizontal capabilities. Especially in the early-stage space, this allows them to evaluate potentially relevant technologies early on.

The list of investors is led by large OEMs, such as GE, Siemens, Bosch and Cisco, but also by information technology and software players such as Alphabet, Intel and Microsoft. This demonstrates, how the worlds of manufacturing and software are becoming increasingly fused together.

While M&A seems to have a transformational role (either on geographic or business footprint), venture investments are being used as a tool to gradually evolve existing solution portfolios. The consolidation maps on the right hand side as well as the following expert interviews all show a differentiated, diverse picture; what they have in common, however, is how large strategic players are seeking portfolio evolution and synergies through venture investments.

Interestingly, while portfolio synergies are one important aspect, the main decision criterion seems to nevertheless be financial return. The investors that we have interviewed see this as the main proxy for solution success and anticipated product-market fit.



Type of transaction: ---●--- M&A, -●- Venture Investments  
 Vertical: ■ Wearables & VR/AR ■ Data & analytics ■ IIoT platforms & hardware ■ Simulation & design ■ Robotics & (additive) manufacturing

Sources: Pitchbook, Capital IQ, target companies and investor's websites.  
 Note: (1) Consolidator maps include transactions for which transaction value data (€) is available.



# VENTURE INVESTING AT GENERAL ELECTRIC

**Eric Bielke**  
Director, GE Ventures

*“We believe in the power of software platforms to revolutionize the manufacturing stack”*

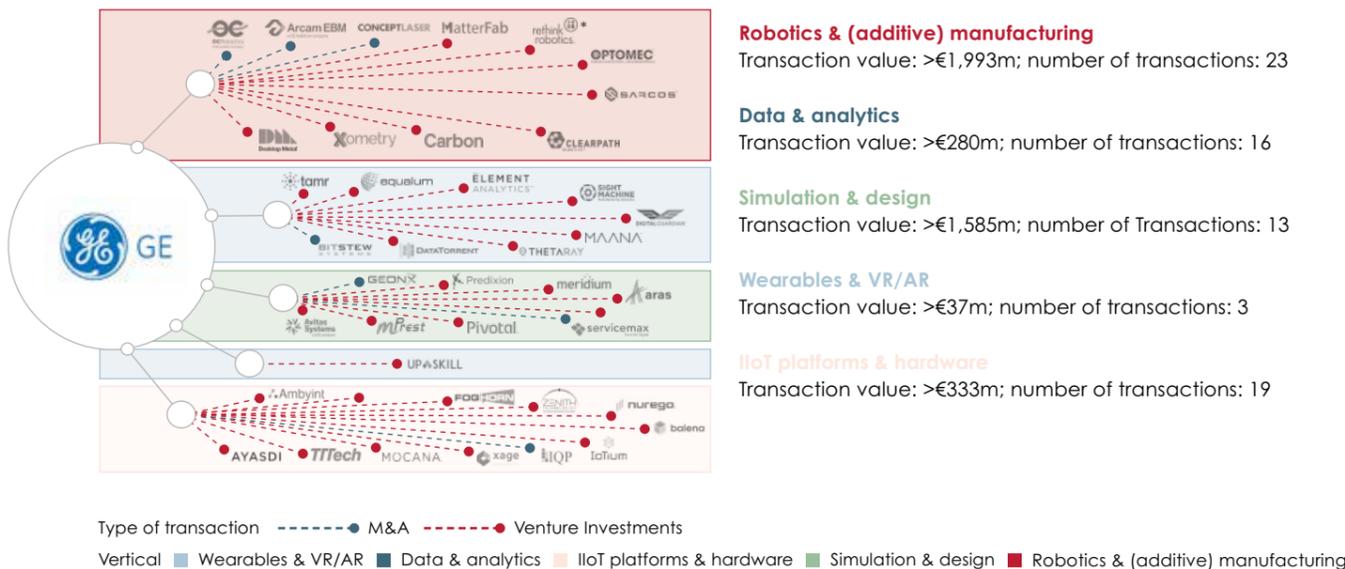
We have been investing over €3bn in smart manufacturing and industrial automation over the last few years including acquisitions across all elements of smart manufacturing. Our investments have manoeuvred GE, in conjunction with GE Digital, into the foremost position in the race to digitally transform manufacturing around the globe.

Close to 70% of our recent investments have been directed toward IIoT & additive manufacturing companies. Going forward we will likely double down on the latter, while taking a closer look on design and simulation solutions. We strongly believe in the power of software platforms revolutionizing the manufacturing stack. Once a

stakeholder in the space has established a digital core based on a software platform, individual building blocks can be added through strategic co-operations and M&A to solve key pain points.

A great example is our investment with Goldman Sachs and SilverLake in Aras Software, an enterprise grade open-source PLM (Product Lifecycle Management) suite. In addition to organic expansion, that funding has enabled Aras to acquire Impresa MRO for in-service assets, and Comet SPDM for simulation management putting the company on the path to become the global market leader in PLM.

GE's M&A and investment activity by vertical



Sources: Pitchbook, Capital IQ, target companies and investor's websites.  
Notes: Consolidator map includes transactions for which transaction value data (€) is available and based on all M&A and investment activities of General Electric and subsidiaries in selected themes between 2013 and 2018. (2) \* - Past investment.



# VENTURE INVESTING AT ROBERT BOSCH

**Dr. Hongquan Jiang**  
Investment Partner, Robert Bosch Venture Capital

*“We see solutions serving AI powered applications or platforms as a critical component of Industry X.0.”*

Over the last five years, we have made significant investments in the area of IIoT, Smart Manufacturing, AI, AR and hardware. Recently we also expanded that focus around blockchain technologies for industrial applications to power IoT with data integrity and identity for machines. Having opened an office in Shanghai in 2018 we'll be increasingly looking to invest into Chinese innovations and entrepreneurs in the aforementioned fields.

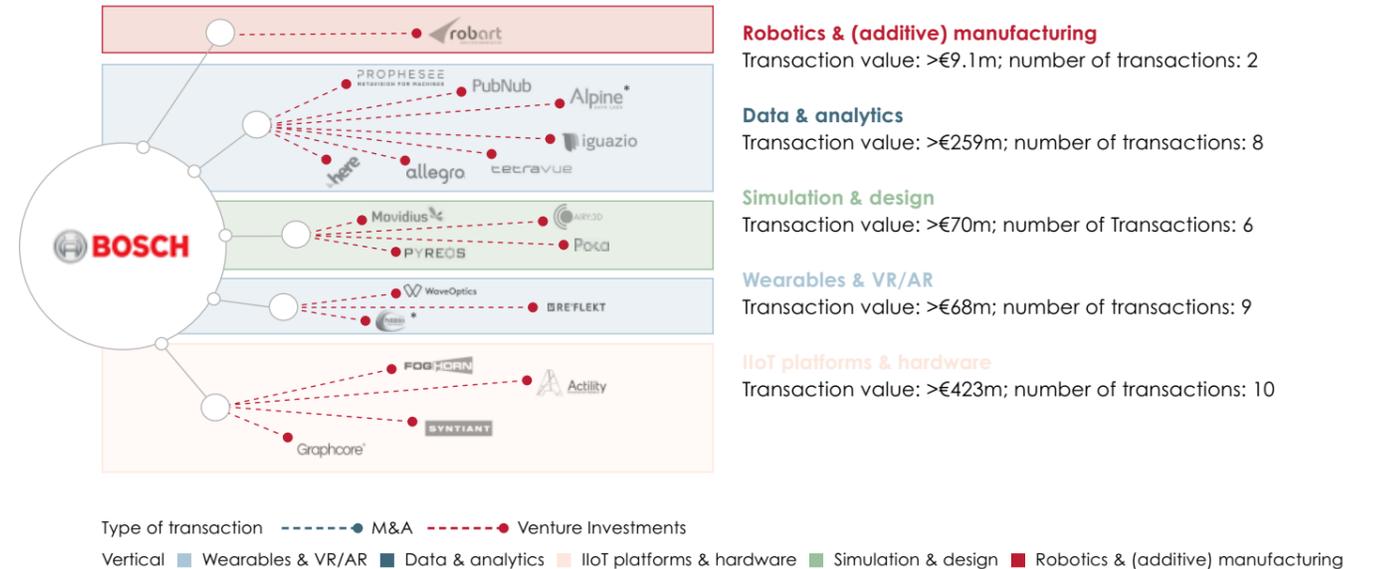
Within smart manufacturing we see solutions serving AI powered applications or platforms as a critical component of the Industry X.0. Efficiently set-up hardware components

play therefore an important role. We see solutions serving AI powered applications or platforms as a critical component of the Industry X.0.

At the AI-processor level, we invested into Syntiant, a provider of deep learning powered ultra-low-energy Neural Decision Processor Units, alongside Microsoft, Amazon, Intel and others as well as into Graphcore, an Intelligent Processor Units optimized for machine learning tasks in cloud and embedded applications, following this theses. Further up in the physical cyber production stack we can see human machine interfaces as well as computer vision and design software suits gaining significant importance.



RBVC's investment activity by vertical



Sources: GP Bullhound research (Pitchbook, Capital IQ, target companies and investor's websites).  
Notes: Consolidator map includes transactions for which transaction value data (€) is available. (2) \* - Past investment



# IV.

## GLOBAL POWERHOUSES

### *Geographic Clusters Of Smart Industry*

GP.Bullhound

1

### China and Korea have started to catch up quickly on U.S. and European innovation

Smart manufacturing patent applications out of China and Korea are growing fast and about to reach European and U.S. levels. This is driven by large R&D budgets, with e.g. China annually spending almost \$400bn on non-pharmaceutical R&D, compared to the European \$322bn.

2

### China 2025 is an outstanding example of a national smart manufacturing strategy

The China 2025 strategy is driving rapid cyberphysical automation on a national level. This coincides with large Chinese corporates – such as Foxconn – pushing for wide-reaching automation and the Chinese IIoT sector to exceed \$52bn by 2019.

3

### Especially U.S. and Chinese players engage in the building of large, global platforms with cross-border M&A

Cross-border M&A is predominantly used by U.S. and Asian consolidators to purchase European assets. During 2013-2018, e.g., foreign strategics have bought €11.3bn of assets in Europe vs. European strategics only acquiring €1.3bn abroad.

4

### The U.S. and Asia are leading the global venture financing league tables by far

Out of \$17.4bn venture funding 2013-2018, U.S. start-ups have received \$11.4bn and Asian start-ups \$3.9bn. European start-ups have only received \$2.1bn during the same time frame, cementing U.S. and Asian leadership in this sector.

GP.Bullhound

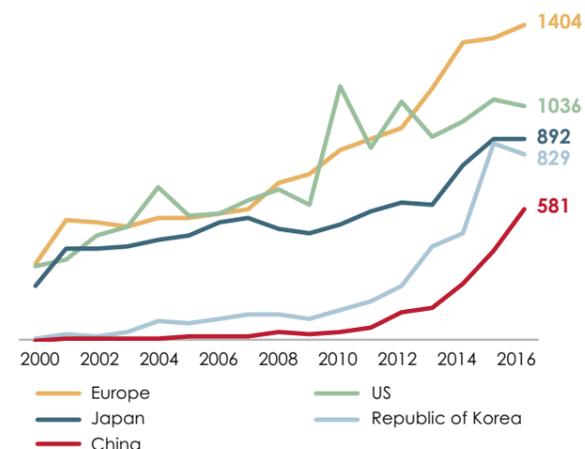


- 63% of global venture funding 2013-2018 in the US
- €11.3bn European assets sold to foreign buyers 2013-2018
- 29% of Chinese GDP in manufacturing
- \$396bn Chinese R&D spend 2016
- \$3.8bn venture funding in Asia 2013-2018

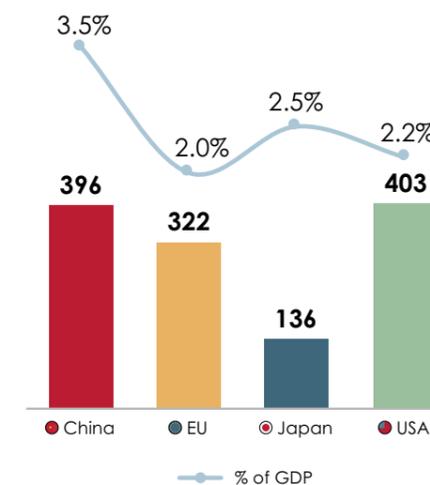
## THE GLOBAL RACE FOR INNOVATION

### Geographic Trends In R&D

Geographic origin of 4IR inventions at the European Patent Office<sup>(1)</sup>



R&D spend in 2016 (\$bn)<sup>(2)</sup>



In the following section, we look at smart manufacturing trends in four major global manufacturing clusters: China, Europe, Japan and the United States.

Out of these four, China has by far the largest manufacturing sector, both in absolute numbers as well as percentage of GDP (29%, translating into \$3.2trn), followed by the EU (\$2.3trn, equivalent to 14% of GDP), US (\$2.2trn, 12%) and finally Japan (\$1.0trn, but a hefty 21% of GDP).

Historically known as the “workbench of the world”, China is showing a particularly remarkable evolution. Smart manufacturing-related patents at the European Patent Office (EPO) have increased across geographies. China (as well as South Korea), however, are now quickly closing in to the more

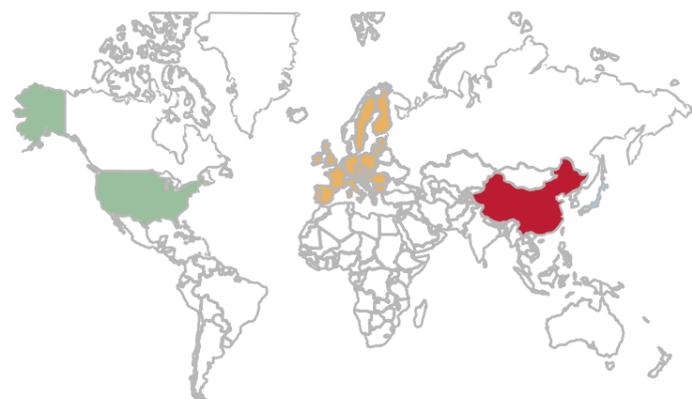
established players in the smart manufacturing space, showing exponential growth from very low levels only a few years ago. This quick catch-up is mirrored by significant R&D investments: in 2016, China has spent more on innovation than Europe and almost as much as the US in absolute terms, translating into the highest percentage of GDP among these four world regions.

Strategically, China and the US are investing especially heavily into the creation of platforms. While the US generates a lot of platform economies via its thriving tech ecosystem, China is pushing hard to create strong platforms of its own via the Made in China 2025 strategy. The effort is paying off: in a recent WEF / McKinsey study, five out of 16 global lighthouses in smart industry were situated in China.<sup>(3)</sup>

Sources: 1. European Patent Office (EPO), “Patents and the Fourth Industrial Revolution”, December 2017 2. [2] GP Bullhound calculation based on OECD, EPPIA and Statista data 3. WEF / McKinsey, “Fourth Industrial Revolution: Beacons of Technology and Innovation in Manufacturing”, January 2019  
Note: (1) 4IR – Fourth Industrial Revolution



# TRENDS BY WORLD REGION



% Manufacturing of GDP <sup>(1)</sup>    % Workforce in Manufacturing <sup>(2)</sup>    Factory Automation Market <sup>(3)</sup>

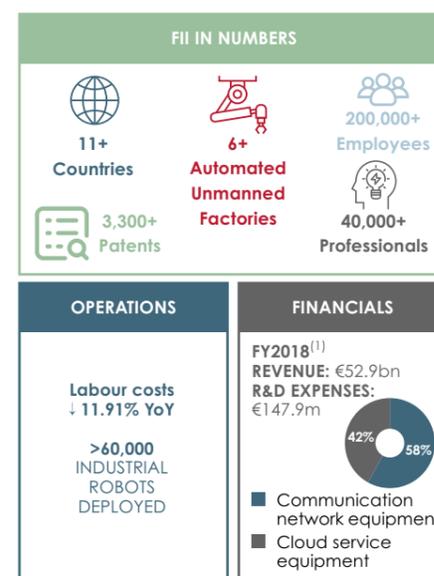
Region	% Manufacturing of GDP <sup>(1)</sup>	% Workforce in Manufacturing <sup>(2)</sup>	Factory Automation Market <sup>(3)</sup>	Key Trends
United States	12% \$2,235bn	9% 15m	\$20bn	» <b>Themes:</b> Predictive analytics, IIoT, autonomous logistics and advanced materials » <b>2025:</b> projected market share in the global Cobots market - 18%
EU	14% \$ 2,309bn	14% 35m	\$24bn	» <b>Themes:</b> Smart Factories, IoT and digital design, simulation and integration » <b>2018:</b> market share of global factory automation market - 30%
China	29% \$ 3,245bn	14% 112m	\$28bn	» <b>Themes:</b> Predictive analytics, Smart Factories, Cobots and high performance computing » <b>2025:</b> projected market share in the global Cobots market - 33%
Japan	21% \$ 1,039bn	16% 11m	Asia - Pacific	» <b>Themes:</b> Robotics, Cobots, IIoT and AI » <b>2025:</b> projected market share in the global Cobots market - 18%

### Key Trends

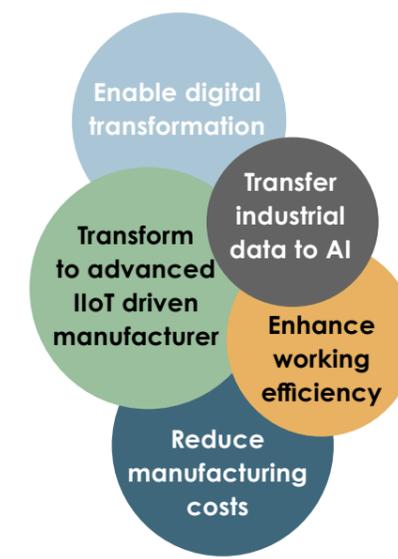
# Large-Scale Greenfield Automation: The Case Of Foxconn Industrial Internet



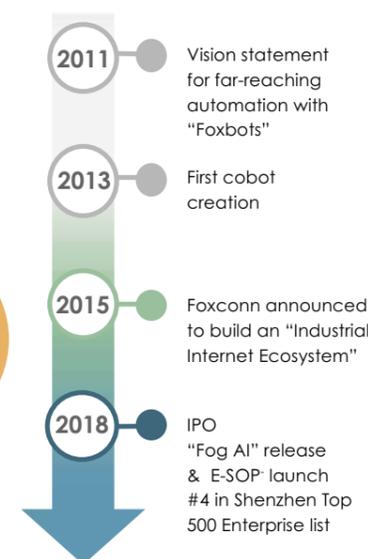
### Key Highlights <sup>(1)</sup>



### Strategic Objectives



### Timeline



The China 2025 manufacturing strategy is an interesting case, as it stipulates the policy of an entire country to push for rapid cyberphysical automation. A leading example in this context is Shanghai-listed Foxconn Industrial Internet (FII), as it represents an entire company transforming from electronics manufacturer to smart industry OEM.

Electronics manufacturing is already a highly automated sector, so this evolution makes sense. Falling short of the original plan of deploying one million "Foxbots" to replace a corresponding number of human workers, FII has managed to create the first listed pure-play smart manufacturing player.

This ties into the already highlighted theme of concentrated platform building in China. The local market environment is certainly supportive of this: the Chinese Industrial Internet-of-Things (IIoT) sector is forecast to exceed 350bn Yuan (\$52bn) in 2019. FII's current development focus on machine learning and software orchestration reflects very well the current strengths of China's ecosystem as a whole. Together with the recent immensely large funding rounds for horizontal platforms, as e.g. SenseTime and Horizon Robotics, we should expect more successful smart manufacturing platforms to emerge in China.

Sources: 1. World Bank national accounts data and OECD National Accounts data files. 2. OECD, OECD Employment Outlook. 3. Statista, 2018

Notes: (1) Revenue split is based on 1H2018 financial results. (2) Fog AI - a smart control system for prediction of the fire probability and optimization of evacuation plan. E-SOP - UWB based positioning platform based on facial recognition technology and behavioral analysis enabling efficient workload allocation. Sources: 1. Ecns.cn "Foxconn unit to focus on R&D" 2. Foxconn Industrial Internet official website

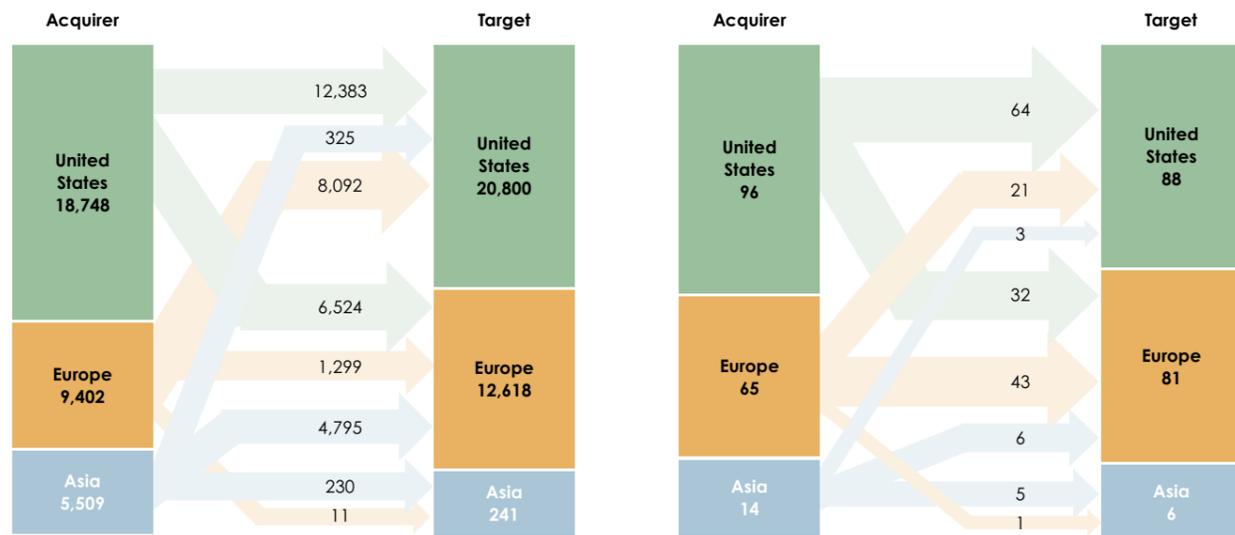


# CROSS-BORDER M&A ACTIVITY

## Trends In Global Consolidation

By deal volume (EURm)

By number of deals



One of the most insightful M&A indicators are cross-border acquisitions, as they provide visibility on consolidation trends and the emergence of global platforms and cross-border technology transfers.

In this context, Europe emerges as the main consolidation target for both US and Asian players, while some cross-border consolidation seems to be going on from Europe to the US.

Overall, the large majority of European transaction value is subsumed by either US or Asian acquirers (€11.3bn vs. only €1.3bn domestic European acquisitions). On number of deals, the trend is not quite as pronounced: 38 European companies in the space have been acquired by non-European acquirers vs. 43 domestic

acquisitions. The US ranks second in cross-border activity with €8.4bn acquired by foreign acquirers vs. €12.4bn domestic deal value. The large majority of Asian M&A volumes was outbound, predominantly to Europe.

Looking at the top landmark transactions during 2013-2017, the largest and most widely publicised one was the acquisition of German robotics OEM KUKA by Chinese group Midea. The remaining large landmark deals are broadly split between European acquirors investing into US footprint and technology as well as the other way round. Overall, a review of cross-border transactions again confirms the theme of strategic players concentrating into full-stack platforms.

# Landmark Cross-Border Deals

Transaction	Date	Size (EURm)	Sector	Summary
Midea / KUKA	13/07/2016	4,570	Electrical Equipment	» <b>Seller:</b> Voith » <b>Acquired:</b> 62.81% » <b>Rationale:</b> Synergies for improvement of factory automation
SIEMENS / Mentor	31/03/2017	4,213	Automation/ Workflow Software	» <b>Seller:</b> Elliott Management » <b>% Acquired:</b> 100.00% » <b>Rationale:</b> Expansion in the electronic design automation software segment
DAIMLER / here	4/12/2015	2,850	Communication Software	» <b>Seller:</b> Nokia » <b>% Acquired:</b> 100.00% » <b>Rationale:</b> Acceleration of open location platform development
KION / DEMATIC	1/11/2016	1,940	Logistics	» <b>Seller:</b> AEA Investors, Ontario Teachers' Pension Plan » <b>% Acquired:</b> 100.00% » <b>Rationale:</b> Become a one-stop-supplier for intelligent supply chain and automation solutions
SIEMENS / AVEVA	1/03/2016	896	Multimedia and Design Software	» <b>Seller:</b> Bank of America Merrill Lynch » <b>% Acquired:</b> 100.00% » <b>Rationale:</b> Growth of digital business & expansion in the industry software
General Electric / Arcam	28/12/2016	645	Industrial Supplies and Parts	» <b>Seller:</b> 3D Systems, Elliott Management » <b>% Acquired:</b> 76.00% » <b>Rationale:</b> Enhancement of additive manufacturing business
General Electric / CONCEPT LASER	12/12/2016	549	Electrical Equipment	» <b>Seller:</b> Founder (Frank Herzog) » <b>% Acquired:</b> 76.15% » <b>Rationale:</b> Enhancement of additive manufacturing business
MIR	25/04/2018	222	Electrical Equipment	» <b>Seller:</b> Esben Østergaard, Søren Jørgensen, Torben Rasmussen » <b>% Acquired:</b> 100.00% » <b>Rationale:</b> Expansion of the portfolio of advanced intelligent automation products

■ Data & analytics ■ Simulation & design ■ Robotics & (additive) manufacturing

Sources: Pitchbook, Capital IQ, Company websites and press releases. Notes: (1) Data on deals cover the period from 01/01/2013 to 31/12/2018 (2) Transactions with the RoW are not included.

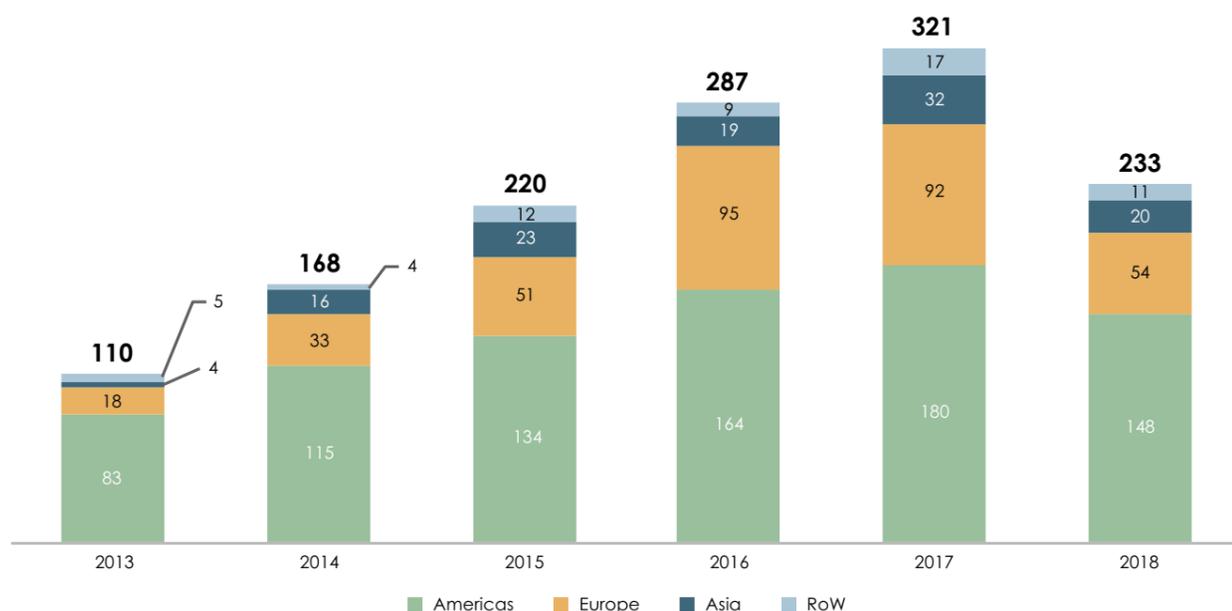
Sources: Pitchbook, Capital IQ, Company websites and press releases.



# GLOBAL FUNDING TRENDS

## Funding Trends By World Region

Venture funding rounds by region 2013-2018  
(Number of rounds)



Another important indicator for global trends are funding rounds and volumes by world region. Looking at the number of rounds for each region, it is notable how the number of deals has increased significantly between 2013 and 2017; the 2018 numbers are probably not yet entirely reliable due to a reporting lag on early stage transactions.

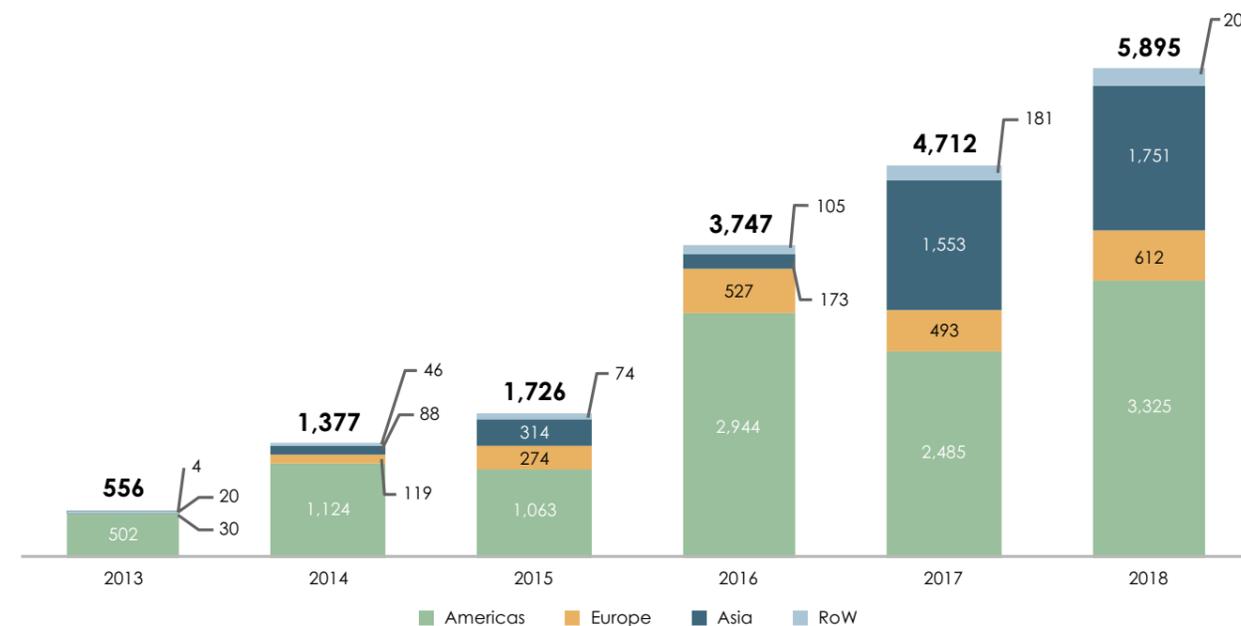
Very interesting in this context is the distribution of funding rounds vs. funding volumes between the US, Europe and Asia. Europe has seen a tremendous growth in funding rounds, reaching five times as many transactions in 2017 as in

2013 and showing much more activity in terms of number of transactions than Asia. Looking at volumes, however, Europe is massively behind the rest of the world, with more than five times the investment in the US and almost double in Asia.

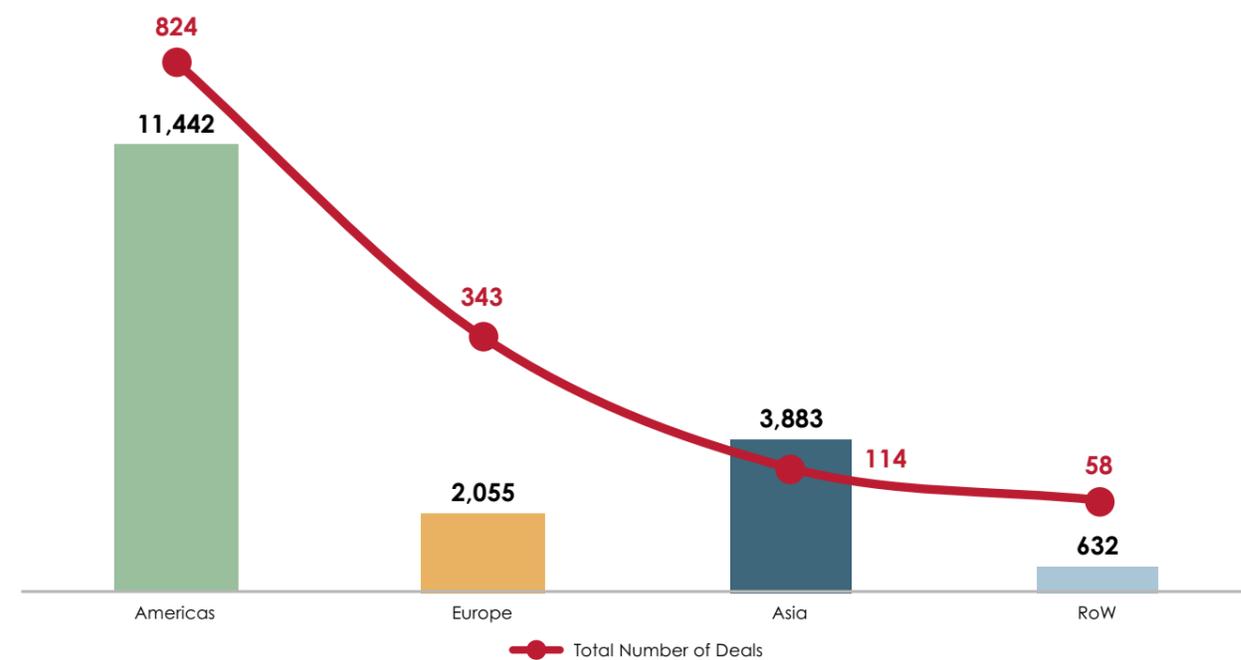
This is an indicator for the early stage nature of the European market as well as fewer follow-on rounds. As we will show in the following section, European start-ups tend to be acquired earlier through M&A and thus being taken from the market. At the same time, the US and China are investing heavily in placing big bets.

Sources: Pitchbook, Capital IQ, Company websites and press releases.

Venture funding volume by region 2013-2018 (EURm)



Total funding volume by region 2013-2018 (EURm)



Sources: Pitchbook, Capital IQ, Company websites and press releases.



# GLOBAL TECHNOLOGY INVESTMENTS

## Connecting The Dots Between East And West

**Michael Prah & Denis Tse**

Partners, Asia-IO Advisors, Hong Kong

At Asia-IO, we focus on pursuing Smart Manufacturing private equity opportunities that arise from the convergence of operational and information technology across the technology stack: from components, hardware systems, to software and services; and industrial companies upgrading their manufacturing capabilities and reshaping their business models.

To date, our investments enhance infrastructure that support intelligent manufacturing deployment; enable high-reliability smart factory build-out; or solve the technological and supply chain bottlenecks in the manufacturing of next-generation products.

The technologies powering Smart Manufacturing are global and supply chains are interconnected. With offices in Hong Kong and Seoul, and partners in Europe and North America, we invest in cashflow-positive opportunities worldwide.

Up to today, we have led or co-led eight investments in Europe, Korea, Hong Kong and North America over a combined US\$1.3 billion.

We focus on companies with an enterprise value between US\$50m and US\$500m, emphasising the Asian dimension in the value creation plan of our portfolio companies.

North Asia's industrial powerhouses of Greater China, South Korea and Japan account for more than 50% of worldwide manufacturing value-add and consequentially together are by far the largest market for smart manufacturing solutions and services. They are also home to many global champions in areas of semiconductors, robotics, drones or AI - critical building blocks of industry 4.0.

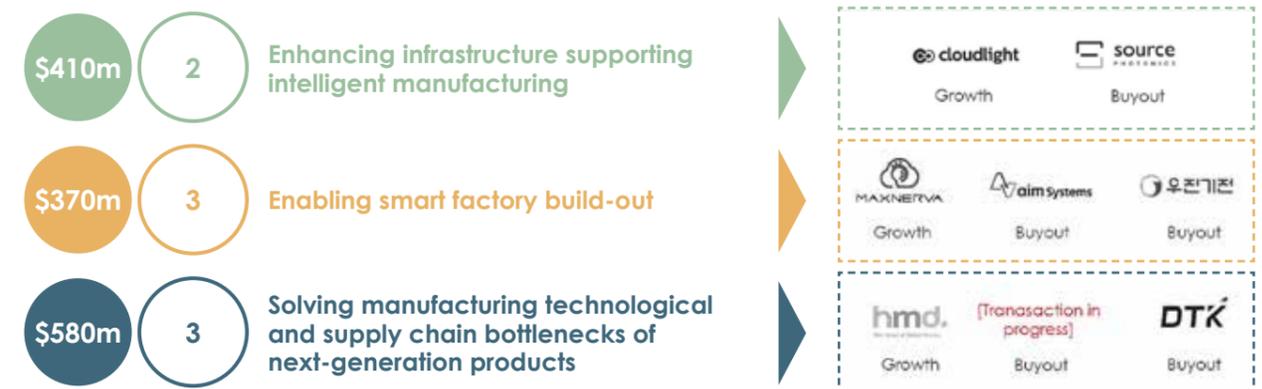
In developing the Asian "angle" we work with a number of the region's largest and most innovative industrial OEMs, often investing jointly in transactions. This provides us with a deep understanding of these market makers' roadmaps and their strategic priorities and gives our portfolio companies access to collaboration opportunities, such as introduction to large potential new customers, co-development programs and distribution or manufacturing partnerships.

More generally, we specialise in identifying and solving value chain bottlenecks, bringing core technologies to new markets/ customers and bulking up for scale (frequently through buy-and build) and multi-market presence.

In the context of mid-sized companies, often owner-led or carve-outs from larger organisations, these activities help to elevate them to the next level and making them ready for capital markets or strategic acquisitions.



Key investment themes since 2015



Selected key investments





V.

## ENTREPRENEURS AND INVESTORS

*Key People, Start-Ups And Investors  
Shaping The Industry Of Tomorrow*

GP. Bullhound

1

### The landscape of companies is skewed towards mature verticals

Out of the companies in our data set, almost a third are active in IoT, a further quarter in robotics and more than a fifth in data and analytics. Simulation and design as well as wearables & VR are still relatively small and early stage.

2

### The overall ecosystem is still quite early-stage with many companies exiting to strategics

In both Europe and the U.S., the large majority of companies are either at seed or venture stage. A relatively large proportion of companies in the data set has been acquired through M&A (32% in Europe, 19% in the US).

3

### Founders are generally experienced, technical and tend to have worked with relevant strategics

Founders in smart manufacturing tend to be above 30 years of age (especially in the US) and the large majority have a technical background. Many combine academic as well as relevant strategic experience.

4

### Investors into smart manufacturing tend to be specialized and looking for platforms

Out of the top 10 venture investors in smart manufacturing, all of them either have a specific focus or an explicit investment strategy in this field. The main investment thesis seems to be platform-focussed or full stack investments.

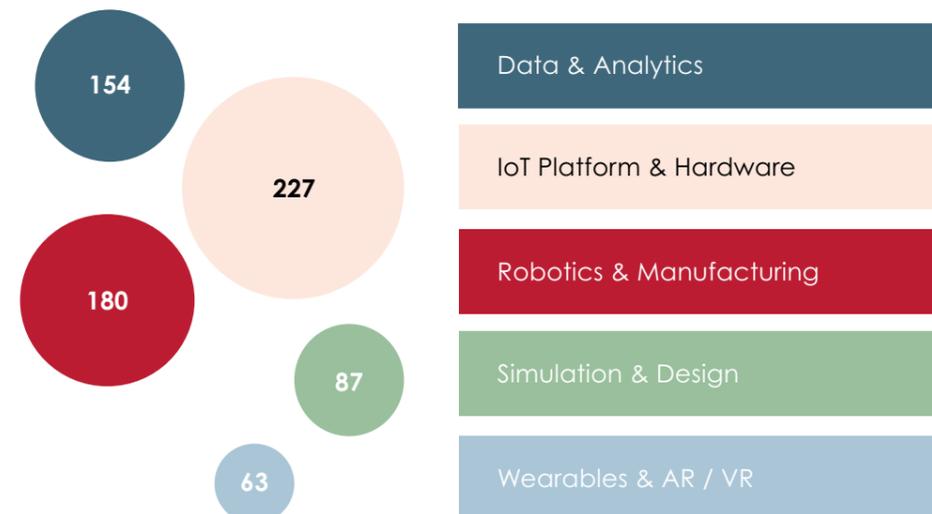
GP. Bullhound



## FINDING A FORMULA

### *For Founders Of And Investors In Smart Manufacturing*

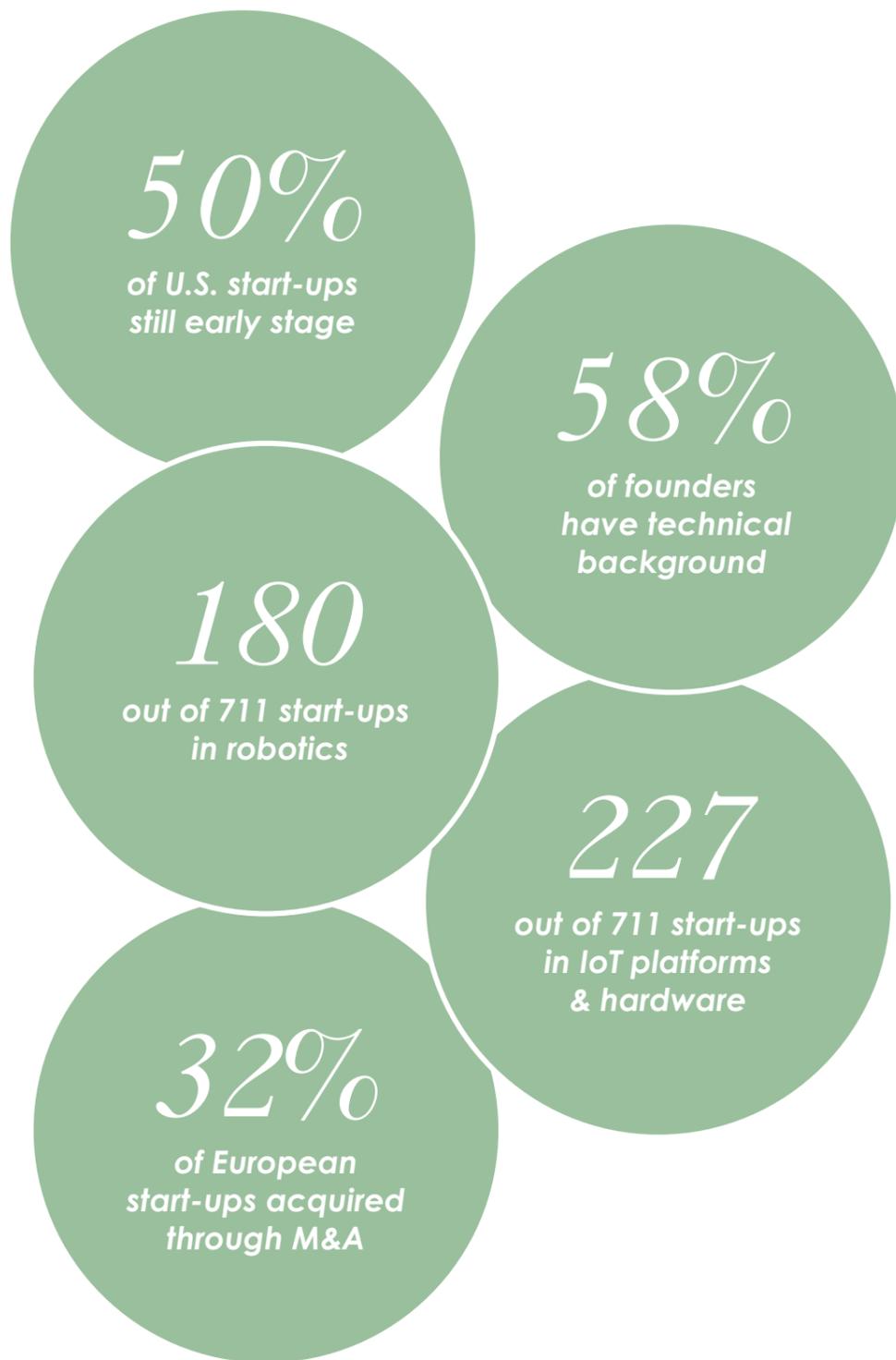
*Landscape of companies per vertical*



Since 2013, our analysis shows a total of 711 companies who have undergone a financing or M&A transaction. While this is a very diverse ecosystem across many different verticals, it is also tightly interwoven in terms of investors, strategics and founders.

The number of companies per vertical already provides some insights as to their relative maturity: the most populous vertical is IIoT platforms and hardware, reflecting the relatively long development runway IIoT already had. Second is robotics and manufacturing, which is dominated by robotics start-ups as well as 3D printing, shortly followed by data and analytics.

Simulation and design (mostly digital twin) as well as wearables and AR/VR seem to be a bit earlier stage and currently contain fewer companies. The big debate in the investment community currently is whether to focus on full-stack start-ups only or whether vertical solutions can create sufficient "platform pull" to create ecosystems within their specific layer of the cyberphysical production stack. We will be looking at examples for both models on the following pages, together with some of the most prominent investors as well as founders in the space.



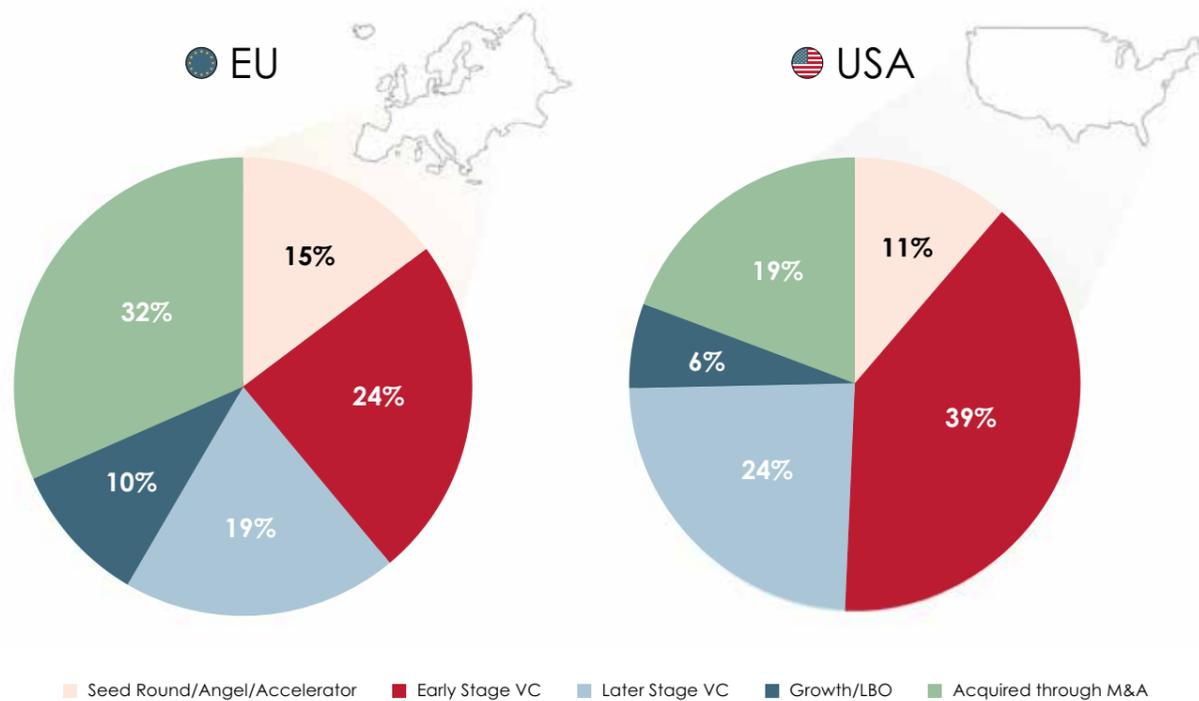
Sources: Pitchbook, Capital IQ, company websites, GP Bullhound analysis  
 Note: Data on deals cover the period from 01/01/2013 to 31/12/2018.



# FORMING AN INVESTMENT THESIS

## Investment Strategies In A Quickly Evolving Ecosystem

Stage of financial investments



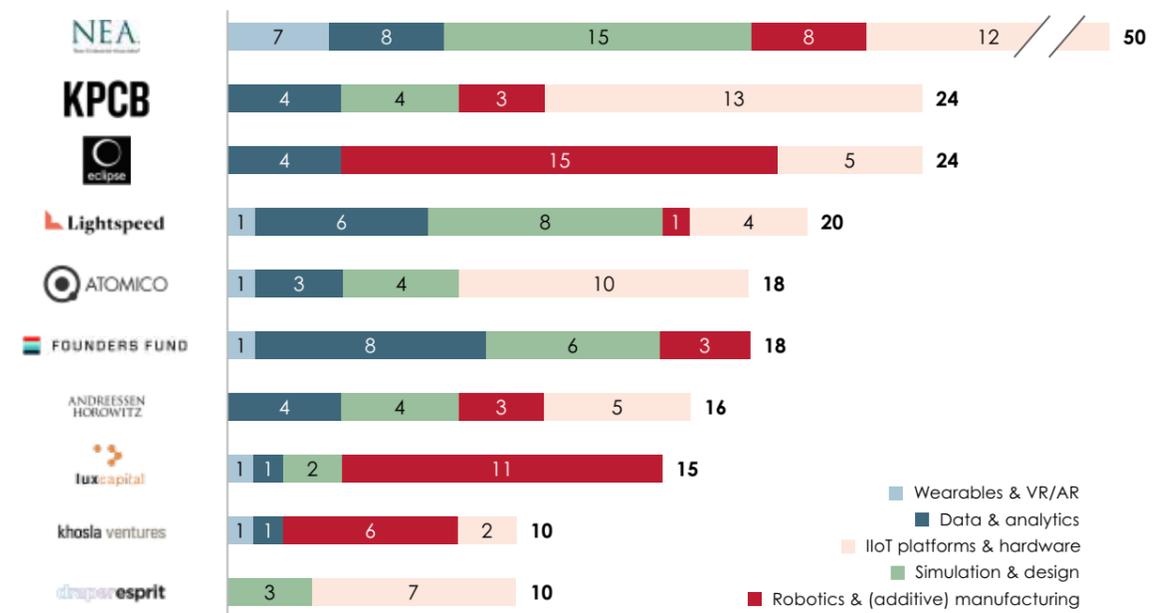
In order to better understand the relative degree of maturity of the ecosystems in the US and Europe, we have looked at the current financing status of the companies in our data base.

What is notable is that in Europe a much larger proportion of companies has been acquired by strategics (32% vs. 19% in the US). At the same time, more companies seem to have had seed round as their latest financing status (15% vs. 11%), while early and late-stage VC rounds seem to be much more prevalent in the US.

This reflects on differences in financing environments – more VC funding available in the US – but also potentially on different founding cultures. While it is relatively normal to engage in repeated financing rounds in the US, it seems that European founders prefer to bootstrap their companies and /or sell them relatively early to a strategic.

# Landscape Of Key Financial Investors

Investments by vertical of selected financial investors (excluding strategics)



Beyond strategic investors, smart manufacturing is a very VC-dominated world. While we have excluded seed and incubation funds as well as corporate VCs from our analysis, the leading financial investors in this space nevertheless have concluded a significant and growing number of investments.

The list of the top-10 selected venture investors includes a few names that are either exclusively focused on the sector (such as eclipse) or on physical high technology in general (such as Lux Capital). One key theme for these seems to be robotics and additive manufacturing, with a particular focus on "full stack companies", which offers a solution covering both software and hardware aspects.

Another thesis is the vertical platform investment, which covers specific layers in the cyberphysical production stack while adding enough value and providing sufficient lock-in to create sustainable and thriving ecosystems.

These tend to be on the later-stage side of the investment cycle. One example is e.g. the IIoT platform Ubisense, which was recently acquired by international private equity firm Investcorp. By providing unique hardware sensors combined with a software layer, Ubisense has created a solution that is both highly embedded and integrates into a variety of other systems. This ability to integrate into a variety of ecosystems seems to be another success factor for smart manufacturing investments.

Sources: Pitchbook, Capital IQ, company websites, GP Bullhound analysis  
Note: Data on deals cover the period from 01/01/2013 to 31/12/2018.

Sources: Pitchbook, Capital IQ, target companies and investor's websites.  
Note: Data on deals cover the period from 01/01/2013 to 31/12/2018.



## INVESTING INTO THE LEADERS

### *Of The Emerging Smart Industry Ecosystem*

**Siraj Khaliq & Ben Blume**

*Partner & Principal, Atomico Industry 4.0 Initiative*

We are at the beginning of an epochal shift in manufacturing (a \$12trn sector globally or 17 percent of global GDP). With inexpensive sensors, cheap wireless communications infrastructure, highly scalable cloud-based data processing and novel machine learning methods, the building blocks are in place for a new Machine Age.

Dubbed Industry 4.0, these advances have not gone unnoticed by traditional large manufacturers. They have no choice: fierce competition from nimble new challengers from China mean European and US manufacturers need to step up just to stay competitive.

A shift from mass, uniform manufacturing to small batch size, customized products means traditional methods become unsuitably expensive. And customers, whether consumers or businesses, demand ever quicker turnaround times.

By some estimates, Venture Capital investment in internet-of-things in Industry ("IIoT") was \$769m in the first quarter of 2018, roughly eight times what it was the same quarter five years earlier.

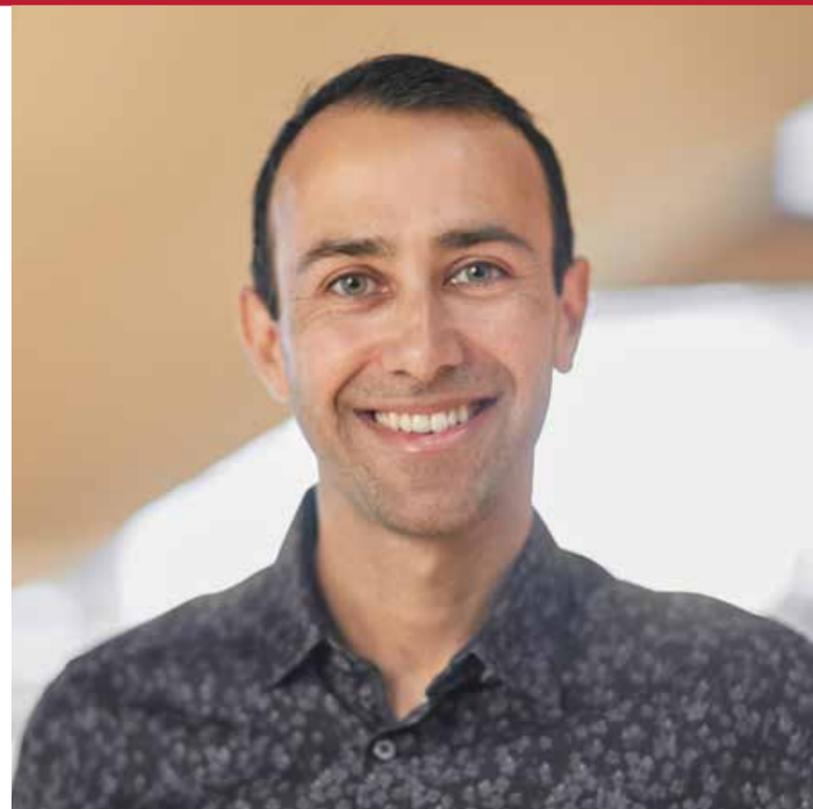
At Atomico, we think of these opportunities in terms of five key areas which are converging to shape smart manufacturing: Analytics/Orchestration, Computer Vision, Robotics, AR/Wearables for control, and AI-Driven Design. These are all by themselves key changes to traditional manufacturing. Taken together, they represent no less than a transformation.

AI and computer driven agent will, over time, be given nearly complete agency over making critical decisions on the factory floor. Quality Control will be driven by machine-learned inspection and evaluation processes that are far more robust than those today that rely on human interpretation. Industrial robotics are moving from being prohibitively expensive for mid/smaller applications to being cheap, adaptable and safe enough to use for smaller tasks, often alongside humans. Wearables allow humans to interact with

existing and next generation equipment in a way that gives them "superpowers" - reducing the reliance on human skill / memory, and overlaying valuable information into their field of view when executing complex tasks. Design for objects, components, facilities will be driven not just by guesswork and human skill to a multi-dimensional, integrated analysis of the requirements and functional capabilities.

At Atomico we have already made multiple investments into this field, including Scandit focused on computer vision for logistics and supply chains, CloudNC, which is automating CNC milling, and Oden, which adds an analytics and control layer for injection moulding factories. But we still believe we're only at the beginning.

Luckily for us as European investors, manufacturing is a core competency of the continent, and we believe the region is well poised to create global winners in the Industry 4.0 space. Importantly, these ventures are also highly positive for the world in the long run. Higher efficiency, better & more customized end products, reduced waste / environmental impact, increased safety and variety in human labour all come together to make a compelling case for this progress. This transformation of manufacturing may well play a key role in helping humankind not only improve our quality of life but also tackle the many environmental challenges of our time.



*Selected key investments*

GRAPHCORE



SCANDIT



ONTRUCK



automation  
HERO\_

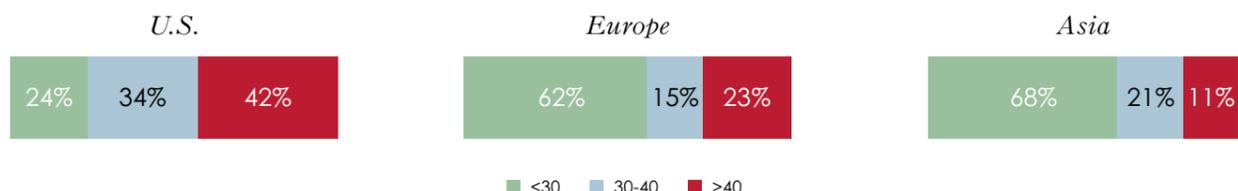


# Age At Foundation

## EXCEPTIONAL TECHNICAL TALENT

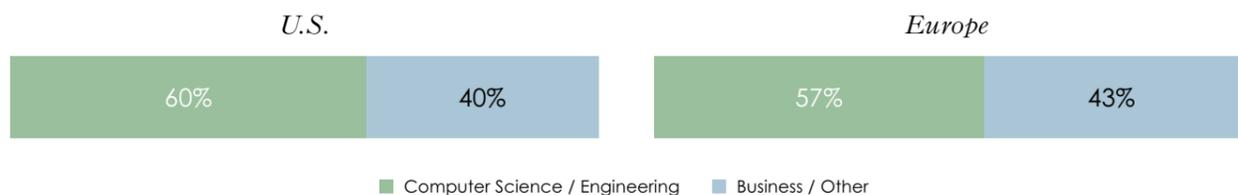
### Education & Experience Of Smart Industry Founders

Age at foundation



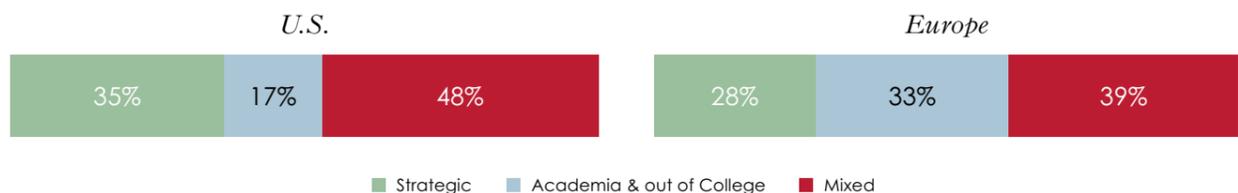
....Most of the founders of smart manufacturing start-ups in Europe and Asia are below 30 compared to the U.S. with the average age at foundation 38

Educational background



....Most of the founders have educational background in Computer Science and Engineering

Previous experience at strategic player



....Cisco and IBM are top contributors to entrepreneurs landscape in smart manufacturing

## Key Founders' Selected - Previous Work Experience



The final, and arguably most important dimension in this ecosystem are the founders of smart manufacturing companies. We have tried to gain some insights on them by screening a sample of 100 companies from our bigger data set.

Overall, founders' age distribution seems very diverse with the US being skewed slightly towards more experienced founders than Europe and Asia. In both Europe and the US, the extremely technical nature of this field is reflected by the vast majority having studied computer sciences or engineering versus a relatively small proportion of business or other graduates.

In addition, previous experience seems to be an important differentiator: especially in the US, many founders have collected first experience at major strategics, while almost a third of European founders have founded their first start-up out of university, or as a research institute spin-off.

The list of relevant strategics encompasses OEMs clearly anchored in the manufacturing world (such as Siemens, GE and Bosch), but also highly relevant software names and next-generation manufacturers, such as Tesla.

While the greater age and corresponding more extensive strategic experience of US founders to some extent expresses the different start-up culture in this market, it also affirms the notion that Europeans tend to build vertical technological solutions (often as academic spin-offs), while Americans seem to focus more decidedly on platform creation.

On the following pages, we will briefly profile some of the companies that we believe should be worthwhile to watch across the smart manufacturing technology stack.

Source: GP Bullhound analysis: Founders of top-41 capitalized U.S., 14 European start-ups 6 Asian start-ups.



# SELECTED COMPANY PROFILES

## Across The Smart Manufacturing Stack

<p><b>HQ:</b> Munich <b>Year:</b> 2013 <b>Total funding:</b> 22m</p> <p>Provide full transparency about risk exposures in 1-n-tier supply chains.</p>	<p><b>HQ:</b> San Leandro <b>Year:</b> 1980 <b>Total funding:</b> 101m</p> <p>Application software for real-time data infrastructure solutions.</p>	<p><b>HQ:</b> San Francisco <b>Year:</b> 2018 <b>Total funding:</b> 194m</p> <p>Enables flexible factory robots with intelligent software, production data and machine learning.</p>
<p><b>HQ:</b> Redwood City <b>Year:</b> 2009 <b>Total funding:</b> 206m</p> <p>Digital enterprise platform for AI and IoT.</p>	<p><b>HQ:</b> New York <b>Year:</b> 2010 <b>Total funding:</b> 155m</p> <p>Business analytics for complex data through preparing, analyzing and visualizing Big Data.</p>	<p><b>HQ:</b> Montréal <b>Year:</b> 2016 <b>Total funding:</b> 91m</p> <p>Element AI is an artificial intelligence solutions provider.</p>
<p><b>HQ:</b> Palo Alto <b>Year:</b> 2010 <b>Total funding:</b> 129m</p> <p>Artificial intelligence company developing a general intelligence for robots.</p>	<p><b>HQ:</b> Kaiserslautern <b>Year:</b> 1986 <b>Total funding:</b> PE-held</p> <p>Smart information management software for the entire business process.</p>	<p><b>HQ:</b> Mountain View <b>Year:</b> 1999 <b>Total funding:</b> 82m</p> <p>Developer of a self-driving supply chain technology for businesses designed for self-driving enterprise.</p>
<p><b>HQ:</b> Munich <b>Year:</b> 2014 <b>Total funding:</b> 33m</p> <p>Integration of smart sensor systems and artificial intelligence to maximize asset performance.</p>	<p><b>HQ:</b> Hong Kong <b>Year:</b> 2014 <b>Total funding:</b> 1.38b</p> <p>Artificial intelligence company that focuses on innovative computer vision and deep learning technologies.</p>	<p><b>HQ:</b> Chicago <b>Year:</b> 2014 <b>Total funding:</b> 259m</p> <p>Predictive analytics platform designed to help people and machines work better, smarter and faster.</p>
<p><b>HQ:</b> Munich <b>Year:</b> 2011 <b>Total funding:</b> 67m</p> <p>Developer of an intelligent Big Data technology designed to analyze and visualize every process in a company.</p>	<p><b>HQ:</b> San Diego <b>Year:</b> 2010 <b>Total funding:</b> 99m</p> <p>Next generation AI based self-driving technology designed to automate commercial equipment.</p>	<p><b>HQ:</b> Munich <b>Year:</b> 2013 <b>Total funding:</b> 45m</p> <p>Indoor spatial intelligence digital twin platform intended to digitize industrial facilities</p>
<p><b>HQ:</b> Berlin <b>Year:</b> 2015 <b>Total funding:</b> N/A</p> <p>Image search engine that is used as a software-as-a-service.</p>	<p><b>HQ:</b> San Francisco <b>Year:</b> 2017 <b>Total funding:</b> \$19m</p> <p>AI- and RPA-based Intelligent process automation platform.</p>	<p><b>HQ:</b> Somerville <b>Year:</b> 2014 <b>Total funding:</b> 28m</p> <p>Developer of a manufacturing application development platform for IoT enabled tools and applications.</p>
<p><b>HQ:</b> New York <b>Year:</b> 2011 <b>Total funding:</b> 45m</p> <p>Industrial IoT company that brings predictive maintenance to new markets.</p>	<p><b>HQ:</b> Santa Clara <b>Year:</b> 2009 <b>Total funding:</b> 309m</p> <p>Industry's next generation data platform for AI and analytics.</p>	<p><b>HQ:</b> Berlin <b>Year:</b> 2014 <b>Total funding:</b> 8m</p> <p>High-end machine learning solutions for robotics and process control.</p>

■ - Intelligence ■ - Design ■ - Orchestration

<p><b>HQ:</b> Santa Clara <b>Year:</b> 2010 <b>Total funding:</b> 120m</p> <p>IoT platform-as-a-service (PaaS) for device management and application enablement.</p>	<p><b>HQ:</b> New York <b>Year:</b> 2014 <b>Total funding:</b> 14m</p> <p>Developer of a data acquisition and analytics platform intended to monitor and optimize production in real time.</p>	<p><b>HQ:</b> San Francisco <b>Year:</b> 2014 <b>Total funding:</b> 41m</p> <p>Developer of robots designed to have human-like intelligence.</p>
<p><b>HQ:</b> San Francisco <b>Year:</b> 2015 <b>Total funding:</b> 198m</p> <p>Builds sensor systems to combine wireless sensors with remote networking &amp; cloud-based analytics.</p>	<p><b>HQ:</b> Santa Clara <b>Year:</b> 2013 <b>Total funding:</b> 121m</p> <p>Developing end-to-end ecosystem to support cloud connected smart machines.</p>	<p><b>HQ:</b> Boston <b>Year:</b> 2013 <b>Total funding:</b> 80m</p> <p>Enables device manufacturers, app developers, and software companies to leverage the power of the IoT.</p>
<p><b>HQ:</b> Waltham <b>Year:</b> 2016 <b>Total funding:</b> 11m</p> <p>Smart device solutions to enable high performance collaborative industrial robotics.</p>	<p><b>HQ:</b> Labège <b>Year:</b> 2009 <b>Total funding:</b> 287m</p> <p>The world leading provider of connectivity for IoT devices.</p>	<p><b>HQ:</b> Singapore <b>Year:</b> 2011 <b>Total funding:</b> 154m</p> <p>Grey Orange produces Hardware &amp; software products for the warehousing industry.</p>
<p><b>HQ:</b> Beijing <b>Year:</b> 2012 <b>Total funding:</b> 249m</p> <p>Cloud computing platform that provides IaaS-based flexible cloud services.</p>	<p><b>HQ:</b> Paris <b>Year:</b> 2010 <b>Total funding:</b> 105m</p> <p>Smart Energy Management, Machine-to-Machine(M2M) and IoT services.</p>	<p><b>HQ:</b> Zurich <b>Year:</b> 2009 <b>Total funding:</b> 37m</p> <p>Software for barcode scanning, text and objects recognition and real-time insights through AR.</p>
<p><b>HQ:</b> San Francisco <b>Year:</b> 2011 <b>Total funding:</b> 14m</p> <p>Provider of augmented reality training solutions.</p>	<p><b>HQ:</b> Shenzhen <b>Year:</b> 2013 <b>Total funding:</b> 169m</p> <p>Intelligent technologies for every human, everywhere through 3D image sensors and smart cameras.</p>	<p><b>HQ:</b> Munich <b>Year:</b> 2017 <b>Total funding:</b> 0.025m</p> <p>Producer of smartwatches for industrial use with manufacturing apps connecting to an IoT backend.</p>
<p><b>HQ:</b> Sunnyvale <b>Year:</b> 2012 <b>Total funding:</b> 279m</p> <p>LiDAR sensors and software to capture and process real-time 3D mapping data.</p>	<p><b>HQ:</b> Los Angeles <b>Year:</b> 2010 <b>Total funding:</b> 119m</p> <p>Wearable devices and software to empower the workforce.</p>	<p><b>HQ:</b> Burlington <b>Year:</b> 2015 <b>Total funding:</b> 395m</p> <p>3D metal printing in design &amp; manufacturing.</p>
<p><b>HQ:</b> Somerville <b>Year:</b> 2011 <b>Total funding:</b> 87m</p> <p>Developing powerful and accessible 3D printing systems designed for printing intricate figures.</p>	<p><b>HQ:</b> Cambridge <b>Year:</b> 2002 <b>Total funding:</b> N/A</p> <p>Developer of real-time location systems that provide enterprise business automation services.</p>	<p><b>HQ:</b> Munich <b>Year:</b> 2016 <b>Total funding:</b> N/A</p> <p>Franka Emika develops and designs cutting-edge, high-performance industrial robots.</p>
<p><b>HQ:</b> Redwood City <b>Year:</b> 2013 <b>Total funding:</b> 354m</p> <p>Intersection of hardware, software &amp; molecular science to enable 3D manufacturing.</p>	<p><b>HQ:</b> Odense <b>Year:</b> 2015 <b>Total funding:</b> N/A</p> <p>Developer of a gripper system platform designed to handle industrial robots.</p>	<p><b>HQ:</b> Stuttgart <b>Year:</b> 2017 <b>Total funding:</b> N/A</p> <p>Online B2B marketplace for industrial sheet metal processing.</p>

■ - Interface ■ - Production

Sources: Crunchbase, PitchBook, Company Information  
Note: (1) Total funding in EUR, unless otherwise specified



## VI. THE VISION

### *Intelligent Manufacturing In The Future*

GP.Bullhound

1

#### Most smart manufacturing technologies will still require 5-10 years until mainstream adoption

According to Gartner, most smart manufacturing technologies will still require 5-10 years until full mainstream adoption. This includes technologies where we see the highest value potential, especially IIoT, 3D printing, predictive analytics, digital twin and machine learning.

2

#### There will be three main archetypes of smart manufacturing deployments

Depending on use case and scalability, smart manufacturing deployments will likely fall into three archetypes: large scale, smart automated plants; highly adaptable customer-centric plants; and small-scale, mobile facilities "in a box".

3

#### A large proportion of activities in advanced economies can be automated

Looking at the German economy as an example, 54% of working hours fall into "easily automatable activities". This will have significant implications for up-skilling of existing employees and future qualification requirements.

4

#### "Being human" will be ever more important in an environment run by algorithms

As activities are being increasingly automated, "EQ" will become increasingly more important than IQ: while IQ can be replicated by algorithms, human qualities will remain an important differentiator.

GP.Bullhound



3 types of smart manufacturing plant archetypes

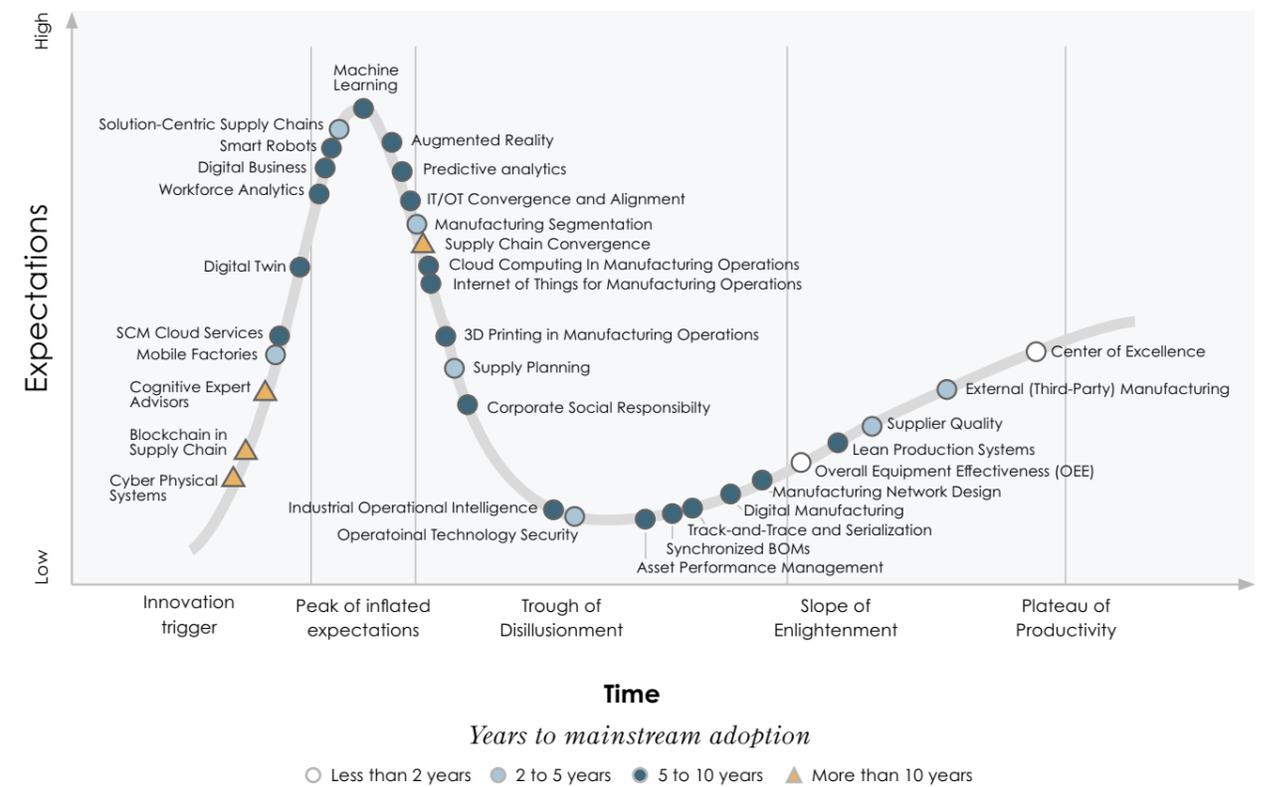
5-10 years until mainstream adoption

54% of working hours in easily automatable activities

## OUTLOOK

### A Glimpse Into The Future

The Gartner Manufacturing Tech Hype Cycle



The digital transformation trend that many manufacturers started a few years ago continues stronger than ever. Given the complexity of the systems involved, one of the key questions will be which technologies will reach maturity and when.

The Gartner hype cycle for manufacturing technology gives a good indication. According to Gartner, the more service-orientated technologies as well as digitisation of existing systems are on the right, pushing towards maturity. On the left, the

more cutting-edge technologies, such as predictive analytics, smart robotics and AR / VR, still need to evolve through the hype cycle.

This indicates that a gradual evolution is under way; nevertheless, most technologies are placed in the two to ten years window to mainstream adoption, indicating significant changes to the way how we work and produce over the next decade.

Source: Gartner (2018), "Manufacturing Technology Innovation Hype-cycle", available at <https://www.manufacturing-operations-management.com/manufacturing/2018/06/manufacturing-technology-and-it-trends-update-spring-2018.html>



## RE-INVENTING THE FACTORY STACK

### *A VC's View Into The Future*

#### **Robin Dechant**

*Smart Manufacturing Expert, Point Nine Capital*

<https://medium.com/@robindchnt>

At Point Nine, we focus primarily on investing in B2B SaaS and Marketplaces and helping early-stage companies to achieve their full potential.

In the last few years, we have seen tremendous growth in the number of startups that are trying to solve problems such as machine downtime or quality issues in the manufacturing sector. This growth has been accompanied by an increase in the capital available and also more investors who are willing to invest in manufacturing startups, as the data in this report confirms.

However, we are still at the very early stages of making manufacturing more automated and smart. So-called lights-out factories are close to non-existent and only highly repetitive work can potentially be automated. Furthermore, new entrants have struggled so far with the industry's long sales cycles, the complex integration required for different machines and systems, and the move from the pilot stage to production—also known as pilot purgatory. Therefore, the biggest competitor for a startup is not another company but the status quo.

That said, I think we are now at a tipping point and the pressure to adopt new technologies is increasing. First, there is a dearth of talent in the manufacturing field, and this is not expected to improve in the near future. It is likely to be easier for software companies to enter new industries (see Alphabet's activities in autonomous cars, for example), than for traditional industrial companies to hire top-notch developers. Second, because of worldwide wage increases, efficiency gains due to outsourcing and globalization have reached a natural limit. Third, competition among manufacturing companies worldwide is increasing.

All of these trends will enhance the development of the industry and force companies to evolve. The manufacturing industry accounts for 19% of European GDP, so there is a lot to lose if companies do not invest in new technologies. I believe that there is a greenfield opportunity to build very big businesses in this sector—the stickiness of products and the massive potential for expansion from one factory to another are unique in this industry.

In contradiction to some headlines, however, I think that the digitization of the manufacturing industry is not specifically about replacing people with robots but more about leveraging software to make machines and human workers smarter and able to work together more effectively.

While this is obviously great news for new entrants, in my opinion, incumbents need to take more risks. Innovation cannot happen from the inside only; I would encourage corporates to try out new products, work together with startups and carry out more M&A.

Founders tell me that the best companies they work with have both a clear vision of how to digitize their businesses and transparent guidelines on how to work with startups. Based on my experience, unfortunately, this is still the exception and I would love to see this change.

As Jeffrey Immelt, former CEO of GE, highlighted some years ago, "If you went to bed last night as an industrial company, you're going to wake up today as a software and analytics company." With this in mind—good morning!

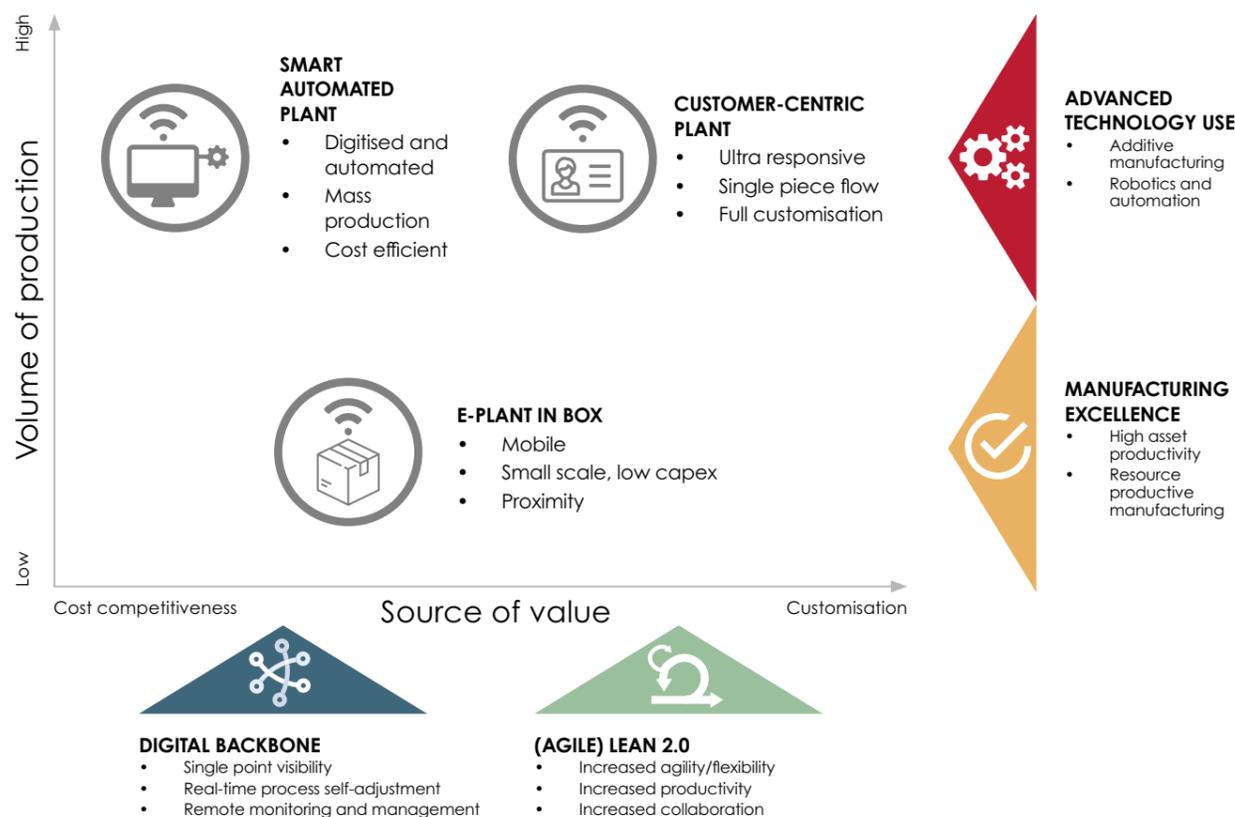




# CYBERPHYSICAL PRODUCTION BY 2025

## Fundamental Changes In The Future of Work

Emerging archetypes for the “plant of the future”



The plant of the future will likely have three different archetypes, where digitised manufacturing concepts are implemented to varying degrees.

The first archetype is the e-plant in a box, suited to small production runs. It is mobile, of a small scale and close to end customers. Because of its low capex, it will be the first type for greenfield roll out.

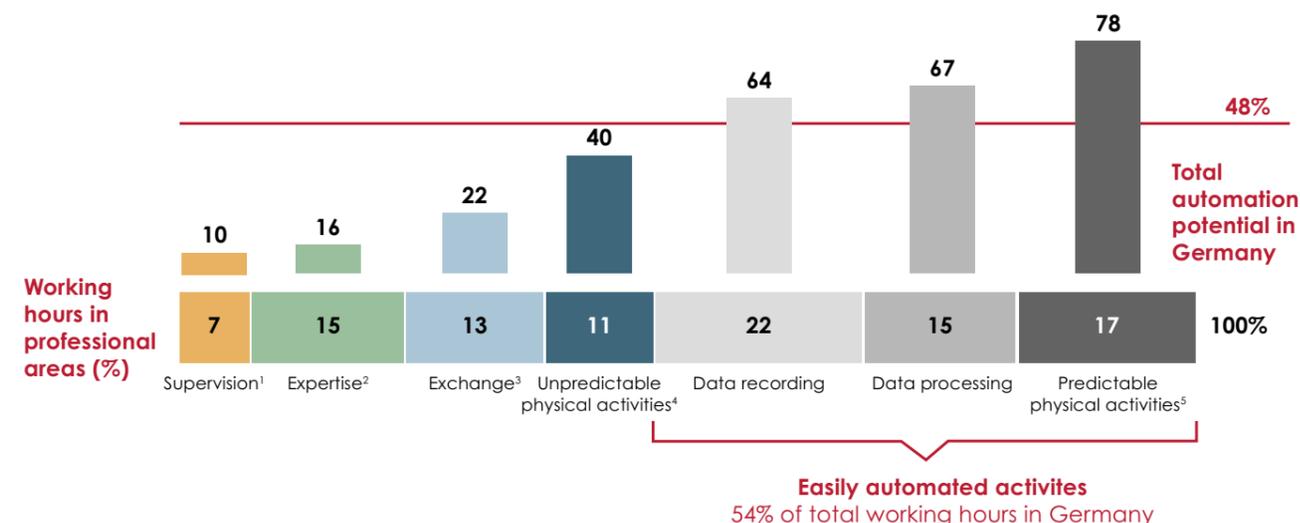
Large production runs will either be fulfilled by smart plants focussed on cost-efficient mass production,

or customer-centric plants with high configurability and customisation. While smart automated plants automate standardised processes and thus put a specific focus on cost efficiency, customer centric plants will allow individual piece flow and hypercustomisation.

All plants will be built on some form of digital backbone and emerging manufacturing technologies. They be agile, collaborative and provide automated quality control.

# PROPORTION OF AUTOMATABLE TASKS

Example: share of activities that can currently be automated in Germany (%)



1 – Supervision & development of employees  
 2 – Contribution of expertise to decision-making process, planning and solution of creative non-conventional tasks  
 3 – Knowledge and expertise exchange with the parties involved  
 4 – Execution of physical activities and operations by machines in unpredictable situations  
 5 – Execution of physical activities and operations by machines in predictable situations

What does all this imply for the “real world”? We looked at Germany as an example for a highly industrialised economy as to how many activities can be fully automated in future – a recent study from McKinsey says: a lot.

Overall, the study estimates the total automation potential in Germany at 48% of all current working hours. Especially in data recording, data processing and predictable physical activities, there seems to be a lot of saving potential – the study implies that 54% of all activities in Germany have very high automation potential.

This implies significant changes on the labour market. It has to be noted, however, that in previous industrial revolutions, more jobs have overall been gained than lost.

In addition, a recent study by BCG and Ipsos found that 70% of respondents would prefer some of the less exciting parts of their jobs automated by AI.<sup>(1)</sup>

Up-skilling should therefore be a major theme for manufacturers and policy makers alike in industrialised nations. Gartner, however, has found in a survey that more than half of manufacturers lacked skilled workers to support digitisation plans and had no formal skills development plans for existing employee.<sup>(2)</sup>

Up-skilling will be the make-or-break factor whether jobs will migrate away from existing manufacturing clusters or not. We can probably expect an entire new ecosystem of platforms and service providers to emerge around the issue of digitisation training and improved collaboration.

Source: McKinsey – Industry 4.0 – How to navigate digitization of the manufacturing sector

Sources: McKinsey Global Institute, US Bureau of Labour Statistics, BCG / Ipsos, Gartner  
 Notes: Rounding of numbers may result in a deviation of the total sum, 1 BCG / Ipsos (2018), “Artificial Intelligence – Have no Fear”, see <https://www.bcg.com/d/press/2018-employees-familiar-with-ai-both-welcome-and-fear-194884>, 2 Gartner (2018), “Let’s Get Digital: Findings from Gartner’s Factory Digitization Study”, Jacobson, 2018 Gartner Supply Chain Summit



## MAKING AI HUMAN

### *A Researcher's View*

#### Amélie Cordier

*Dr. in Computer Science with Specialisation in AI,  
President of Behaviors.ai and Chief Scientist at Hoomano*

Dr. Amélie Cordier has been researching human/machine interaction for over 15 years. She focuses on how to improve our current, rudimentary and limited human/machine interaction by programming more skilled AI, lifting interaction from manual (keyboard) to sophisticated verbal to possibly non-verbal

**You propose to teach AI to learn problem solving rather than creating an "adult AI" that is guided by exhaustive algorithms. Can you explain the concept and its future relevance?**

What you describe is called developmental learning. So far, what we have done with automated intelligence or with computer programming in the general sense is implementing algorithms able to solve very specific problems in a narrow application setting. The problem with that is, when AI is in an unpredictable environment the algorithm will not be able to deal with the inherent eventuality. What we want to do is create algorithms that are able to learn how to solve problems, not to learn to solve problems. The 'how to' is very important, because if we manage to implement the ability to learn, maybe we can create AI techniques / algorithms that will be able to adapt to unpredictable environments – that is the goal we are targeting.

**How will developmental learning AI change the workplace in the medium to long term?**

I think there are maybe three fields where we see the effective applications of developmental learning making progress at the moment: firstly, natural language acquisition, where you teach robots how to name objects by interacting with them; secondly, navigation and locomotion, teaching robots how

to learn quickly to adapt a motion strategy when disrupted and, lastly, dexterity, helping robots to understand how to interact with the environment, as well as interpret the consequences of their actions.

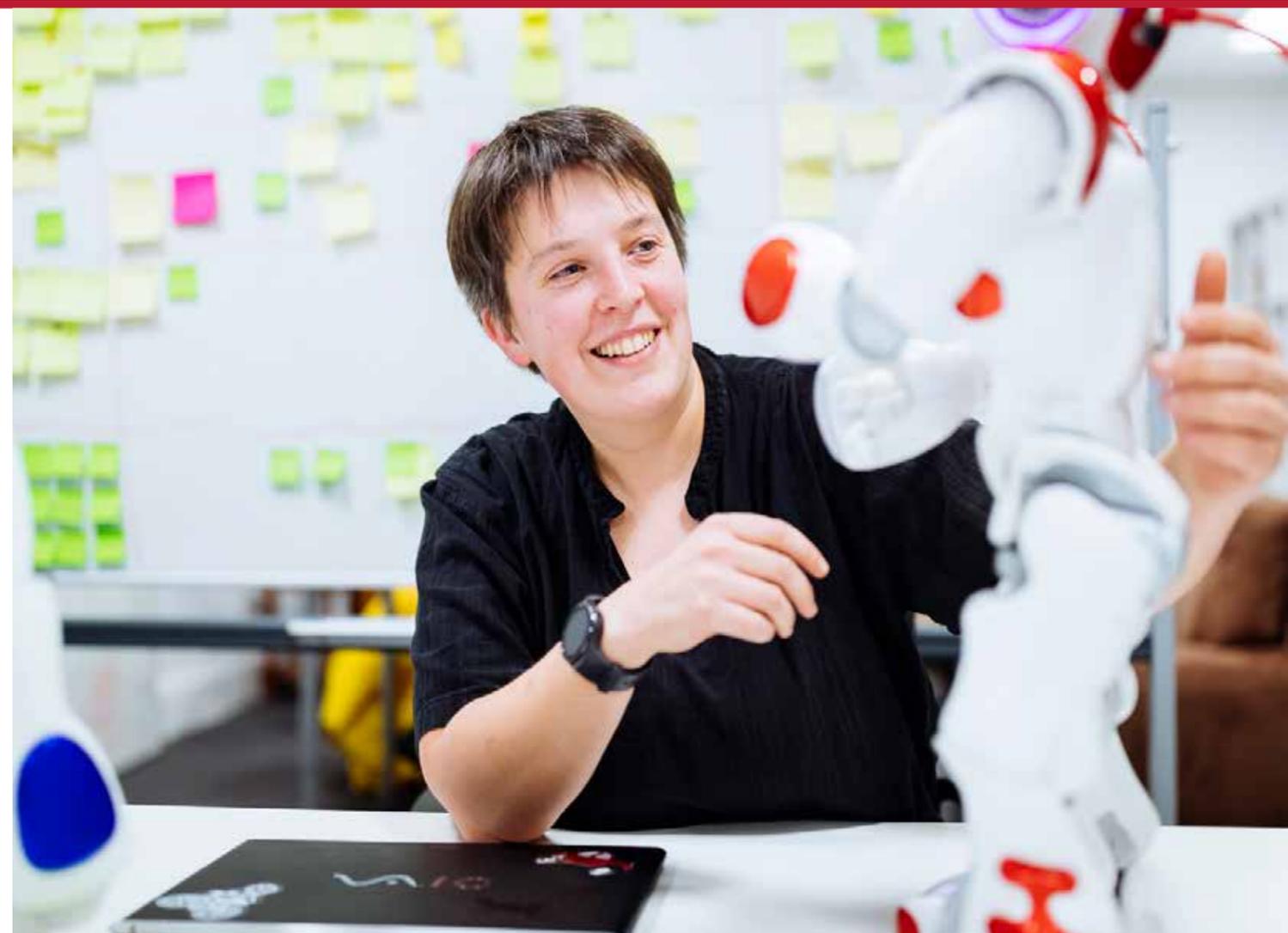
The latter, dexterity, has just been named number one trend of ten breakthrough technologies in 2019 by MIT Technology Review Partners together with Bill Gates – a topic I am working on at the moment with one of my students.

Once robots learn how to interact with our world, it will make them universally deployable in not just our streets, or at home but foremost in factory settings. In order for robots to be flexible in achieving goals & objectives in differing environments and situations, robots need to be able to break-down goals into sub-goals and learn how to achieve those by itself.

However, the next step is to significantly widen the scope, through better reasoning, knowledge and knowledge representation. AI is still very bad at performing reasoning. For all "what" questions, Alexa, Google Home and Co. have answers but the "why" questions are the big challenge.

**Teaching AI "why", is teaching it about the ethics and habits that form the basic understanding of human interaction. How do you see this being something we can tackle and how do you think we should go about it?**

That's a very good question. Ethics is a strong concern for a lot of people interested in AI, be they researchers, entrepreneurs or the general public. I think the problem is not AI, the problem is humanity,



and the only thing that AI does is increasingly shedding light on the basic problems of humanity. To me, AI is the mirror of society, it reveals the flaws, biases and history of us as we feed it with our data. Of course, a recruiting AI will select male developer engineers if the data we feed it with is inherently biased towards male developer engineers. But maybe it is actually easier for us as a society to blame AI for that bias and get over it together, than having to blame each other.

So to me there are basically two ways forward from the question of AI being good or bad for us:

a) Reject – as it can and will be used to influence politics, consumer purchase behaviour and human interaction in the wider sense;

b) Embrace – use AI to change the future, filter out the bias and flaws of society actively to grow further. I believe there's no point in being pessimistic, because if you are, there's no point in waking up tomorrow morning. I'm not saying that people aren't going to do bad things with AI, I'm not saying that the big companies can't turn against us and use our data to decide the world they want us to live in. What I can do at my scale, is to decide to do the best I can to educate people around the topic of AI so together we turn it into something good.



# THE LONG ROAD AHEAD

## *Ten Predictions For The Future Of Manufacturing Work*

### 1 **Borderless ecosystems will be the production platforms of the future**

As integration of different pieces of software and hardware becomes more and more important, silos will disappear. The future will be held by platforms with strong ecosystem pull and accessible, upgradable architectures.

### 3 **Predictive manufacturing and elastic factory lines will lead to ever-accelerating product cycles**

In some highly advanced fields, such as electronics, it is already possible to feed designs directly from CAD to the front of the line. Together with predictive manufacturing algorithms and agile machinery, this will lead to ever shorter product cycles – like the move from waterfall to scrum in software.

### 5 **Skills will be a key driver for social and economic success**

While automation does not necessarily mean job losses, societies will need to adapt to changing work patterns. Up-skilling will be a key driver to make sure that jobs are gained in the same economies where they are lost.

### 2 **Increasing role of AI: AI-guided design and production will become a reality**

AI holds great promises that have, however, been on a conceptual stage up to now. With the now beginning rapid digitisation of manufacturing chains, AI will be able to live up to its full potential.

### 4 **Augmentation instead of automation: AI, AR and robotics could create a new job miracle**

Many complex tasks may never be fully automated. What can be done, however, is to increase workers' productivity by providing them with augmentation technology. This will enable quick adaptation to new, previously unknown tasks and maybe even the rapid up-skilling of previously unskilled workers. Augmentation technology may hence lead to a new job miracle.

### 6 **Diminished need for low cost labour will lead to a wave of on shoring or re-shoring**

As automation becomes more and more ubiquitous, we expect to see a diminished need for low cost labour – which will result in increased "on shoring" and end market proximity.

### 8 **Meaningful new strategic players and platforms will emerge in 2019 / 2020**

So far, the smart manufacturing world has been dominated by the existing large strategics and platforms on the OEM and technology side. Given the immense recent financing rounds for new platforms, we expect those to scale to meaningful size soon.

### 10 **"Being human" will be the most important skill of them all**

While we have seen the potential of machines to replace humans, there are certain skills and abilities of humans that cannot be replaced: most importantly, anything that requires "EQ" as opposed to IQ. Therefore, leveraging EQ – being truly human – will be a key differentiator in the future.

### 7 **Ever-changing pace of "new new" technologies: nanotechnology, bio-manufacturing and many more**

What we are seeing now in smart manufacturing is only the beginning. Progress will continue: once nanotechnology becomes more scalable, we will see further developments in this direction; the same applies to biological production and many other new technologies, which we may not even be aware of today.

### 9 **Industrial players who do not adapt to their new environment will be subsumed by technologically advanced as-a-service players**

"XaaS" or the outcome economy provides significant benefits to customers and users alike. We expect that only these OEMs will be long-term successful who will be able to transform to an "as-a-service" business model.



# METHODOLOGY

## Our methodology and sources

For this report we did an in-depth assessment of the state of smart manufacturing technology to date. We have taken a global approach with focus across the cyberphysical production stack. As part of this, we have analysed how the major incumbents and entrants communicate on their strategies on the light of their tangible actions in the field: R&D, investments, acquisitions and partnerships. We have as well analysed how the funding and M&A market activity has developed.

The report is based on aggregated data from a number of transactional databases including CapitalIQ, Pitchbook, Mergermarket, Crunchbase and supported by public news and company press releases. The majority of the transaction data throughout the report covers the range from January 2013 to December 2018. However, specific mentions could occur outside of this time span.

Our sources only include public data (e.g. press articles, public databases and websites). The accuracy of the data sets underlying our analysis is therefore limited to the disclosed data.

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# ACKNOWLEDGEMENTS

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