Metaprogramming Environment 4 Industry 4.0

Eriss
European Research
Institute in Service
Science

UNIVERSITEIT VAN TILBURG

Michael P. Papazoglou

Executive Director - ERISS
Tilburg University,
The Netherlands
email: mikep@uvt.nl,
http://www.eriss.org

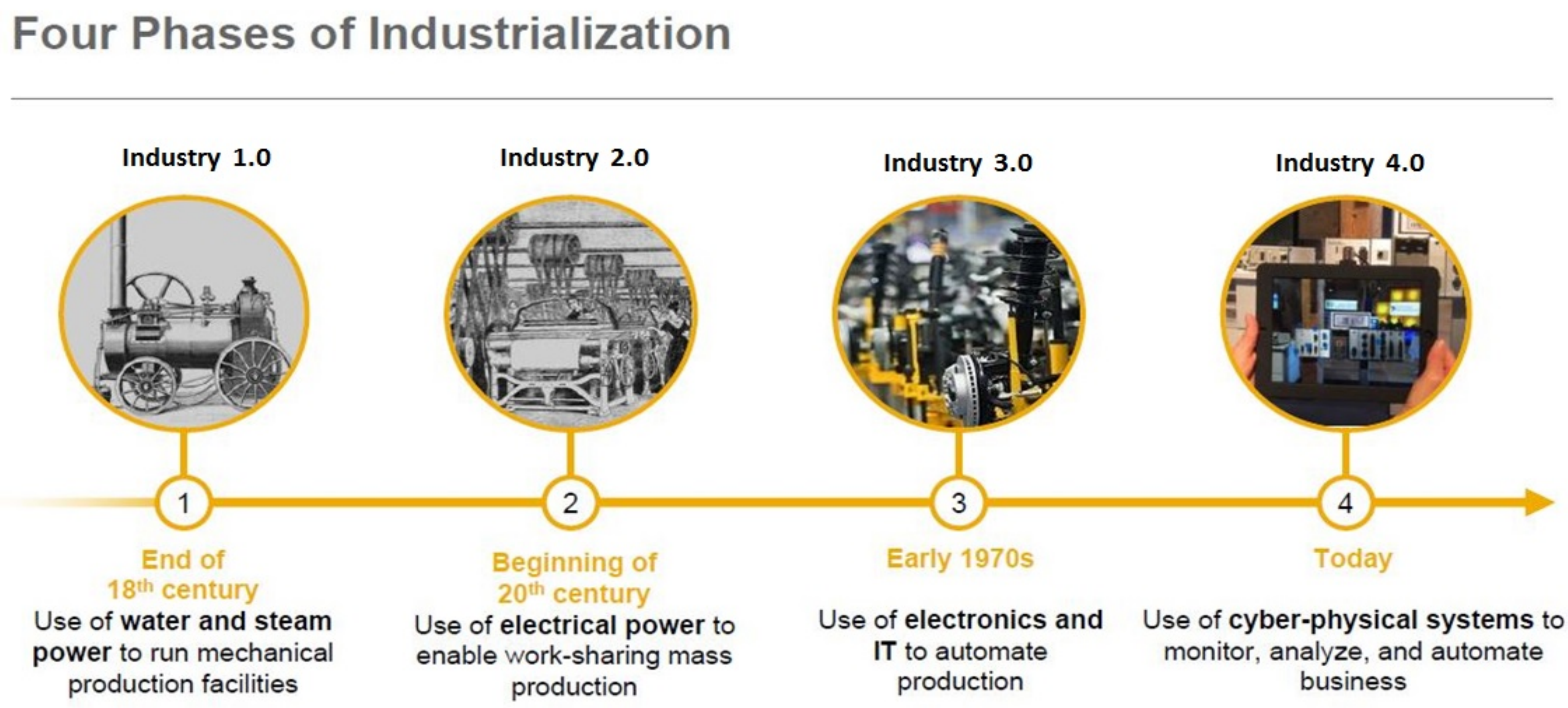
AGENDA

- An Introduction to Industry 4.0
- Digital Twins & Model-driven Manufacturing
- Examples of Use:
  Manufacturing Blueprint Data Model & Programming Language
- Closing Remarks


facilities
global
process
future
production
manufacturing
industrial
IoT
business
cloud
strategy
augmented
customization
autonomously
technical
high-tech
revolution
smart
systems
engineering
chain
automation
reliability
connectivity
digital
robot
intelligent
logistics
computer
work
cyber
fourth
tech
technology
industry 4.0
tasks
virtual
security skills
resources
machine
factory
interoperability
society
project
strategic computing

An Introduction to Industry 4.0

The 4th Industrial Revolution



What is Industry 4.0?

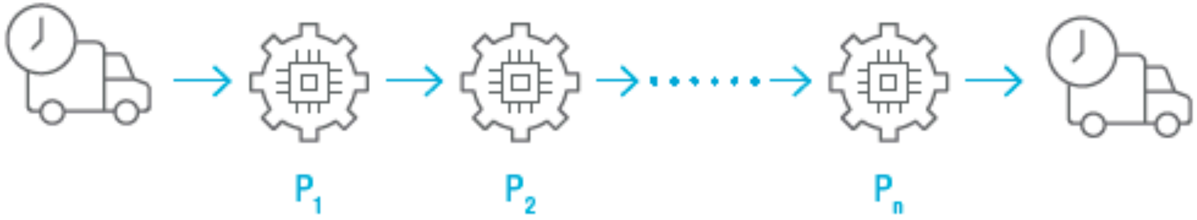
- Industry 4.0 is a new level of organisation and control over the entire value chain of the life cycle of products. It is geared towards increasingly individualised customer requirements.
- This cycle begins at the *product idea and extends through to development and manufacturing, all the way to the 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

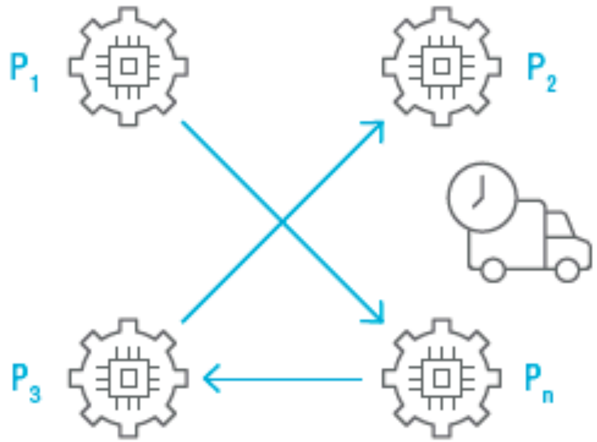
Conventional manufacturing

- 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

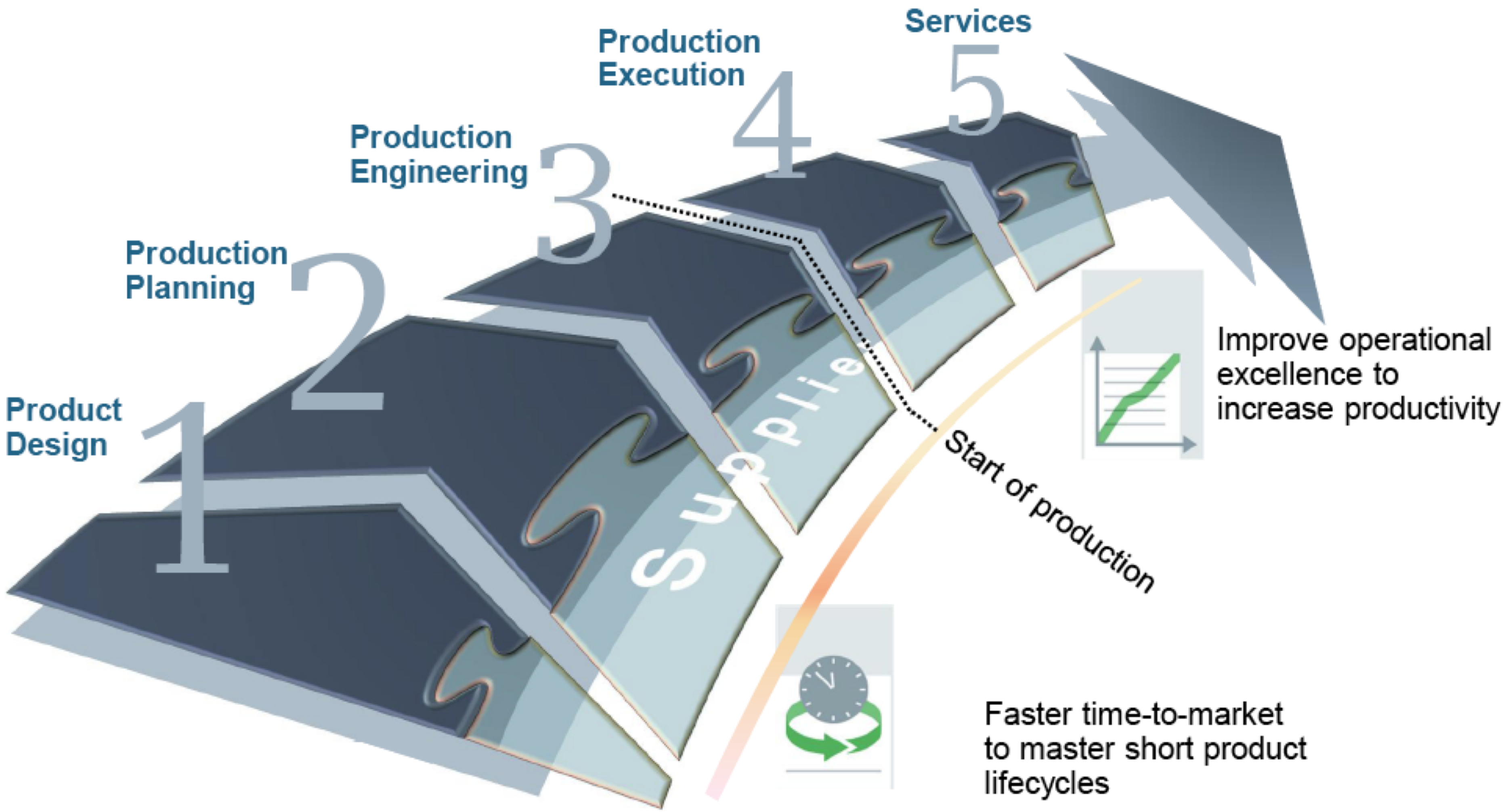


Source: GPS Consulting

Properties of Industry 4.0

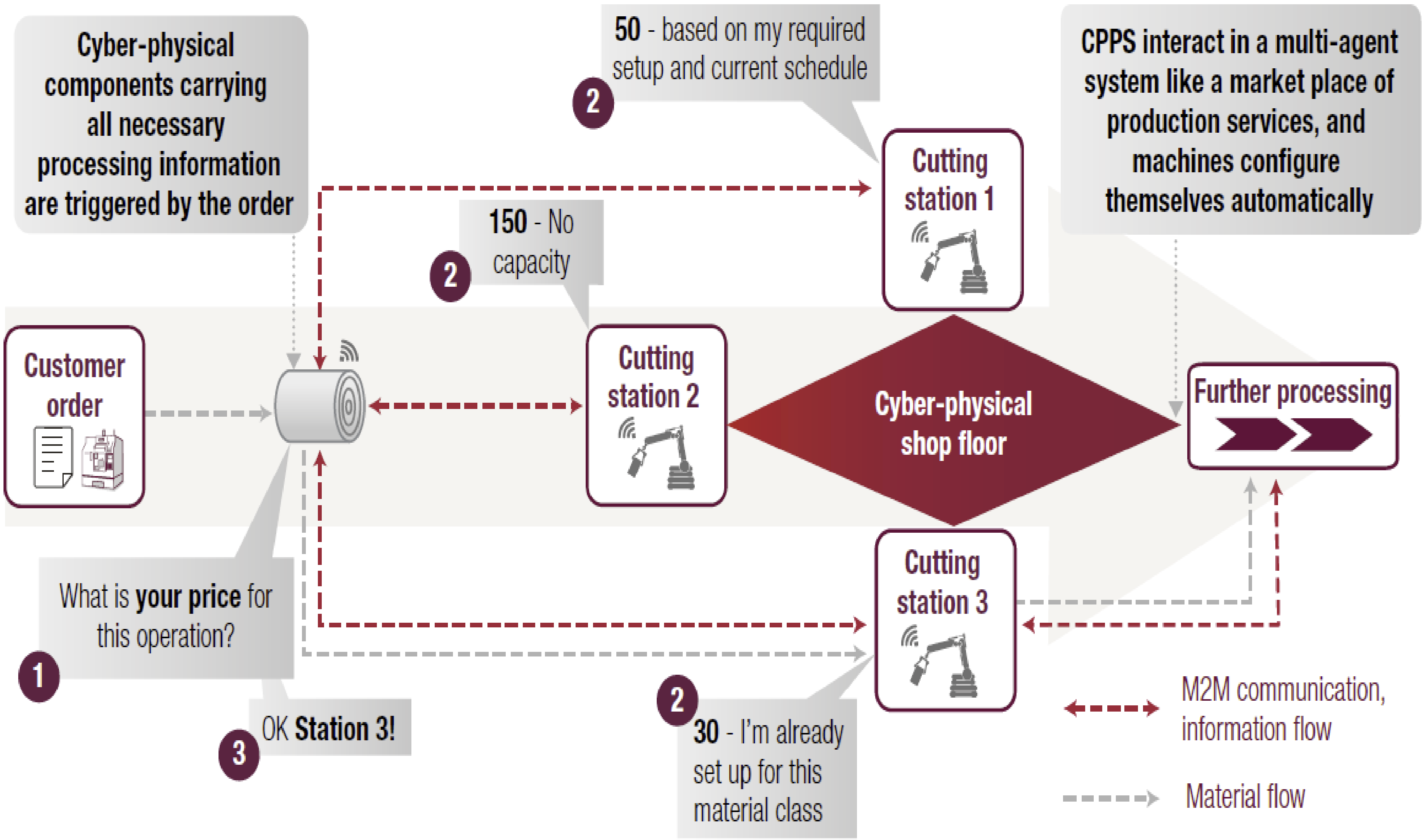
1. **Digitisation of all physical assets and processes**
2. **Integration of vertical and horizontal value chains**
3. **Control and visibility:**
   – As products move from ideation and development to end of life, the wealth of data produced at every stage of the manufacturing lifecycle can create a 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.

The Future of Manufacturing with Industry 4.0



Source: Siemens AG, 2016

Industry 4.0 Smart Factory

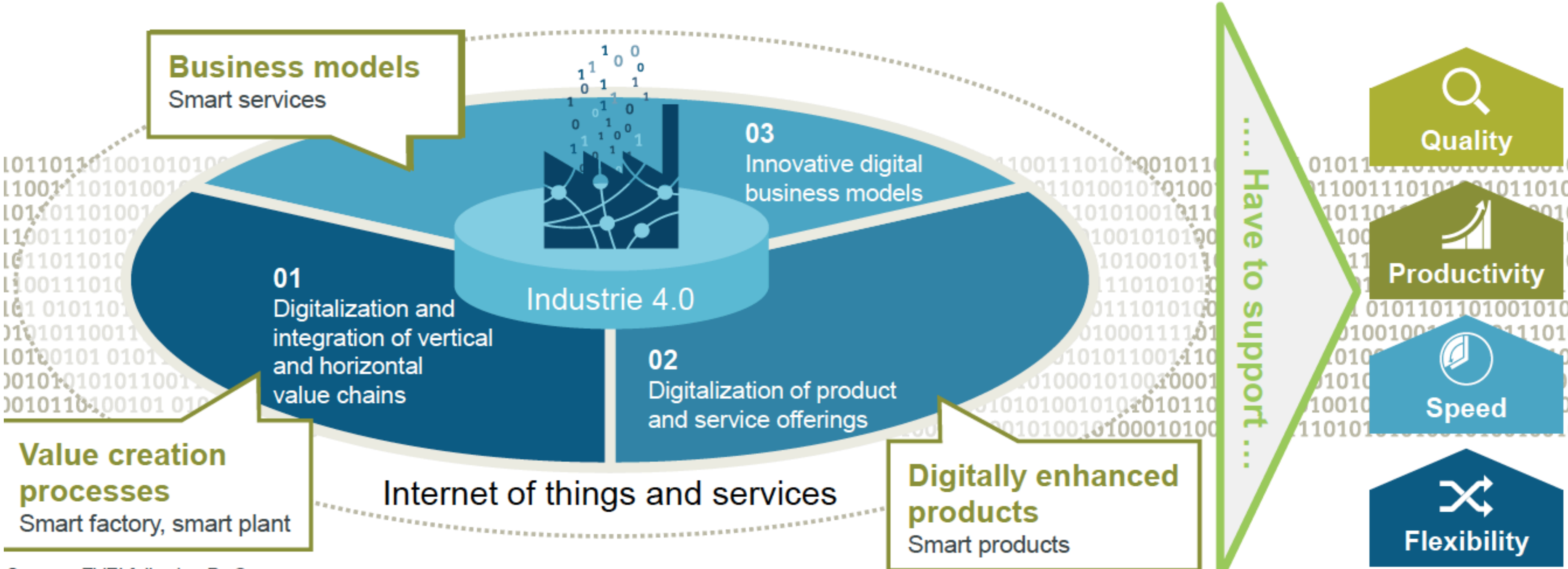


CPPS = CYBER-PHYSICAL PRODUCTION SYSTEM
M2M = MACHINE-TO-MACHINE

Source: Capgemini. Consulting

Digitization of Business Models, Processes & Products

Holistic view is needed!
Digitalization impacts business models, value creation processes, products



Source: ZVEI following PwC

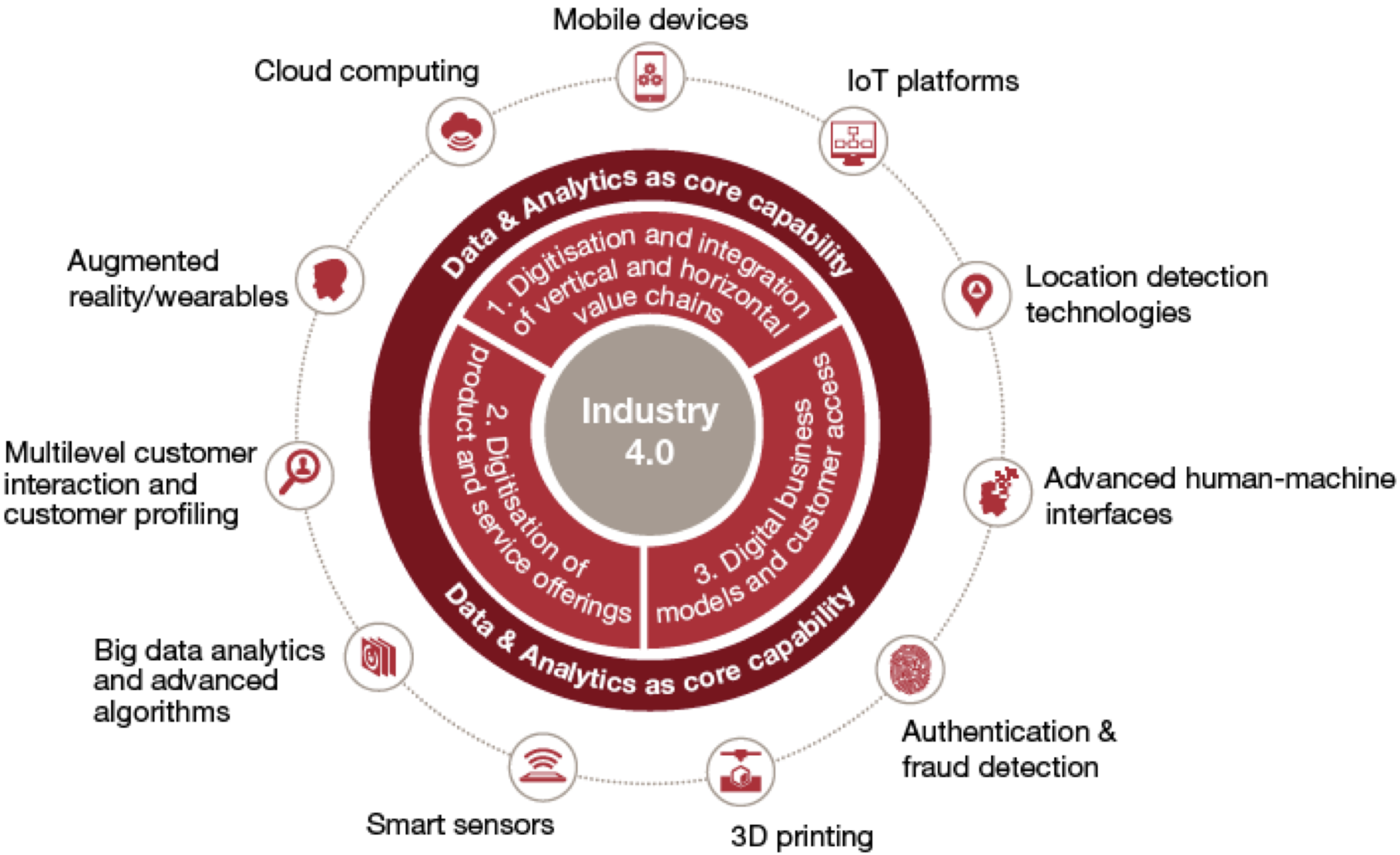
Industry 4.0: Revenues & Greater Efficiency

Additional revenues from:	Lower cost and greater efficiency from:
Digitising products and services within the existing portfolio.	Real-time inline quality control based on Big Data Analytics.
New digital products, services and solutions.	Modular, flexible and customer-tailored production concepts.
Offering big data and analytics as a service.	Real-time visibility into process and product variance, augmented reality and optimisation.
Personalised products and mass customisation.	Digitisation and automation of processes for a smarter use of human resources and higher operations speed.
Improved customer insight from data analytics	Vertical integration from sensors through MES to real-time production.
Increasing market share of core products	Horizontal integration of manufacturing networks, as well as track-and-trace of products for better inventory performance and reduced logistics.

Based on PWC, 2016 Global Industry 4.0 Survey

Industry 4.0 Enabling Technologies

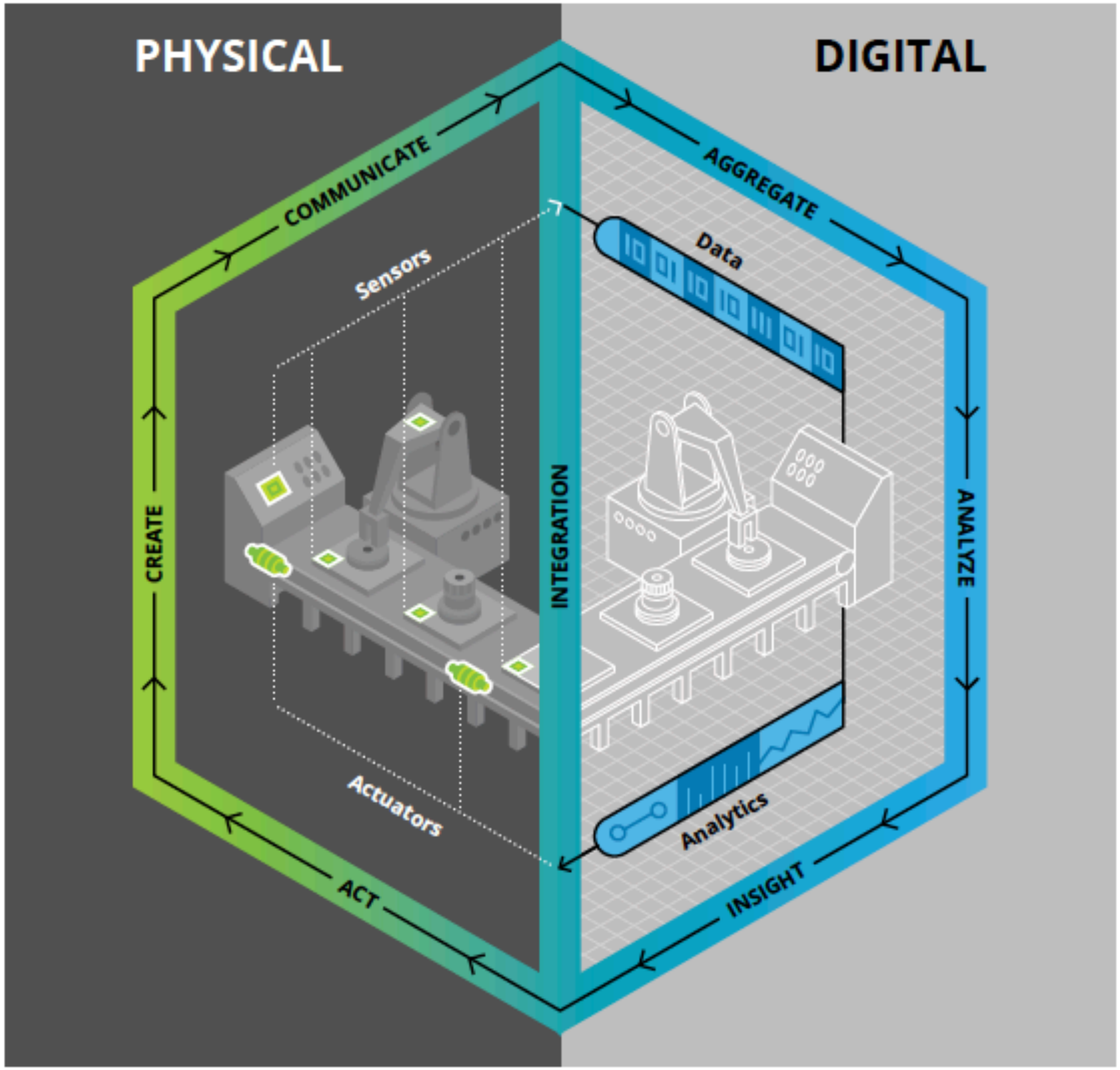
Industry 4.0 is Big Science!!



Source: PWC, 2016 Global Industry 4.0 Survey

Digital Twins & Model-driven Manufacturing

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.

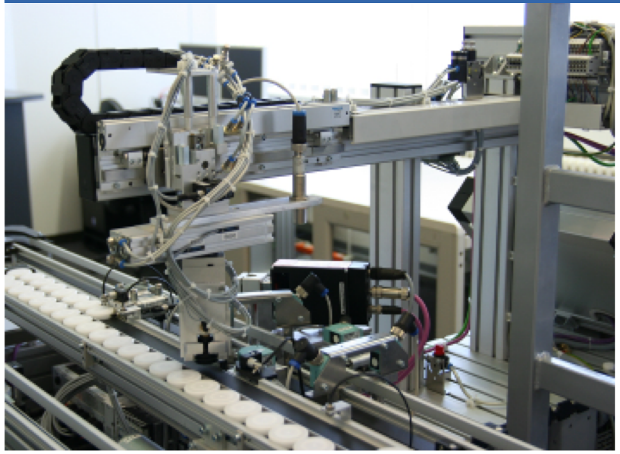
Enables manufacturers to overlay the virtual, digital product on top of any physical product at any stage of production on the factory floor and analyse its behaviour.

- 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.

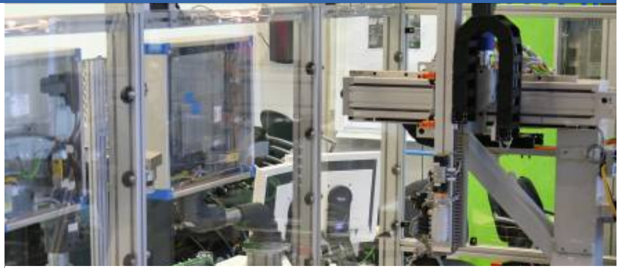
Digital Twin & Product Engineering Trends

Digital Product Engineering



Human Empowerment thro' Digital Product Ideation

- Enable customers & engineers to test scenarios and designs before the products are made.
- Provides accurate representations of finished products in real-world scenarios, review and evaluate concepts and alternatives, tweak and adjust and modify designs.
- Product ideation followed by automation components and manufacturing processes



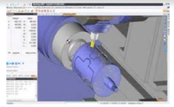
Engineering & Programming Paradigms

- Model driven SW development
- Component based engineering
- Knowledge based design & engineering

Model-driven Manufacturing

- Model-Driven Manufacturing (MDM) is strategy and architecture to realize the Industry 4.0-based digital twin and digital thread concepts.
- MDM is the strategy of departing from drawings and other means of product definition, e.g., natural language descriptions, and moving to interactive 3D models.

Product Ideation & Design



- 3D Augmented Reality
- Product Requirements
- Digital Product Derivation & Configuration

↓ Transformation

Platform-Independent Manufacturing Model

- Cloud-based Modular Mfg Ops
- Digital Production Processes
- Planning & Scheduling
- Dispatching
- Digital Threads

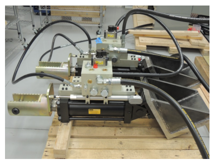
↓ Transformation

Platform-Specific Manufacturing Model

- Equipment & Process Automation
- Programmable Logic Controllers
- Distributed Control Systems
- IoT Gateways
- Machine Monitoring Sensors

↓ Execution

MDM feedback loop – Product optimization



Plant floor equipment & resources

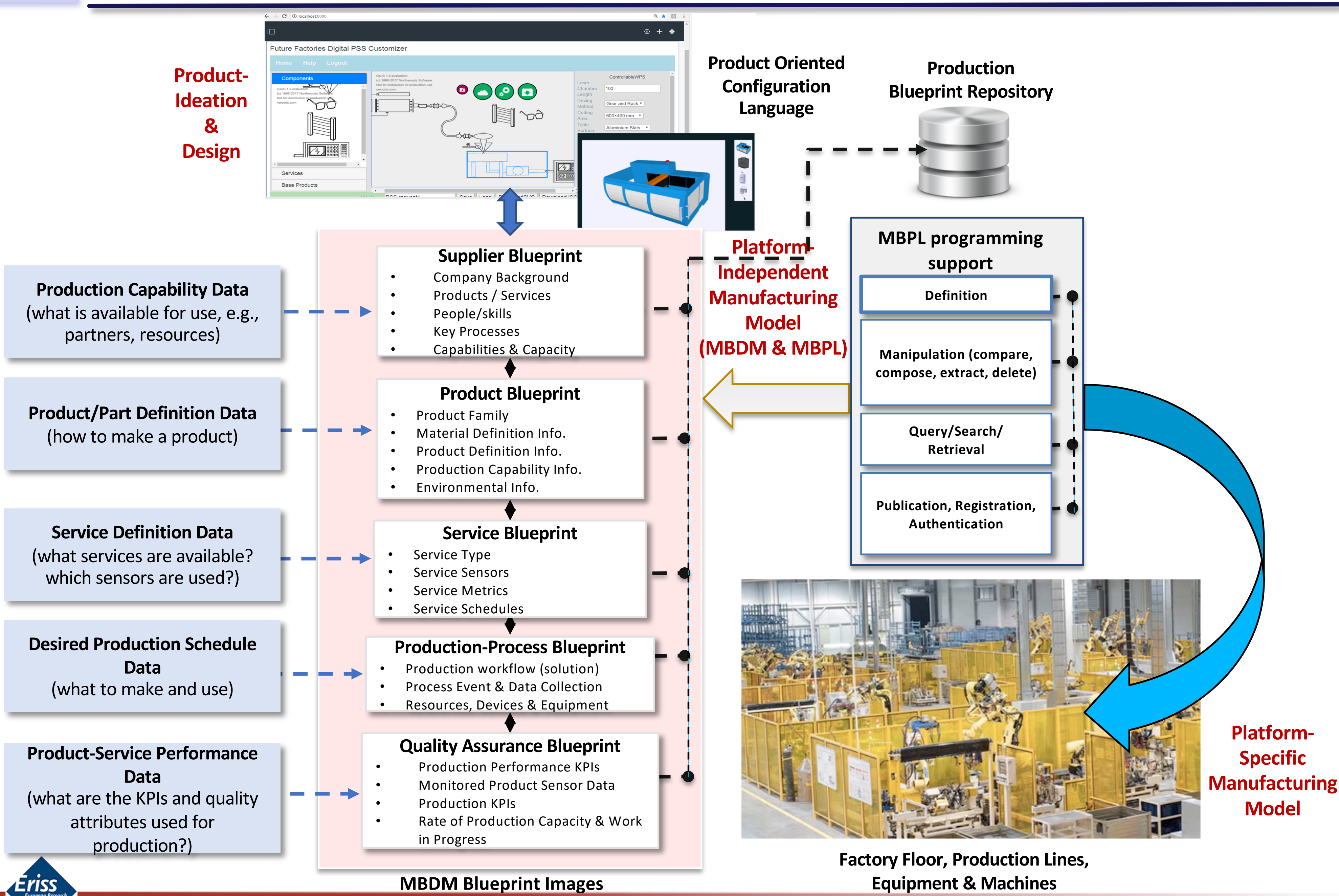
Model-driven Manufacturing

- *Product ideation and design sessions* specifically designed to meet customer specific objectives thro' Product-Oriented Configuration Language (PoCL):
  - Digital product features framing: PoCL supports different types of complex innovative shapes and helps streamlining collaboration between stakeholders, while checking the consistency and satisfaction of customer's requirements in-line with the customization process.
  - Progressive product configuration sketching and framing: PoCL employs cross-functional teams, such as product engineers and service designers, who it engages with customers to create conceptual drawings for final assessment and approval of a virtual product.
- *Meta-Programming Environment:*
  - Automated processes that stretch across multiple facilities where processes are executed collaboratively by partners distributed across production networks.
  - Improving visibility at each stage of an end-to-end production process. Visibility into process, data and material flows across a production network increases the efficiency of production management.
  - Leverages data from connected equipment and processes directly into new analytics and event triggering capabilities into systems of record and process workflows into the value chain.
  - adjusting output based on supply and demand.

Manufacturing Blueprint Data Model & Language

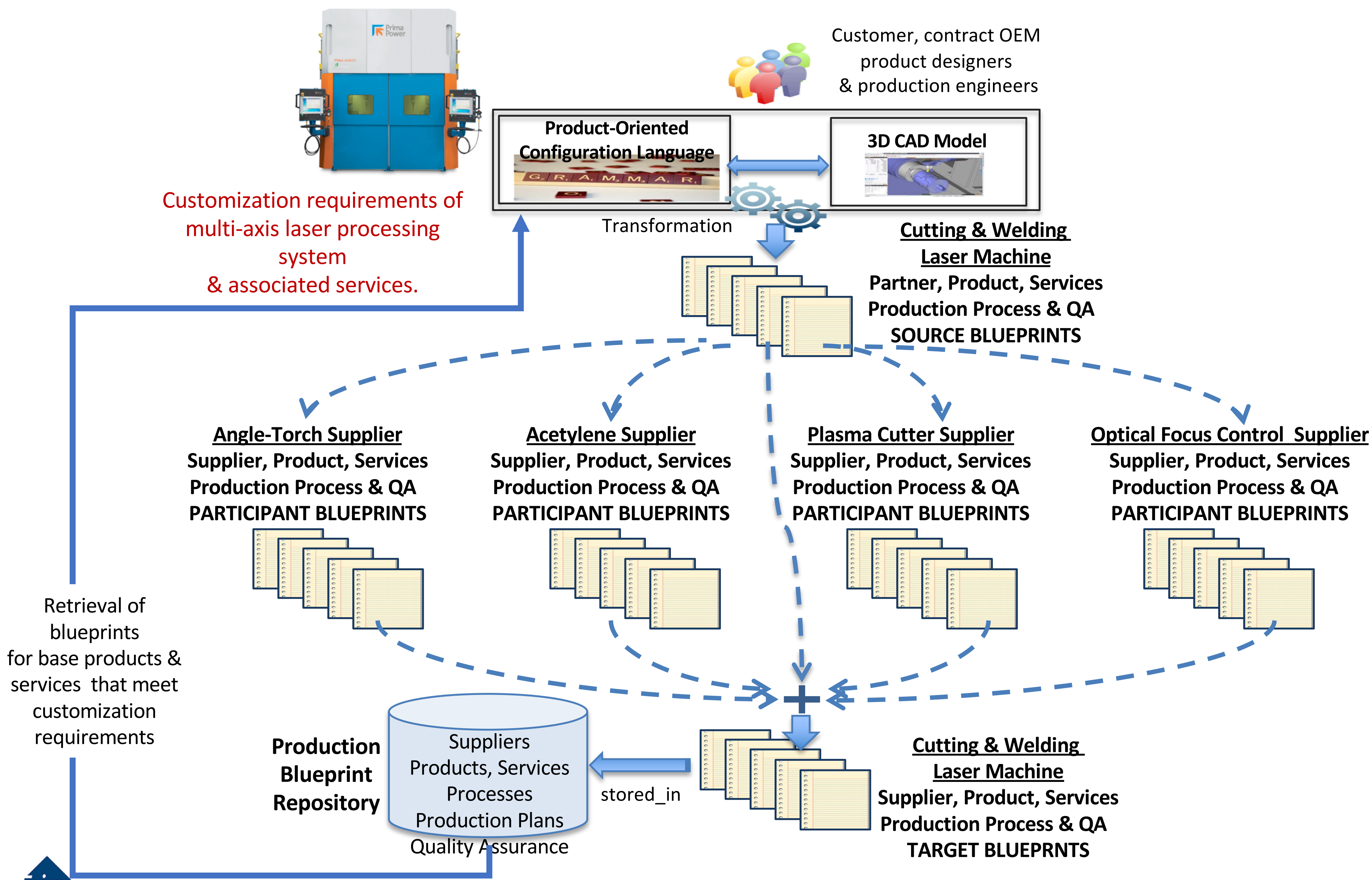
- Manufacturing Blueprint Data Model (MBDM) & Programming Language (MBPL):
  - Foster the development of flexible manufacturing processes and novel applications;
  - Based on formal semantics, supported by an appropriate ontology and programming manufacturing domain-specific language;
  - MBDM incorporates the explicit representation of product design which it transforms to product description artifacts;
  - MBDM exhibits generic properties that apply to smart manufacturing applications of all kinds;
  - MBDM generic properties are extendable and be specialized to cater for specific application requirements;
  - MBPL converts generic product representation schemes to composable production-level activities and processes.

Meta-Programming Environment

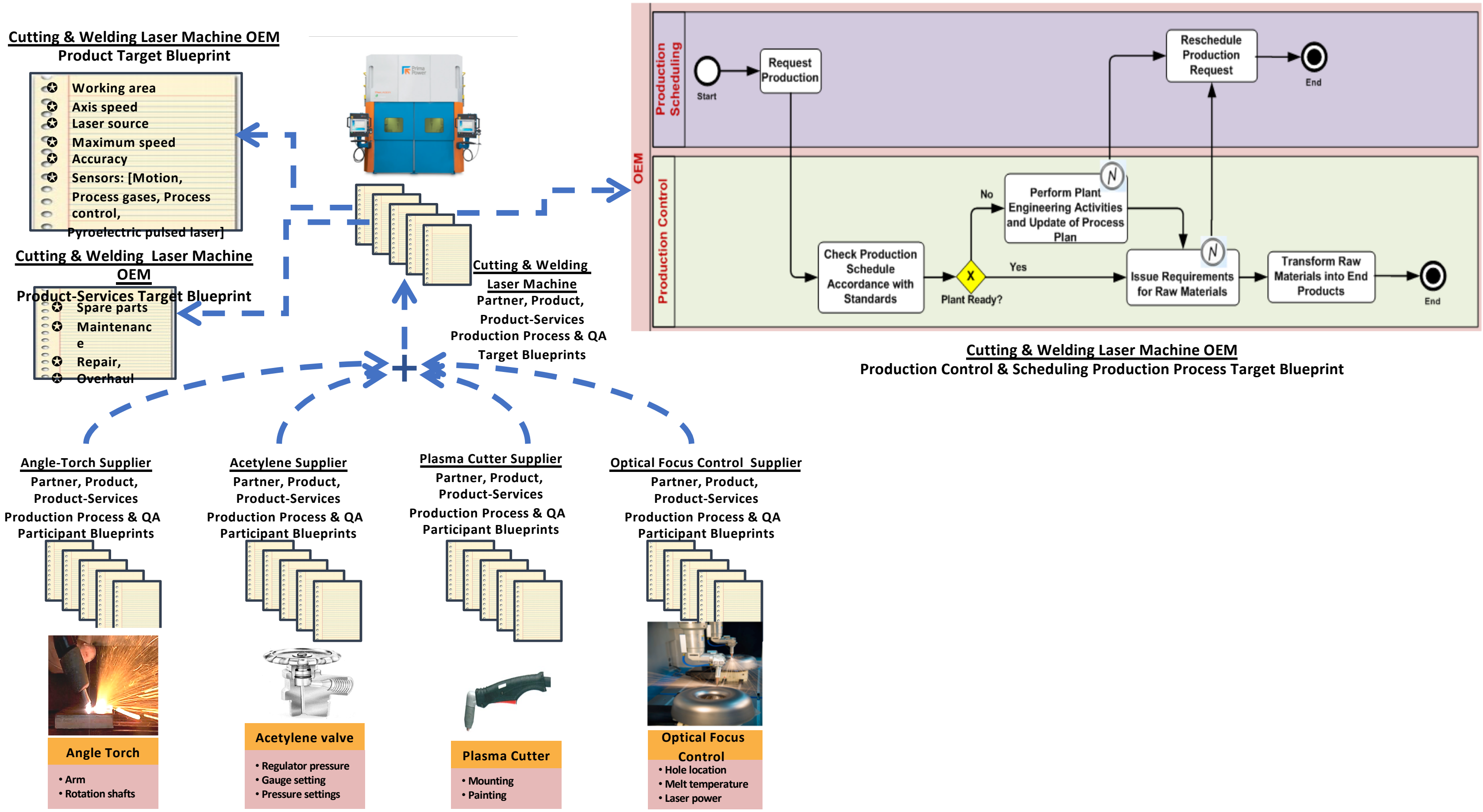


Examples of Use: Manufacturing Blueprint Data Model & Programming Language

Example of use: Model-driven Product Engineering



Example of Meta-Programming Environment



Closing Remarks

Concluding Remarks: Metaprogramming Environment For Industry 4.0

- Enables a concurrent, collaborative design process where users examine and define requirements, propose solution architectures, demonstrate and exchange ideas with stakeholders, and consider product feature tradeoffs.
- This approach results in developing digital footprints of the logical application of product fabrication and production processes, which it maps to implementation details of the targeted factory-floor platform.
- More demand-driven, automated, optimized & sustainable.

OPTIMIZED

Rapid Customized Value Creation

DEMAND-DRIVEN

Spontaneous Collaboration

SUSTAINABLE

Minimize negative environmental impacts while conserving energy & natural resources.


THANK YOU