Smart Connected Digital Factories: Unleashing the Power of Industry 4.0 and the Industrial Internet

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AGENDA

- An Introduction to Industry 4.0
- Smart Connected Factories
- Big Data & Analytics in Smart Connected Factories
- Closing Remarks


facilities
global
manufacturing
process future
production
industrial
IoT business
cloud
strategy
augmented
customization
autonomously
revolution
smart
systems
engineering
chain
reliability
connectivity
digital
robot
intelligent
high-tech
computer
automation
work
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tasks
virtual
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security skills
resources
interoperability
society
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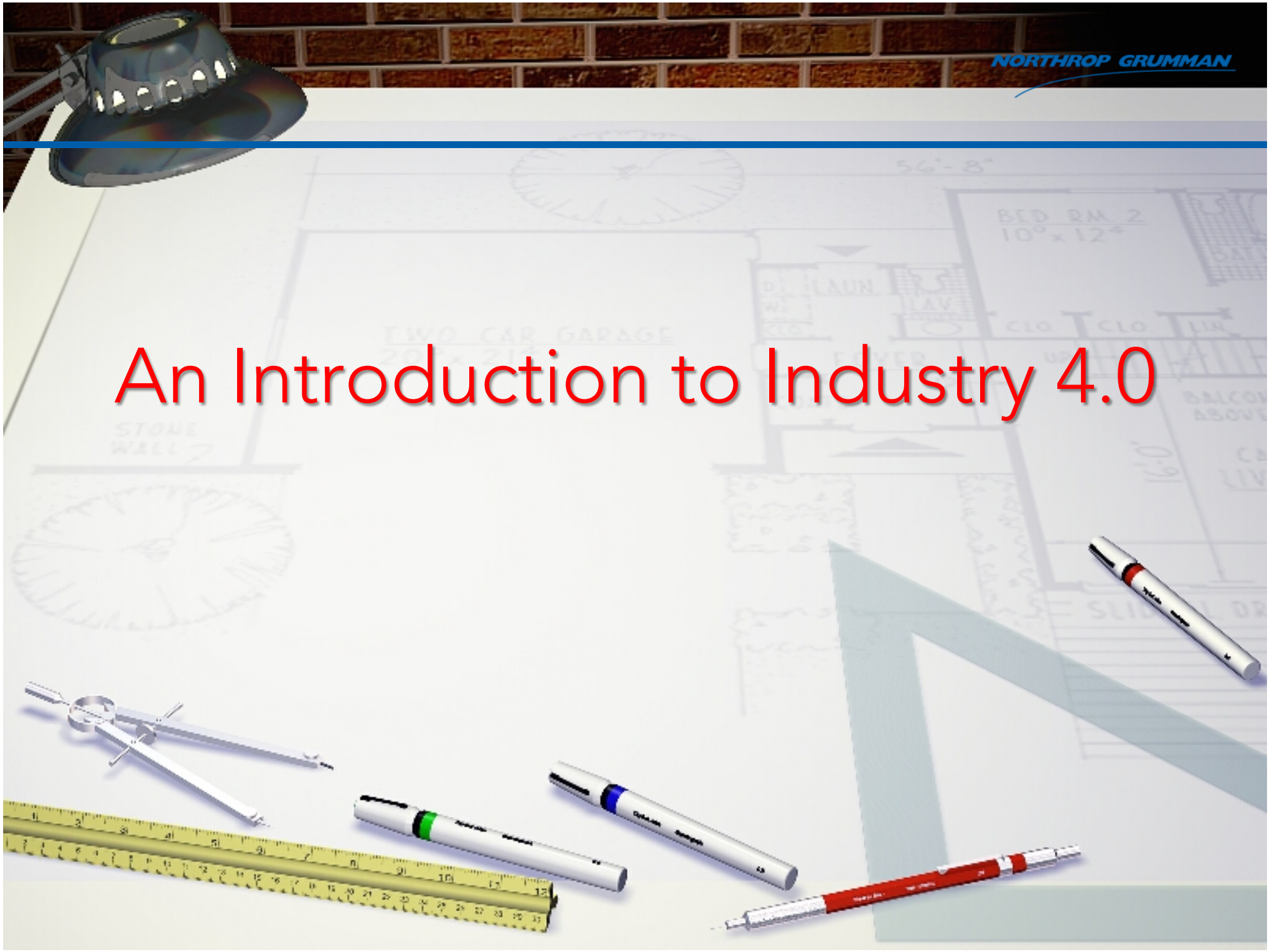
4.0
strategic computing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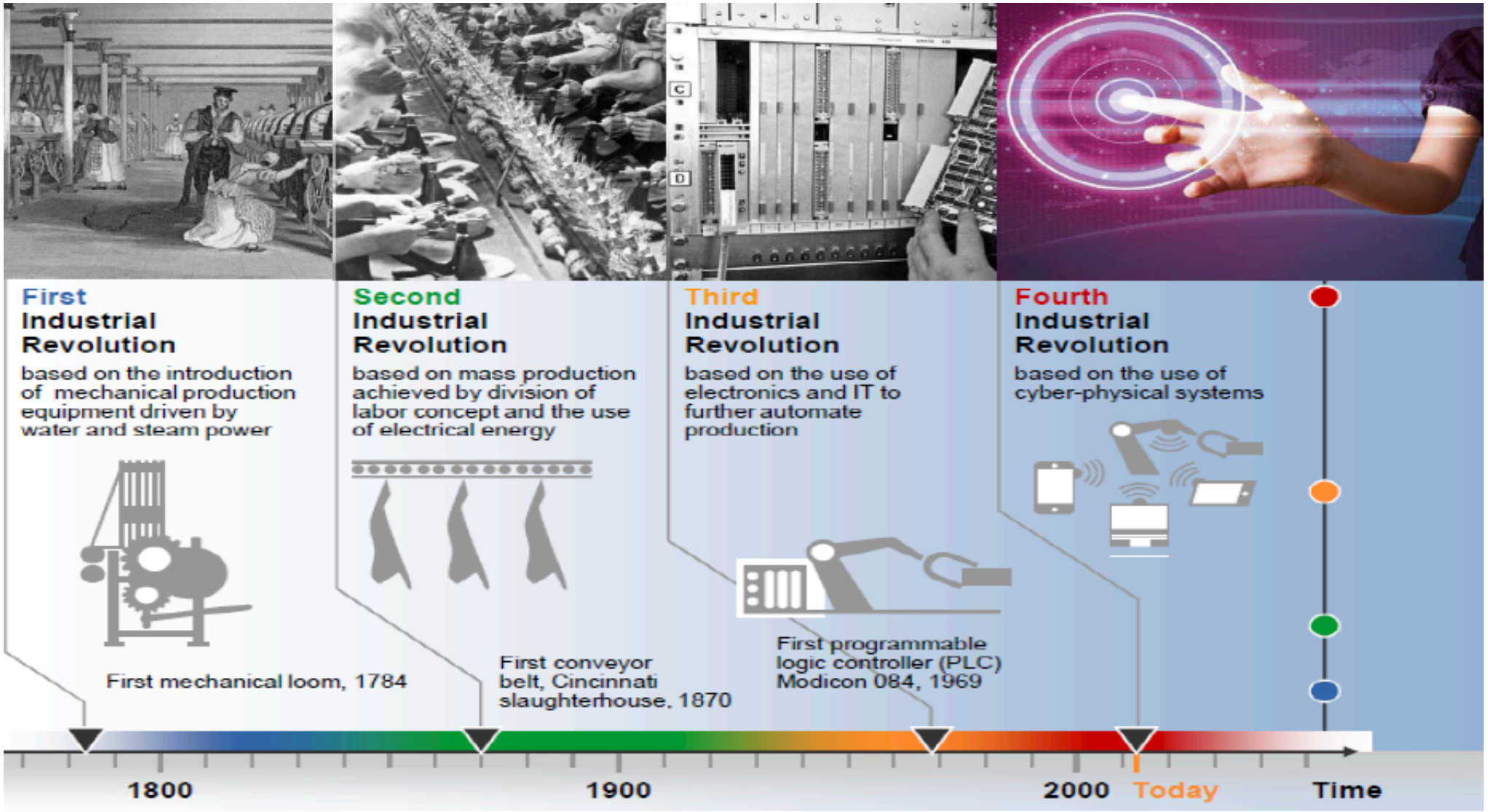
An Introduction to Industry 4.0

The 4th Industrial Revolution



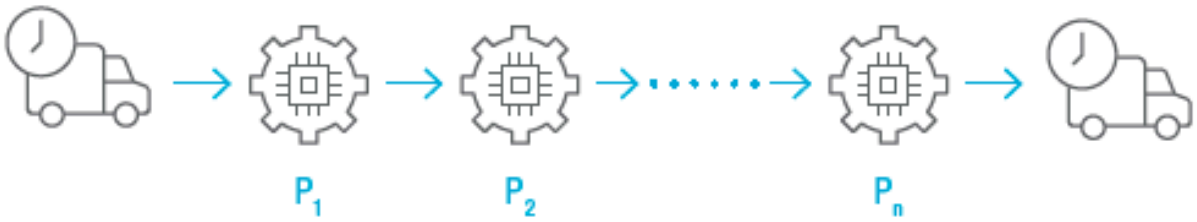
What is Industry 4.0?

- Industry 4.0 is a new level of organisation and control over the entire value chain of the life cycle of products. It is geared towards increasingly individualised customer requirements.
- This cycle begins at the product idea, covers the order placement and extends through to development and manufacturing, all the way to the product delivery for the end customer.
- It is based on the digitisation of the entire production environment:
  - availability of all relevant information in real time by connecting all instances involved in the value chain.
  - ability to derive the optimal value-added flow at any time from the data.
  - connection of **people**, **things**, **services** and **systems** to create dynamic, optimised value-added connections within and across companies.
    - These can be optimised according to different criteria, e.g., costs, availability & consumption of resources.

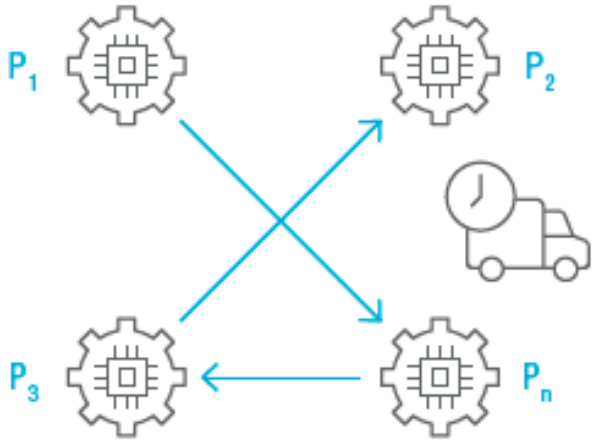
The Road to the 4th Industrial Revolution

Digitized manufacturing takes adaptability to the next level

Conventional manufacturing
- Mass production
- Large quantities
- Small margins
- Sequential value chain
- Long turnaround time
- Low flexibility



Digitized manufacturing
- Custom production
- Small quantities, short run
- High margins
- Changing collaborative partnerships
- Short turnaround time
- Highly flexible and adaptive

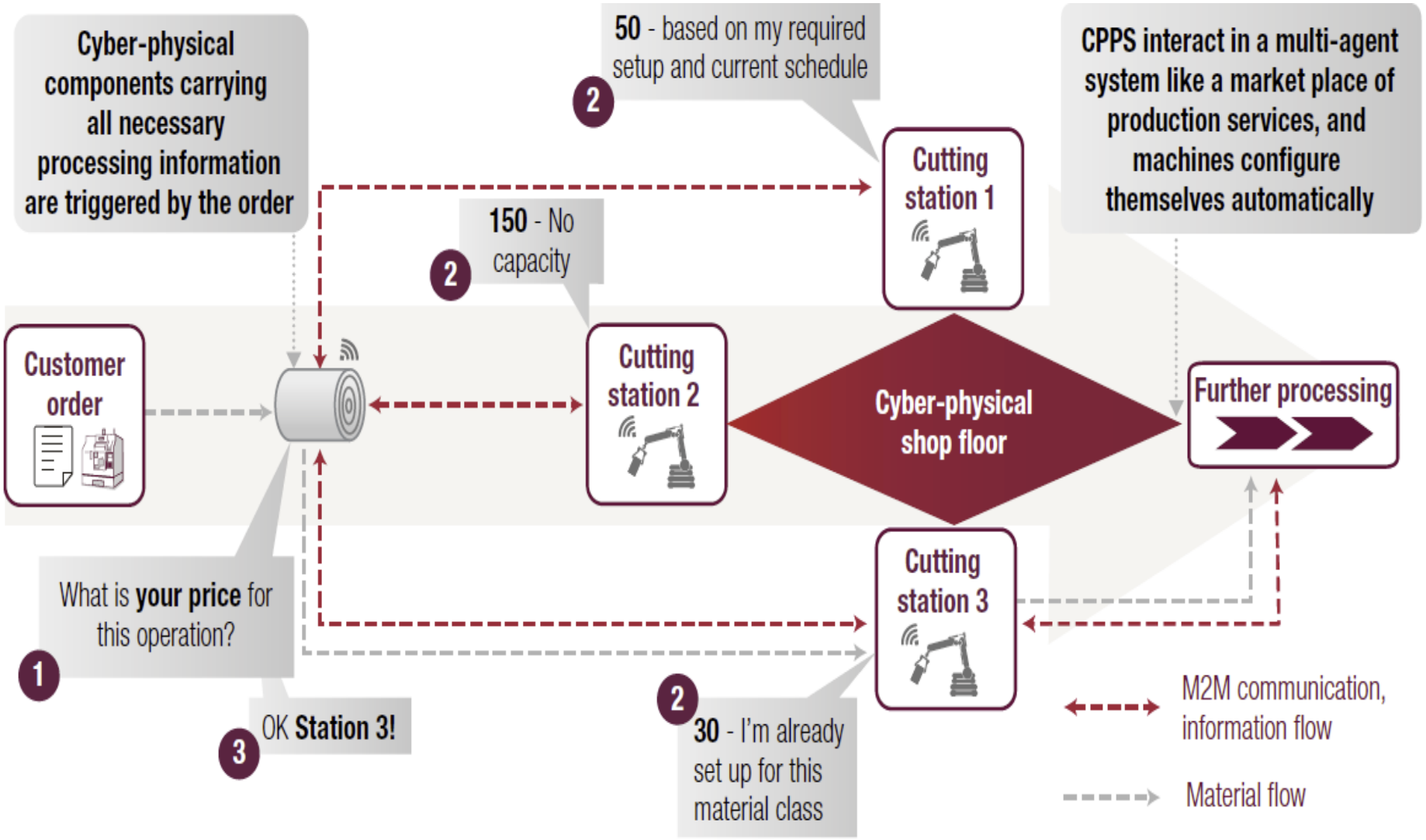


Source: GPS Consulting

The 4th Industrial Revolution: The Big Picture

Source: Capgemini Consulting

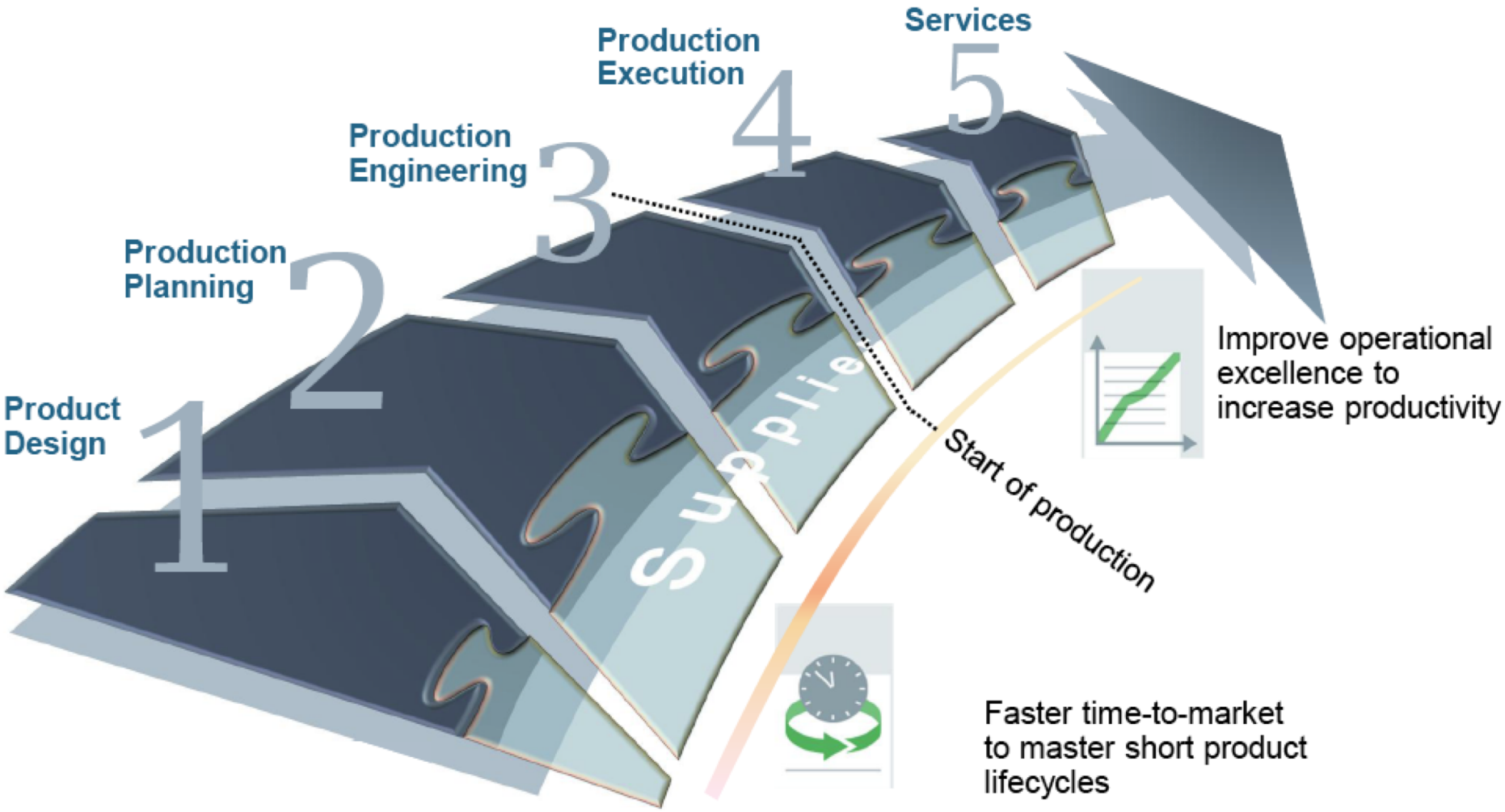
Industry 4.0 Smart Factory



CPPS = CYBER-PHYSICAL PRODUCTION SYSTEM
M2M = MACHINE-TO-MACHINE

Source: Capgemini. Consulting

The Future of Manufacturing with Industry 4.0



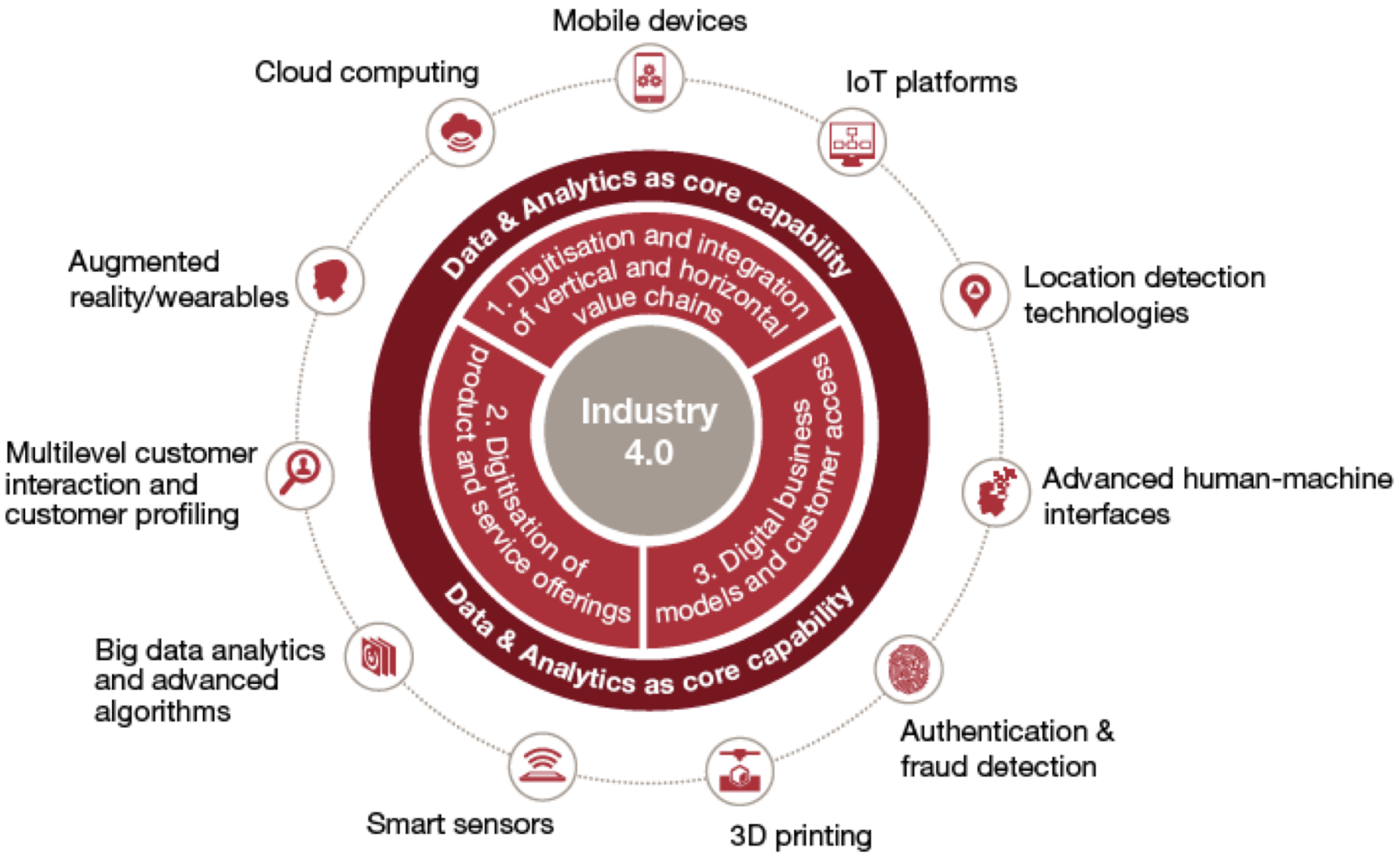
Source: Siemens AG, 2016

Properties of Industry 4.0

1. **Digitisation of all physical assets and processes**
2. **Integration of vertical and horizontal value chains**
3. **Control and visibility:**
   - As products move from ideation and development to end of life, the wealth of data produced at every stage of the manufacturing lifecycle can create a product's "digital thread," which denotes the aggregated, product-specific data stream that combines information from a variety of systems and sources.
4. **Actionable insights:**
   - The convergence of the IoT, processes and analytics is generating a new world of big data, which is enabling new capabilities such as tailored customer offerings, predictive solutions, streamlining production processes and adapt to changes.
5. **Human-centred automation:**
   - Improve user experience so that information is presented in the context of manufacturing tasks performed, leading to better decision-making and new possibilities for improvement.

Industry 4.0 Enabling Technologies

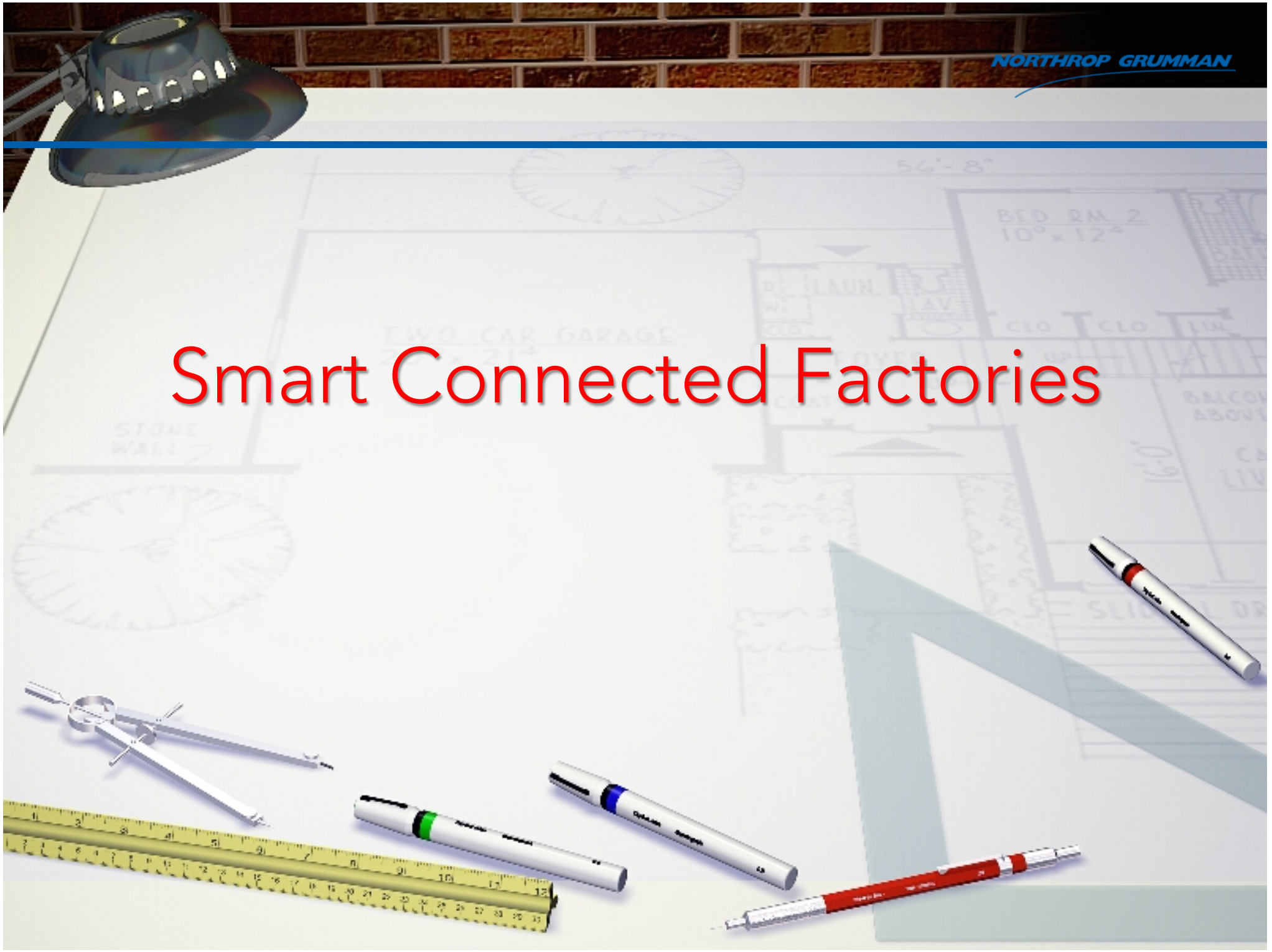
Industry 4.0 is Big Science!!



Source: PWC, 2016 Global Industry 4.0 Survey

The Cloud Connection to the Industrial Internet

- Cloud-centred manufacturing, extends the concept of virtualisation to a shared diversified collection of manufacturing resources e.g., machine tools & factories, offers those resources – in the form of SaaS model - and deploys them at scale to form production lines in response to customer demand.
  - manufacturing service providers can engage in new, flexible arrangements leading to better utilisation of manufacturing capabilities & provide heightened levels of quality and value
- "Edge analytics" greatly reduces the amount of raw data that must be stored on servers, either on premises or in the cloud, and reduces the amount of network traffic being generated.
  - Collecting and analysing data close to the endpoints means that action can take place locally in real or near-real time.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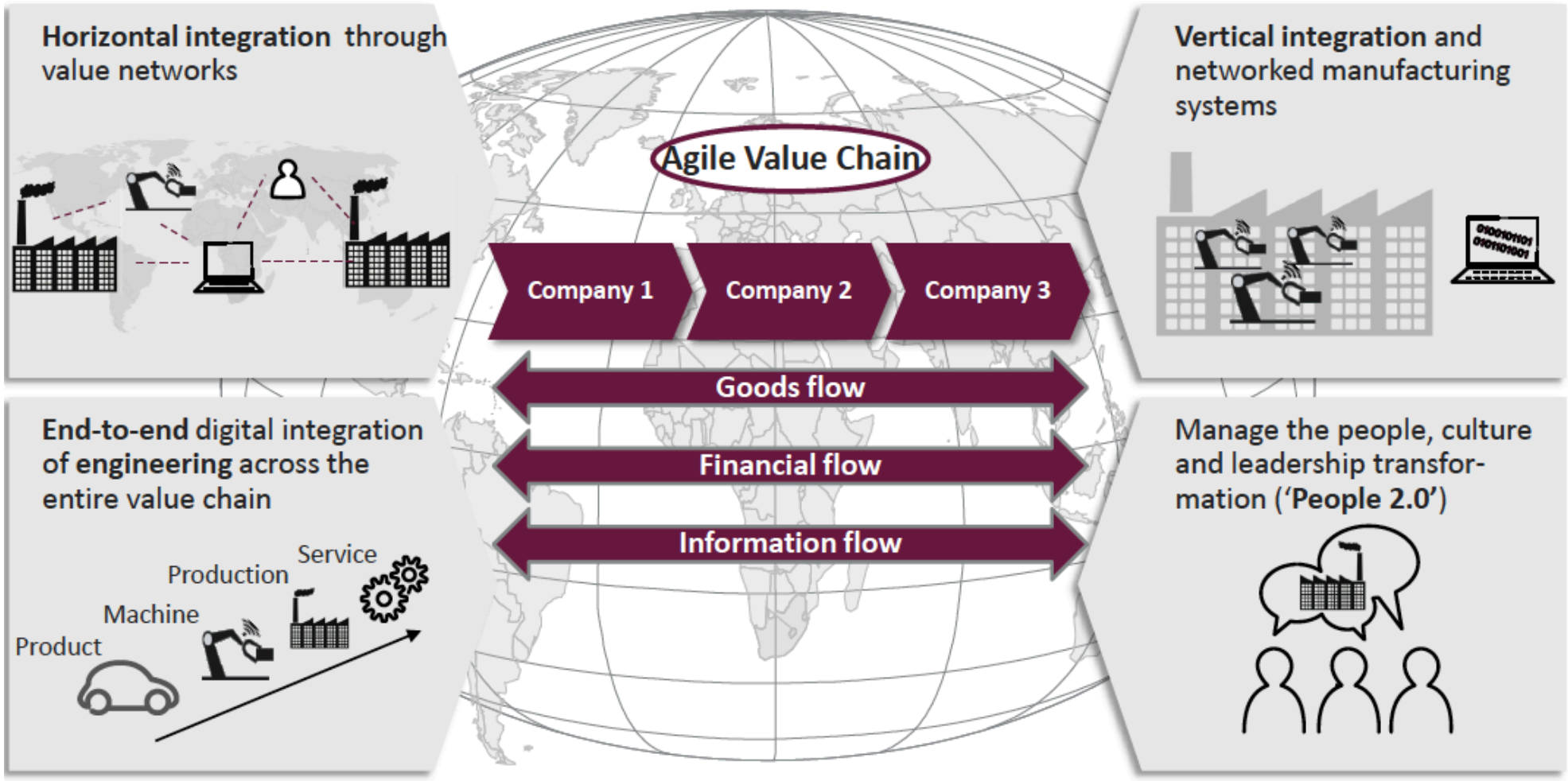
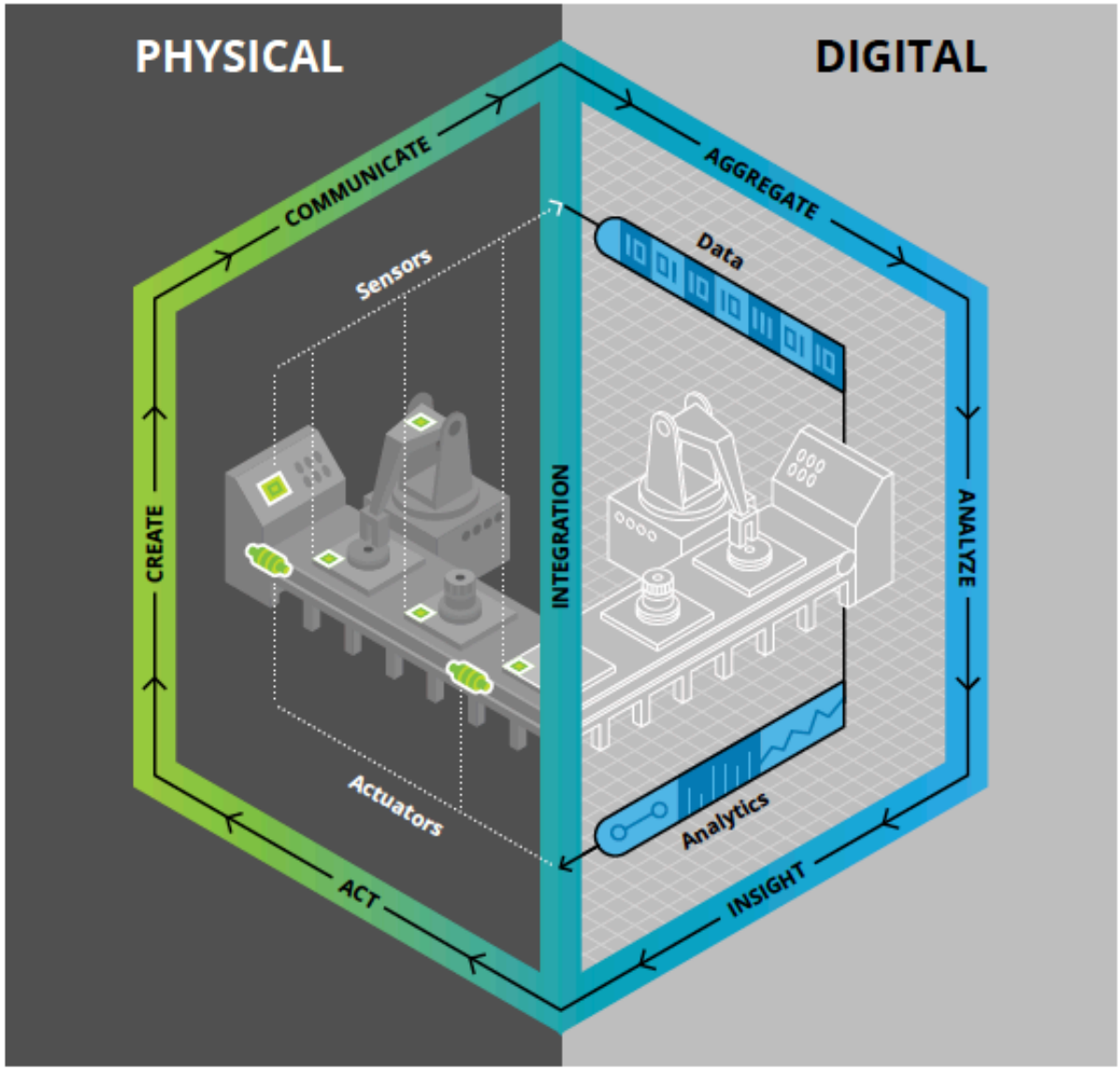
Smart Connected Factories

En route to Smart Manufacturing Networks



Source: Capgemini Consulting 2015

The Digital Twin: Connecting The Physical & Digital Worlds



Source: Deloitte series on Industry 4.0, 2017.

Digital Twin:

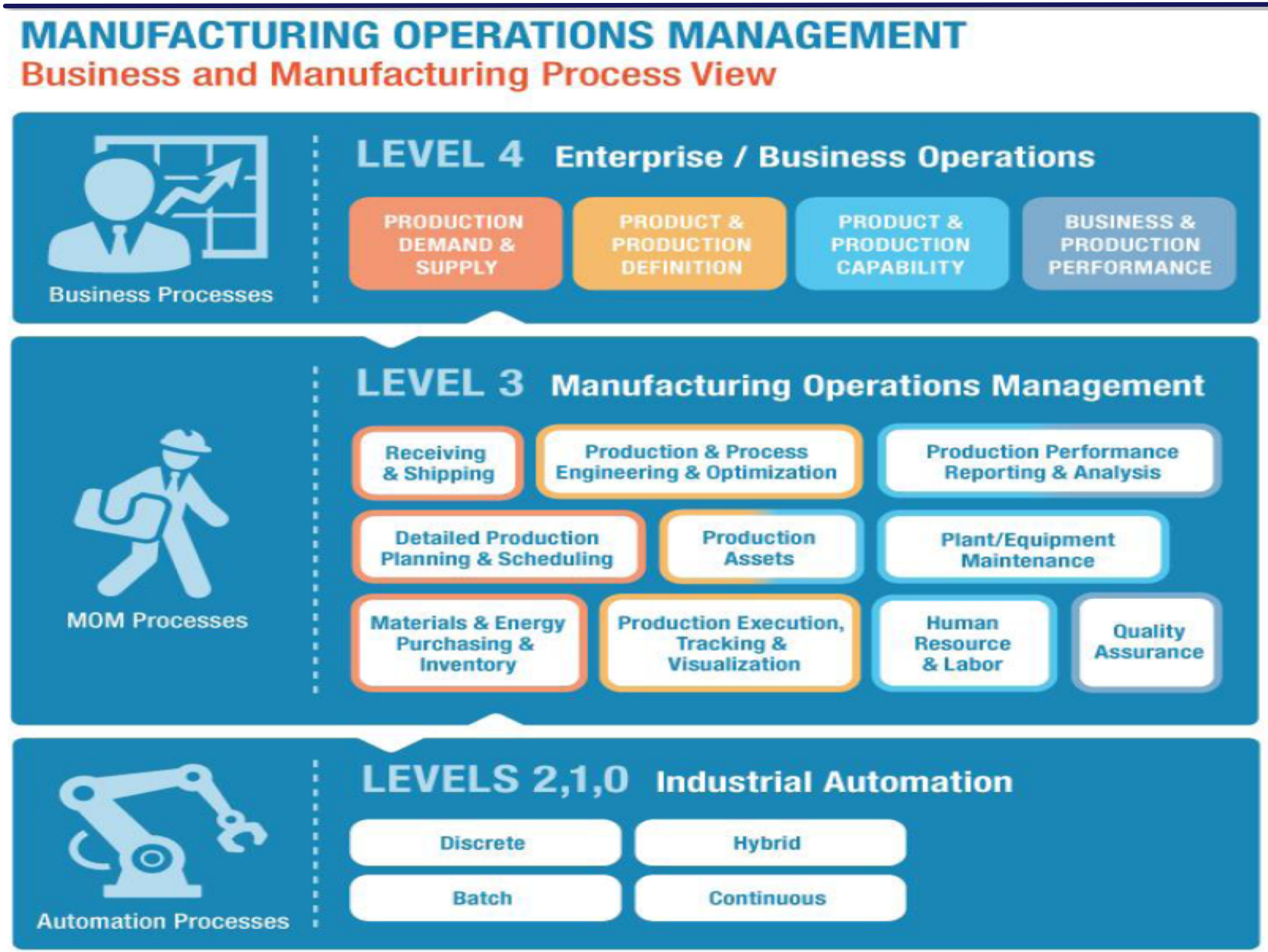
A digital representation of a physical product or process to enable testing before physical implementation.

Enables manufacturers to overlay the virtual, digital product on top of any physical product at any stage of production on the factory floor and analyse its behaviour.

- Manufacturers can have a complete digital footprint of the entire manufacturing process spanning product, production, and performance.

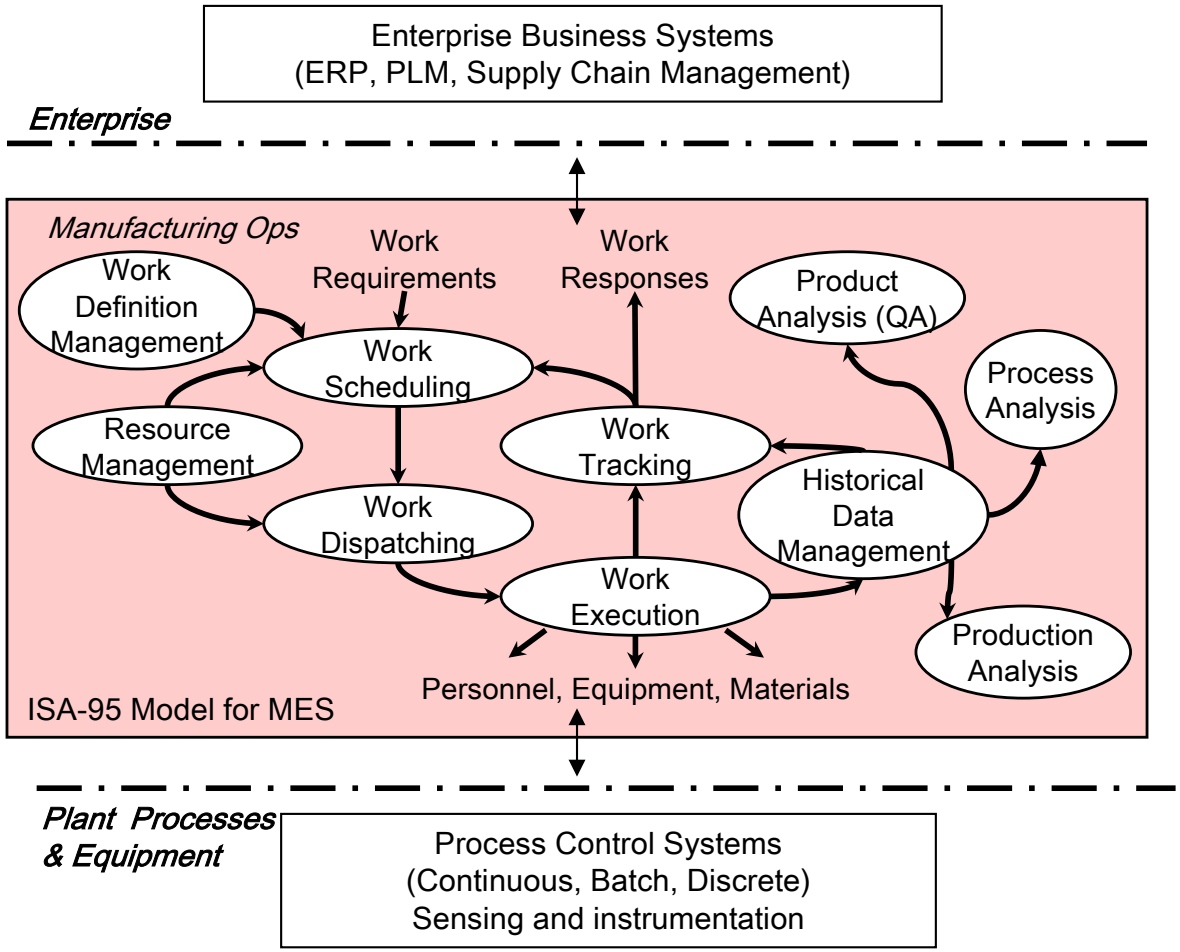
Product designers and engineers can make informed choices about materials and processes using visualisation tools, e.g., 3D CAD/CAM tools, during the design stages of a digital product and immediately see the impact on a physical version of the product.

Manufacturing Operations Management



Source LNS Research, May 2013.

Factory Model: Connecting the Enterprise to the Shop-Floor



Automate Business Processes

Automate Mfg Events & Ops

Automate Equipment Ops

KEY CHALLENGES

Disconnect between Enterprise & Shop-floor Applications

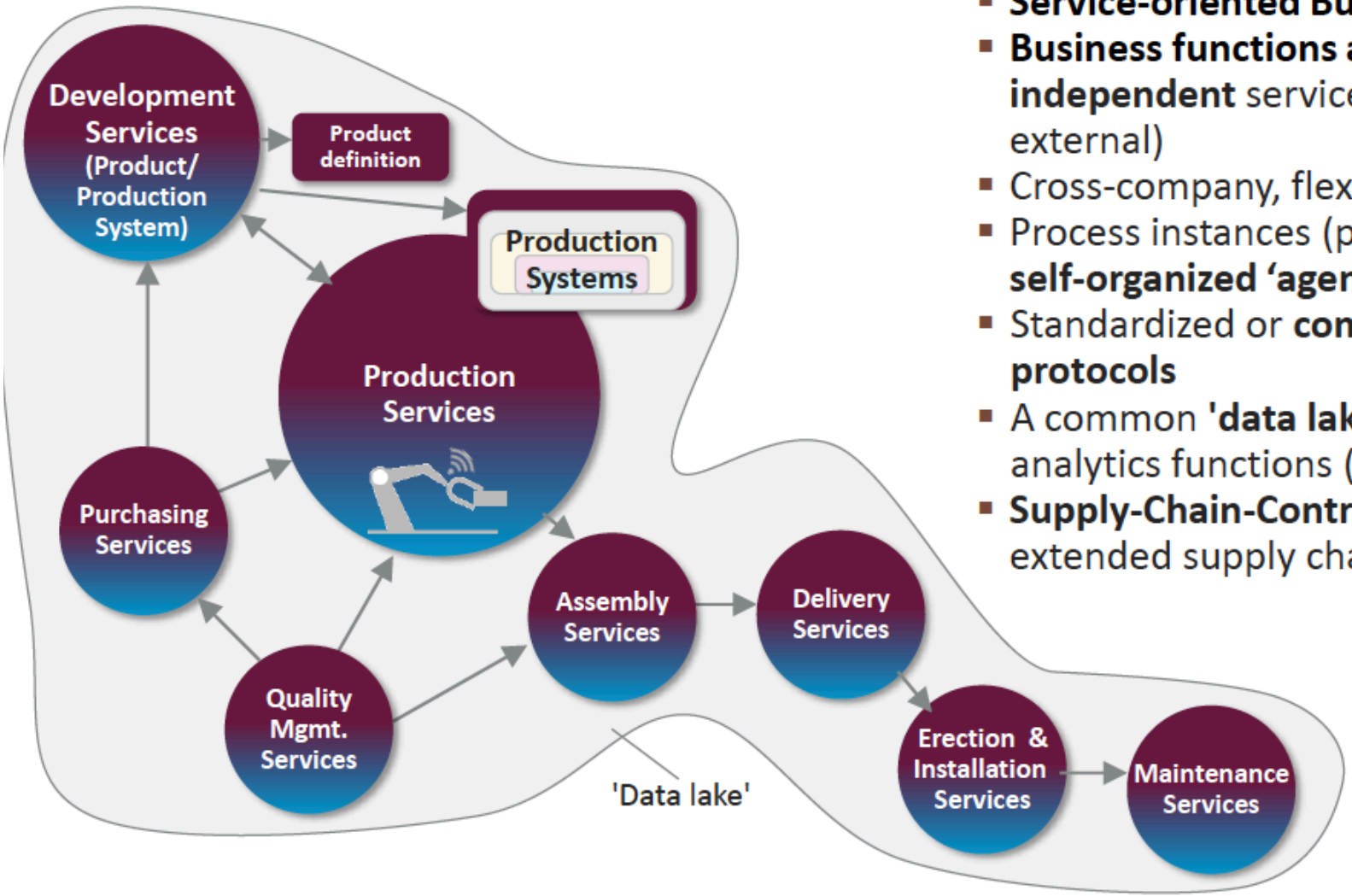
Disconnect between PLM & Manufacturing

Limited point-to-point connections between Business IT & Factory Automation

Lack of visibility into plant/enterprise ops to help eliminate bottlenecks

Unable to identify work order performance related to on-time completions & quality

From Smart Factory to Agile Value Chains



- **Service-oriented Business Architecture**
- **Business functions as** self-contained/ **independent** services (internal and external)
- Cross-company, flexible process flow
- Process instances (products/orders) as **self-organized 'agents'**
- Standardized or **common interfaces/ protocols**
- A common **'data lake'** as platform for analytics functions (Big Data)
- **Supply-Chain-Control tower** providing extended supply chain transparency

From Smart Data to Smart Manufacturing Networks

Smart sensors help merge disparate data into streams of actionable info. & allow assets to be monitored and optimized from anywhere in real-time.

Smart machines are able to monitor key components & environmental conditions with min. human intervention.

A smart factory can self-optimize performance across a broader network of assets, self-adapt to & learn from new conditions, & autonomously run entire production processes.

Integrating a permanent or temporal coalition of production systems of geographically dispersed smart factories, suppliers & customers to better achieve joint production objectives.

Smart Sensors

Smart Machines

Smart Factory

Connected Factories

Data from Products, Systems, Sensors, Processes ...

"Smart data to Smart Manufacturing Networks"

Data → Data analytics → MfG Intelligence → MfG Innovation → Value Generation

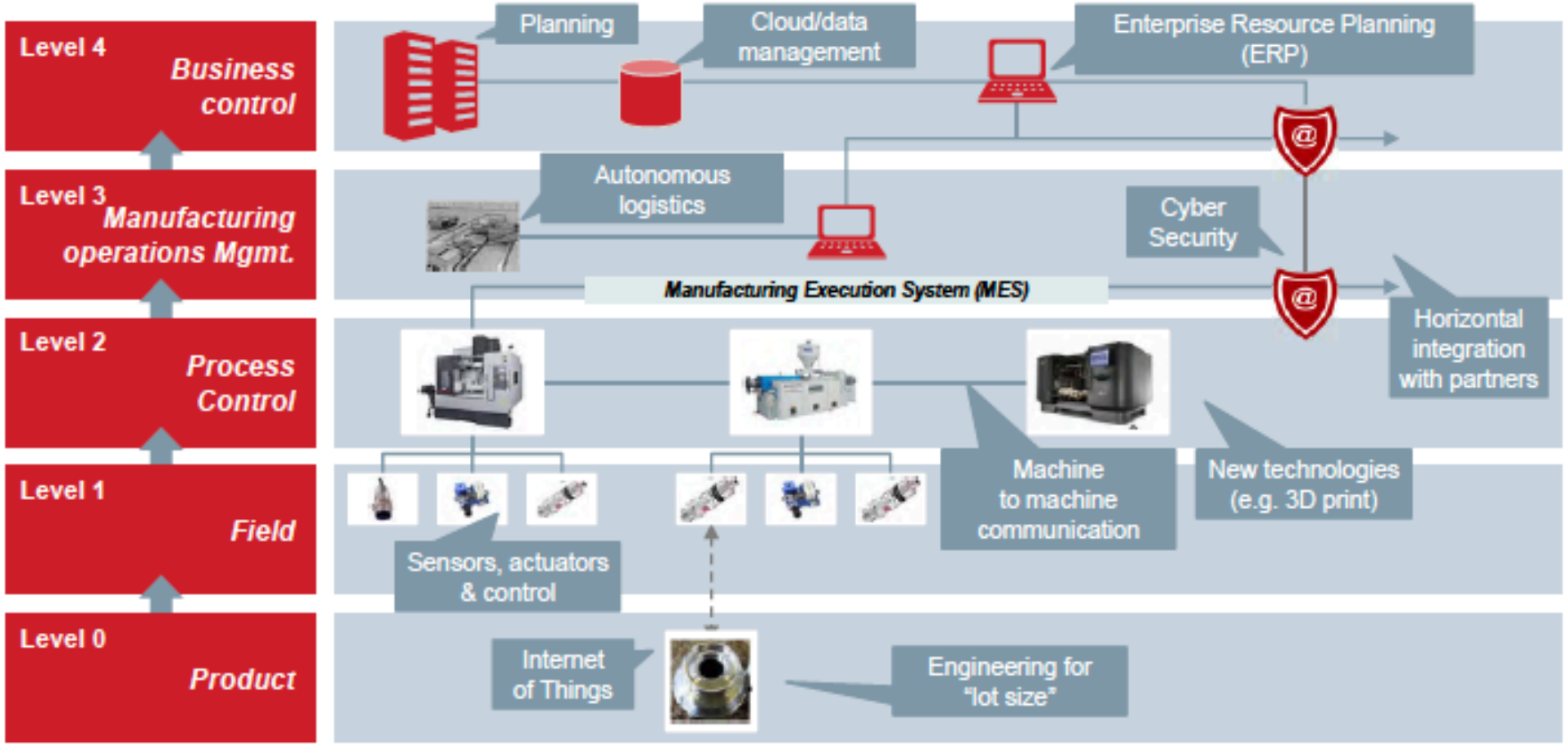
Customer Advantage

- Better Customised Products
- Better Performance
- Lower Costs
- Saving Energy
- Reduce Risks
- New Business Models

Domain know-how + Device know-how (IoT) + Analytics know-how = Smart Data

Vertical Integration within a Factory

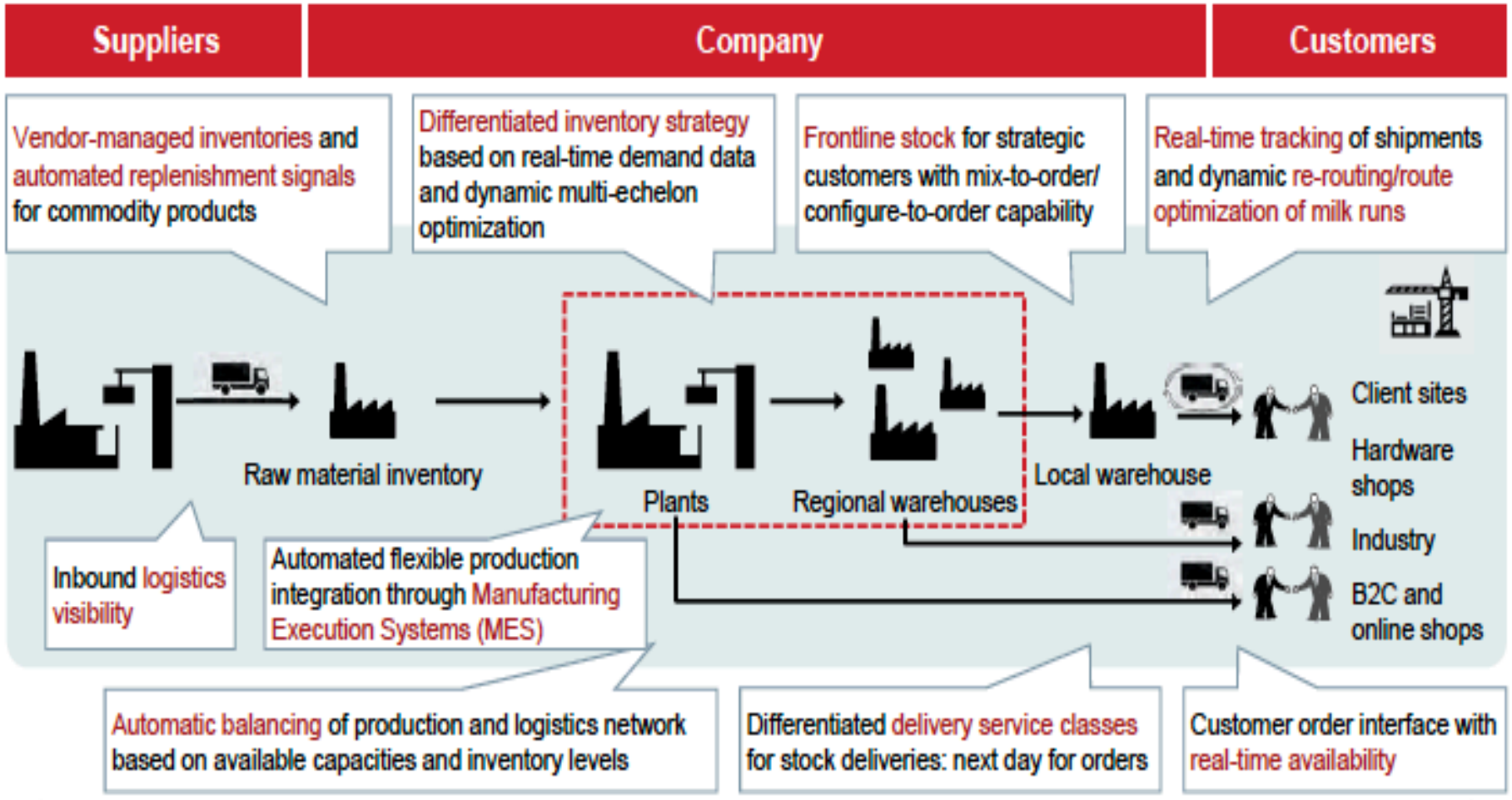
Vertical integration of production activities within smart factories from product design and development and the various shop floor applications, devices, IoT, robot and equipment is necessary to enable production.



Source: PWC 2016

Horizontal Integration between Factories

Horizontal integration is combined with vertical integration to offer the prospect of coordination of orders, materials flow and production data, with all geographically dispersed entities, e.g., customers, distributors and channel partners, materials and sub-product suppliers, contract manufacturers, and technology solution providers, to achieve end-to-end, holistic integration through the entire value chain.

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Big Data & Analytics in Smart Connected Factories

Resources, Processes & Data are Behind it All !

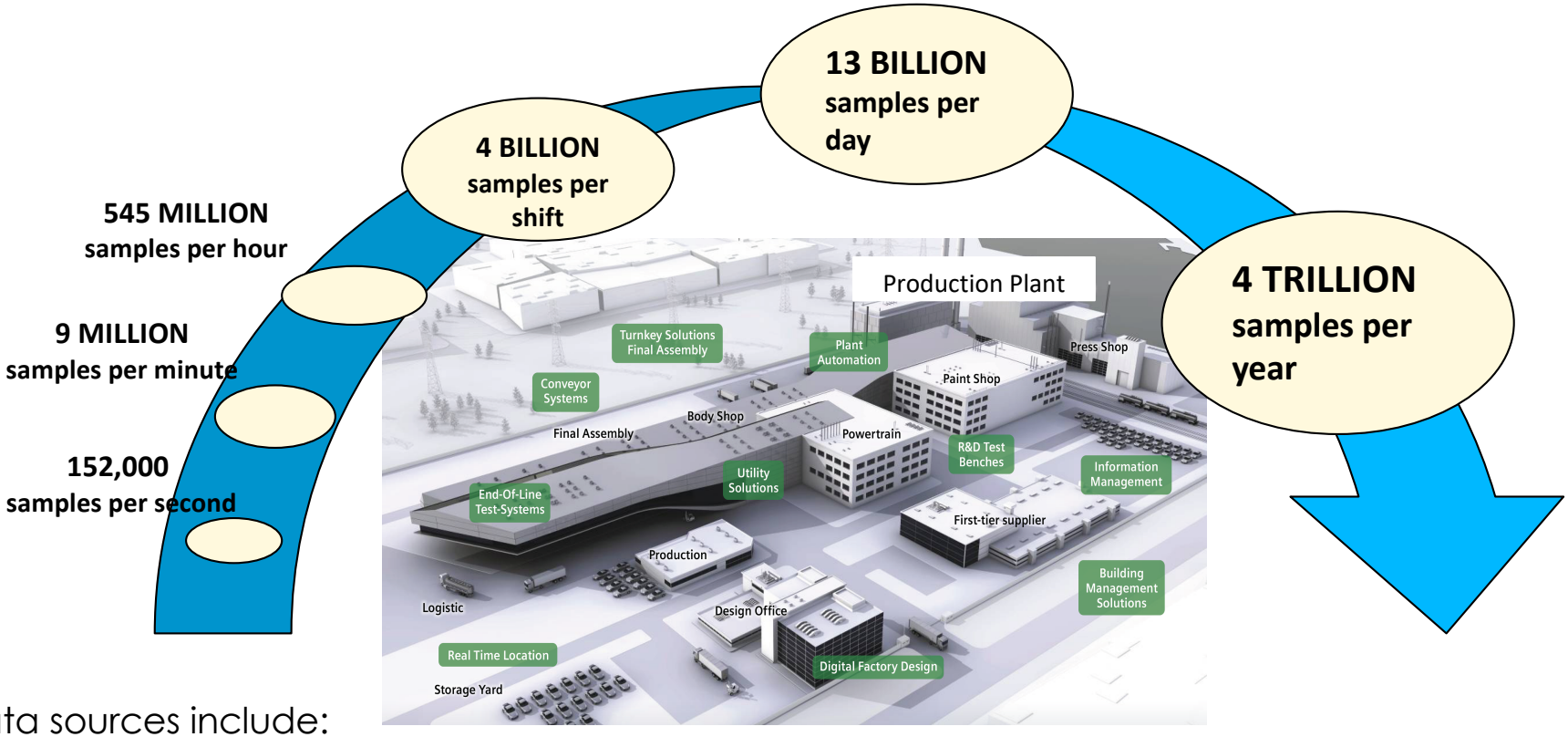
Understanding the Hourglass --

<---- Suppliers, Partners, Machines, Components, Materials, Devices, Humans, …

<--- Production processes

<--- Production, Distribution, Sales, x*, data

Production Plant Data



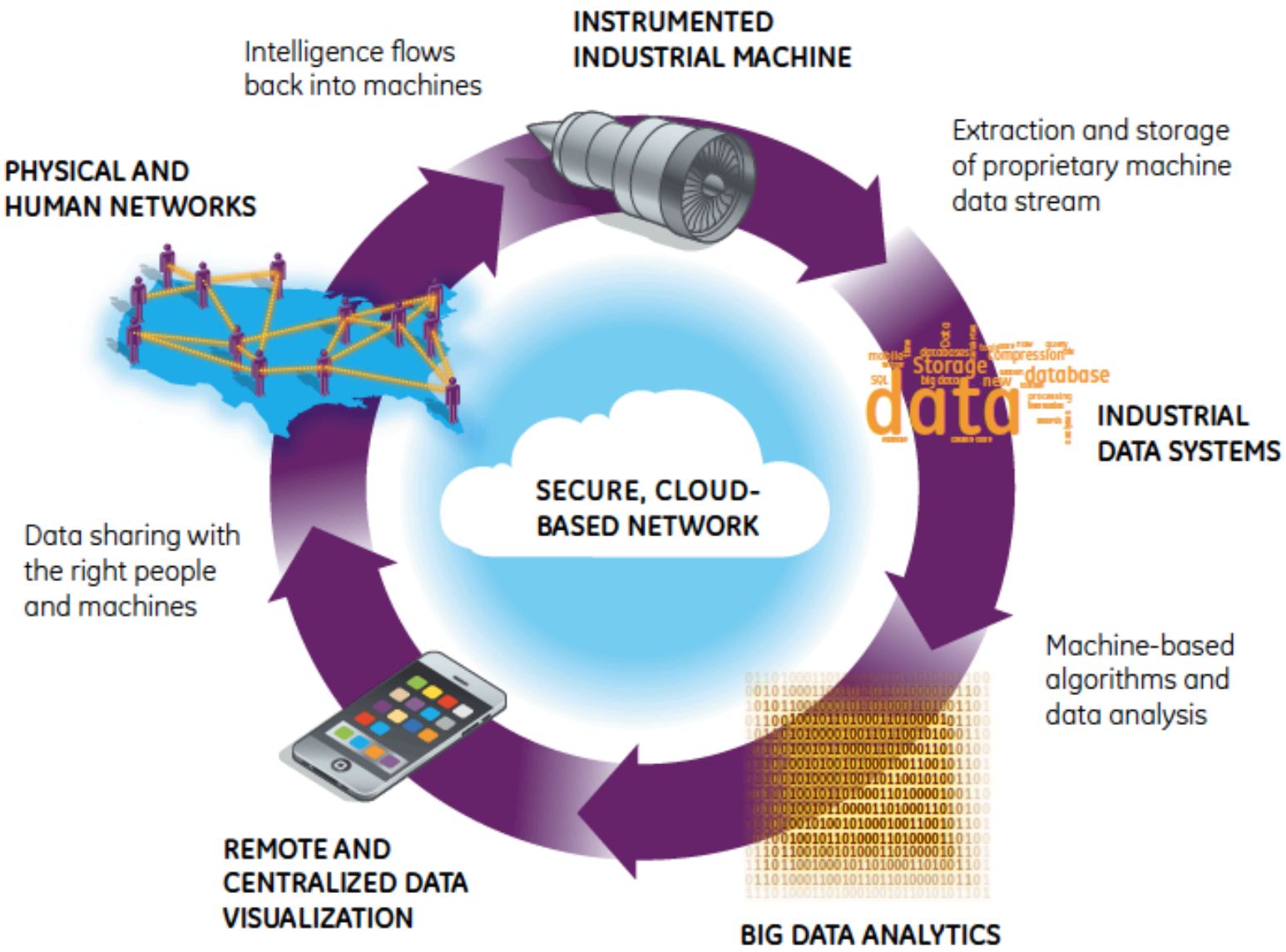
Data sources include:

- External data sources: e.g., user groups, social media, focus groups, or surveys to build customer data.
- Internal data sources: for data capture and analysis (e.g., an integrated ERP system provides data on products, processes, & people at all levels & departments in organization).
- M2M interaction: Smart sensors can collect data directly from machines and equipment. Built-in, low-cost sensors can detect a wide range of attributes, including location, weight, temperature, vibration, flow rate, humidity, and balance.

The above figures reflect the data generated from just one of many production lines that produce a particular consumer packaged products.

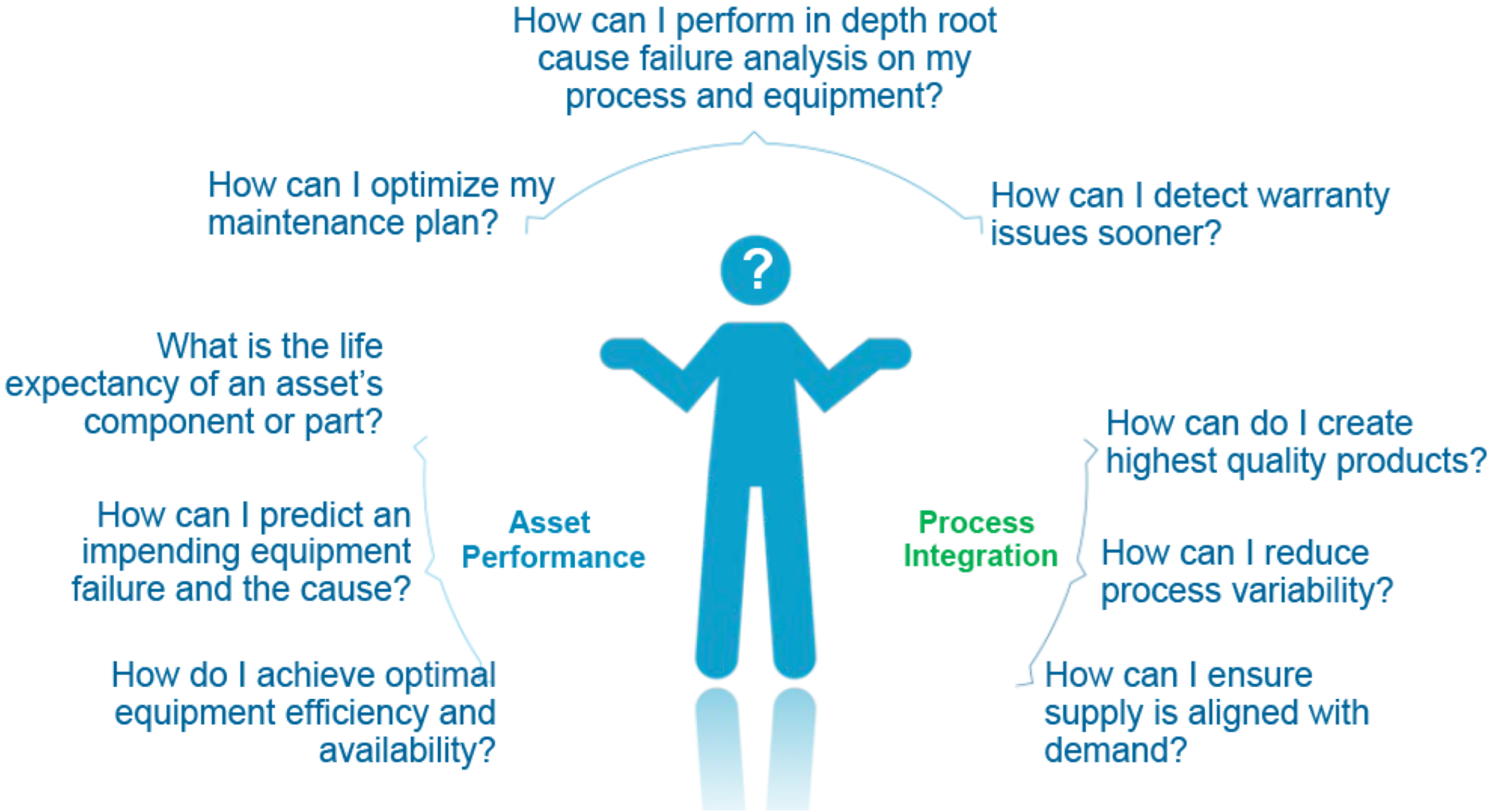
Source: GE Intelligent Platforms.

Industry 4.0 Data Loop

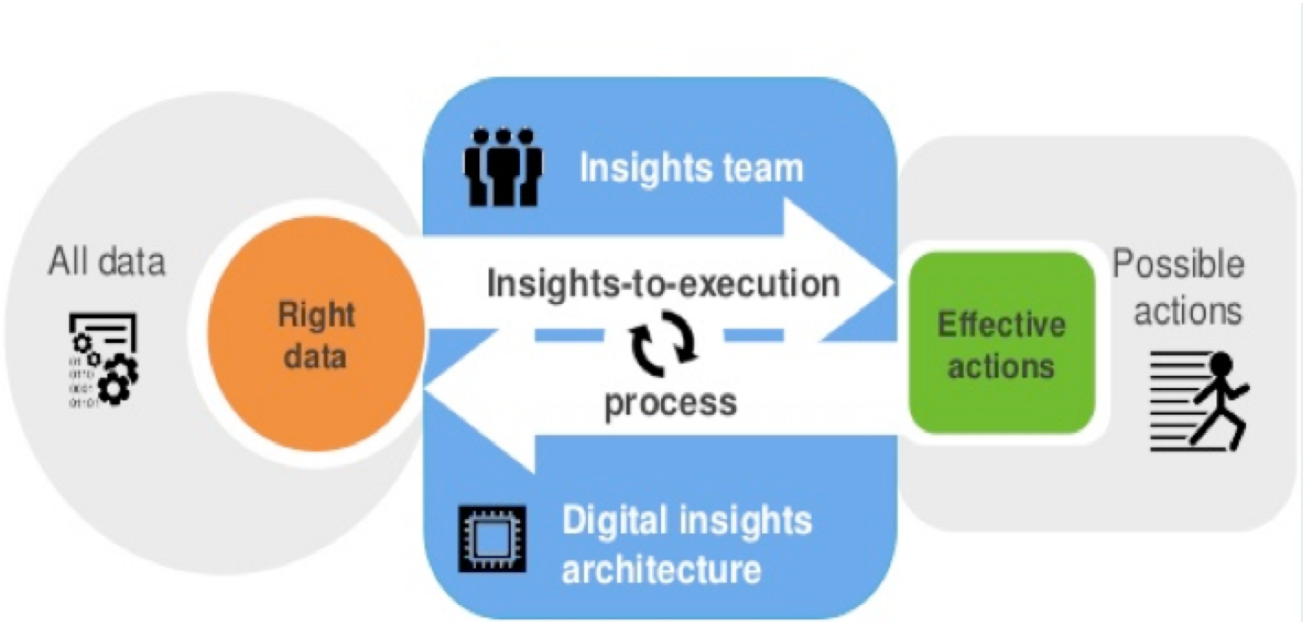


Source: General Electric

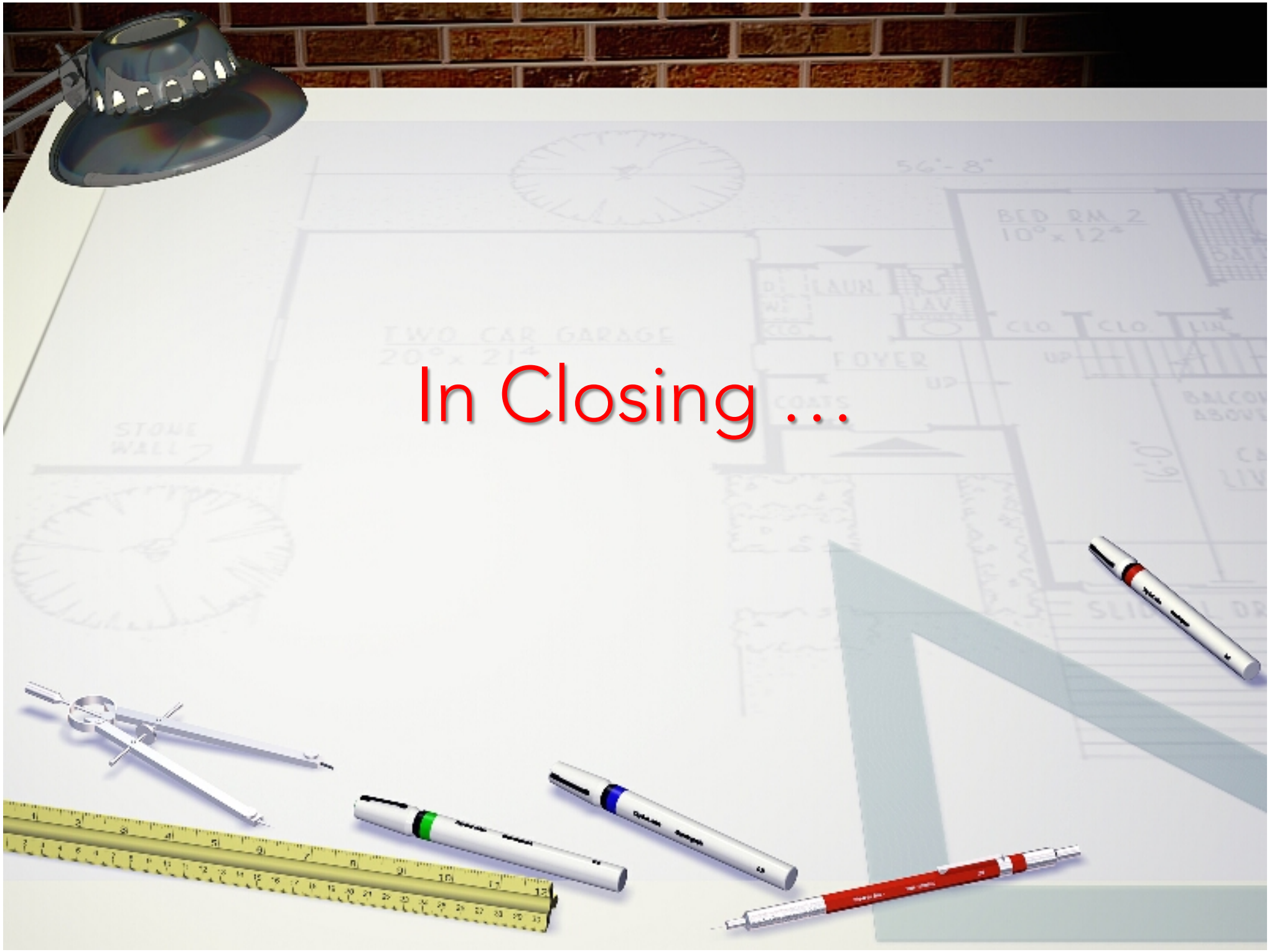
Smarter Analytics: Improved Resource & Process Performance



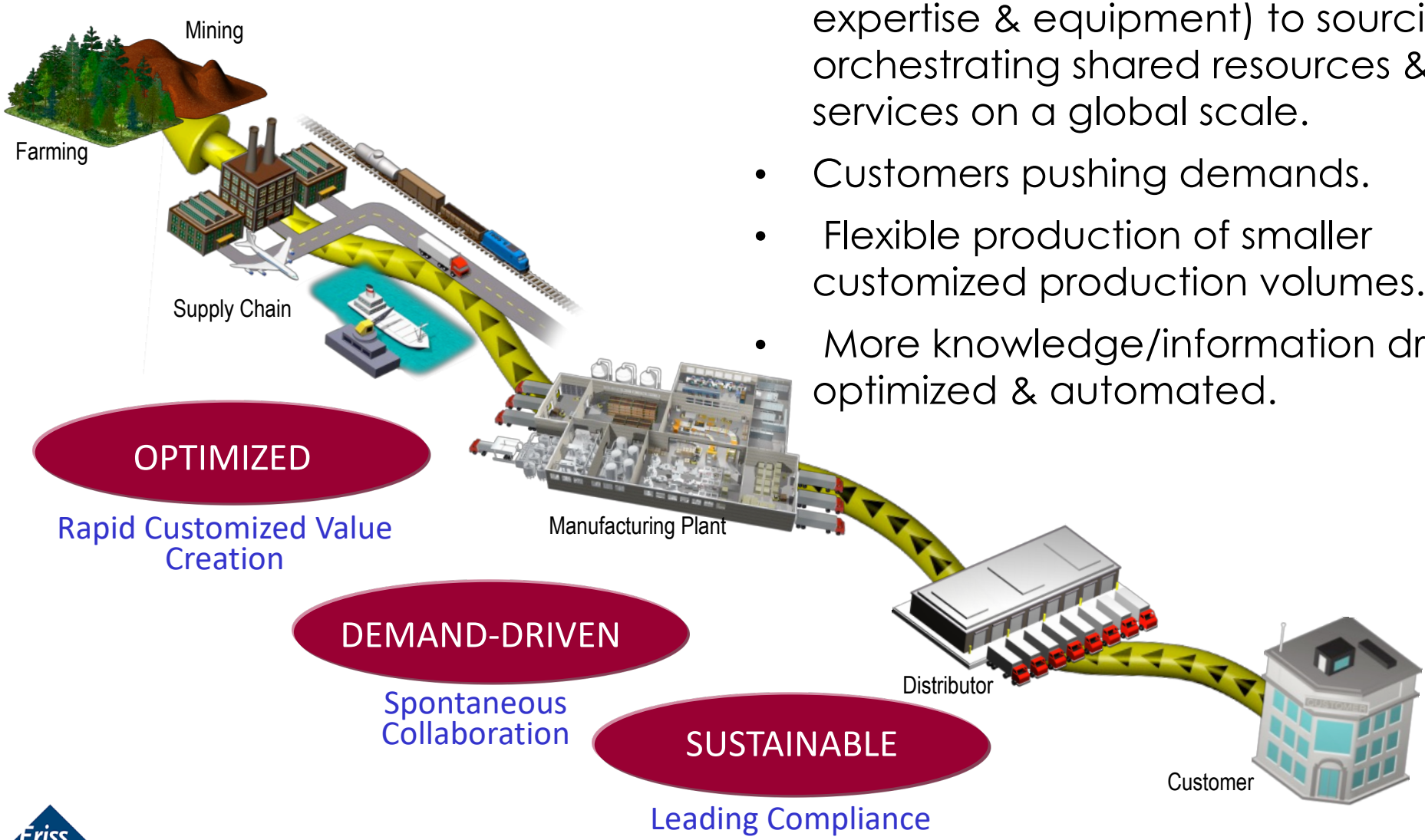
Smarter Analytics Lead to Systems of Insight



Source Forrester Research, July 2015.


In Closing …

Concluding Remarks: What is so Different about Smart Manufacturing?



- Transitions from "owning & operating" dedicated assets (including people, expertise & equipment) to sourcing & orchestrating shared resources & services on a global scale.
- Customers pushing demands.
- Flexible production of smaller customized production volumes.
- More knowledge/information driven, optimized & automated.

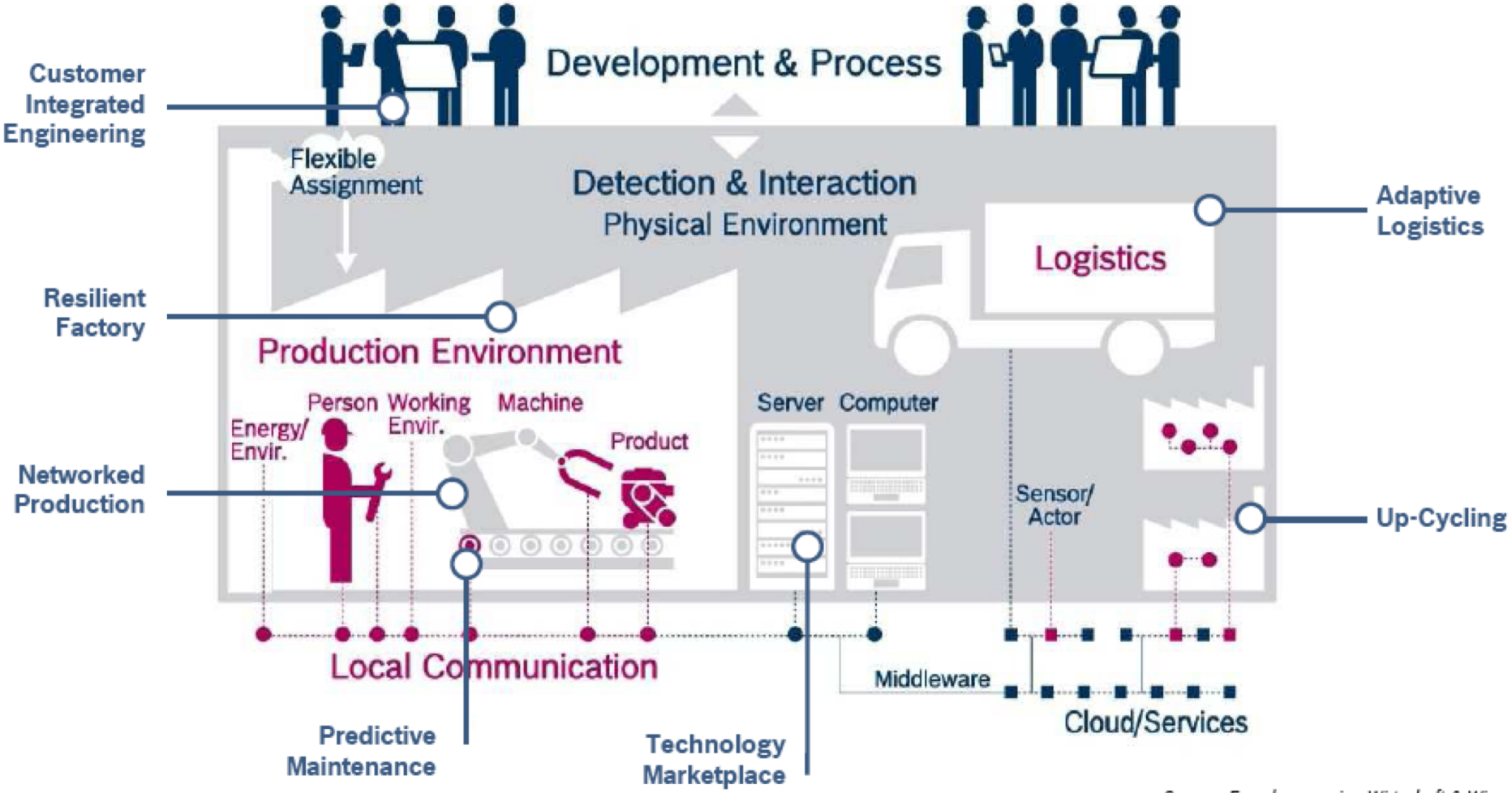

THANK
YOU

R&D Challenges – Open Research Problems

STRATEGIC R&D OPPORTUNITIES FOR IoE	
Science & Engineering Foundations	**Robust Effective Construction of Systems & Infrastructure**
	• Devise cost effective system, design, analysis & development
	• Create domain-specific architectures & frameworks
	• Enable more na ractions
	• Offer assumptio ed decision-making.
	• Synthesize & evo predictable behaviour (diagnostics, pro
	• Anticipate emer ctions.
Systems Engineering	**Improved Performa utational & Physical Systems**
	• Create methods ation, & validation of IoE
	• Develop IoE-bas afety, resilience, adaptability, flexibility, reusab
	• Consider roles o g of human knowledge & behaviour
	• Incorporate unc asoning & decision-making
Applied Development and Deployment	**Effective and Relia erability Mechanisms**
	• Create universal ge heterogeneous systems
	• Build an inter-connected and interoperable shared development infrastructure
	• Provide advanced abstraction mechanisms to manage complexity of IoE programming, evolution, monitoring & mgt that span the digital & physical divide
	• Develop flexible IoE design methods based on Agile & DevOps

Shift from Traditional to Smart Factories

➔ **New business models** through the convergence of IT & production



Source: Forschungsunion Wirtschaft & Wissenschaft